Investigation of Mechanical Properties of Recycled Polypropylene

By

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This Thesis is Submitted to Dublin City University in Fulfilment of the requirement for the award of the degree of

Doctor of Philosophy (PhD)

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Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work and has not been taken from the work of others and to the extent that such work has been cited and acknowledged within the text of my work.

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This work is dedicated to my beloved parents, wife and daughters

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ABSTRACT

Every year there is an increase in the amount of plastics formed by all types of processes, such as extrusion, blow moulding, injection moulding, etc. The recycling of waste plastic materials is developing at a manufacturing process scale, and its aim is to increase further the sales of plastic products by reducing raw material costs. However this economic argument is only one of the reasons why it is important to recycle these materials. The other is environmental.

Each time an item of plastic material passes through the manufacturing process, its quality is reduced. Some plastic material can be recycled over and over again. This research concerns the number of times polypropylene (PP) formed by the injection moulding process can be recycled. The work focuses on the quality of the material after each recycling operation. Material was passed through the forming process up to three times. Also, since it is possible to improve the quality and reliability of the polypropylene, by adding a percentage of fresh "raw" material, the study included an investigation to optimise the mechanical properties using this approach.

The moulding process was used to produce products whose mechanical properties could be measured to provide an indication of the quality of the material at that stage. The relationship between the moulding process parameters and the quality of the subsequent products was analysed, and this was extended for cases where the material was recycled twice or three times through the equipment. The powders produced in these trials were then mixed with different percentages of raw material, and passed through the equipment again to produce products whose mechanical properties could be measured.

To reduce the number of permutations a Design of Experiments (DoE) method was implemented to define the moulding process conditions which resulted in the optimum product quality for material being recycled once, twice or three times. A 2^k Factorial Design (FD) technique was also used. Different mathematical models were obtained to show the relationship between the process parameters, the number of times the material was recycled, and the product quality. This was extended to show the effect of adding a percentage of raw material to the powder mix.

All the mathematical models were verified by further experimentation. The results show that these models can predict the mechanical properties of the products adequately, once the processing parameters have been defined.

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CHAPTER 1

INTRODUCTION

1. Introduction

The main objective of this chapter is to introduce the research topic and explain the aims of the work. A general introduction to the themes addressed in the study is followed by an explanation of the research objectives. A review of what constitutes research is also undertaken, and the link between survey method and experimental work for the effect of the recycling process on the quality products at each stage is considered. An outline methodology of the main stages in the research process for this thesis is then provided. An examination of the theoretical foundation that underpins the study follows, and this discussed in relation to the methodological literature. To this end, this chapter describes the research approach used in this study and the link between theory and practice. An outline of the significance and contribution of this study is then provided, followed by the outline structure of the thesis.

1.1. Background to the Research

The plastics industry is one of the fastest growing major industries in the world. Every year in thermoplastic materials, there is an increased level in the amount of plastics used in all types of products. Over the past 20 years, recycling of plastics materials, (RPM), has grown and increased dramatically. This is important not only from the point of view of recycling rejects but also from the economic perspective and marketing of the plastics industry since recycling allows energy and materials to be reused and creates development [1]. Income recycling rates are currently rising fast [2]. Also, recycling of plastic reject would reduce the cost of operation processing [3]. The recycling of plastic industrial reject materials has been taking place for decades in the United States. While there is no documented evidence as to when the recycling of plastics first came about, a form of such was always utilised by the plastic industry [4]. Plastic recycling has become an established national industry [5]. Plastic industry in the United States is now in its second century, the most important developments having occurred since 1910 [6]. The number of plastics recycling businesses has trebled since the 1990s, with more than 1,700 businesses, which are handling and reclaiming plastic providing support both economical and environmental and are responsible for sustaining plastics industry and related organisations. The plastics industry invested more than $1 billion to support increased recycling within the United Sates in that period between 1990 and 1998 [7]. More than 1,000 quality products made with packaging from recycled plastic are now commercially available [8]. Currently most plastic recycling in the UK entails processing of reject material from industry and municipal sold west, i.e. polymers left over from the production of plastics. This is a relatively simple and economical approach to recycling, as there is a regular and reliable source and the material is relatively uncontaminated. Process scrap represents some 250,000 tonnes of plastic waste extracts in the UK and approximately 95% of this is recycled. This process is usually described as reprocessing rather than recycling [9]. Since the 1950s, plastics have grown into a major industry, which impacts our lives in providing improved packaging to giving us new textiles and to permitting the production of useful new products.

In fact, since 1976, plastic has been the most used material in the world and was recently voted one of the top materials [10]. The plastic process industry has been modified and developed in numerous ways, and now there are different types of mould equipments used in manufacturing plastic products [11]. That market orientation is an important determinant of business performance as there is a positive relationship between market orientation and sales growth [12]. A modern system for the development and manufacturing of new products are strongly connected to market demand [13]. In this investigation a comprehensive study on the state –of- the recycling plastic materials and a focus on the quality of recycling products were carried out. This issue can be translated into a generic question: How to develop a quality product of the recycling process so that they are able to perform their quality tasks involving several recycling stages, in the manufacturing plastic industries. This anomaly sets the scene for the research presented in the thesis. The research presented in this thesis is based on a study, which investigates the effects of the recycling process of plastic materials on the quality of the resulting recycled products finished at several recycling stages. The survey study combines topics discussing the state of recycling and analysis of processes successfully implemented in Industrial practice in the recycling of plastic materials to improve the products quality and return to the market [14]. Fig.1.1 shows the recycling steps of the plastic process.

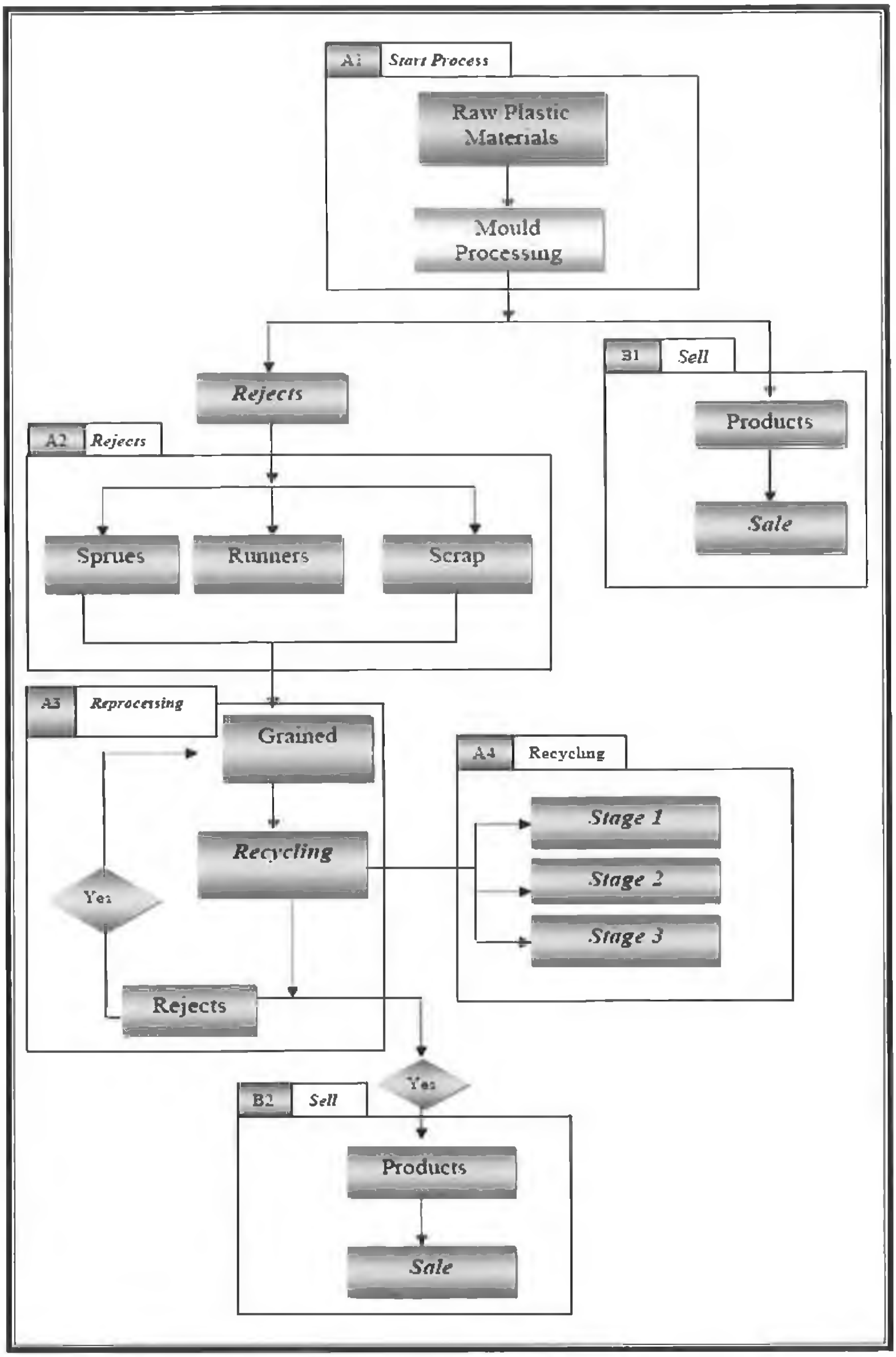


Fig. 1.1: Recycle steps of plastic process.

This study concerns the determination of the most effective process at each stage of the recycle process. Although recycled plastic would assume a greater share of the markets, the primary question is aimed at identifying which of the parameters reduce the quality of recycled products in the plastic industry.

This data has been plotted to show the best recycling materials, thereby greatly enhancing the overall impact and providing a much more intuitive link between the moulding machine parameters and the products quality at each recycling stage. In this study, statistical analysis was carried out to assess which input parameters reduce quality in moulding production of thermoplastics. The proposed concept involves quality sensitivity analyses by considering the process parameters as variables to define the relationship between process parameter variation and final product quality. Recycling is likely to reduce environmental burden since it reduces virgin material production in general [15-16]. Recycling is the recovery of the economic value and energy of reject materials. It can also be of industrial reject and any numerous other types of reject [17-18]. The plastics industry as a whole will have to encompass a viable secondary or tertiary recycling capability. The environmental setting for the plastic industry is such that the existing plastics recycling industry has undergone substantial expansion and development since 1980. This opinion is partially supported by the prediction of a recent survey on the future of the plastics industry [19].

The main objective of this chapter is to introduce the research topic and explain the aims of the work. A general introduction to the themes addressed in the study is followed by an explanation of the research objectives. A review of what constitutes research is also undertaken, and the link between survey method and experimental work for the effect of the recycling process on the final quality products at each recycling stage. An outline methodology of the main stages in the research process for this thesis is then provided. An examination of the theoretical foundation that underpins the study follows is also discussed in relation to the methodological literature.

1. 2. Materials Study and Description of Method

In this work, survey research methods are implemented to collect data from the manufacturing organisation. To improve and solve problems subsequently, it has been used in the current research, to develop a method and explanation for some of the findings on a more comprehensive basis. Adams and Schvaneveldt [20]. Generated new information or knowledge using this approach which, in turn, can be applied to solve problems, improve the quality and provide abetter understanding of conditions in a given area.

The three sections in the questionnaire were developed in order to address the overall objectives and are presented at the end of this chapter. An examination of the study's contribution from the survey method and experimental work is then discussed in order to highlight the need for the work.

In this research, a questionnaire survey was submitted to industry in the Republic of Ireland and United Kingdom. The data was analysed using statistical package for the social sciences (SPSS) software to analyses the results and also to determine the relationship between the recycling process and final quality of the product to determine which input parameters reduce the quality at the various recycling stages.

The survey questions have used different parameters (such as, screw rotation, barrel temperature and nozzle temperature) of the plastic mould machine. The results were analysed to obtain feedback within this parameters which were evaluated to determine their response of increasing / decreasing product quality through each stage of the recycling process. SPSS techniques were used to evaluate responses and identify the optimal process inputs parameters. The materials studied for the questionnaire, include the most common types of traditional thermoplastics material used in the manufacturing plastic industry, and in durable products such as those described in Table 1.

The second aim to this to study was to examine the effects of injection mould parameters on the product quality at each recycling stage. Tensile testing was carried out on numerous samples of polypropylene (PP) material. The results were analysed to obtain feedback on which parameters had a significant effect on product quality. Design of Experiments (DoE) has also been applied, to study the effects of process parameters using the injection-moulding machine, HM7.

The experimental plan was based on 2^K Factorial Design (FD). Linear and quadratic polynomial equations were developed to predict the yield strength (Y) and ultimate tensile strength (UTS) for the different recycling stages. Set of mathematical and statistical methods were used to predict and optimise a dependent response, which was affected by several independent parameters Chapter six will cover in detail this topic.

The research reveals good information from the two research methodologies, such as, the questionnaire and experimental work, which can be applied to solve problems within the process and improve the quality of the final recycled products.

Table 1.1: Various thermoplastic materials used in industry [15].

No.	Code	Materials Name	Applications
1.	PP	Polypropylene	Pipes and pipefitting, beer bottles create shells, capacitor dielectrics, cable insulation twines, ropes, bags, food packaging, fibres, table and chairs, etc.
2.	PS	Polystyrene	Packaging, lighting fittings and toys, containers food , foam and coups, etc.
3.	PE	Polyethylene	Food containers, milk bottles and plastic food bags, etc.
4.	PVC	Polyvinyl Chloride	Insulation of wire for domestic electricity supply domestic hosepipes and fittings, siding, carpet backing and windows, soles of footwear, bottles, pipe, fittings and packaging sheet are major rigid markets, etc.
5.	PET	Polyethylene terephthalate	Soft drink bottles, fibres and many other injection-moulded consumer product containers, etc.
6.	LDPE	Low- density polyethylene	Low-loss electrical wire covering blow molded and large rotationally molded containers, Bottle, and packaging film, Shopping bags, etc.
7.	HDPE	High–density polyethylene	Dustbins used to make bottles for, milk, water bottle, juice, and laundry products create and mechanical handling pallets, pipe, bags, film etc.
8.	ABS	Acrylonitrile butadiene Styrene	Shelves, sheet, safety helmets, camper tops, automotive instrument panels, and other interior components, pipe fittings, home-security devices, etc.
9.	EPS	Expandable polystyrene	Make foams for packaging and thermal insulation in the building and construction market, etc.

1.3. Research Questions

The research questions are used as a guide to address the study and are used as a starting point for analysis [21] [22]. In general, these questions are developed in order to address the issues raised from the research objectives as presented in the section 1.6. As a result of the generic questions initially renewed, more specific research questions have evolved and are outlined as follows:

1. Why and how recycling are process implemented within the plastic, industry in Ireland and the United Kingdom?
2. How does the recycle process affect on the quality on the product at each recycle stage?
3. What is the relationship between the process parameters and product quality at each recycle stages?
4. How does the recycled process affected on sell of recycling products in the different recycle stage?

In the context of this study, three hypotheses are formulated, for the purpose of offering a clear framework and direction to this research, as well as to guide the collecting, analysing and interpreting of data [23]. In order to answer these questions, a number of propositions are developed during the literature and presented in chapters, four and six which examine in detail the issues involved.
Analysis of the research questions involved bivariation correlation and "ANOVA" test, applied to exam the quality of the recycled process at each recycling stage.

1.4. Problem Definition

The strategy of developing mixed material is extremely useful for recycled PP. Since PP undergoes a rapid and deep degradation phenomena, with subsequent decrease in mechanical properties. The problem investigated by this research is considered amongst the basic problems, which focus on the quality of the product at different recycling stages. Often during the manufacturing process of traditional thermoplastic materials there is a vast number of rejects (that is, scraps) after the moulding process, although this problem is solved by one of the most common recycling techniques, in mixing raw PP and recycled PP to produce products with desired quality. This practice is very common in industry where plastic rejects are ground and reintroduced into the processing apparatus together with raw material. The main problem related to this practice is choosing the right amount in percentage of recycled PP to be mixed with the raw PP at the mixing stage.

Much research reviews the properties of several percentages mixture, with particular reference to the effects of the amount of the recycled PP used in the mix. A brief overview of the models used to predict the properties of mix is also given. As previously outlined, the preparation of mixed PP is, in general, a very useful way of managing plastic recycling. The analysis and prediction of the mechanical properties of PP mixture is extremely complicated, as the different level of parameters used dramatically affects these properties. This is the reason for different in results published previously in literature. This study led to identification to an optimum and subsequent improvement in product quality at varies recycling stages by the various mixed percentages of raw material with recycled polypropylene (PP) plastic materials.

1.5. Aim of the Research

The primary objective of this research is to develop a mathematical model to describe the behaviour of plastic materials PP, for each recycling stage, using different recycling parameters with injection moulding machine, HM7. The following points identify the core of this research study:

1. To identify the economic and marketing benefits of recycling traditional thermoplastic materials.
2. Effect of the length/ duration of the recycling process on the mechanical properties.
3. The effect of the process parameters on the quality of recycled products.
4. To analyse the quality performance versus the product cost.

1.6. Research Hypothesis

This research thesis examines and develops the hypothesis though implementing two methods, such as, that of questionnaires and experimental work, for each recycling stages. This research also examines the premise that both quality and marked orientation do indeed improve recycle.

Considering performance in the manufacturing thermoplastics. The following points can be considered:

1. Relationships between numbers of recycle processing and product quality. Also, the percentages of raw material used with recycled materials to improve and achieve optimal quality products for second and third stage in recycling.
2. Effects of the process inputs parameters on the quality of the product for each recycling stage.
3. Relationship between recycle processing and market at each recycling stages.

The research analyses considered quality product, input process parameters and market orientation as the independent variable (X1, X2 and X 3) and recycle performance (Y), as the depended variable. The statistical analysis was done using the" SPSS" software to determine the correlation between the variables of the study, as well as the significant effect of the independent variable on the dependent variable by using "ANOVA" test. Each hypothesis was discussed and tested based on the findings of the statistical analysis, which is presented in chapter four. The correlation matrix indicated that there is a high relationship between X_1, X_2 and $X_3$with the depended variable. As indicated, there results are analysed in chapter four and six.

1.7. Preliminary Research

This is the starting point of the research. A comprehensive literature survey on the subject of the recycling process of thermoplastics was actively conducted. This study will be reviewed in chapter three.

1.7.1. Designing the survey

The preliminary research is used in identifying the areas, which need to be addressed in designing of the implementation framework. Following this, the most important phase of the work was the design of the survey. Two kinds of survey method have been used in this work.

1. Web based survey, (requiring a web page on the internet).
2. Traditional postal survey.

During this stage a pre- test and a pilot test of the survey was conducted. Chapter three will cover in depth this topic.

1.7.2. Survey analysis

Data collection has been done by survey methods and some statistical tools have been implemented for the data analysis such as frequency, cross –tabulation and correlation. Also, graphical representation (such as, pie chart and bar charts) along with a discussion which followed the results of the analysis. Chapter fife will cover in detail this section.

1.8. Significance and contribution of this study

There has been little or no substantial research carried out in involving questionnaire methods in the aspect of recycling within the manufacturing plastics industrial and laboratory work using several stages with mixed material. This research is therefore important as it addresses the need for this in both Ireland and the United Kingdom. In general, there are five main areas where the work presented in this thesis provides a significant contribution to knowledge in the following manner:

1. The literature review addresses the gaps in the recycling process and related operations involving plastic materials. Literature focuses on the aspects of survey using plastic materials resource and mixed polypropylene recycled material with the PP raw material at different percentages to be development.

2. The study identifies the economic and marketing benefits of recycling traditional thermoplastic materials.
3. The study examines and carries out a comparative study on the aspects of recycling process implementation between survey method and experimental work.
4. The study investigates possible linkages between the recycling process and final product quality at each recycle stages.
5. The study investigates the effects of process parameters during the injection-moulding machine HM7 with PP plastic materials on the quality of recycled products at several recycling stages.
6. The study offers a proposed solution in providing predicted and optimised mould process parameters.

1.9. Overview of the Thesis

This thesis is divided into seven chapters. A description of each chapter is described below:

Chapter 1"Introduction":

This chapter present a brief introduction to the research topic area and explains the aims of the work and subsequent problem statement. The research addressed in this study is followed by an explanation of the research questions and aims of the research. An explanation on why questionnaire and experimentally selected as a comparison study is also presented. This chapter also describes the research approach used in this study and the link between theory and practice.

Chapter 2"Literature Review":

This chapter presents a review of existing literature on the subjects in accordance to the aims of the research that have been outlined in the previous chapter. A critical evaluation of the recycling process in literature and other related areas is undertaken to determine the research work that has taken place, as well as to identify gaps in the literature that will provide the framework for this research study and direction for the empirical research. The literature review is divided into four sections with the specific sections as follows.

- The first section provides an overview of the recycling process of plastic materials.
- The second section presents the technologies used in this study, such as "Injection Mould ", and classification of mould equipments.
- The third section provides an overview for mechanical properties of mixed polypropylene (PP) plastic material.
- The final section of this chapter focuses on the related work for an application of Design of Experiments (DoE).

Chapter 3 "Designing the Survey and experimental procedure":

This chapter describes the methodologies used in this work and presented as follows:

- The first section provides a detailed survey using questionnaire's designed into three sections; section A: company profile; section B: recycling of plastic materials and section C: selling of recycled products. In this chapter, two techniques are highlighted which have been used to assemble data collated in response to survey conducted and analysed using "SPSS" statistical software.
- The second section describe the first traditional post survey method technique which was used to assemble data from the Republic of Ireland and United Kingdom plastic companies.
- The third section of this chapter focuses on the second online survey method technique, which was used in this research.

The final section of this chapter presents the study using an experimental work to collect data, and analysis techniques used Design Experimental V.7 software. This section is divided into three points:

- *Material study*: This section involved raw, first, second and third stage with recycling polypropylene (PP) plastic material. Each every stage using grinder samples with several process parameters used to determine the effect on the mould sample using injection mould HM7 machine.
- *Tensile Test:* This section is presented to evaluate recycling properties for several sample parameters in which mechanical properties are affected after the moulding process and to analyse all the response data using Experiment Design Software V7.
- *Statistic design V7 Software, FD Technical*: This section highlights the limitations and implication in developing response data witan experimental plan based on 2^K Factorial Design (FD) for each recycle stage.

Chapter 4 Survey Results ad Analysis:

This chapter covers the analyses of the results obtained from the survey. The results of three hypotheses testing are provided in chapter's fife and six.

Chapter 5 Experimental Design:

This chapter provides a detailed description on the experimental design modelling which has been applied to study the effects of processing parameters on the mechanical properties by using the injection-moulding machine HM7. Data from the experimental tests were carried out using Design of Experimental (DoE) statistical techniques. The tests were conducted on controlled-moulding samples at different parameters, to examine yield strength (Y) and ultimate tensile strength (UTS) at different recycling stages. 2^K Factorial Design (FD) were applied by using "ANOVA "test to produces models at each stage.

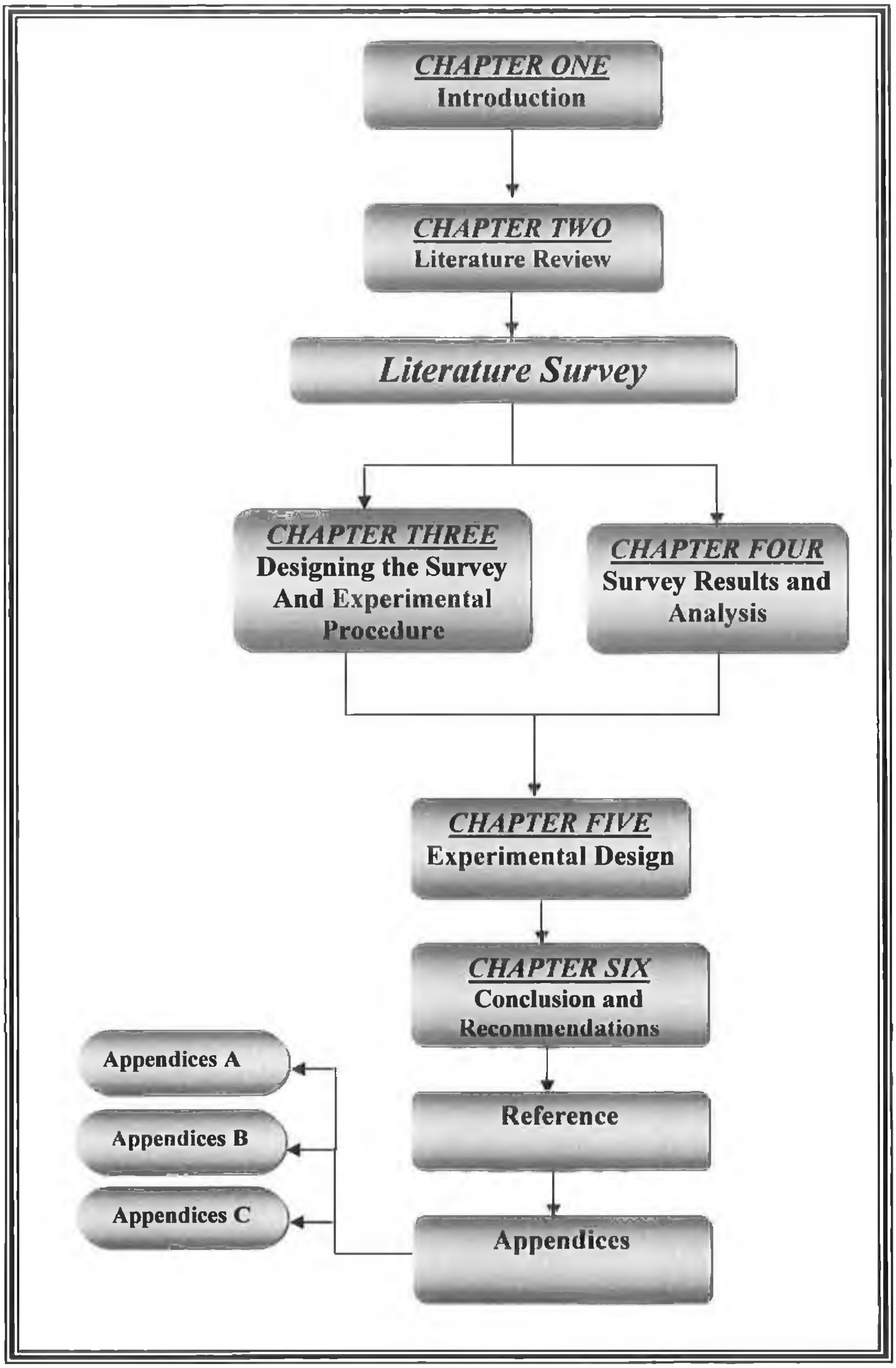
Chapter 6 "Conclusions and Future Work":

This chapter presents the main results associated to this research. It also outlines the thesis contribution and recommendation for future work based on the present study.

Finally Fig.1.2 shows the schematic diagram of research out line Fig. 1.3 shows the method of approach used in the present study for the two methods, as also provided in chapter three.

1.10. Chapter Summary

This chapter introduces the research topic area and summarises the aims of the work. It provides a general introduction to the background of the research addressed in this study and also gives an overview of the methods describing the methodology. This is followed by an explanation of the research questions and aims of the research. A brief introduction on recycling of several thermoplastic materials and the implementation of recycling process for rejects of plastic materials coming from the plastic industry. This chapter also describes the research approach used in this study and the link between theory and practice.


CHAPTER ONE
Introduction
CHAPTER TWO
Literature Review
Literature Survey
CHAPTER THREE
Designing the Survey And Experimental Procedure
CHAPTER FOUR
Survey Results and Analysis
CHAPTER FIVE
Experimental Design
CHAPTER SIX
Conclusion and Recommendations
Reference
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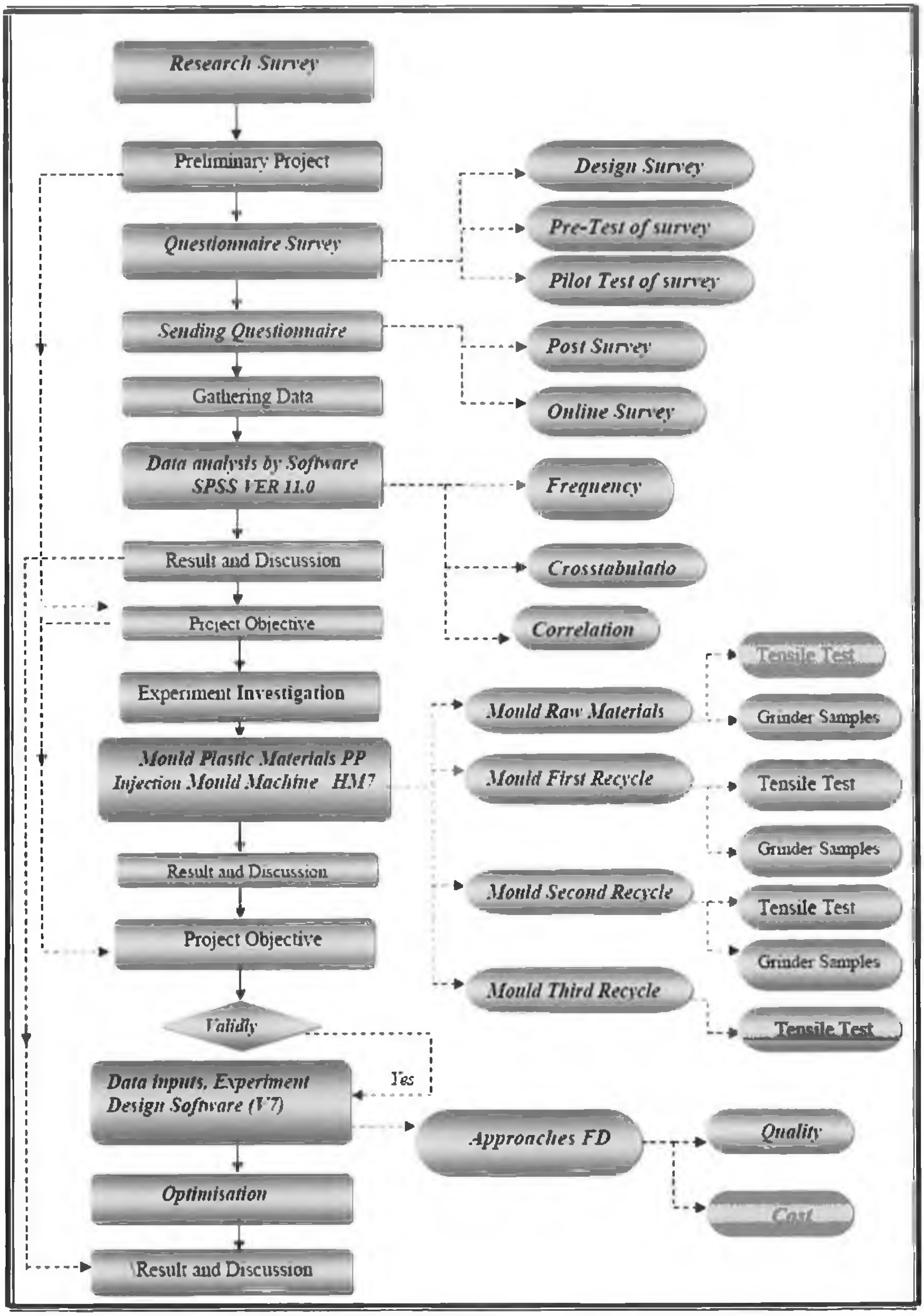


Fig. 1.3: The method of approach used in the present study.

CHAPTER 2
LITERATURE REVIEW

2. Literature Review

2.1. Introduction

This chapter provides the reader with a clear explanation to what is involved in this process, and also presents the relevant work that has been done by applying these methodologies to the recycling process using addition of raw polypropylene (PP) to recycled PP and also using various mixtures of PP with the other plastic materials. Fig. 2.1 shows a schematic of the demonstrated reject and sale recycling products.

2.2. Purposes of Literature Review

In line with the purpose of compiling a literature review, as mentioned above; this chapter presents a review of existing literature in developing the theoretical and experimental understanding on the following topics, in accordance to the aims of this research; (1) recycling process of plastic materials; (2) rcycling process of mixed polypropylene (PP) plastic materials; (3) application of Design of Experiments (DoE). A critical evaluation of the maintenance literature and other related areas is undertaken to determine the research works that had been done, as well as to identify gaps in the literature that will provide direction for the empirical research. In the context of this study, three hypotheses are formulated, for the purpose of offering a clear framework and direction to this research, as well as to guide the collecting, analyzing and interpreting of data. This chapter provides the reader with a clear explanation as to what is involved in this process, and also presents the relevant work that has been done by applying these methodologies to the process. Fig. 2.2 shows a link between business, manufacturing strategy and recycling process.

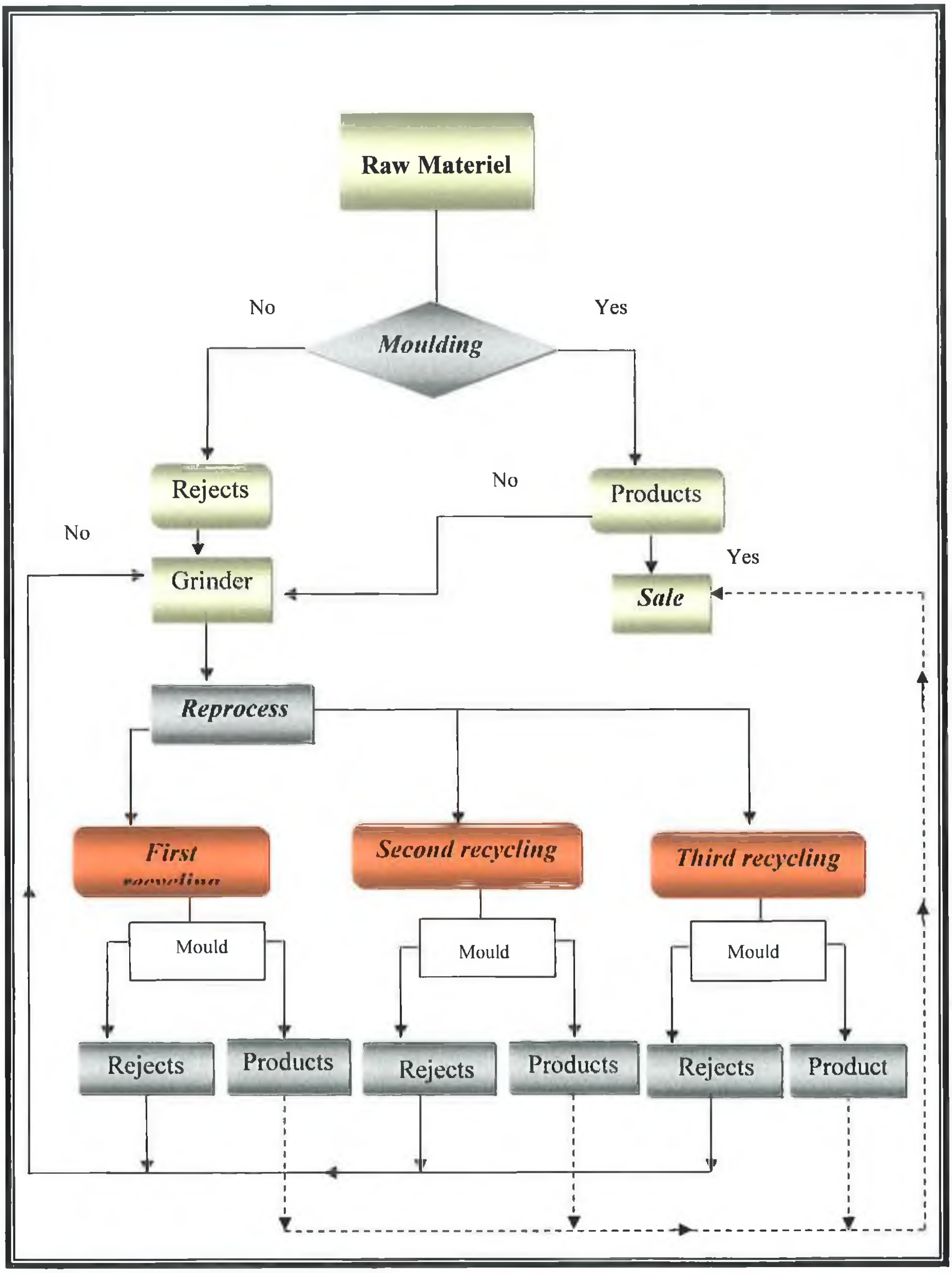


Fig. 2.1: Schematic diagram of demonstrated rejects and sale recycling.

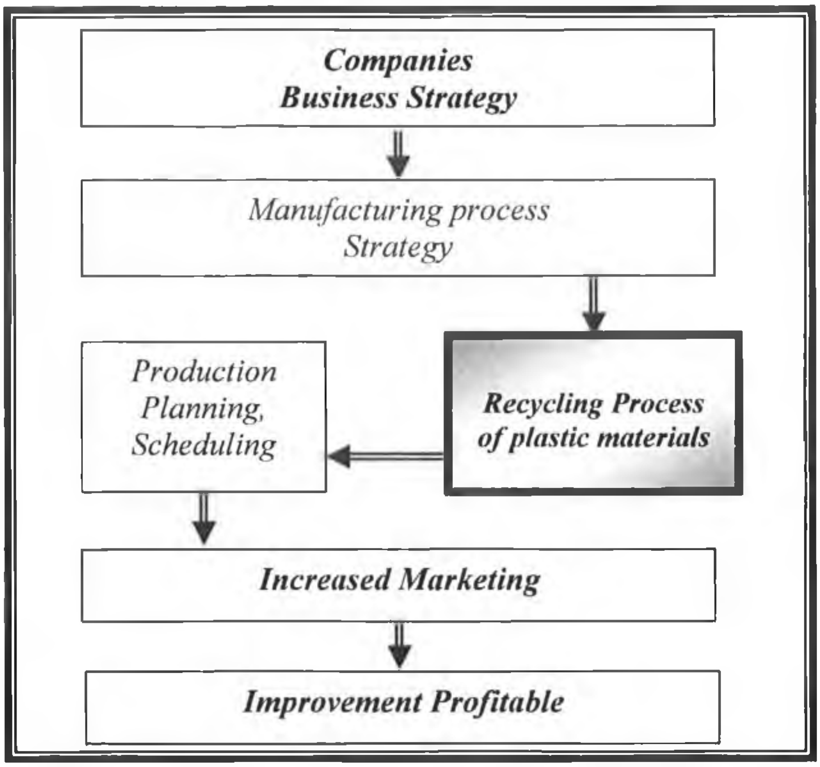


Fig. 2.2: The link between business, manufacturing strategy and recycling process.

2.3. History and Background of Recycling Plastics

Currently, most of plastic recycling in the UK entails the reprocessing of rejects from industry and municipal solid waste (MSW), i.e. polymers left over from the production of plastics. This is a relatively simple and economical way to recycle [24]. The recycling of plastic waste is unlimited to rejects from manufacturing [25]. The utilisation of reject at various stages is presented in Fig. 2.2. In 1988, only 1% by weight of all discarded plastic was recycled in Florida [26]. This represents 13% of the total packaging material. From 1985 to 2000, plastic packaging was predicted to increase by 77% PP, PET and HDPE are the major recycling plastics technology offer more economically attractive alternatives for plastic recycling or disposal.

Since the 1950s, the processing of plastics have grown into a major industry affecting our lives, from providing improved packaging to giving us new textiles and permitting the production of useful new products. In fact, since 1976, plastic has been become the most used material in the world and was recently voted one of the top materials [27]. In the USA, around two –third of all petrochemicals are used in the production of plastic. 25% of these plastics were recycled representing an increase by 25% of recycled materials being returned to the market [1]. An important series of articles were published in "Kunstoffe-Germany Plastics" in 1978, when the articles provided a detailed description of developments in plastic recycling in many countries [28-29]. This could provide the basis of a substantial tertiary plastics recycling industry [30].

2.4. Definition of Recycling

Recycling may be defined as any activity involving reclamation, recovery or reuse of materials; in other words; any method of extracting value in the form of energy or material from waste generated at any time in the life cycle of a product. Recycling may be mechanical, chemical or thermal [31]. Recycling is only sensible if the cost of processing the rejects increases the value of the recycled product. When the recycling of plastics first came about, a form of it was utilised by the plastic industry in its infancy. Various plastic manufacturers learned that rejected parts and trim from the fabrication process could be reused in the process to contribute in the formation of new plastic products [32].

The plastic process industry has modified and developed numerous methods, and now there are different types of mould equipments used in the manufacture plastic products [14]. Injection moulding is one of the most versatile and important processes for mass production of complex plastic parts [15]. Injection moulding is the most important method used for producing different plastic shapes [16].

2.5. Types of Recycling

The methods by which value may be regained from waste or used plastics may be divided into three categories:

- Mechanical recycling secondary.
- Chemical recycling tertiary.
- Thermal recovery quaternary

At each level of the original structure, in which the material and then the polymer itself, is further dismantled, it may be argued that reuse is not really a form of recycling, as many materials for instance are intended for repeated use. Mechanical recycling may be primary or secondary, while the third categories have an exact relationship [31].

Due to the mechanical recycling secondary poorer properties of recycled material, some companies establish a maximum percentage of recycled material to be added to raw material, according to the product to be manufactured and their improve quality [33-35]. This study involves identifying profitable uses for each recycling stage.

2.6. Utilisation Technology for Recycled Plastics

Recycling of plastic materials is sensible for reducing the cost of operation processing [36]. The recycling of commercial and industrial reject materials from plastic and textiles to metals and paper has been occurring for decades in the United States. Various plastic manufacturers are aware that rejected parts and trim from the fabrication process may be returned to the process to aid on the formation of new plastic products. This procedure, known in the plastics industry as regrinding, can be repeated numerous times, as long as the additional percentage of raw materials produces products with good. Any excess rejects may sell to other smaller firms to enable future utilization /re-processing of the plastic [31]. The plastic process industry has been modified and developed in numerous ways. Now there are different types of mould equipments used in the manufacture of plastic products [14]. Currently, most plastic recycling in the UK is based on process rejects from industry, such as, polymers left over from the production of plastics. Process rejects represents some 250,000 tonnes of the plastic waste raisings in the UK and approximately 95% of this is recycled. This is usually described as reprocessing rather than recycling [36].

2.7. Recycling as an Economic Activity

The manufacturing plastic companies began to recognise the problems inherent in the recycling polices that over-emphasise the materials supply at several stages, and to see the potential cost saving and other economic benefits that recycling offers. In the early 1990s, a wide range of "market development "policies were adopted by state of market development policies either sought to influence on the profits. Demands, directly through companies purchasing or requiring certain product to process minimum recycling content; promote recycling via taxes, fess, and other pricing instruments [37].

If states are to achieve and maintain recycling rates of 50% or higher, then they will need to intensify these efforts and build domestic capacity to absorb secondary materials into their economies. This would imply a significant industrial shift from resource extraction to materials recycling; creating important economic opportunities for urban and rural regions, alike. In order to realise these opportunities; new varieties of economic development planning will be required, focusing on analysis of local re-utilisation of these materials when considered as waste meanwhile, environmental concerns have continued. Today, environmental awareness reaches beyond localised concern about public health; to include large –scale impacts of resource extraction and use upon natural ecosystems. In order to remain relevant to the broader environmental challenges facing society today, recycling or material policies of the future must address the consumption as use of materials as their disposal, seeking to minimise environmental harm at each stage of a products life [37]. As the preceding discussion should make clear, the arena of policy in which companies have sought to influence large-scale recycling markets is in-depth. Many different types of approaches have been tried, and there has by now significant real – world experience with many variations on each approach. An understanding of large-scale market forces in the economy is of elemental importance to all aspects of public policy, as it is of particular importance to recycling, since market realities fundamentally shape the willingness of businesses to participate in the secondary materials economy, significant market and no market barriers to the broader use of secondary materials do indeed appear to exist, even in the absence of government intervention to remove the remaining distortions. Recycling rates are currently rising fast, with additional action; this trend can be expected to accelerate. Environmental economics suggests how to analyze and rectify these barriers and distortions. The basic scenarios include processing and marketing in each plastic material [37]. Fig. 2.3 illustrates the integration of economic development and planning between the manufacture of the recycling process and market; financial department in businesses plastics company.

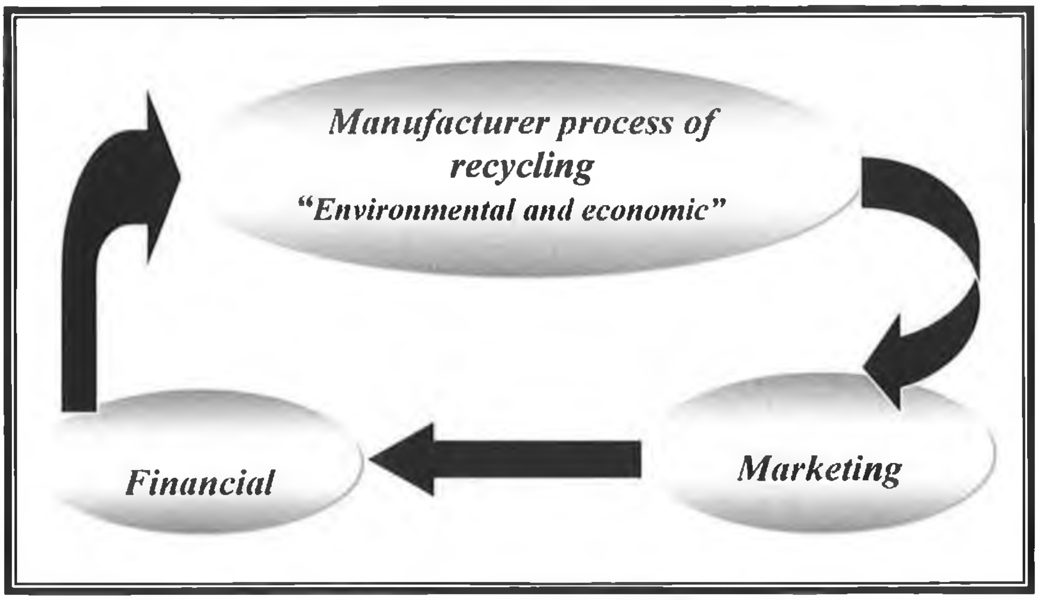


Fig.2.3: Integration company department.

2.8. Review of Some Previous Studies on the Surveying of the Recycling Process of Plastic Materials

A survey directed to the post-consumer of recycled plastics was designed to quantify the amount of recycled plastic bottles in 2002. The results indicated that 13 million pounds increased total post-consumer plastic of recycled bottles in 2002. A questionnaire was developed and mailed to Elko County in Nevada-USA. The questionnaire was used to obtain information pertaining to current recycling practices and potentials for recycling in Elko County [6]. These studies have investigated the recycling in Nevada -USA. This study looked at the public and private sector activities in the recycling market development, and its recycling activities. Some companies import secondary materials that are processed to their specifications. In Nevada, much of the industrial plastic scrap was recycled. It was found that the majority of recycling markets require suppliers to deliver plastics separated according to the required product. The study also analysed the market trends and the factors that affected demand of such recycled products. It was demonstrated that manufacturers using raw materials to produce their products would affect the recycling market. The study also shows that small numbers of Americans have realised the importance of recycling on the environment. Since 1980, the number of people using recycled materials has increased by nearly 20 percent. The high cost of oil and gas can cause companies seek for cheaper recycled plastics. The main advantage of using recycled plastic is that the cost of a recycled material is not affected as much by the fossil fuel market in raw plastic. The recycling industry should reduce their prices to gain more consumers of recycled goods [8]. The data from the survey method was sought from over 150 recycling companies; information about the quantity of recycling material was requested. The questionnaire asked the respondents to identify all materials that they recycle from a list developed for each industrial category. The results show that 3,377,000 tonnes of material were diverted from landfill during 1999-2000 - reflecting the activities of 75 recycling companies in the United State of America [9].

Ref [38] has described the Plastic and Chemicals Industries Association, (PACIA), survey study have carried out, named the "National Plastic Recycling Survey". The survey gathered data from the years, 1993-2000, on the recycling and reprocessing of plastic in Australia. The PACIA has established systems for the collection and reprocessing of pre-consumer industrial scrap and post-consumer plastics waste. The demand for recycled plastics, used for the production of new products was analyzed. From 1997 to 2002, the total recycling rate of plastic in Australia has increased from 7.0% to 13.4%, as shown in Fig. 2.4 [38].

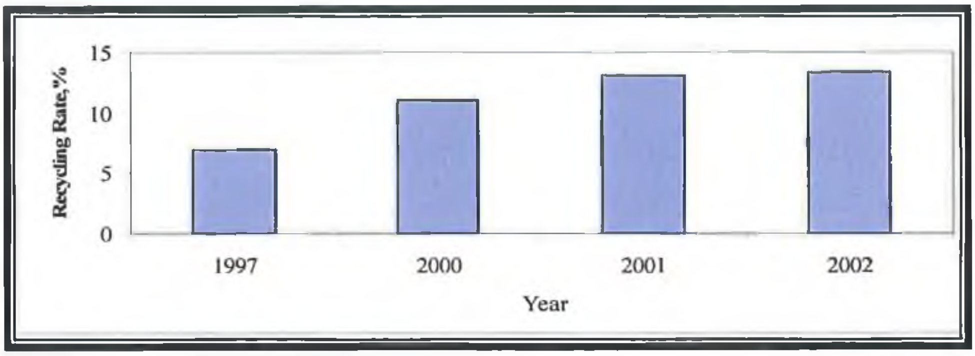


Fig. 2.4: Total plastic recycling rate (1997-2002) [38].

In 2003, PACIA again, carried out the National Plastics Recycling Survey. The survey gathered data for the 2002 calendar year. Results show a total of increased recycling plastic materials from the 2000 to 2002 [38]. The total recycled quantities of different plastic materials were reprocessed in Australia from all sectors, as shown in Fig. 2.5. It is important to note that the recycling performance of each plastic material is more easily distinguished by its recycling rate, as some plastic material have lower consumption volumes, and some are used most widely in long-term applications.

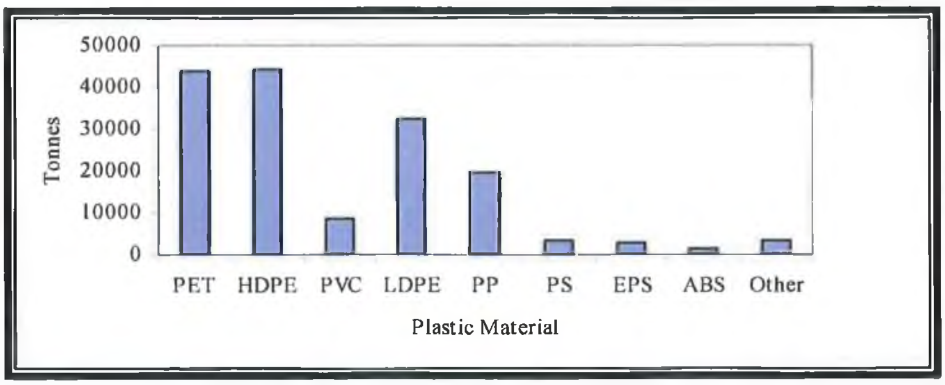


Fig. 2.5: Total recycling of individual recycling plastic materials [38].

In 2002 over 100, 000 tonnes were reprocessed locally and 43, 000 tonnes exported for reprocessing. In 2002 the recycling rate was slightly higher than in 2001 by 13.1%. The survey collected data on total plastics recycling, comprising of local plastics reprocessing and exported waste plastics destined for reprocessing [38]. Other studies have been carried out for different recycled materials. These studies investigate the affect of marketing on the various recycled materials [39]. The survey analyses, showed the effect of the recycling process on the market of the final recycled products. Recycled products include paper, plastic and glass. The analyses involved the scrap of the products that come from the municipal and go to the manufacturers to produce the final products. Manufacturers were using mixed raw materials to produce their products with good quality [40]. Fig. 2.6 shows schematic of various recycling waste and process mould equipment.

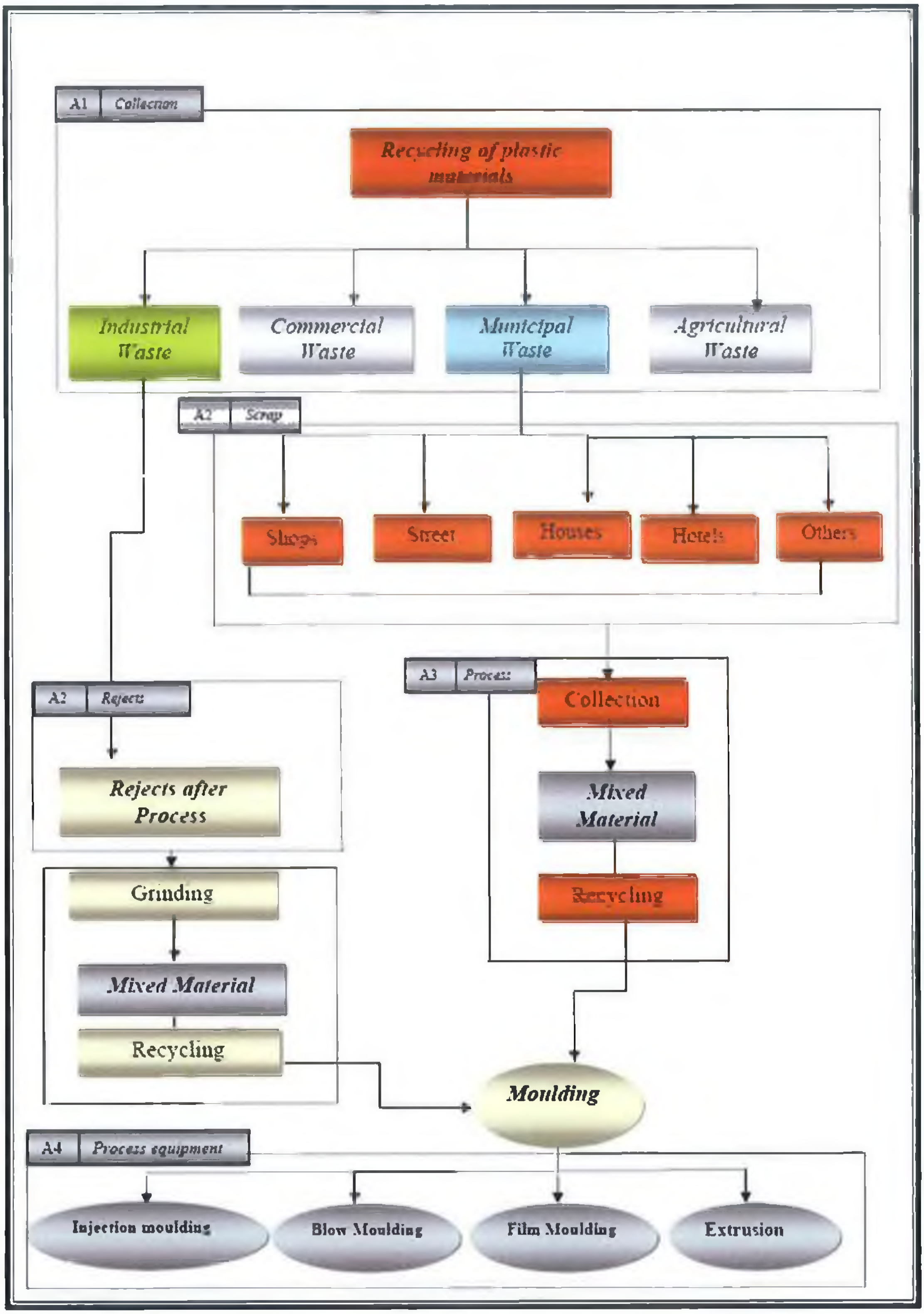


Fig. 2.6: Schematic of different recycling waste and process mould equipment.

2.9. Injection Moulding Technology

In the injection moulding process, a plastic material is injected under pressure into a mould. In the case of thermoplastic injection moulding, the material is supplied in pellet form, dried melted and injected into the mould where the material cools and solidifies. Thermoplastic materials account for 80% of all injection-moulding materials worldwide [41-42]. The process allows the manufacturing of complex shapes in a wide range of materials. The process can also be highly automated and is capable of achieving high production rates with a high level of reliability [43].

This makes the process ideal for mass production. In addition, components are produced in a single operation with minimal waste [44]. During injection moulding the heated plastic material is injected into a mould and stamped out. This process changes the properties and causes the recyclable life to severely decline [8]. The method is suitable for mass production with complicated shapes, and a large part in the area of plastic processing. The injection system consists of a hopper, a reciprocating screw and barrel assembly, and an injection nozzle. The nozzle connection is shown in Fig. 2.10. Fig. 2.11 shows two and three-plate moulds [45].

2.9.1. Type of moulding processes

The plastic process industry has been modified and developed in numerous ways, and now there are different types of injection mould equipments used in manufacturer plastic products such as [46]:

- Injection Moulding.
- Blow Moulding.
- Extrusion Moulding.
- Film Mould.

Injection moulding is one of the most versatile and important operations for mass production of complex plastic parts [15]. Injection moulding is the most important of all the commercial methods of plastic processing [16]. Injection moulding in the western world is becoming increasingly competitive as the manufacturing base for many plastic materials has re-located to the east [17]. There are different types of moulding method present in the manufacturing industry, such as; blow mould, injection mould and extrusion mould and all process are used in the recycling of thermoplastic materials as shown in Fig. 2.7 [46].

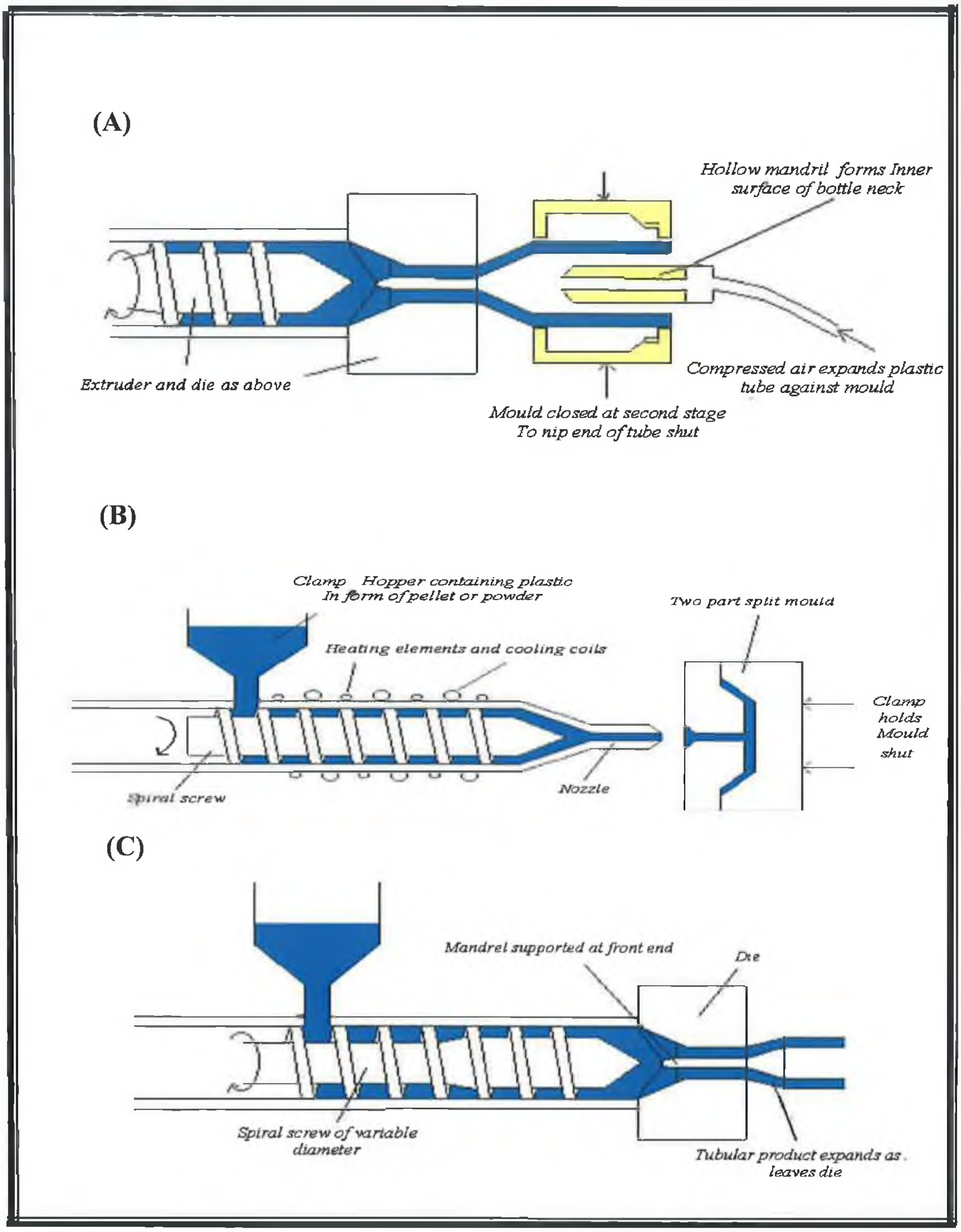


Fig. 2.7: Process mould techniques, blow moulding (a), injection moulding (b) and extrusion (c) [54].

Plastic is one of the world's faster growing industries. It involves a rapidly increasing number of industrial, commercial and domestic applications, giving rise for the need to expand existing development strategies and create new dimensions at design and manufacture stage. Injection moulding has the advantage that moulded parts can be manufactured in unlimited quantities of products [47].

Injection moulding is the most important process used to manufacture plastic products. Today, more than one third of all thermoplastic materials are injection molded, and more than half of all polymer-processing equipment is for injection moulding .The injection moulding process is ideally suited to manufacture mass-produced parts of complex shapes that require precise dimensions [48].

Injection moulding is one of the most common processing methods for thermoplastics. Nowadays, a multitude of different types of injection-moulded exist as shown in Table 2.1 to different mould products. In the injection moulding process, a thermoplastic in the form of granules or powder, passes from a feed hopper into a barrel where it is heated until it becomes soft. It is then forced through a nozzle into a relatively cold mould, which is clamped tightly closed. After the plastic is cooled and solidified, the article is ejected and the cycle is repeated. The major advantages of the process includes its versatility in moulding a wide range of products, the ease with which automation can be introduced, the possibility of high production rates and the manufacture of articles with close tolerances [49]

Table 2.1: Shows different plastic products produced by the mould process [50], [51].

Mould Process	Applications
Injection Moulding	Different types of injection-moulded products, such as, domestic applicable washing machines, dishwashers, air-conditions, office equipment kitchen utensils such as, spoons, knives, forks, kettle, toaster machine. Vehicle moulds include, panel, car lamp housings, automobile filters, car brake sockets and vents and factories mould include combs, syringes, paint brush handles, crash helmets, telephones, mobile phone, gearwheels, brief cases, television cover housings, typewriters, computers cover, keyboard, automotive parts, medical equipment and communication facilities home appliances, pipe fitting, bin, chair, vegetable box, drawer, baby chair, baby walk, toys, tray mould, MDF floors molding and door hands.
Blow Mould	Different type and size of container and bottles.
Film Mould	Plastic sheet i.e. cups, plate, trays, pipes, house siding, door, window seals and flooring i.e. skirting, end-caps, reducers, T-mouldings, stair noses, and quarter rounds, etc.
Extrusion Mould	Plastic sheet, such as, packing fruit, food, roof sheet garments, textiles, daily-use articles and industrial products, such as, plastic bags in different size and types, plastic films in several forms and formats, paper board and cloth material Ice-pop filling and sealing machines and different size tubes.

2.9.2. Injection moulding materials

The synthetic materials used in the injection moulding process are generally termed plastics or polymers. Strictly speaking the terms have different meanings. A plastic is defined as organic, synthetic or processed materials that can be easily shaped or formed. Alternatively, a polymer is defined as a complex, organic, polymerised compound consisting of repeating. Structural units that can be shaped or formed [52]. Thus, polymers are a subgroup of plastics as most plastics are development in the field of thermoplastic are associated with Polypropylene (PP), Polyethylene (PE), Polystyrene (PS), and Polyvinyl Chloride (PVC) thermoplastics which represent 85% of the world's production [53].

2.9.3. Injection moulding process stages

Injection moulding is a continuous process consisting of several different distinct stages. The stages can be classified from either a machine or materials perspective [53]. From a materials perspective, as the material progresses from raw state to final form, it is heated to molten form (heating stage), injected under pressure (filling stage), pressurised to full density (packing stage) and allowed to solidify (cooling stage). It is then ejected from the mould. These main stages are illustrated in fig. 2.8 in processes cooling commences as soon as the materials leaves the heated barrel while in other processes the material is heated over an entire cycle [45]. Fig. 2.9 shows a single-screw injection-moulding machine and its components.

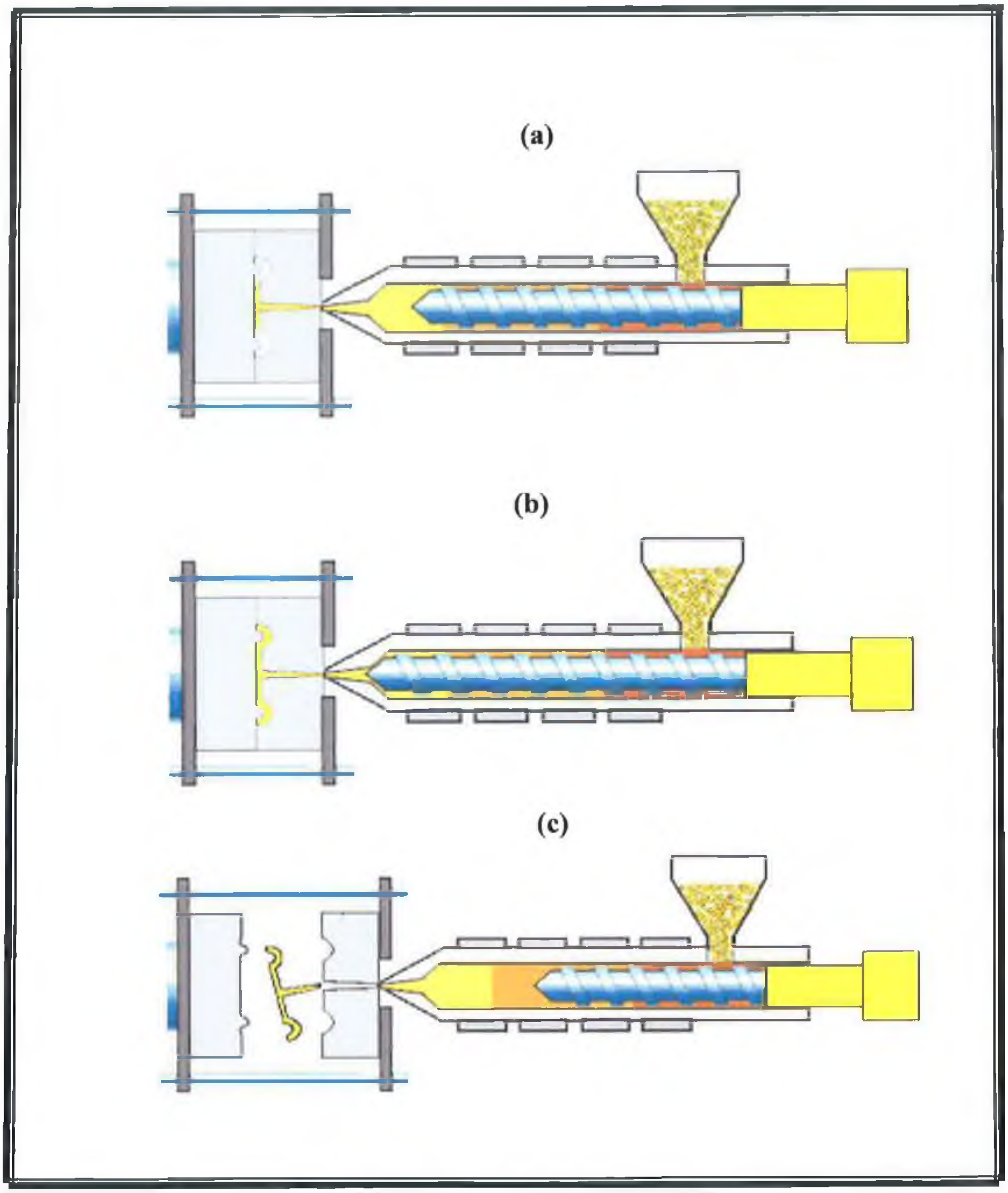


Fig. 2.8: Main stage in the injection moulding process (a) filling (b) packing and cooling (c) [46].

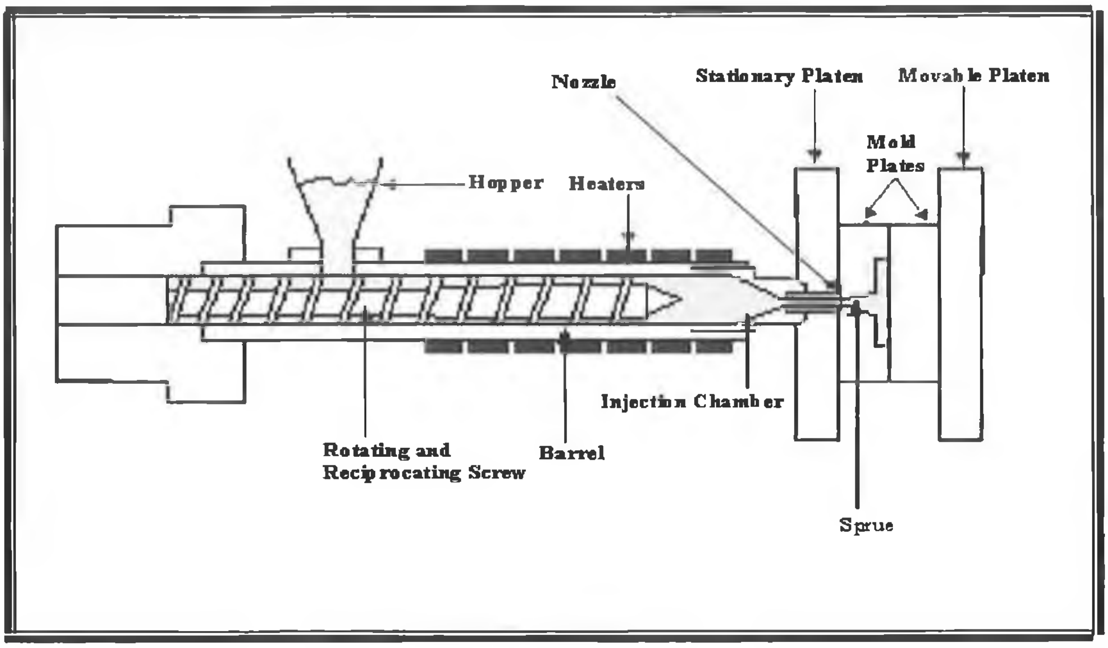


Fig. 2.9: A single screw injection-moulding machine for thermoplastics, showing the plastic zing screw, a barrel, and band heaters to heat the barrel, a stationary platen, and a movable platen [45].

Components of the single parts of injection –moulding machine include [47]. Fig. 2.10 shows nozzle connection.

(1)TheHopper

Thermoplastic material is supplied to the moulder in the form of small pellets. The hopper on the injection-moulding machine holds these pellets. The pellets are gravity-fed from the hopper through the hopper throat into the barrel and screw assembly.

(2)The Barrel

As shown in Fig.2.11 the barrel of the injection-moulding machine supports the reciprocating plasticizing screw. It is heated by the surrounding electric heater bands.

(3)The Reciprocating Screw

The reciprocating screw is used to compress, melt, and convey the material. The reciprocating screw consists of three zones as follows:

-The feeding zone

-The compressing (or transition) zone

-The metering zone

(4)The Nozzle

The nozzle connects the barrel to the sprue brushing of the mould and forms a seal between the barrel and the mould. The temperature of the nozzle should be set to the material's melting temperature or just below it, depending on the recommendation of the material supplier. When the barrel is in its full forward processing position, the radius of the nozzle should nest and seal in the concave radius in the sprue brushing with a locating ring. During purging of the barrel, the barrel backs out from the sprue, so the purging compounds can free fall from the nozzle. These two-barrel positions are illustrated below.

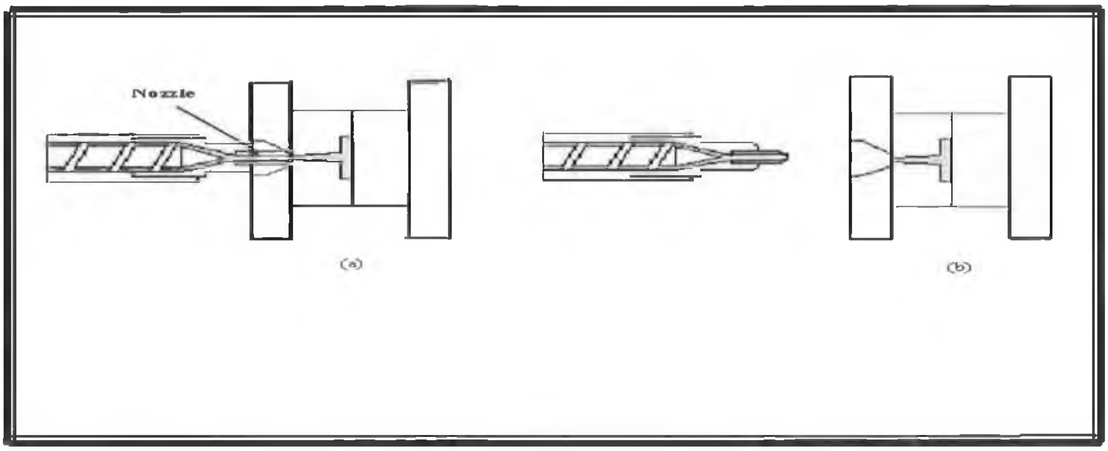


Fig. 2.10: Nozzle connection [45].

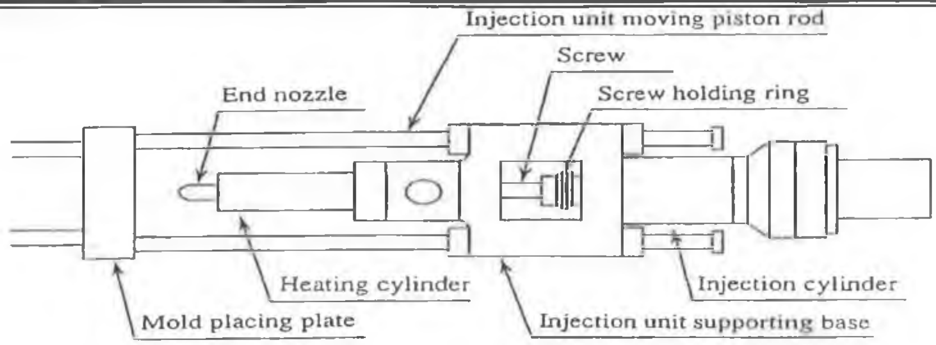


Fig. 2.11: Part of injection unit [54].

Injection moulding is a method to obtain moulded products by injecting plastic materials molten by heat into a mold, and then cooling and solidifying them. The method is suitable for the mass production of products with complicated shapes, and takes a large part in the area of plastic processing. The process of injection moulding is divided into four major steps as shown below.

• ***The Mould***

The mould system consists of tie bars, stationary and moving plate, as well as molding plates (bases) that house the cavity, sprue and runner systems, ejector pins, and cooling channels, as shown below. The mould is essentially a heat exchanger in which the molten thermoplastic solidifies to the desired shape and dimensional details are defined by the cavity. A list of terms and a pictorial of their position on a typical mould is shown in Fig. 2.12.

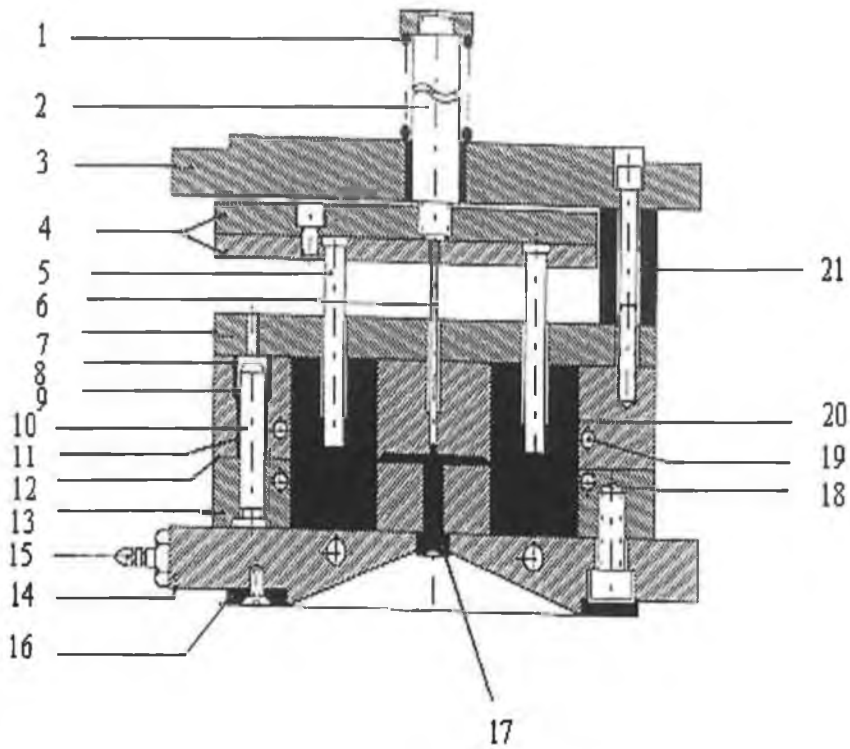


Fig. 2.12: Type of mould [48].

The moulding is completed in the following keys as shows in Table 2.2.

Table 2.2: Shows the part of moulding [48].

No.	Part of Mould	No.	Part of Mould
1.	Compression sring	12.	Parting line
2.	Ejector bolt	13.	Cavity retainer plate
3.	Movable clamping plate	14.	Stationary clamping plate
4.	Ejector and ejector retainer plates	15.	Plug for cooling line connection
5.	Ejector pin	16.	Locating ring
6.	Central sprue ejector	17.	Sprue bushing
7.	Support plate	18.	Cavity line
8.	Straight bushing	19.	Cooline line
9.	Cavity retainer plate	20.	Cavity insert
10.	Leader pin	21.	Support pillar
11.	Shoulder bushing		

• ***<u>Two-plate mould</u>***

The vast majority of moulds consist essentially of two halves, as depicted Fig. 2.13. This kind of mould is used for parts that are typically gated on or around their edge, with the runner in the same mould plate as the cavity.

• ***<u>Three-plate mould</u>***

The three-plate mould is typically used for parts that are gated away from their edge. The runner is in two plates, separate from the cavity and core, as shown in figure 2.10. From a machine perspective, (see Fig. 2.8), the cycle commences with the injection stage, during which the mould is filled; a holding stage where the mould is brought up to pressure and the materials allowed to cool. This is followed by mould opening, component ejection and mould closing stage.

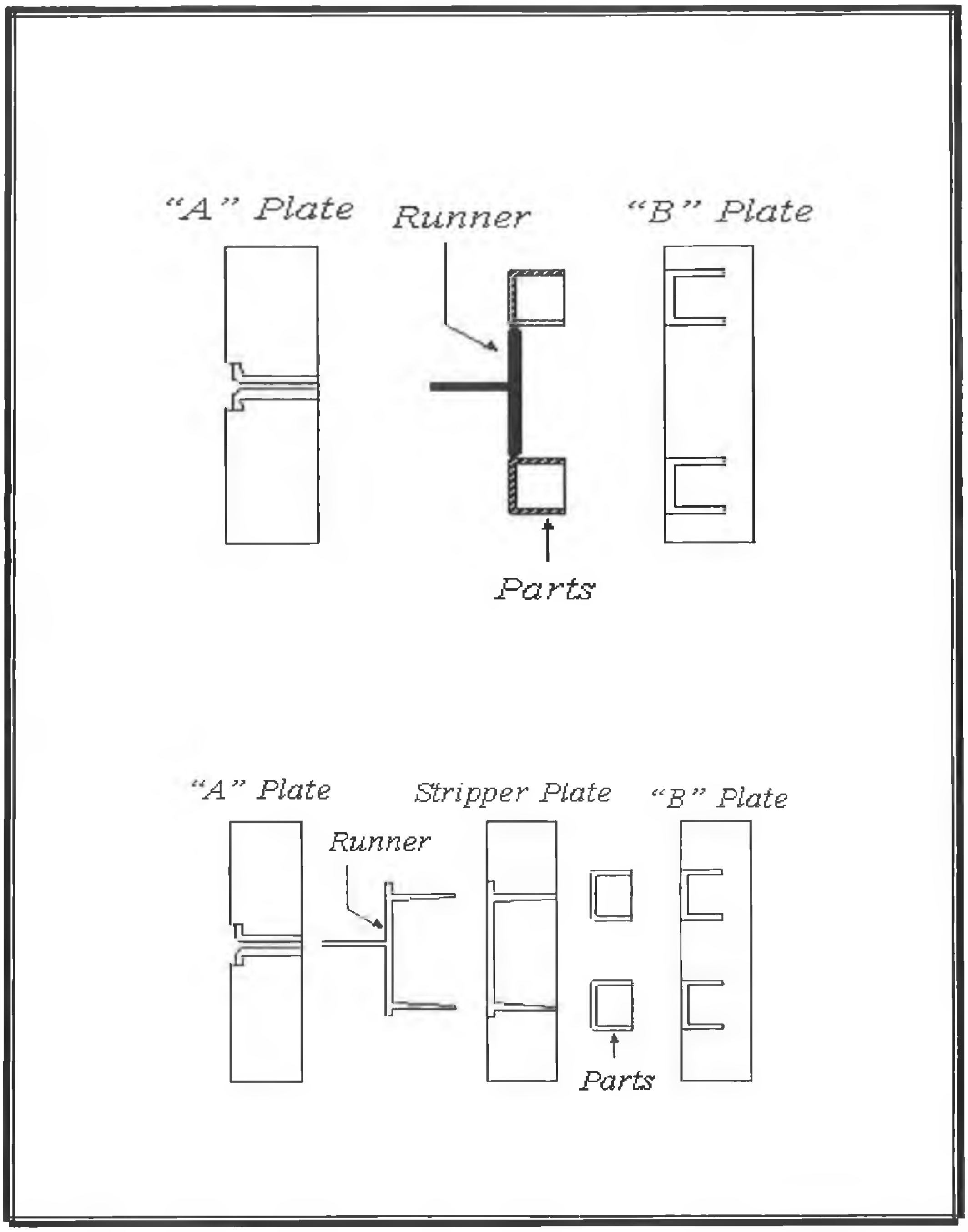


Fig. 2.13: Two and three-plate mould [45].

The proportions of both the cycle and profiling as shown are indicative of the time spent on each stage in the cycle. The injection moulding process is completed in the following stages [55]. Fig. 2.14 shows the typical injection moulding cycle.

- *Mould Closing:* This stage should be as quick as possible, but not so fast as to cause damage to the parting surface of the injection mould.
- *Mould Filling ;* The plastic melt is forced to fill the cavity of the mould.
- *Mould Packing*; After the plastic is injected, the pressure is increased to consolidate the plastic in the cavity.
- *Cooling ;* This stage consists of cooling the plastic from its injection temperature to its ejection temperature.
- *Ejection;* In this stage the mould is opened and automatically ejected.

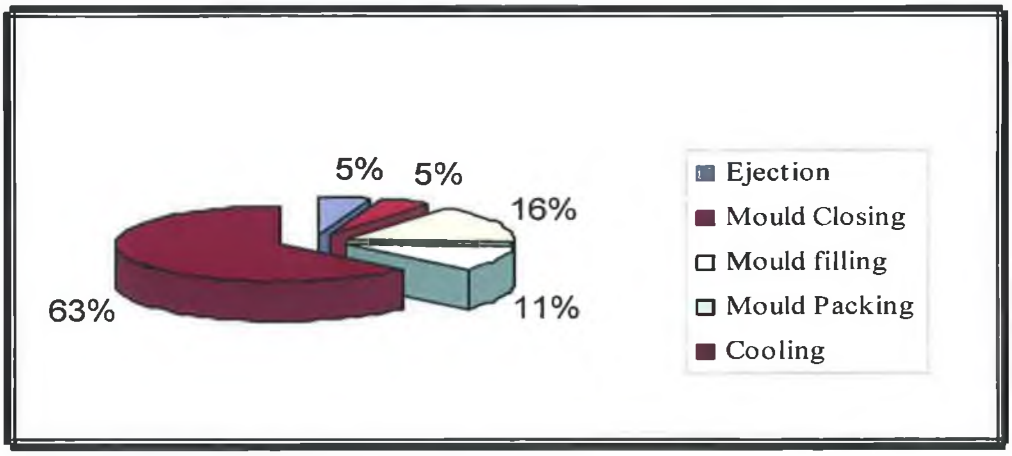


Fig. 2.14: Typical injection moulding cycle [55].

During each of these process stages, it is necessary to control the dominant process parameters in order to produce acceptable moulded products [55]. The main parameters that influence the process fall into four categories; barrel temperature, nozzle temperature, mould temperature and screw rotation. These are the process parameters that affect the products quality as shown in Fig. 2.15 [56].

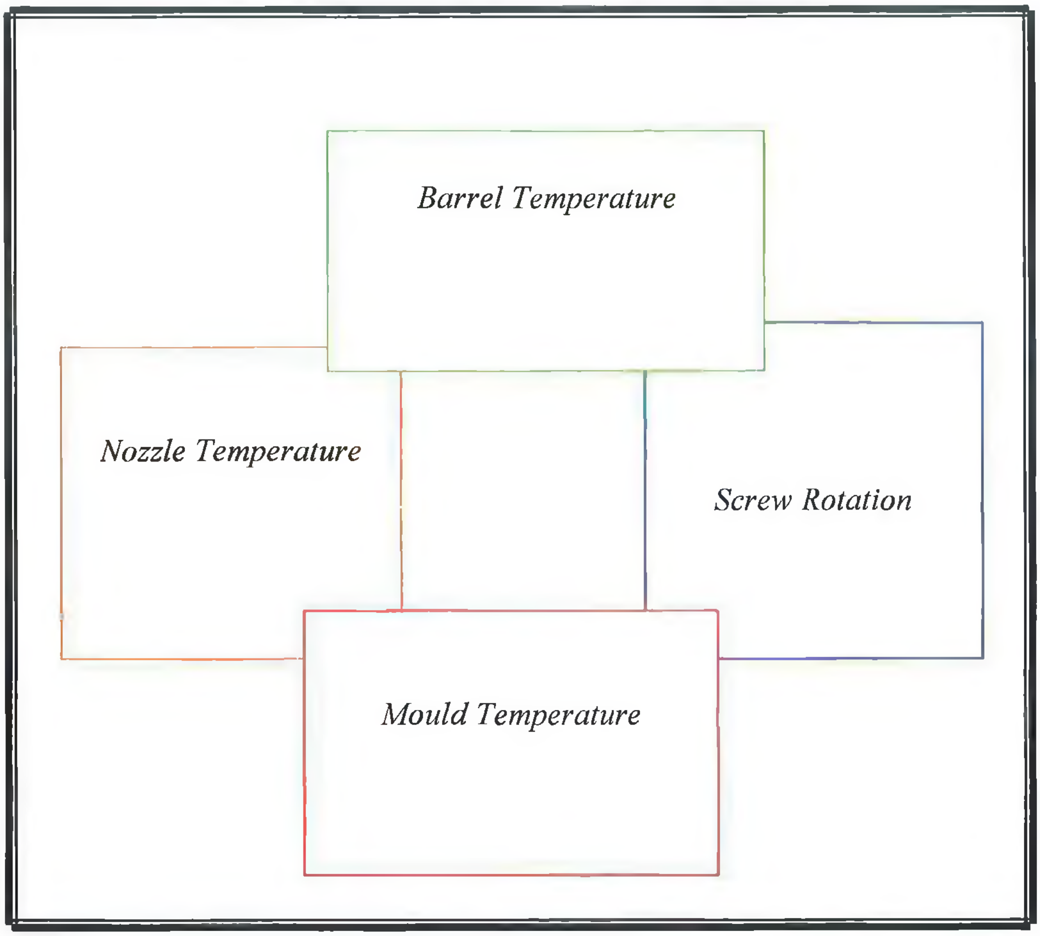


Fig. 2.15: Primary injection moulding parameters [56].

2.9.3.1. Heating stage of the injection moulding process

During the heating stage, the plastic materials in the barrel is heated by electrical band heaters and where applicable, friction arising from screw rotation. The most important temperature is the actual melt temperature, the temperature where the materials must be heated to before it is injected into the cavity. All materials have a range of temperature at which can be efficiently processed and still maintain their optimum mechanical properties. For amorphous materials, which actually melt, the range is smaller [57]. Most injection moulding machines achieve this melt temperature by gradually heating the materials as it moves from the rear of the barrel towards the nozzle.

2.9.3.2. Filing stage of the injection moulding process

During the filing stage, the molten materials are forced either by the plunger or screw through the nozzle of the cylinder into the mould. The molten plastic is directed through a runner system into the actual mould cavity. As the material enters the cavity, a frozen layer develops upon contact with cooler mould walls [58]. During filling, the materials in the central core continues to flow generating frictional heat which is conducted across the frozen layer to the mould wall, Initially the conduction of heat across the frozen layer is rapid as the layer is relatively thin. This conduction allows more materials to solidify, increasing the frozen layer thickness. An equilibrium condition is reached when the frictional heat is generated at the same rate as it is dissipated across the frozen layer. These effects can be demonstrated experimentally by variation of the injection rate between cycles. The pressure, under which the materials are injected, is referred to as the injection pressure and is determined by the viscosity of the materials and the flow rate required to fill the mould. [54]

2.9.3.3. Packing stage of the injection moulding process

The packing stage comprises of two phases, pressurisation and compensation [58]. During the pressurisation phase, the plunger or screw continues to move forward, forcing additional materials into the mould. This is possible because molten plastic is compressible, and with the injection pressure it is possible to inject molten materials into the mould. The applied pressure is called the holding pressure and is applied to a cushion of materials in the barrel that transfer to the mould by the connection nozzle to solidify plastic products [59].

2.9.3.4. Cooling stage

During the cooling stage the materials just inside the frozen layer, which is subject to the maximum shear stress, freezes. The materials in the centre of the core solidify at a slower rate and are subjects to lower shear stresses. The combined action allows the materials to relax, typically, reduced orientation is observed towards the centre of the cavity [60, 61]. Fig. 2.16 shows injection moulding cycle stage.

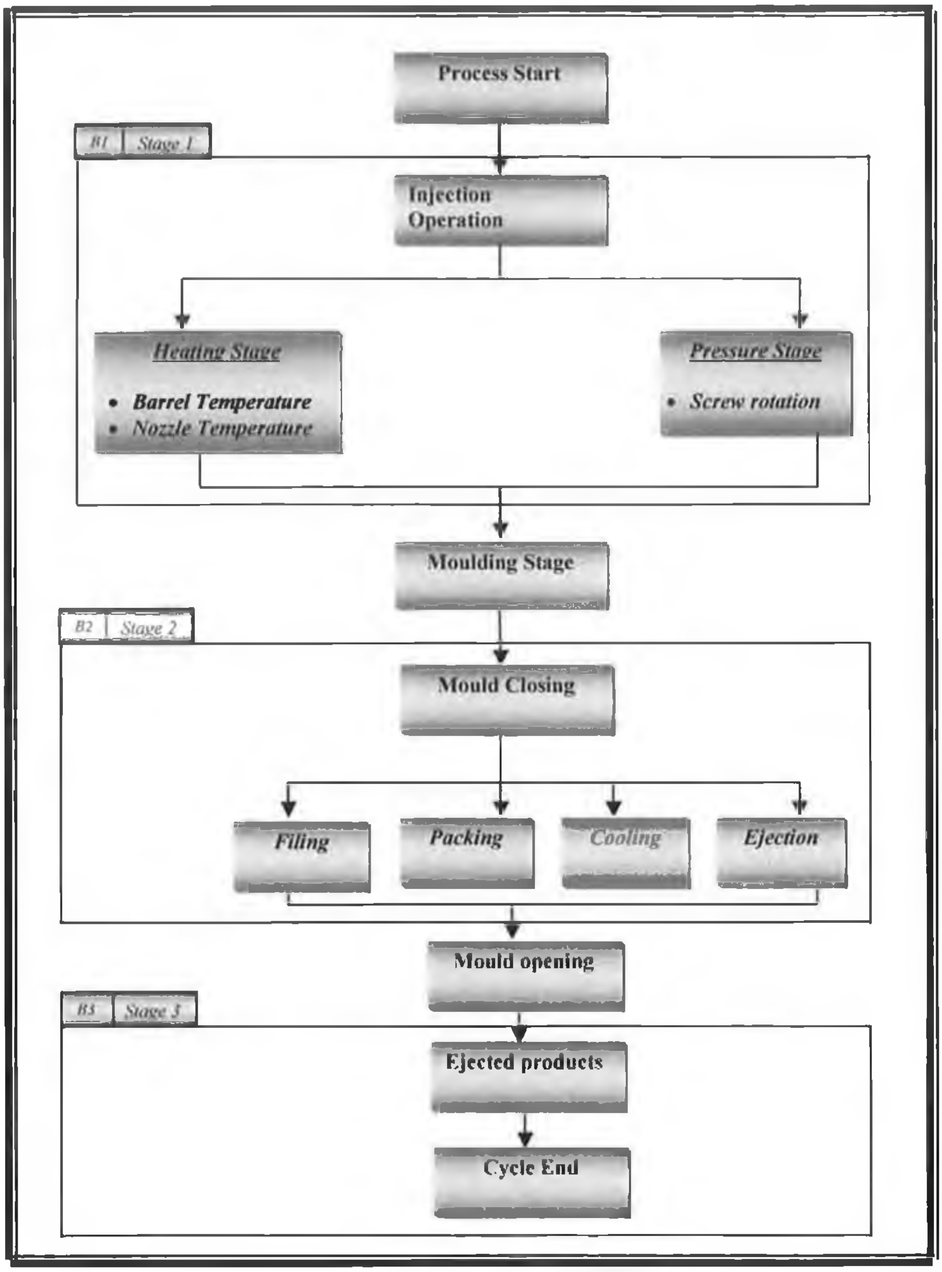


Fig. 2.16: Injection moulding cycle stage.

2.10. Review of some Previous Studies on Recycling Process of Mixed (PP)

Recently, mixing raw plastic materials with the recycled materials would improve the product mechanical properties, which would contribute in clear environment [62-63]. The approaches of mixed plastics materials were found to give better mechanical properties [64]. Poor mechanical properties are most to achieve when recycling the plastic material twice or more [65]. The percentage of raw material in the mixture with the recycled, and the injection moulding process parameters such as mould temperature and barrel temperature, speed etc, are the main factors that would affect the quality of the final product [66-67]. The recycled materials have been correlated with the number of reprocessing steps and compared with those obtained by reprocessing raw materials of the same composition; the properties of the secondary material decreased with the number of mould steps, and the additions of raw materials to the recycled are responsible of obtaining excellent mechanical properties, in different plastic materials [68]. Fig. 2.17 shows recycled materials percentages for various types of plastic materials; thus it is apparent that PE is the most recycled material nowadays and PP has a quit high percentage of recycled material as well [69].

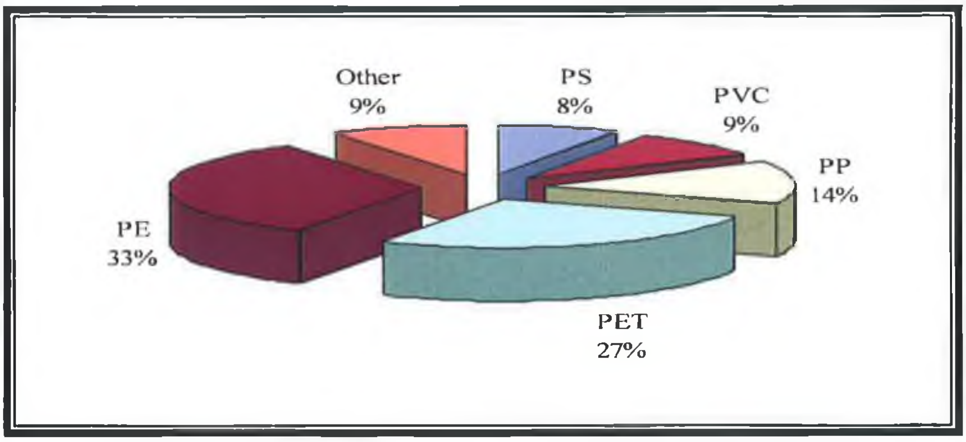


Fig. 2.17: Different materials that are usually recycled [8].

Martins and De Paoli [70] have presented the extrusion moulding for 13 processing. They were using formulations containing raw PP (H201) with the recycled materials polypropylene with an additions antioxidant. They evaluated the effect of processing parameters on the mechanical properties. The temperature was ranging between 180 and 210°C with screw rotation 50 rpm. The results indicated that the addition of raw material PP has improved the quality of the recycled materials. Agrawal, et al. [71] have investigated the effects recycling process on the mechanical properties by using extrusion moulding. The samples were prepared by mixing the raw polypropylene PP (H020SG) with recycled PP. The additional percentages of raw PP were, 60:40 (recycled PP: raw PP), the melt temperature ranges between 100 to 230 °C. The results indicated that the mechanical properties have been improved after the addition of raw PP material.

Aurrekoetxea, et al. [72] have discussed the use of recycling materials by using injection moulding machine model (SM6100) Moutell. The recycled materials PP were mixed with the raw PP plastic material. Scanning electron microscopy (SEM) was used to study the fracture surfaces; the effects of recycling on the fracture behaviour of PP and change in morphology were studied. The injection parameters used are melting temperature at 200°C and screw rotation 200 rpm. The results indicated that the increase in the yield stress is due to the higher degree of crystallinity of the recycled materials. Incarnato, et al. [73] has studied the effects of recycling process on the mechanical properties of PP. In this study the raw material PP has been added with the following to recycle PP (V/R, 70/30 and V/R 50/50) the relationship between process parameters and mechanical properties were investigated. The moulding temperature ranges between 210 and 240°C and speed of 80 rpm were used. Mechanical Properties testing were carried out by using tensile testing machine model (4301), with speed of 50 mm/min, Young modulus and yield stress were measured. The results indicated the empirical correlation between rheological properties and molecular structure parameters.

Tall, et. al [74] has developed a mixture of recycled PP with the raw martial PP, of injection moulding process. The parameters were: temperature ranges between 200 and 220°C, mould temperature 30 °C and speed 75 rpm. Mechanical properties were measured with an Instron machine model (5566). The mixture was a composite material consisting of 20% of PP raw material, 20% talc and 60% recycled PP. The results indicated that the mechanical properties were improved by adding 20% of raw materials.

Another author Tsenoglou et al. [75] have described the effects of the temperature of the second recycling on the mechanical properties of PP plastic material. The material was also analysed by using high performance liquid chromatography. The temperature ranges between 230 and 280 °C. Using the second recycling PP material reduced the final product quality. Espert, et al. [76] have studied the effect of cellulose fibres as reinforcements in recycling the PP plastic material. They mixed the PP plastic material with 40 wt % of cellulose at temperature ranges between 210 and 250°C with the gas flow of 80 ml /min. The results indicate that an improvement in the mechanical properties of PP could be obtained by the addition of cellulose fibres. Tiganis, et al. [77] have studied the effects of recycling of PP in several times. They investigated the effects of process parameters on the mechanical properties by using injection moulding at temperature ranges between 120 and 130°C, the desirable mechanical properties was achieved with no significant in the different recycling time.

Martins and De Paoli [78] have investigated mixing of raw polypropylene PP-H201 with the recycled PP. They have prepared samples by using injection-molding machine. RSM was used to optimise the mechanical properties of PP, The mechanical properties was achieved good product quality. Bonelli, et al. [79] have studied the effect of recycled PP (H503) in compatible mixture raw polypropylene and high density polyethylene (HDPE), by using extrusion moulding at temperature ranges between 190 and 215°C and screw rotation of 100 rpm. A mixture of 50/50, PP/HDPE was mixed. The results confirm good mechanical properties were obtained by using mixed materials. Phinyocheep, et al. [80] has discussed the mixed raw polypropylene with rejects rubber of (NR, SBR and BR). They investigated mechanical properties of three materials by using injection machine type HMC. The process parameters were; speed 70 rpm and temperature range between 190 and 220 °C. SEM was used to explore the morphology of the additional materials (75/25, PP/rejects rubber). It was found that impact strength was improved and the tensile strength was slightly decreased. Ross and Evans [81] have investigated the mixed polypropylene raw PP with addition of fibres. Mould temperature ranges between 180 and 190 °C. The results indicated that good mechanical properties were obtained with the fibbers addition.

Ref [82] has studied the effects of recycling on the mechanical properties of polyethylene terephthalate (PET). The raw material has been mixed with the recycled PET and without modifier (PP-graft-MA) to characterize the mechanical properties of the modified PET. The results indicated that the mechanical properties were improved by adding the modifier.

Bertin and Robin [83] have investigated the effect of mechanical properties on the recycling of a mixture of two plastic materials namely: high–density polyethylene (LDPE) and Polypropylene (PP). The study was carried out by compounding the usage of single-screw or twin –screw extruder. Mixtures of different raw materials have been prepared to compare mechanical properties of both raw and regenerated materials. The results indicated that the mechanical properties of mixed materials have been improved. Blom, et al. [84] have studied the effect of mixing raw PP with recycled high density polyethylene material on the mechanical properties. The investigation was carried out by using injection-moulding machine with different process parameters such as temperature between 190 and 210 °C, injection pressure of 3.22 MPa and mould temperature of 40 °C. The results indicated that a percentage of 50% of PP/HDPE would lead to good impact properties and poor tensile properties.

Dintcheva et al. [85] have investigated post-consumer film coming from green house, polyethylene (PE) were characterized to evaluate the mechanical properties, the experimental tests have been carried out in different recycling steps, by using extortion molding. The results indicated that the mechanical properties decrease with the number of reprocessing steps and also at secondary materials. Kallel et al. [86] have discussed the effects of mixing two plastic materials PE/PP on the mechanical properties, by using injection-moulding machine. The process parameters were: temperature ranges between 210 and 235 °C for the mixed PE/PS, also temperature range between 190 to 210°C for the PE/PP and mould temperature was 30°C. Scanning electron microscope (SEM) was used for the fracture surfaces of mistrals. Two mixtures of, PE/PS and PE/PP of 80/20 and 40/60 were prepared respectively. The result has indicated that the impact properties were increased for the mixed materials. Another author, Kim et al. [87] have studied two material (Ethylene Propylene Diene Monomer) EPDM and PP. PP was the commercial extortion grade of SK chemical (R930Y) and Korea Petrochemical (1088). The waste EPDM powder was obtained by the vulcanized EPDM, the compounds were mixed at a percentage of

70/30 and 75/25. The process parameters were; temperature ranges between 200 and 235 °C and extrusion speed of 50, 70, 100, and 150 rpm. The results demonstrate that the best mechanical strength was obtained at a percentage of 30 wt % PP at speed of 100 rpm. Rachtanapun, et al. [88] has studied the microcellular of HDPE/ polypropylene (H704-04) mixtures. They investigated the effects of process parameters on the mechanical properties by using injection moulding, at temperature ranges between 135 and 175 °C and speed of 100 rpm. Mixtures of HDPE/PP at various weight ratios (70:30, 50:50 and 30: 70 w/w) were prepared. Data were analysed by using statically (ANOVA) test with SAS software. The results show that the mixed materials HDPE/PP with weight 50:50 and 30:70 had improved the properties of the final product. Chang-sik Ha, et al. [89] have studied the effect of combining cellulose on the properties of raw and recycled materials of HDE, PP, PS and PVC (7/1/1/1), mixture was investigated in table kneader internal mixture, temperature was 180 °C and speed of 60 rpm. Tensile strength was measured by using tensile test machine model (HM25) with a speed of 10 mm/min. SEM was examine the fractured surfaces of the commingled mixed. The results indicate that the tensile strength was increased with the increasing the cellulose content. Santos, et al. [90] have investigated the product quality of a mixed plastic materials of PP with the high–density polyethylene (HDPE) which was processed by using extrusion moulding. It was found that a temperature range between 150 and 250 °C. Mould produces products with good qualities.

Ragosta, et al. [31] have studied the mixed recycle materials, ethylene–propylene copolymer with the raw PP plastic material. The results show that the mechanical properties such as elongation at break and impact toughness were improved by addition raw PP. Mehrabzadeh and Faramand [92] have studied the polyethylene's (PE) and PP. The samples were prepared by mixing them in (a Haake Buchler Rheomix 750), internal and then a compression-moulding machine was used. The hydrolytic was treated. SEM was used to study fracture surfaces of the plastic materials. The results indicate that the mechanical property such as tensile strength of the PP/PE was improved after hydrolytic.

Arroyo and Bell [93] have studied the effect of fibres on the mechanical properties of PP and ethylene propylene- diene (EPDM), 50/50 in PP/EPDM. An addition of fiber content around 10% was mixed, the moulding temperature ranges between 210 and 230 °C and speed of 40 rpm. Response surface methodology (RSM) was used in this study to predict and analysis effect of reinforcing fibres on properties. Tensile test was carried out using testing machine model (T-4301), and speed 50 mm/min. Fracture surfaces of several composites were observed on model a JEOL T-330A scanning electron microscope (SEM) to study the composite and interface morphology. The results indicate that the mechanical properties have increased with the addition of 10% fibres.

Santos and Pezzin [94] have investigated mixing of recycled polyethylene (PET) and raw PP with percentages of 3, 5 and 7 %(w/w) of PET fibres by using injection process moulding temperature ranges between 106 and 160 °C and screw rotation of 11 rpm. Tensile test was carried out using testing machine model (ISO -527) at speed of 50 mm/min, the tensile properties were determined using five samples for each composition. Impact strength and surface hardness were also implemented. SEM was used to examine the fibre dispersion. The results indicated that the addition of PET in PP does not change significantly the PP tensile strength but the impact properties of the PP have been significant increased. Kukaleva, et al. [95] have studied a mixture of raw PP with 77-wt% of recycle high-density polyethylene (HDPE). Injection moulding process was used to produce the samples. Mechanical properties such as, Young modulus, yield stress and elongations at break were measured by using an Instron testing machine model (4467). The fracture surfaces were conducted using SEM model JEOL JSM (840A). The results demonstrate that good mechanical properties have been obtained by using the above mixture. Albano and Sanchez [96] have studied the properties of mixing raw PP material and recycled high-density polyethylene (HDPE). The addition of 5% to 20% of PP was used to improve the quality of the finished products. Mechanical properties after compression moulding were measured by using a tensile testing machine model (1431-6), speed of 25 mm/min, and impact strength measurements were made. The results indicate that an addition of 5% PP improved the mechanical properties of this material.

Ismail and Suryadiansyah [97] have investigated the effects of recycled rubber (RR) and raw PP. The mechanical properties and morphological of PP was examined. An injection temperature of 190 °C and speed of 50 rpm were used. Tensile test were carried out to examine the properties using tensile testing machine with a speed of 50 m/min. SEM was carried out to gauge the tensile fracture surface of PP/RR mixed materials. The results indicated that the tensile strength and Young modulus of the mixed material was decreased with increasing rubber content in the mixed material. Kim et al. [98] have investigated the mixture of recycled ethylene propylene diene-monomer (EPDM) powder with raw PP plastic material. Samples were prepared by using injection-moulding machine at temperature ranges from 200 and 235 °C and screw rotation of 100 rpm. Samples were prepared by mixing EPDM and PP with ratios of 25/75 and 30/70. The mechanical testing measurement was carried out by tensile testing machine with speed of 50 mm/min. SEM was used to study the morphology of the mixed material. The results indicate that the mechanical properties of mixtures were improved by adding raw PP material. Vaccaro, et al. [99] have developed a model for the predictions of yield strength of plastic PE/PP. The moulding temperature ranges between 190 and 200 °C and speed of 50rpm were used. Three different sets of mixture were prepared with addition of polyolefin's. Mechanical properties were measured by using tensile machine with speed of 10 mm/min. The results indicated that the mechanical properties are in good agreement with the predicted model. Tall, et al. [100] have reported an experimental design using response surface methodology to predict the mechanical properties of the mixed polyolefin's with recycled materials produced by using injection. The results indicate that the developed model was accurate.

Blom et al. [101] have studied the effects mechanical property of mixed two material PP/HDPE. Injection moulding were using various process parameters to produce samples with different ranges, the barrel temperature ranged between 190 and 210°C, mould temperature was 40°C and injection pressure was 3.22 Mpa. The results indicated that the 50% mixed were achieved poor quality.

Cheng-Hsien and Wan-Jung [102] have investigated the effects of various process parameters on the characteristics of the weld line of an injection mould. Two materials PP (PRO-FAX6331-8) and HDPE (L H606) were used. The Taguchi method was applied to study the individual contribution of process parameters on the tensile strength. Four process parameters that can be independently controlled such as temperature, mould temperature, speed. The results indicate that the process parameters have slight effect on the tensile strength of the HDPE, microstructure of weld line is clearly observed. Wyser et al. [103] have studied the recycling of PP and silicon oxide-coated polyethylene terephthalate (PET). No significant improvement in the tensile behaviour of the mixed materials. Susan and selke [104] have investigated the effects of mechanical properties for mixtuer two material HDPE/PP. Mechanical properties were carried out using testing impact strength of mixed material, the samples has produced with various ranges of process parameters of injection moulding machine. The temperature ranges were between 135 and 175 °C and speed was 100rpm, the mixture was also prepared three weight ratios 70:30, 50:50 and 30:70. SAS software were employed to analyse the effects of mixing material. The results indicate that improve mechanical properties have been achieved at mixture range 50:50 and 30:70.

Scaffaro et al. [105] have studied the mixing of raw and recycled polyethylene (PE). In this study, they optimized the processing parameters such as temperature, composition, mixing speed and mixing procedure. Injection mould was used to produce the samples. The temperature range was between 170 and 210°C, the mixture was prepared with two percentages: 75/25 and 50/50. The results indicate that good mechanical properties have been achieved, also the process parameters has small effects on the products quality of the mixed material.

Ceni Jacob, et al. [106] has mixed the virgin ethylene propylene diene monomer (EPDM) and recycled PP with percentages of 70/30 EPDM/PP. SEM was used to examine the fractured surface. The results indicate that the mechanical properties of the mixture were superior. Chang-Sik, et al. [107] has investigated the effect of mixing three plastic materials on the mechanical properties. The three materials are: high-density polyethylene (HDPE), (PP) and polyvinyl chloride (PVC) and, HDPE/PP/PVC the mixing percentage is 8/1/1. Temperature of 180 °C and speed of 60 rpm were used. The results show that the mechanical properties were not significantly increased. Santana and Manrich [108] have investigated the effects of mixing two raw plastic material namely: (polystyrene-b-ethylen-co-butylene-bstryrene)(SEBS) with two recycled materials PP (H-603,opp) and high impact polystyrene (HIPS). The samples were fractured in liquid nitrogen and covered with gold before being examined with the microscope. The results indicate that good mechanical properties were achieved. Marco et al. [109] have studied a mixture of raw PP and recycled HDPE. The results indicate poor tensile properties and impact strength. Hwang et al. [110] have studied the recycling of a mixture of two materials PP and polystyrene. The results demonstrate that a product with good quality can be produced with these recycled materials. Santos et al. [111] have studied the mixture of raw PP with the recycled HDPE. The temperature was ranged between 150 and 180 °C and high 210 and 250 °C. The results indicate that after mixing the materials the product quality has been improved.

Finally, the present research considers the review of some works done with the estimation of recycling operation cost. Leu and Lin [112] have studied the cost–benefit analysis of the resource material recovery centre and the implications of this pilot program on the municipal solid waste disposal. It was concluded that cost–benefit analysis of the operation for the period of high raw material prices the recycling center can operate in the black by resale of the sorted recyclable materials alone.

Palmer and Walls [113] have studied three prices of recycled materials base policies for solid waste reduction such as; deposit refunds, advance disposal fees and recycling subsidies. The results indicate that the deposit refund is the least costly of the policies and that 7.5% reduction of the wastes has been gained. Rebeiz and Craft [114] have investigated the cost of recycled process of soft drink plastic PET which being collected from land filling, incineration, and recycling wastes to be concerted into useful products. Establishment of markets for the cost-effective use of recycled products are developed. It has been shown that the development of new construction materials using recycled plastics is important to both the construction and the plastics recycling. Hallberg et al. [115] have investigated the external cost of recycled materials developed by the commission of the European Union. The results indicate that a high degree of recycling is preferable, at least when considering external costs, because external costs of manufacturing of new materials and disposal costs are higher.

The theoretical cost saving arising from the recycling of raw materials found in municipal solid waste has been investigated by Lea [116]. The result indicated that the plastic materials have high inherent energy content while the energy cost saving from recycling is negligible, especially when sorting costs are considered. Diamadopoulos, et al. [117] have studied the municipal solid waste recycling, the model they suggested have considered all costs in present values. Namely: recycling of products, disposal of solid wastes economic benefits include revenues coming from the selling of the recycled goods, and those originating from extending the life of the landfill. It was shown that recycling brings about a significant reduction in the mean annual cost of solid waste management by 35%, as well as an increase in the life of the landfill by 6 years.

2.11. Chapter Summary

This chapter provided a comprehensive and up-to-date literature review on the subject of recycling process with a brief description of the injection mould machine as applied to polymers, and its accompanying definitions beginning from recycled of plastic materials to conduct reprocessing mixed polypropylene. This is followed by a discussion on the Design of Experimental requirement to optimise inputs process parameters in the process of injection moulding HM7; briefly discussed several tools and techniques, which have been used in the study. In line with the purposes of literature review, this chapter presented a review of existing literature in developing the theoretical understanding on the following topics with the specific purposes, in accordance to the aims of this research.

Finally this chapter compares the application of recycling process with some common thermoplastic materials, and also review what has been done within statistical design methods, FD. Following the preliminary research effort and literature review, the next phase of the research work will be the selection of research methodology for collecting information, which will be addressed in chapter three.

CHAPTER 3

DESIGNING OF SURVEY AND EXPERIMENTAL PROCEDURE

3. Research Methodology

3.1. Introduction

The preliminary research effort and literature review assist in determining the areas that need to be addressed in designing of the implementation framework. Following this, the most important phase of the research work comes follows; that is, the selection of research methodology for collecting information that will illuminate the topic. Therefore, it is essential to gain a good understanding of the issues surrounding the research methodology prior to initiating the fieldwork. The purpose of this chapter is to provide an overview of research methodologies and a justification for the selection of the methodologies implemented in this study to address the objectives of the research. The chapter starts with an overview of research in general and a description of research philosophies; since it is an integral part of any research work. This follows by making explicit descriptions of various terminologies relating to the research methodology that will be used frequently throughout the thesis. The chapter then presents the research methodology chosen (that is, a questionnaire survey research, in elaborating the research instrument and process, as well as the statistical analytical tools and tests used in this study). A survey is an important means to identify and understand people's attitudes, behaviours, and characteristics and to assess any activities in any field. On daily basis, the results of surveys are used by policy-makers, the media, and market researchers to describe the population, to make critical decisions and to analyse how various groups feel about a range of topics [121]. A survey is a systematic method used to collect data from more than one source in order to answer one or more questions typically arranged on a form called a questionnaire. This survey is the foundation for research on recycling of plastic materials. It includes a wide spectrum of recycling practices, as well as measures and indicators used in the industry [64]. The survey study combines topics discussing the state of recycling and analysis of processes successfully implemented in industrial practice [122].

3. 2. Research Process of This Study

The research process is usually described as a sequential process which involves several clearly defined steps. However, according to Blumberg [123] it does not necessarily require that each step is completed before going on to the next one. Despite these real life variations, the idea of a basic sequence is useful in developing a research project and in keeping things orderly as it unfolds. Some methodologists (Berger et. al) suggest that the use of research models [124]:

- Offer a guide that directs the research action, helping to reduce time and costs to a minimum.
- Help to introduce a systematic approach to the research operation, thereby guaranteeing that all the aspects of the study will be addressed and that they will be executed in the right sequence.
- Encourage the introduction of an effective organisation and coordination of the project.

Sarantakos [5] presented a research model in terms of steps and elements, as outlined in Table 3.1.

Table 3.1 - The research model [124].

No.	STEPS	ELEMENTS
1	RESEARCH PREPARATION	▶Selection of research problem ▶Defining research objective ▶Formulation of hypothesis ▶Selection of research methodology
2	RESEARCH DESIGN	▶Selection of sampling procedures ▶Selection of methods of data collection ▶Selection of statically tool
3	EXECUTION	▶Data collection
4	PROCESSING	▶Data inputs ▶Analysis of data view
5	REPORTING	▶ conclusion of the findings ▶ Interpretation of results

Another author, Punch [125] put forward another model of research, which shows research questions with hypothesis as shown in Fig.3.1. The research questions are the straightforward ones of '*what*' (what question is the research trying to answer? what is it trying to find out?) and '*how*' (how will the research answer these questions?). This model of research helps to organise the planning, execution and writing up of the research.

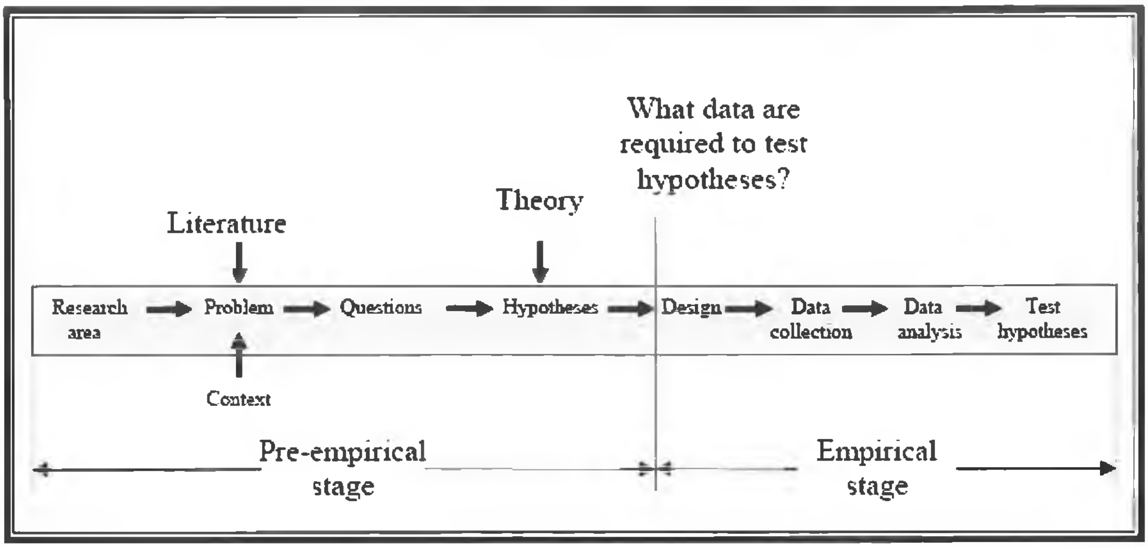


Fig.3.1: The research model – Punch [125].

In adopting the two research models as described in Table 3.1 and Fig.3.1, Fig.3.2 illustrates the research journey of this study. This provides a structured guidance to understand the link between each process and tasks at the various stages of the research work. The details of research philosophies, research methodology and research design employed in this study are discussed in the following section.

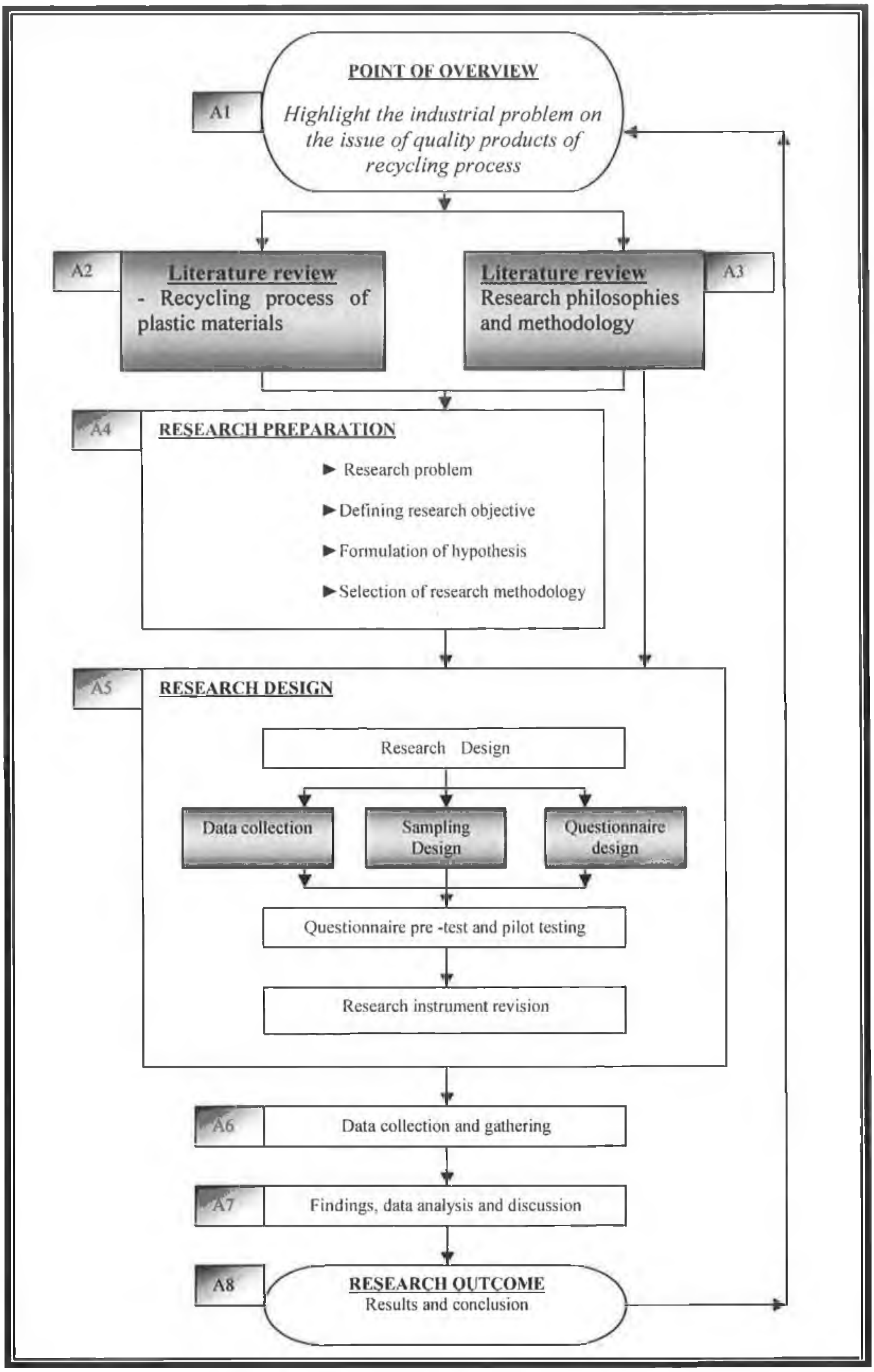


Fig.3.2: Summary of research process.

3.3. Research Methodology

In the literature, it is found that there exists, differences between authors description in the definition of a research methodology. Various researchers offer different definitions according to their own personal views. According to Sarantakos [124], a research methodology seems to be defined in at least two ways. In one form, methodology is identical to a research model employed by a researcher in a particular project. Another definition relates the nature of methodology to a theoretical and more abstract context.

Here, a methodology is supposed to offer research principles related closely to a distinct paradigm translated clearly and accurately. In terms of prominent operational features of a research methodology, Easterby-Smith et al [126] described that a research methodology will explain and justify the particular research strategy and methods used in the study.

Flynn et al [127] outlined a methodology and recommended the following steps be followed:

- Establish the theoretical foundation.
- Select a research design.
- Select and implement a data collection method.
- Analyse data and present work.

The process of the theoretical foundation establishment is discussed in the following section. Accordingly, the selection of the research methodology and description of the data collection method are described. The results and data analysis may be referred to in chapter four of this thesis.

3.3.1. Theory verification and theory building

Flynn et al [127] believed that there are two ways in which the theoretical foundation can be established, (such as, by 'theory verification' or 'theory building'). According to Wolcott [128], this is the distinction between "theory-first" and "theory-after". In theory-first research, it starts with a theory, deduces hypotheses from it, and designs a study to test these hypotheses. This is theory verification. On the other hand, theory-after research does not start with a theory. Instead, the aim is to end up with a theory, developed systematically from the data that has been collected. This is theory building (or called theory generation).A similar explanation was given by Flynn et al [8] in differentiating these two research purposes.

Theory verification is the approach used where the focus is on testing the hypotheses rather than analysing its origin. In using this approach, the hypotheses are constructed before the research starts and then tested when the data is obtained.

On the other hand, theory-building studies utilise information in different ways and the starting point is based on propositions, assumptions or problems rather than definite hypotheses. Information is collected in order to define the propositions, and thus they are grounded in data even before the actual theory building begins [125].

This study utilises the theory verification approach, as the research hypotheses were set down following a comprehensive literature review. The information collected during this research period was used to clearly define the research hypotheses and address the issues raised from the research objectives in section 1.6 of chapter one, in order to answer the research questions. The aim here is to substantial useful information and guidance for the recycle processing.

Historically, there has been a correlation between the purpose of the research (whether it is aimed at theory verification or theory building) and the approach used in the research (qualitative or quantitative). Quantitative research has typically been directed primarily at theory verification, while qualitative research has typically been more concerned with theory building [125]. While this correlation is historically valid, it is by no means perfect, and there is no necessary connection between purpose and approach, as pointed out by various authors for example, Hammersley [129] and Brewer and Hunter [130].

3.3.2. Exploratory Versus Explanatory

Before designing the research, a decision has to be made about the overall strategy and what the most useful data collection methods are. Marshall and Rossman [131] suggest that there are four different purposes for undertaking a study: (1) exploratory, (2) explanatory, (3) descriptive and (4) predictive all of which are employed here. Each of these asks different kinds of research questions, employs different strategies even though there is often considerable overlap between them.

This study is both exploratory and explanatory in nature as it is difficult to completely separate the two methods. Ryan, et. al [132]. Describes the distinction between exploration and explanation as rather ambiguous. On the explanatory side the research will attempt to explain the reasons for the practice being introduced and hence to draw conclusions regarding the link between the introductions of recycling processes in the different stages of the firms examined. The descriptive element of the research is also important as description is the foundation of knowledge according to, Preece [133]. As in highlighted this thesis, the descriptive and predictive, experimental work can then be used to construct an explanation or be fitted into an explanatory framework [134]. Identifying relationships between different variables will also achieve a certain level of prediction in which stage to obtain a good product quality.

Descriptive and explanatory elements represent two different levels of understanding. The distinction between them is particularly relevant to the purpose of a piece of research. Description is concerned with making complicated things understandable. Explanation, alternatively involves finding the reasons for things, events and situations, showing why and how.

A good way to make contrast is to say that description focuses on what is the case, whereas explanation focuses on why and how something is the case [125]. The descriptive element of the research is also important since "description is the foundation of knowledge" [133]. As depicted in this thesis, the descriptive work can then be used to construct an explanation or be fitted into an explanatory work [134].

Identifying the relationships or correlation between different variables will also allow a certain level of prediction to take place, although care will be taken in this study so as not "to assume that all observed relationships are casual" [132]. Pinsonneault and Kraemer [135] differentiated between descriptive and explanatory in terms of purpose for a survey research:

i) The purpose of survey research in description is used to find out what situations, events, attitudes or opinion are occurring in a population. It aims to describe a distribution or to make comparisons between distributions.

ii) The purpose of survey research in explanation is used to test theory and casual relations. It aims to ask about the relationships between variables.

This study use a combination of descriptive and explanatory approach in nature where the research will attempt to examine the aspect of recycle and the linkage between the recycle process and the product quality in each stage employee involvement in the companies examined.

3.3.3. Quantities versus Qualitative

Combining a qualitative and quantitative approach facilitates the acquisition of both experimental and survey data. The results of the qualitative and quantitative investigation allow the research propositions to be addressed in a rich and rigorous way, and serve to guide clearly the final conclusions.

This combination method is one based upon wide agreement. Researchers such as Bryman [136] Burgess [137] and Denzin [138] suggest that the best way to carry out research in areas where people are involved is to use a combination of qualitative ad quantitative techniques. Simon et al [139] assert that the use of both quantitative and qualitative techniques help to obtain a clearer picture of reality making sense, and answering many of the questions raised by the critics of traditional empirical research. Also believes in the strength of using more than one technical in a study and states that the various strategies are not mutually exclusive. The previous arguments have helped contribute to the decision to combine qualitative and quantitative methods in this study. A use of either quantitative technique alone in the thesis would not have been substantial due to the nature of the research questions and propositions. Relying solely on laboratory experimental work would have resulted in a lack of survey information on why and how quality changes in quality products at different recycled stages and the selling of recycled products measures were made.

3.4. Research design

There are many definitions of research design offered by various researchers or authors. Kerlinger [140] defined research design as a plan and structure of investigation so conceived as to obtain answers to research questions. The plan is the overall scheme or program of the research. It includes an outline of what the investigator will do from writing hypotheses and their operational implications to the final analysis of data. A structure is the framework, organisation, or configuration of the relations among variables of a study. A research design expresses both the structure of the research problem and the plan of investigation used to obtain empirical evidence on relations of the problem. According to Blumberg [21], the essential element of research design provides a guideline to the kind of answer the study is looking for, methods to be applied to find them, techniques to be used to gather data, kind of sampling to be used and how will time and cost constraints be dealt with [21].

3.4.1. Observation

An observation consists of the systematic gathering, recording and analysis of data in situations where the method is more appropriate (usually in terms of objectivity and reliability) and able to yield concrete results. The major advantage and disadvantage of observation as a research method is that it is very largely a 'real time' activity [141]. While the participant observers role offers a degree of insight into a situation unlikely to be found in any other method (particularly when the researcher is also counted as an employee of the company under investigation), the role can be both physically and psychologically exhausting, with issues of ethics and confidentiality to consider as well. At the other end of the scale the pure observer is rather detached from the situation under study, and often looked upon with suspicion by those being observed. Therefore, the researcher is unlikely to understand truly what is happening in the situation and why things happen. In addition, any form of observation entails (quite difficult to attain) high level of cooperation by many members of an organisation and the organisation as a whole, (for political as well as practical reasons) [141].

3.4.2. Experimentation

An experiment is usually a process of controlling all the variables so that by varying one while holding the others constant, the effect of the input variable upon the output variable can be determined [141]. It follows that a basic requirement for the conduct of an experiment is that one must be able to specify all the relevant variables. Experiments are usually undertaken to determine if there is a causal relationship between the variables under investigation.

3.4.3. Survey research

Baker [141] describes a survey research as a systematic gathering of information from a sample of respondents for the purpose of understanding and/or predicting some aspects of the behaviour of the population of interest. Consideration of these definitions indicates that surveys are concerned with:

- Fact-finding.
- Asking questions.
- Persons representative of the population of interest.
- To determine attitudes and opinions.
- To help understand and predict behaviour.

Pinsonneault and Kraemer [135] defined survey research as a quantitative method, requiring standardised information from and or about the subject being studied. It has three distinct characteristics. First, the purpose of the survey is to produce quantitative descriptions of some aspects of studied population. Second, the main way of collecting information is by asking people structured and predefined questions. Third, information is generally collected about a fraction of the study population, called a sample, but it is collected in such a way as to be able to generalise the findings to the population. Hart [142] states that the survey research is the most usual form of primary research undertaken and attributes its popularity to the following factors:

i) Survey research provides the researcher with the means of gathering qualitative and quantitative data required to meet such objectives.
ii) One of the greatest advantages of the research is its scope; a great deal of information can be collected from a large population, economically.
iii) Survey research confirms to the specification of scientific research; it is logical, deterministic, general and specific.

Alreck and Settle [143] considered that the main advantages of survey research are as follow; comprehensive, customised, versatile, flexible and efficient. Comprehensive means that the method is appropriate to almost all type of research, where as the other four advantages are closely interrelated and boil down to the fact that one can design surveys to suit all kinds of problems and budgets.

3.4.4. Data collection methods

The choice of data collection method, such as postal questionnaire, email questionnaire, telephone interview and face to face interview, is significant because it also affects the quality and cost of data collected [135]. The major methods associated with qualitative data collection are interviews, observation and these methods was using also in this study.

Diary methods, while the principal methods associated with quantitative data collection are postal questionnaire and online (web page-based) questionnaire surveys. Each method has a range of options, primarily linked to the objectives of the research, and each has its strengths and weaknesses. Table 3.2 summarises the main range of the major methods [144].

Table 3.2 - Main ranges for qualitative and quantitative data collection methods [144].

Methods	Main Range
Face-to-face interviews	Highly formalised and free-ranging conversation.
Observation	Observation alone, participant observation (Whether implicit or explicit).
Diary	Simple journal/record of events, personal journal recording perceptions, feelings, reflecting, insights etc.
Postal questionnaire	Factual and closed (e.g. yes/no).
Web page-based survey	Factual ,close-end.
Telephone survey	Spontaneous, scheduled appointment.
Survey (both interview and questionnaire)	Stratified sample, random sample or selected.

Moser and Kalton [145] described five methods of data collection as follows: documentary sources, observation survey, postal questionnaire survey, interviewing, and combinations of the above. According to Moser and Kalton [145] and Fowler [146], the choice of collection methods depends on the research topic, the sample frame, characteristics of the sample and resources. It is clearly one of the most important decisions in this study as it has implications for the rate of response, the survey instrument and the survey cost.

The survey research using postal and online questionnaire approach of this thesis is presented, as shown in Fig.3.3.

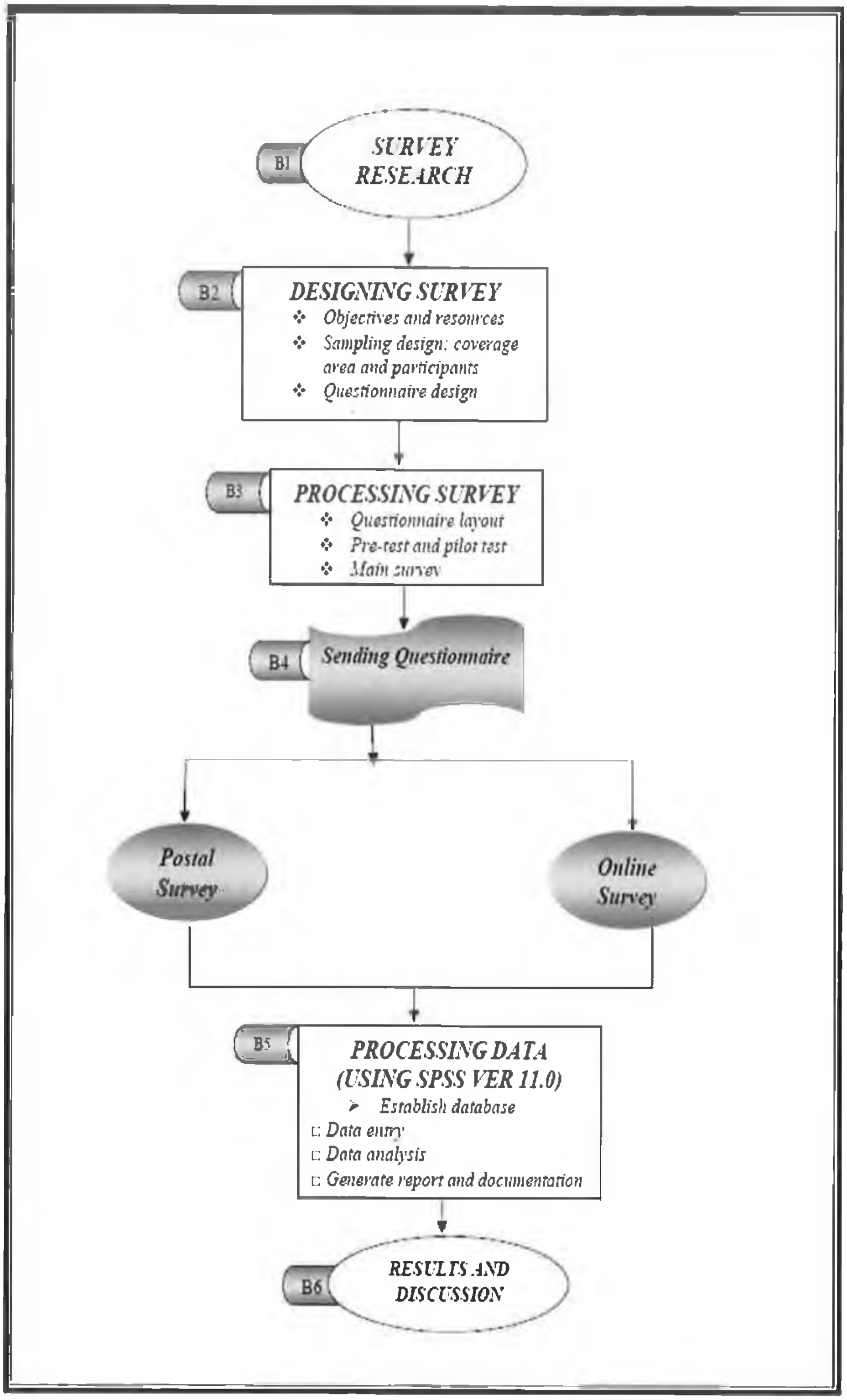


Fig.3.3: Survey research using postal and online questionnaire approach.

3.5. Designing the Survey Instrument

The survey questionnaire in this study was developed based on previous relevant empirical studies found in literature. Where possible, the study would make use of frequently used and tested measures and indicators as well as questions. These steps are necessary to address the issue of reliability and validity raised [146]. The questionnaire was destined to capture information about the recycle practices and the implementation level of the recycling process in plastic industry. The questions have been divided in to three sections as would be described below in the questionnaire content:

- Company profile.
- Recycling of plastic materials.
- Marketing and sale of recycled products.

This study concerns plastic materials arising as a result of scrap and runners. Also the survey questionnaire involves some traditional thermoplastic materials, such as PP, PS, PVC, etc and some of the designs key questions have been used in the three optimum recycle stage, first recycle, second recycle, and third recycle. Some survey-designed questions were related to some variables such as “Increased, Decreased, No Change“, communication techniques questions have been used for variable questions to obtain new information, which would be optimal for, the plastic industry.

3.5.1. Survey Objectives

A survey is a systematic method used to collect data from more than one source to answer one or more questions typically arranged on same form of questionnaire [146]. The survey is the heart of this study; to decide which recycled stage is the most efficient in production of top quality plastic. Recycling of plastic materials is widely used and processes are currently in place, to gather information from the plastic industry. Performance details from traditional thermoplastic materials have been used to prepare the required questionnaire on the recycling process. Comprehensive data has been collected from the plastic industry for analyses by Statistical Package for the Social Sciences (SPSS) software. This study used two techniques to obtain good responses. The first postal survey was carried out in the Republic of Ireland and United Kingdom. The secondly survey was conducted online. This study attempts to analyse obtained by the data survey from the plastic companies. The survey objectives are as follows:

- To determine the percentages of rejects from thermoplastic for each different plastic materials.
- To determine the percentages of recycling materials which have been used.
- To determine which process inputs increase or decrease the quality of recycling products.
- To determine which recycling stage has indicated increased or decreased quality of the recycled product.
- To determine what percentages are affected by the sale of recycled products.

3.5.2. Coverage of Survey

The target coverage, for this survey is the plastic manufacturing industry sectors.
It is worth noting that many companies are involved in activities appropriate to two or more industrial sectors. According to custom and practice using the Kompass system a company is classified according to the principal activity, for selected plastic companies from the Republic of Ireland and United Kingdom, under the following headings;

- Products and service group: Ireland and UK Kompass directory.
- Total number of companies: 200 companies.
- Description: Kompass database to selecte Ireland and UK companies independently. The Kompass system is a marketplace for business and has served European business and industry for some fifty years. Its usefulness has caused it to grow continuously from its origin in Switzerland to its present coverage of more than sixty countries in all continents [147] and [148].
- Nature of Business: Manufacturing of plastic.
- Number of employees [21-50; 51-100; 101-250; 251-500; 501upward].

- Mould equipment: injection moulding, extrusion moulding and blow moulding.

3.5.3. Limitation of postal questionnaire survey method

Disadvantages of this method of information gathering include the low response rate and lack of interaction between researcher and respondents [145]. Since a questionnaire survey should be viewed, as in this case, as an important instrument of research and a tool for accurate data collection, an effective questionnaire has therefore to be carefully designed, to eliminate as far as possible the disadvantages involved, and to elicit a positive response from the respondents.
According to Walker [30] researcher should be clear about the reasons why each question in a questionnaire is asked in justifying: i) the purpose of asking it; ii) its format; and iii) the manner in which data gathered will be analysed. Whitman [121] and Czaja and Blair [150] identified several important factors and procedures any questionnaire design should take into consideration when designing questionnaires, which are as follows:

- Question is clear and unambiguous,
- Wording of questions.
- Formatting the questionnaire.
- Length of the questionnaire.

These important factors are also cited as by Sudman [151] and Fink [152]. An inexperienced researcher would regard this as the easiest part of the survey design [152]. The research employed in this study involved designing a postal survey questionnaire and web-based survey and mailing them to the manufacturing companies in the plastics industry. As a general rule, experts recommend asking continuously "why am I asking this question" for every question and to be able to tie-in with the objectives of the survey. Apart from the above, the guidelines proposed by Sudman [151] and Fink [152].

3.5.4. Steps in questionnaire construction

Questionnaires are constructed in a very sophisticated and systematic way. The process of construction goes through a number of interrelated steps, and offers the basis for the research stage to follow. According to Sarantakos [23] the following are commonly mentioned steps of questionnaire construction:

Step 1: Preparation

In the first place, the researcher decides on the most suitable type of questionnaire and determines the way it will be administered. As well, a search of relevant questionnaires that might have already been developed by other investigators is undertaken. If suitable questionnaires are founds they can either be adopted for the study or used as guides in the construction of a new questionnaire.

Step 2: Constructing the first draft

The research formulates a number of questions, usually a few more than necessary, which directly relates to aspects of the research topic.

Step 3: Self-critique

These questions are tested for relevancy, clarity and simplicity, as well as for complying with the basic rules of questionnaire construction.

Step 4: External scrutiny

The first draft is then given to experts or to persons with practical expertise in the area of investigation, for scrutiny and suggestion. The critique offered by the experts will be considered and eventual changes are implemented.

Step 5: Pilot test

In most cases, a pilot study is undertaken to check the suitability of the questionnaire. A small sample is selected for this purpose and the respondents requested to respond to the whole of the questionnaire. The results are then analysed and interpreted.

Step 6: Revision

The pilot test usually results in some minor or major changes. If the changes are minor, the researcher will proceed to step 3.8.2.

Step 7: Formulation of final draft

In this final draft, apart from implementing the suggestion derived from the pilot test, the researcher works on editing the text, checking for spelling mistakes, instructions, layout, space for response, pre-coding and general presentation of the questionnaire to Sudman [151]. Apart from the problem of response error that has a bearing on the reliability and validity of the survey and consequently the research study, the problem of low response rate has always been a major cause of concern to any researcher. In general, it is believed that the factors that contributed to the relatively low response in this postal survey questionnaire are:

i) The length of the questionnaire, which contained a list of specific and many closed-form questions.

ii) The time pressures on the managers (that is, a lack of available time)

iii) A lack of knowledge regarding the questions being asked.

iv) Fearing that handing over such information may negatively impact on his/her company.

These reasons are similar to those often cited in literature for similar studies [153], [154], [155] and [156]. According to Moser and Kalton [145], it is not the loss in sample numbers that is serious, but the likelihood that the non-respondents differ significantly from the respondents. There are various types of non-response and some will be mentioned below:

i) Companies outside the population.

ii) Companies refusing to co-operate.

iii) Change of address or wrong addresses.

3.5.5. Questionnaire content

Basically, the questionnaire is a set of questions used to capture the experiences and the practices of the organisation with respect to its recycled thermoplastics. A total of twenty-three questions, which has been classified into three sections:

a) Section A: General information

This section contains five questions (Questions A1 to A5). This covers the information concerning company characteristics in terms of type of industry, ownership status, and number of years in operation, number of employees, methods of processing plastics, approximate turnover and achievement awarded. The industry or manufacturing group classification is similar as classified in KOMPASS [147] and [148]. A numbers of five digitals are used for coding of the responses in this survey.

The main purpose of these questions is to gather information about the company characteristics and background. The information from this section will be used to find if there is any correlation between company background and other variables measured such as level of recycling technology practice in Irish and UK in plastic industry.

b) Section B: Recycling of plastic materials

This section contains fifteen questions (Questions B1 to B16). It covers the information concerning the level of recycling, the integration level, use of advanced manufacturing technologies, as well as the obstacle and the motivation of implementing automation in the production line.

The information from questions B1 (invest in the recycling of rejects), B3, B4 and B7 (percentage of rejects), B5 (recycling introduced), B6 (level of recycling varies by unit operation) and B8 (input parameters) will be used to examine the level of recycle process and integration with several stages affected on the quality, cost, productivity. As for the questions B11, B12and B13 (type of quality, cost, productivity used), B10 (economic benefits), B14, B15 (reduce the quality), will be used to understand the complexity of production and recycled process technology used in the company. The data will be used to find if there is any correlation between the level of products and recycled practice as well as with other variables measured. This information is linked to the testing of hypothesis H1and H2. As for question B9 (obstacles of implementation of why recycling was not used in each year), the data will be used to understand the issue of implementation and employee resistance to quality change, as has been presented in chapter two.

c) Section C: Marketing and sale of recycled product

This section contains six questions (Questions C1 to C6). In the first part (Questions C1 to C2), it covers the information concerning these involved in the sale of products. The questions are referred to the (Questions A2, B1 and B2). In the second part (Questions C3), the percentage of profits comes from the sale of recycled products. It investigates the issue of troubleshooting methodology used, major breakdown occurred according to the area, technology and implementation stages, as well as the availability of recycle manual. The questions C 4 (How has the sale of recycled plastic materials affected sales), C5 (market benefits of recycling) relate with the (B10), question, and C6 (rate the cost of each recycling process at different stages. This information is linked to the testing of hypothesis H3. As for the questions concerning the several traditional of plastic materials such as (PP, PS, PVC...etc), that is, questions B5 to B13, C4 and C6, the limitation of these questions is four years as questions (B5, B9, B10 and C4, C5), from (2001 to 2004) were developed and adopted based from previous study on recycle implementation in manufacturing plants, conducted by (PACIA) in Australia [38].

The limitation of this question is that the answer will be described based on the respondent's opinion. Thus, this question could be very subjective and will be treated with caution [156]. The information from these questions will be used to examine problems or obstacles faced by the recycle function. In addition, the data will be used to examine how important the process factors are in affecting the overall function of quality of products. This information is linked to the testing of the third hypothesis, H3.

d) Re-contact

At the end of the questionnaire under *"RE-CONTACT"* section, the respondents were queried on their willingness to participate and be contacted again in case some further information was required. The respondents are requested to specify the preferable mode of further contact as well as: through: email, questionnaire or interview.

3.6. Processing the Survey

The questions included in the survey were reviewed to ensure that they were all linked to the objective of the study and are easy to understand. A cover letter (refer to Appendix A) was printed using the official letterhead of DCU Mechanical and Manufacturing Engineering School, Ireland, and signed by the head of school and the supervisor. The letter was written to explain the purpose and the benefit of this study to the participants. This letter also informed the participants that the information will be treated as strictly confidential. As a token of appreciation and to encourage better response rate, a lucky draw was conducted for all the respondents who completed and returned the survey questionnaire (refer to Appendix A).

3.6.1. Questionnaire layout

The postal questionnaire survey materials in question were printed in booklet form, (refer to Appendix A). The questionnaire has eight pages, which was divided into three sections: general information, recycling of plastic materials, marketing and sale of recycled product. A cover letter, a reply postage paid envelope and description of lucky draw competition also included in the envelope, which was delivered using a post.

3.6.2. Pre-test and pilot test

It is acknowledged that by its nature, the survey methodology selected to carry out this fact-finding or collection of information is difficult to administer, bearing in mind the many factors to be considered in carrying out a sound survey. Thus, in accordance with standard practice of professional survey bodies and due to its wide use in research surveys, pre-test and pilot test surveys are carefully carried out in this research. The purpose of conducting (a pre-test pilot test) was to test the questionnaire before embarking on the complete study. The aims of this pilot study were to test the approach used to solicit participants and to test the survey instrument itself. In fact, a pilot study was made to access content validity, where few questionnaires were administered to leading practitioners and academicians [157, 153].

In this study, a pre-test of the survey questionnaire was conducted on a number of occasions. Sample questionnaires were given and discussed to peers and academic staff in Dublin City University industrial experience, and have finally been revised by the research supervisor. The purpose of this approach was to identify if any obvious issues had not been addressed within the survey or if there were any mistakes in the questionnaire. This ensured that the questions were easy to understand and simple to answer. Different opinions and comments of the respondents were used to determine whether the final draft of the postal questionnaire was acceptable. As for the pilot test exercise, the survey questionnaire was sent to selected companies (ten companies in Ireland and UK). The main objective was to check the suitability and the relevancy of the questionnaire [23]. The respondents had also been asked to make their own comments on the design of the questionnaire. In this pilot test, comments were received from four respondents. There are several reasons for conducting the pilot survey [145]. These are as follows:

1. Test the adequacy of the Kompass database.
2. Show some proof of the variability of the subjects in question.
3. Provide an estimate of the probable non-response rate.
4. Test the suitability of the method of survey.
5. Test the adequacy of the survey instrument.
6. Review the questions.

The pilot survey, often dubbed as the dress rehearsal and a standard practice by many survey practitioners, was selected using a table of random numbers [158]. Based on this selection, ten companies were randomly selected from the target population list. The pilot survey was conducted on the Thursday, 17th February 2005. Closing date for the returns was fixed the 1st March 2005, giving the respondent a total of 12 working days to complete. Four questionnaires were returned, of which one understood and answered all the questions in questionnaires. This is shown in Fig.3.4. It is important to observe that the letter accompanying the questionnaire was signed by the supervisor and included also the official letterhead.

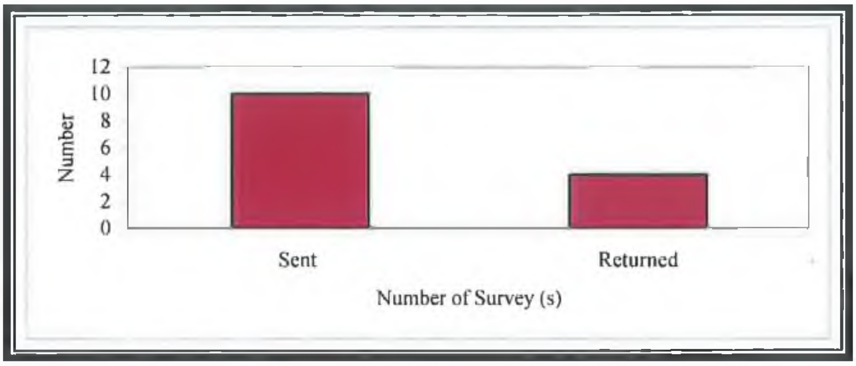


Fig.3.4: Comparison of responses in pilot survey.

3.6.3. Main survey

At the very heart of this research is the main survey. After all the questions were revised, the survey questionnaires were sent directly to the production or quality manager of each plant. It was sent to two hundred companies in Ireland and UK. The research employed in this study involves designing of a postal-survey questionnaire and mailing it to 30 manufacturing firms in the Republic of Ireland and another 170 were mailed to the United Kingdom. Similar were used for the web-based survey and this is discussed in detail fighter 3.5 which illustrates the responses rate of the surveys sent to Ireland and UK questionnaire

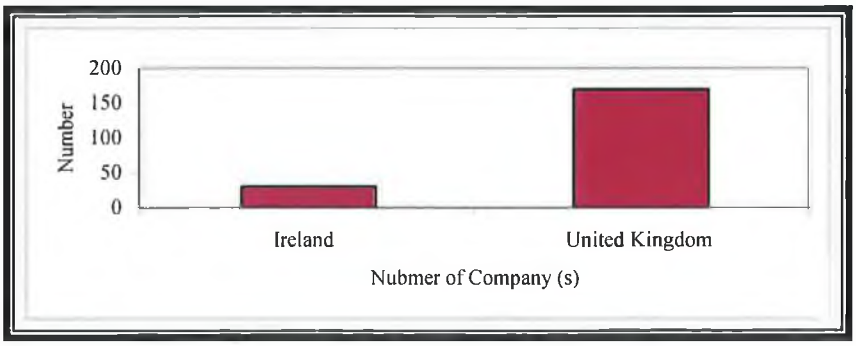


Fig.3.5: Shows the response rate of the survey sended to Ireland and United Kingdom.

A reminder questionnaire was sent by official letter (refer to Appendix A) two month's post initial questionnaire, to those who did not reply back to the questionnaire. Returned replies were collected directly from the school office for data key-in and data processing. Reminders of the first questionnaire were distributed after about a two-month period.

Data collection has been completed by survey methods and some statistical tools have been used for the data analysis; such as frequency, cross -Tabulations and correlation techniques, which have been used to identify the relationship between some variables. Pie and bar chart were plotted.

The main survey was conducted on the 2nd March 2005. Closing date for the returns was fixed for the 31st March 2005. Considering the large number involved in the plastic manufacturing industry in the Republic of Ireland and United Kingdom, the overall response was set low for the first survey. The companies who did not respond to the survey and questionnaire were sent reminders by official letter. Fig.3.6 shows the response number for first and reminder survey in both countries.

This method is more often used to collect information from several companies located around the world and may be used by one or more directors, depending on the size of the companies, to obtain comprehensive information on various topics. The advantage of this survey technique is the ability for asking more in-depth questions which may not be obtained by a personal interview. The benefit of using this method is the relatively short time to collect comprehensive information details.

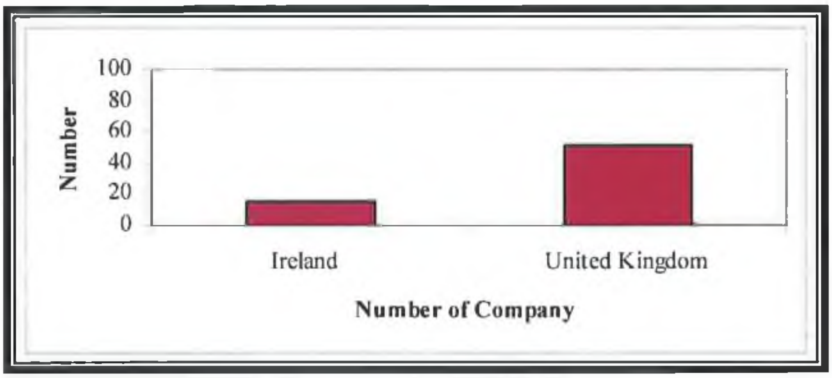


Fig.3.6: Shows the response number for first and reminder survey in Ireland and United Kingdom.

3.6.4. Response Rate

This study focuses on the data analysis of the plastic industry questionnaire. In this survey, the questionnaire itself was sent twice (main questionnaire and reminder, as mentioned above) to the sample population. Table 3.3 shows the total number of response rate, for Ireland and the United Kingdom. The response rate of the main and reminder questionnaire, in Ireland and the United Kingdom was a total of 15.5% and 18%, respectively, as shown in Fig.3.7.

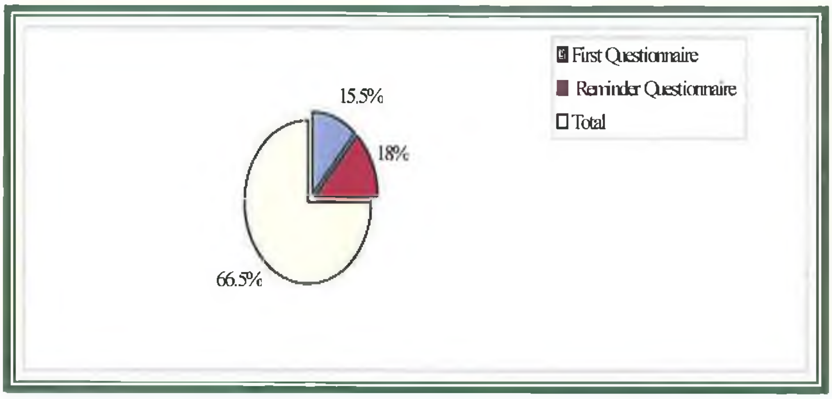


Fig.3.7: Total of response rate of the first and reminder questionnaire in Ireland and United Kingdom.

Table3.3: Response rate for Ireland and United Kingdom.

Type of respondents	Ireland	UK	Total
No. of Survey Sending	30	170	200
First Response	9	22	31
Second Response	7	29	36
No. of Total Survey Response	16	51	67
% of First Response	30	12.9	15.5
% of Second Response	23.3	17	18
% of Total	53.3	29.9	33.5
Total None Response	14	119	133
% of Total	46.6	70	66.5

In the traditional survey, a total of 200 manufacturing plastic companies were selected, and one questionnaire and one reminder distributed.

Fig.3.8 illustrates the total response rate of the traditional postal survey. The total was about 33.5%, as shown in Fig.3.9.

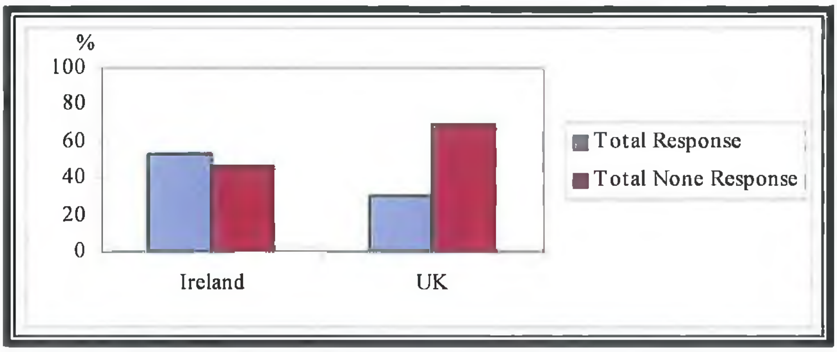


Fig.3.8: Shows the total response rate in Ireland and the United Kingdom.

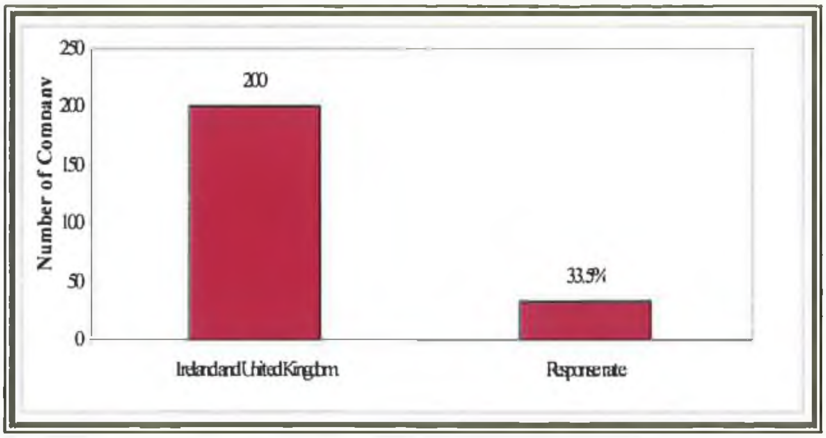


Fig.3.9: Response rate in the traditional postal of the first survey and reminder in Ireland and the United Kingdom.

3.7. Reliability and Validity

If a measuring instrument is developed or found in the literature, how do we assess its quality for use in research? To answer this question, according to Punch [22].

3.7.1. Reliability

Reliability is a central concept in measurement, and it basically means consistency. There are two main aspects to this consistency [141]. First, consistency over time means the stability of measurement over time, and it is usually expressed in the question; if the same instrument was given to the same people, under the same circumstances, but at a different time, to what extent would they get the same score? To the extent that they would, the measuring instrument is reliable, otherwise it is deemed unreliable. Second, internal consistency reliability relates to the concept-indicator idea of measurement. Since multiple items are used, the question concerns the extent to which the items are consistent with each other, or all working in the same direction. This is the internal consistency of a measuring instrument. Various ways have been devised to assess the internal consistency. The best knowns are the coefficient alpha techniques [141].

3.7.2. Validity

A second central concept in measurement is validity. One view of it's meaning is the question: how do we know that this instrument measures what we think (or wish) it measures? In this view, measurement validity means the extent to which an instrument measures what it is claimed to measure; an indicator is valid to the extent that it empirically represents the concept it purports to measure [141].
Content validity focuses on whether the full content of a conceptual description is represented in the measure. Neuman [159] explained that a conceptual description is a space, holdings ideas and concepts, and the indicators in a measure should sample all ideas in the description. In this study, to access content validity, a pilot study was made and questionnaires were administered to leading practitioners and academicians. Based on their feedback, the final version of the questionnaire was sent to the participants. Therefore an experimental pilot study was made and results were carrying analysed using Design of Experimental (DoE) software to predict and optimise the data obtained from injection mould HM7, furthermore using valid inference in some data of experimental work at different recycled stage to establish validation. In criterion-related validity, an indicator is compared with another measure of the same construct in which the research has confidence. In this context, Zeller [160] believed that no foolproof procedure to establish validity, and the validation methods used should depend on the situation. He advocated a validation

strategy: a valid inference occurs when there is no conflict between messages received as a result of the use of a variety of different methodological procedure.

3.8. Data Processing and SPSS Statistical Technique

3.8.1. Data processing

On collection of responses, the process of editing and entering data into the computer is initiated. Pre-coding of questions ends this task. There are four main steps: establish database; data entry; data analysis and generate of report and documentation. The data is divided into one file: Ireland and UK, so that the data could be analysed together.

3.8.2. Statistical Package for the Social Sciences (SPSS) Statistical technique

SPSS has scores of statistical and mathematical function. SPSS is one of the most popular statistical packages which can perform highly complex data manipulation and analysis with simple instructions and very flexible techniques to analysis data handling capability to select using several techniques such as descriptive statistical, contingency tables, reliability test, correlation, T-test, ANOVA, Regression and Logistic regression. The computer software used in the data entry and processing was SPSS (Statistical Package for the Social Sciences) for version 11.0. SPSS is one of the most widely available and powerful statistical software packages. SPSS is an integrated system of computer programmes designed for the analysis of social science data. The system provides a unified and comprehensive package that enables the user to perform many different types of data analysis in a simple and convenient manner. SPSS allows a great deal of flexibility in the format of data. It provides the user with a comprehensive set of procedures for data transformation and file manipulation, and it offers the researcher a large number of statistical routines commonly used in the social sciences [161].

In SPSS, data-management facilities can be used to modify a file of data permanently and can also be used in conjunction with any of the statistical procedures. These facilities enable the user to generate new variables, what are mathematical and/or logical combinations of existing variables, to record variables, and to sample, select, or weight specified cases [162]. SPSS enables the social scientist to perform an analysis through the use of natural language control statements. The text is a complete instructional guide to SPSS and is designed to make the system more accessible to users with no prior computer experience. SPSS will do three basic things for the user [161].

- It helps users to store and organise their data.
- It helps users to manipulate their data.
- It allows users to analyse this data using statistical procedures.

It covers a broad range of statistical procedures that allow the users to summarize data (that is, compute means and standard deviations), determine whether there are significant differences between groups, examine relationships among variables (such as, correlation, multiple regression), and graph results (such as, bar charts, pie graphs).

3.9. Statistical Analytical Tools and Analysis

Quantitative research involves measurement, usually of a number of variables, and across a sample. In addition to the usual descriptive statistics, simple frequency distributions, and cross-tabulations, SPSS used in this study contains procedures for analytical tools and analysis. It covers a broad range of statistical procedures that allows to summarise data (such as, compute means and standard deviations), test reliability and validity of the data, determine whether there are significant differences between groups, as well as to examine the relationships among variables (for both ordinal and interval data). In presenting the statistical procedures contained in SPSS, the focus will particularly be on the statistical procedures and techniques that are used in this study.

3.9.1. Statistical terminology

In discussing this study, certain technical terms and statistic terminologies will be used. Many of them are self-explanatory, and require no special consideration. However, there are terms or terminologies, which are part of a somewhat, specialised vocabulary of statistical research. They are discussed here, to clarify their usage [141,163]. These terms and their short description are outlined as follows:

• *Empirical*

Empirical is a central term in this thesis. According to Ragin [164], empirical means that something (or its impacts) is observable, where 'observation' is broadly interpreted. The essential idea is to use observable, real world experience, evidence and information as the way of developing and testing ideas. He refers "Empiricism" as a philosophical position, which sees observation as the foundation of scientific knowledge. Punch [141] preferred the general term "data" to describe this evidence and information in a research context.

• *Data*

The data is the measurements that are made on the subjects of an experiment.

• *Statistic*

A statistic is a number calculated on sample data that quantifies a characteristic of the sample.

• *Population*

A population is the complete set of individual, objects or scores that the investigator is interested in studying. In an actual experiment, the population is the larger group of individuals from which the subjects run in the experiment that have been taken.

• *Sample*

A sample is a subset of the population. In an experiment, for economical reasons, the investigator usually collects data on a smaller group of subjects that the entire population. Furthermore, conjunction with two group samples is used to determined data obtained from survey and experimental work.

• *Parameter*

A parameter is level of questions calculated on population data survey that quantifies the characteristics of the questions respondent. Furthermore a parameter is a number calculated on experimental data that quantifies the characteristics of the quality of experimental processes. As mentioned above, this research uses several parameters with three levels of recycled stages and each stage in the survey questions are has three scales.

● *Variable*

A variable is any property or characteristic of some event, object or person that may have different values at different times depending on the conditions. Three variables are used in the investigation of this research.

● *Independent variable*

The independent variable in an experiment is the variable that is systematically manipulated by the investigator. In most experiments, the investigator is interested in determining the effect that one stag has on one or more variables. Variable the recycling process is used as the independent variable in this research.

● *Dependent variable*

The dependent variable in an experiment is the variable that the investigator measures to determine the effect of the independent variable. Variable quality and marketing are the dependent variables in this research.

3.9.2. Frequency distribution

In addition to the mean, standard deviation and variance; frequency distributions are a useful way to summarise and understand data [141]. The individual scores in the distribution are tabulated, where absolute numbers and / or percentages may be used. The results can be presented as frequency distribution tables or as graphs such as histograms, bar charts, frequency polygons, pie charts or other graph forms. Fig.3.10 shows a snapshot of variable view of the SPSS page and Fig.3.11 shows a snapshot of a statistical analysis by using frequency distributions.

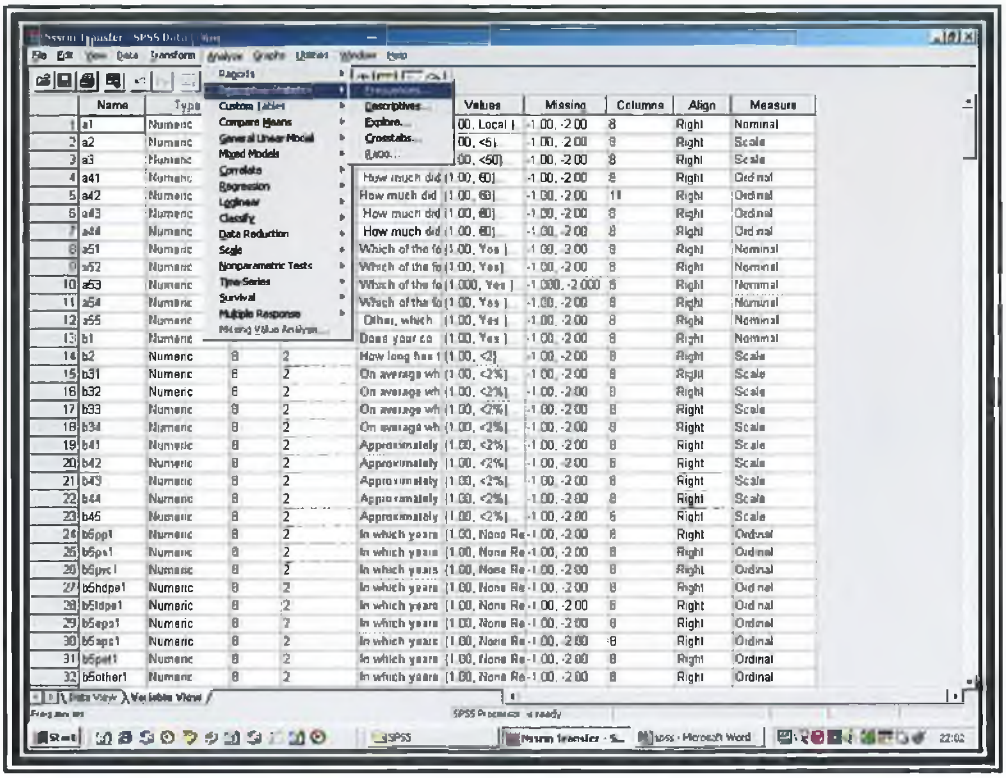


Fig.3.10: Snapshot view of variable view in SPSS software.

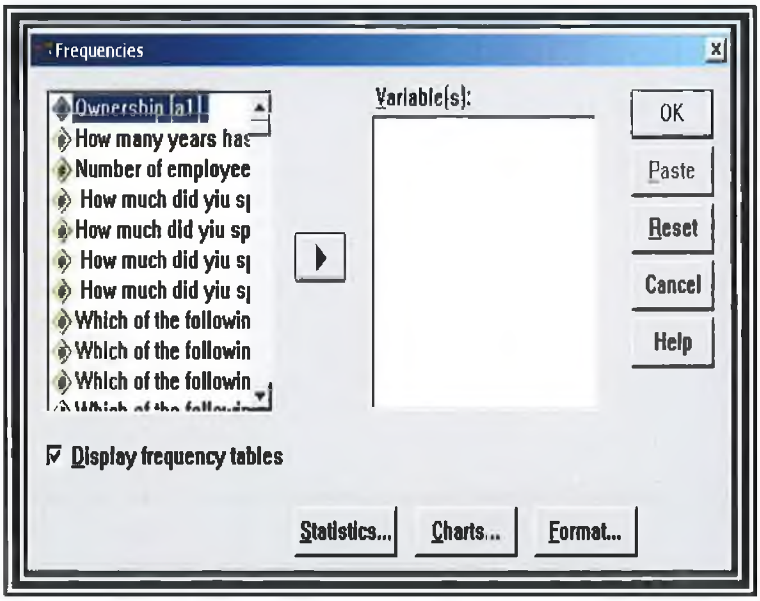


Fig.3.11: Snapshot view of frequency analysis in SPSS software.

3.9.3. Cross tabulation

A cross-tabulation is distributions statistical techniques using the SPSS software to summarise and interpret data. Using cross-tabulation to examine relationship between two or several variables at the same time (nominal or ordinal), cross-tabulation statistical tests are available to determine whether there is a relationship between variables in a table. Furthermore, frequency distributions techniques using one variable at a time are used in order to partially describe data. Alternatively, cross-tabulations used to analyse the relationships between independent and dependent variables, what is, between defined problems and factors contributing to those problems. A cross-tabulation is used in this research to examine questions to identify the aim of the study [165]. The individual scores in the distribution are tabulated, where absolute numbers and / or percentages may be used. The results can be presented as distribution cross-tabulation as tables row and column. Fig.3.12 shows a snapshot view of a statistical analysis using a cross-tabulation distribution.

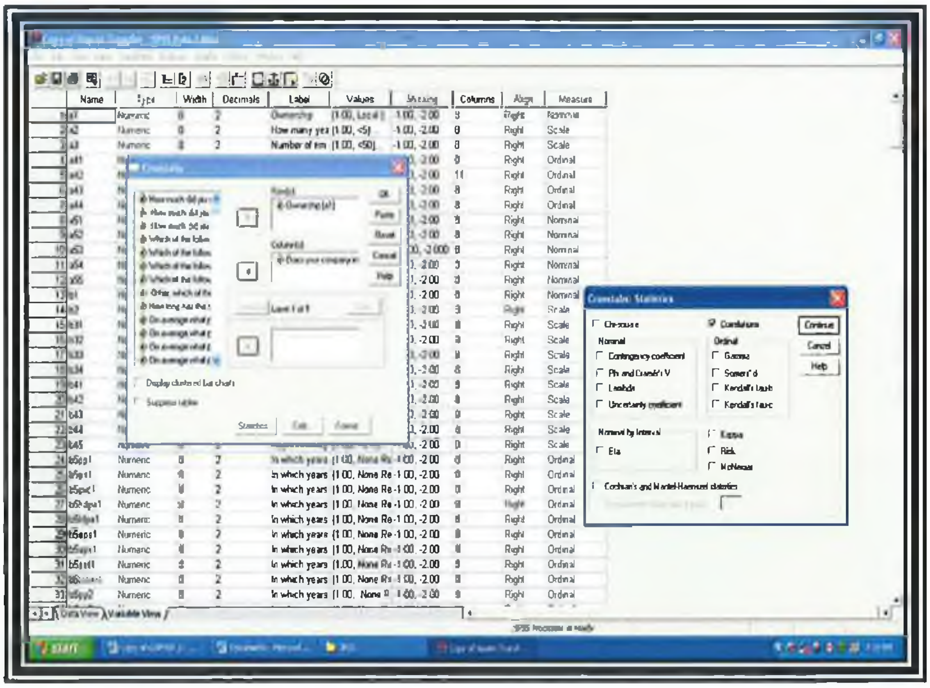


Fig.3.12: Snapshot view of cross-tabulation analysis in SPSS software.

3.9.4. Reliability test for survey instrument

In this research study, an internal consistency reliability analysis was performed for the elements by using the SPSS "Scale Reliability Analysis" procedure. Reliability tests on the survey instruments were performed using the guidelines provided by Saraph et al [166]. Cronbach's alpha (α) is one of the most commonly used reliability coefficients, which ranges in value from 0 to 1 to estimate the value of internal consistency [156,167]. Alpha is measured on the same scale as a correlation coefficient. The closer the alpha is to 1.00, the greater the internal consistency of items in the instrument being assessed [168]. The α value can be calculated from any subset of the elements and it can provide the best illustration as regard to internal consistency. The coefficient α was calculated for each elements. Saraph et al [166] It is also viewed that an α value of 0.7 and above are considered to be adequate for testing the reliability of the elements. Thus, it can be concluded that overall, the survey instrument has high internal consistency and reliability. Fig.3.13 shows a snapshot view of a reliability analysis using SPSS software as some questions exams reliability analysis, (refer to Appendix B).

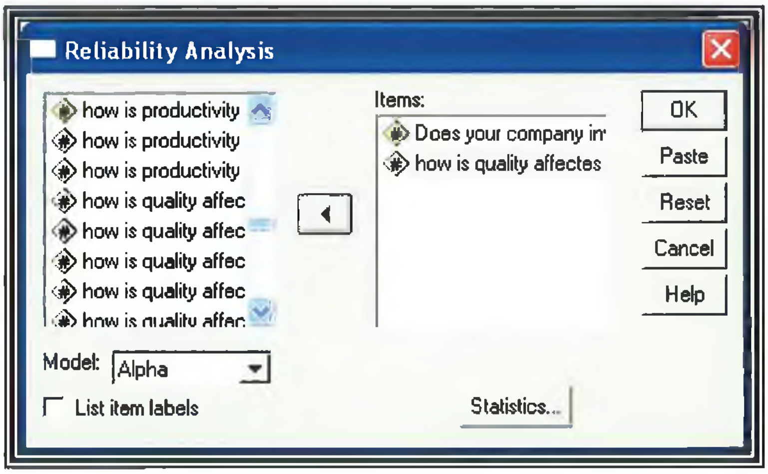


Fig.3.13: Snapshot view of reliability analysis using SPSS software.

3.9.5. Correlation analysis

Correlation is technical statistical analysis deals with the relationship between variables. If a relationship exists between two variables (a "predictor" and a "response"), then it may be possible to estimate the value of the response, by using the value of predictor. It is about determining the magnitude and direction of the relationship [169]. It provides the researcher with a technique for measuring the linear relationship between two variables and produces a single summary statistic describing the strength of the association; this statistic is known as the correlation coefficient [170].

• *Correlation coefficient*

Correlation is a topic that studies the relationship between two variables. A correlation coefficient can vary from "+1" (means the correlation is perfectly positive, that is, very a strong relationship between the two variables) to "–1" (means alternatively - the correlation is perfectly negative between two variables) whereas the relationship is nonexistent if the correlation coefficient equals "0" [162, 171].

• *Level of significance*

A correlation is said to be significant if it is greater than is likely to have arisen by chance. Two levels of significance are generally used; 0.05 or 5 per cent level and the 0.01 or 1 per cent level. The more significant a correlation is, the more confident one can be that there truly is a relationship exists between the variables [164, 171]. Multiple R, R^2, and the significance of the equation are also computed at each stage.

This statistical method provides types of statistical models including R-Square, analysis of variance (ANOVA) and coefficients panel [172, 173]:

- R is a multiple correlation coefficient between the observed and predicted values of the dependent variable. The values of R for models produced by the regression procedure range from 0 to 1. Larger values of R indicate stronger relationships.

- R-Square is determination coefficient (model summary) is used to define the proportion of variability in the dependent variable that can be explained by changes in the values of the independent variables. The values of R squared range from 0 to 1. Small values indicate that the model does not fit the data well. The sample R squared tends to optimistically estimate how well the model fits the population.
- The analysis of variance (ANOVA) indicates whether there is a significant linear relationship between the dependent variable and the combination of the independent variables (P-Test is used to test the null hypothesis that there is no linear relationship). The (P) statistic is the regression mean square divided by the residual mean square. If the significance value of the (P) statistic is small (smaller than say 0.05) then the independent variables do a good Job explaining the variation in the dependent variable. However, if the significance value of F is larger than say 0.05 then the independent variables do not explain the variation in the dependent variable.

3.10. Primary Data

In order to gather the required primary data, three main investigation techniques were considered in this research.

1. Personal interview and observation.
2. Mail questionnaire.
3. Experimental work.

- ***Personal Interview:***

The personal interview involves face-to-face contact between interviewer and respondent. This technique has the advantage of being the most flexible of the survey methods. During the interview itself, the presence of the interviewer permits flexibility in procedure. The questioning can be adapted to the situation; further explanations or clarifications can be requested if desired. It also has the major disadvantages that the technique has the cost of gathering the information and the time necessary to complete even a small survey. This technique was used as the beginner method in this study is to obtained comprehensive information related to this study. This data would be used for feedback and originations for second methods have been used to indicate ability and quality policy.

- ***Mail Questionnaire:***

This method is used to collect information from several companies located around the world and may be used by one or more directors, depending on the size of the company, to obtain comprehensive information on various topics. The advantages of this for survey technique is the ability to ask more in-depth questions which can not be obtained through a personal interview; the benefits of using this method is less time to collect comprehensive information over a short period of time. This study uses a mailed questionnaire to each selected individual company in the Republic of Ireland and United Kingdom. This method was established by one a two directors and also has been started as a pilot test sent to some Irish plastic company to complete the whole questionnaire in order to ensue the questionnaire is fully understandable and to get any suggestions for improvement in this study or to avoid any difficult questions. A survey of the literature has indicated that little work has been done to study the effects of recycle processes on the product quality of plastic materials implementation at several recycling stages. Most of the survey information survey was related to scraps collected from landfill and municipal.

- ***Experimental Work:***

This method is a very important and tool involves process inputs parameters from the injection mould, HM7. The experimental work investigates the effects of recycling injection mould processing parameters such as moulding speed, barrel temperature and nozzle temperature, on mechanical properties of recycle materials.

To carry out this work, different samples have been prepared from polypropylene (PP). The plastic materials have been recycled from raw materials in three stages. To carry out this optimisation, experimental design modelling has been applied. The data was plotted to show the optimum moulding condition to obtain the best properties. Experimental design modelling has been applied to study the effects of parameters during the injection moulding process. Recycling nature of plastic materials has been applied successfully to many traditional thermoplastic types.

3.11. Scaling of Responses

The outcome of this fact-finding survey is to compare the internal factors of the practices of each recycling stage. This requires careful consideration in the questionnaire design. Scales are ways of ordering possible responses to a question. There are four types of scales that may involve numbers, each with different characteristics that determine the suitability of applying statistical test, the types of scales are:

- Nominal scales
- Ordinal Scales
- Interval scales
- Ratio scales

1. A nominal or categorical scale is simply a set of categories, which may or may not be numerically coded. There are many questions in this survey, depending on the type of scale. An example of this is as follows:
   - *Question A5:* Which of the following methods of processing plastic are used in your company? And the possible responses offered are: Extrusion, Injection Moulding, Blow moulding, Film Moulding, and other. This type of question has limited application and is used sparingly .It is possible to code these responses using letters or numbers
2. Ordinal scale; ranking the choices but without quantifying the magnitude of the difference. Example:
   - *Question B13:* Which process parameters inputs reduce the quality of recycling products at each recycling stage? This type of question has limited application and is used sparingly.
3. Interval or Numerical scales; this has equal units of measurement that makes it possible to interpret not only the order of the scales but also the magnitude of the

distance between them. Example: question, B3 and B4: illustrated approximate percentages of rejects coming from the products? (Refer to appendix B).

4. Ratio scale; this is the most efficient method of measurement which has the properties of an interval scale and a fixed origin or zero points makes it possible to compare both difference in scores and the relative magnitude of scores.

   Example:

   - *Question B6:* Approximately how many times does your company recycle the plastic materials? As can be seen from the above measurement scales, all effort in designing questions must be directed to design specific and discriminating questions that can help in distinguishing clearly one respondent from the other.

3.11.1. Response Time

The first response from the postal survey arrived at the mailbox within 7 days of sending the questionnaire to the companies, and two month later the reminder questionnaire was sent to them. There was a month waiting time for the response to the reminder .The total response was approximately 33.5% .The period of time required for postal survey was about four months. In this study the postal survey method were percentages higher than the web-based survey (on-line survey) [145].

3. 11.2. Cost

In the traditional postal survey where the costs involved has been computed that is, paper, envelopes and postage costs, the total of cost for each questionnaire is about €2.20. This finding supports previous finding [174, 175], which concludes that the cost of postal data collection is higher than online methods used.

3.12. Questionnaire analysis

The questionnaire involves three sections, and every section divided into some questions to obtained assistance information for develop and improve implementation of recycles process in plastic industry. And there are links for each section on the questionnaire.

A) Company profile:

Question A 1: ***Ownership.***

This question seeks information about classified ownership in plastic industries: Answers are sub-divided into three groups; Local, Mixed and Foreign. The respondent ticks where applicable to them.

Question A 2: ***How many years has your company been manufacturing plastic products.***

This question enquires how long the company has been established in the manufacturing of plastic materials. It is generally belived that the longer a company has been in operation the more difficult it becomes to accept change to ensure that resistance to change is minimal since these may hinder the introduction of recycling and efficiency improvement initiatives .In this question, there are five options:

- Less than 5 years.
- 6-9 years.
- 10-20 years.
- 21-30 years.
- More than 30 years.

Again the respondent ticked the most appropriate option.

Question A 3: ***Number of employees on site.***

Some experts believe that the number of employees plays a crucial role in the development of quality. The quality of recycling is inversely proportional to productivity and efficiency of its employees. Larger organisations with a high out put of recycling ideally smaller of employees. In this question, there are six options:

- Less than 50 employees
- 50 -100 employees.
- 100-20 employees.
- 500-1000 employees.
- Over than 1000 employees.

- 200-500 employees

Respondent should tick the appropriate one.

Question A 4:** **approximately, how much did you spend training staff in recycling in recent years?

This question seeks to find approximately how much money has been spent in the company training staff in recycling in recent years, this question enquires about the level of money spent for the development of personal skills. Six options are provided over a four-year period (2001-2004).

- € 0
- € 1-4999
- € 5000-9999
- € 10,000-24,999
- € 25,000-49,999
- Over than € 50,00

The respondent should tick as applicable.

Question A 5: Which of the following methods of processing plastics, are used in your company?

This question seeks information on the kind of methods when are used in the plastic industry for each different thermoplastic material. The questions involve five options of mould process:

- Extrusion.
- Injection moulding
- Film moulding.
- Blow moulding.
- Others.

The respondent should tick as applicable.

B) Recycling of plastic materials:

***Question B1** Does your company invest in the recycling of rejects?*

This question is one of the most important questions. It seeks to cover information of the study, and this question is constructed so as to lead to other questions similar to question number B2.

This is to define the implementation and use of recycling in plastic industry. There are two options to this answer:

- Recycle.
- None.

And the respondent should tick as applicable.

***Question B2;** If yes, how long has the company been carrying out recycling?*

This question is raised to provide a comparison between question number A2. To this question, there are five options:

- Less than 2 years.
- 3-5 years.
- 6-9 years.
- 10-15 years.
- More than 16 years.

Respondent should tick as applicable.

***Question B3;** On average what percentage of rejects comes from the process products of fowling years in your company?*

This question seeks information on the average percentage of plastic rejects coming from the thermoplastic process using traditional plastic materials within the last four years from 2001 -2004. Five percentages have been used in this question over the four year period to which provides the majority percentage from the plastic process. This question is crucial to define problems in this study. Less than 2 %, 3-5 %, 6-9 %, 10-15 %, more than 16 %. The respondent should tick as applicable.

Question B4: ***Approximately, how many percentages of rejects come from the process of recycled products?***

This question is important to determine what percentages of rejects come from thermoplastic process in the different materials and this study is indicated in tonnes for responses in different percentages. This question also defines the problems of this study, related to question number B3; a discussion on the percentages of which come from thermoplastic materials. This question is expressed in five different tonnes value for thermoplastic materials:

- Less than 200 tonnes.
- 200-800 tonnes.
- 800-1500 tonnes.
- 1500-3000 tonnes.
- Over than 3000 tonnes.

And in this question, different percentage options are also included: Less than 2 %.

- 3-5 %.
- 6-9 %.
- 10-15 %.
- More than 16 %.

Again, the respondent should tick as applicable.

Question B5: ***In which year was recycling introduced for the following plastic materials?***

This question asks in which years recycling was introduced for the following untraditional thermoplastic, such as PP, PS and PVC. The question asks which materials are not recycled and are recycled over the four last years from 2001-2004 and also to quantify which plastic materials were used during these years. This question is critical to quantify responses for the next question, B6. In this question there are two options:

- Recycled.
- None recycled.

And the respondent should tick as applicable any unit, which has been recycled.

<u>Question B6;</u> How many times does your company recycle the plastic materials?

This question enquires how many times the company recycles the plastic materials. This question seeks information on the specific recycle process used in the plastic industry for each recycle stage. In this question there are four options; first recycling process, second recycling process, third recycling process and more recycling process. The respondent should tick where applicable.

<u>Question B7;</u> On average, in your company what percentage of each plastic material is recycled?

This question seeks information on the average percentage of each plastic material, which is recycled coming from the various recycle stage that is, first recycling, second recycling, third recycling. There are three recycling stages provided in this question and five percentages used in each stage for each plastic material such as, PP, PS, PVC. This question is important to define the percentages and totals for each plastic materials used in recycle. For each recycling stage five options of percentage are produced:

- 0%.
- 1-5%.
- 6-9%.
- 10-15%.
- >16%.

The respondent should tick for each recycling stage.

<u>Question B8;</u> In your opinion, which of the following input parameters reduce the quality of recycled products in your company?

There are many obstacles facing manufacturers in implementing recycle materials in the plastic industry. This question seeks information on the obstacles, which reduce the quality of recycled products in your organisation. There are three options to answer this question for each recycling stage for several plastic materials (PP, PS, and PVC).

- *Process:* An important factor in deciding to implement recycle materials is to organise technology systems. The process for recycling materials has important effect on the production of quality recycled products. This question is related to question number A5. The following methods of processing plastic; extrusion mould, injection mould, blow mould and film mould, and which ever process is used; internal factors such, as screw speed, barrel temperature, mould temperature. Mould shaping, nozzle temperature affect the recycle process and impact on the quality of products. This question is related to question number, B14 and B15.
- *Materials:* Normally, a large quantity of plastic rejects needed for the recycling process. Deformation testing on the recycled materials will decide the suitability of the business to introduce recycling. Also, carry out experimental work for mould plastic materials, PP, to determine the suitability stage of the recycling process. This question is related to question number B10 to the type of several plastic materials is recycled.
- *Personnel skill:* is one of the major obstacles for implementation in recycling materials, based an a process system if the organisation lacks competency and technically skilled, to affect the quality of the recycled products for different levels of recycling such as, first recycle, second recycle and third recycle .In order to over come this obstacle, the decision maker in the organisation has to organize training for staff before implementing a recycle process. The respondent should tick for each recycling stage.

Question B9: Choose the specific reason(s) why recycling was not used in each year.

Each factory or plant consists of several units and each one of these have a role in the production process. The decision to set up a recycling unit depends on several factors, such as quality, cost, value and staff skills. This question seeks information on the specific reasons as to why recycling was not used in each year from 2001-2004. And the following are the most likely reasons:

- Cost of recycling process.
- Change in properties of materials.
- Inadequate personnel skills.
- Cheap Raw material.
- Inability to distribution marketing.
- Reduction in quality.
- Low price sales.
- Decreased market in recycled products.
- Decrease quantity of productivity.
- Others

The respondent should tick where applicable.

Question B10: ***In your opinion what are the economic benefits of recycling plastic materials in your company.***

Normally the implementation of traditional recycling of thermoplastic materials increases gradually over the years due to development. This question seeks information on the economic benefits of recycling plastic materials within the last four years, and this question also relates to question number C5. In this question there are seven factors to answer, which affect the recycle plastic industry:

- Increased productivity.
- Maximizes Sales.
- Reduce process cost.
- Low cost products.
- Maximizes profits.
- More Competitive.
- Other.

The respondent should tick each year as appropriate.

***Question B11:** For each plastic material, how is Cost affected by the recycling process?*

The level of recycling in the plastic industry is largely dependant on the production process. The mould process has a direct effect on the end product; therefore the recycling of plastic materials uses several input parameters, which affect the process and thus cost. This question inquires about the cost of the recycling process for each plastic materials, such as PP, PS and PVC and also enquires about the relationship costs of various materials in each recycling stages. For this question, every stage has been selected with three options:

- Increases cost.
- Decrease cost.
- No change in cost.

This question is related to question number C6, to decide which plastic materials most affects the recycle process at different recycle stage. This question is used as a guide to the cost of plastic materials at different recycle stages.

The respondent should tick for each recycling stage.

***Question B12:** For each plastic material, how is Productivity affected by the recycling process?*

This study involves the benefit of plastics rejects arising as a result of scrap, sprues and runners. This question investigates the productivity of the recycling process for each plastic material such as, PP, PS, and PVC. Also this question inquires about the relationship between productivity at each recycling stage. Eight plastic materials have been selected at three recycle stages; each recycle stage has three options:

- Increases productivity.
- Decrease productivity.

This question is related to question number C5, to decide which plastic materials has more productivity from the recycle process at different stages. This question is used to indicate the productivity of plastic materials in different recycle processes. The respondent should tick for each recycling stage.

Question B13: ***For each plastic material, how is Quality affected by the recycling process?***

This question inquires about how the quality of plastic is affected by the recycling process, for each plastic such as, PP, PS and PVC. The relationships between products quality at different recycle stages were investigated. Eight plastic materials have been selected at three recycle stages; each recycle stage has three options:

- Increases quality.
- Decrease quality.
- No change.

The respondent should tick for each recycling stage this question is related to question number B5. This question decide which plastic materials are more affected by the recycle process at different stages, and this question is used as a guide for which recycle stage has the most significant impact on the quality of plastic materials.
The respondent should tick for each recycling stage.

Question B14: ***When choosing a process, which one of the following has an impact on your choice?***
As mentioned in question B8, there are many obstacles facing processes to implement recycle materials. This question seeks information on the obstacles to implementation of recycling materials in the plastic industry. This question is related to question number B15. This question has indicated many different process parameters on the plastic process and which process parameters have the most effect on the mould products. To answer this question, the following parameters are given:

- Screw speed.

- Barrel temperature.
- Mould shaping.
- Mould temperature.
- Venting.
- Injection pressure.
- Nozzle temperature.
- Hydraulic.
- Cooling.
- Moving piston rod.
- All of the above.

This question seeks information on which process, a parameters impact on the implementation of recycled materials. And is used to determine which factors are important to recycling. This question is compatible to question number B8, and also has selected some process parameters, which reduce the quality of recycled products in the plastic industry. The respondents are required to check all the parameters process, which applies in implementing recycling materials (such as, PP, PS and PVC). The respondent should tick as applicable.

Question B15: ***In your opinion, which of the following input parameters reduce the quality of recycled products in your company?***

This question is concerned with the process factors, which affect the product quality. The there are four options to select, including; Screw rotation; Barrel temperature; Nozzle temperature and Mould temperature. The respondent should indicate which of the above parameters reduces the quality of products for each recycle stage.

C) Marketing and sale of recycled products:

***Question C1:* Does your company sell recycled products?**

This question seeks information on the sale of recycled products. This question has two-answer option; Sell recycles products and do not sell recycle products. This question relates to question number C2. This question is limited to those selling recycled products in the plastic industry. The respondent should tick as applicable.

***Question C2:* If yes, how long has the company been involved in the sale of products**

This question enquires whether the company has been involved in the sale of recycled products and this question is also related to question number C1.This question also has a relationship to question number B2 and also a comparison to C2 and B2, to definite the period of the use of recycles. This question has five answers are options:

- Less than 2 years.
- 3-5 years.
- 6-9 years.
- 10-15years.
- More than 16 years.

The respondent should tick as applicable.

***Question C3:* On average what percentage of profits comes from the sale of recycled products?**

Usually in such companies there is a finance strategy to develop the manufacturing operation and to reduce the cost. The question aims to define the percentage of company profits from recycled products:

- 2%.
- 5%.
- 10%.
- 15%.
- 30%.
- 45%.

• More.

And the respondent should tick as applicable.

<u>Question C4;</u> How has the sale of recycled plastic materials affected sales, during the following years in your company?

This question investigates the increase or decrease of the company sale rates considering the use of recycled plastic materials, during 2001-2004. The respondent should tick for each year as appropriate.

<u>Question C5;</u> What are the market benefits of recycling in your company?

Normally, the implementation of recycling is part of the development of plastic industry. This question provides information on the market benefits on the use of recycling plastic materials over the last four years, and this question is related to question number B7. Nine variables to one or more, which affects the recycle plastic industry, are posed:

- Low price.
- Consumer Satisfaction.
- Increased Productivity.
- Maximizes Sales.
- Financial diversity.
- Reduced process cost.
- Maximizes profits.
- More Competitive.
- Others.

The respondent should tick each year as appropriate.

<u>Question C6;</u> How would you rate the cost of each recycling process?

This question seeks information on the relation between product price and the recycling process. Each recycle stage has three price options:

- Low price.
- Medium price.

- High price.

And this question relates to question numbers B11and B13. These questions are raised in order to give guidance as to which recycle stage attains the optimum price. The respondent should tick as applicable.

3.13. On –line survey

3.13.1. Introduction

Survey research has traditionally played an important role in many areas of the social sciences and business, such as, policy development, marketing and consumer research, health issues, educational practice, media, and political polling [176]. There are several methods that can be considered to collect data in survey research. Each has advantages and a disadvantage of classified methods of collecting data in survey research divided into; mailed survey, telephone survey, personal interview face –to-face, and web-based survey [177]. Over the last decade, electronic surveys have evolved from disk –by-mail survey, to e-mails with embedded or attached surveys and finally to web-based surveys posted on the internet [178]. With web-based survey, participants are usually notified by e-mail to participate in the survey [179]. Internet based technology, such as the world wide web (www) is fast becoming accessible to large segments of society. Usage is doubling every year with a current estimate of one in six people using the internet in North America and Europe [180]. In this research studying the field of recycling process of plastic materials in the plastic industry is implemented through data collecting, questionnaire survey post and web-based survey method as mention above. The two methods (paper questionnaire and web-based survey) are implemented.

3.13.2. Brief history of on-line survey

Beginning in the late 1980 and early 1990, prior to the widespread use of the web, e-mail was explored as a survey mode. As with the web, today, e-mail offered the possibility of nearly instantaneous transmission of surveys at little to no cost. E-mail surveys tended to resemble the liner structure of a paper survey and were generally limited in length furthermore, because e-mail surveys were primarily text-based. The only significant advantage they offered to increased response rates [181, 182]. The web started to become widely available in the early-to mid-1990, and quickly replace e-mail as the internet survey medium of choice. For convenience sample, the web also offered a way around the necessity of having to know respondents e-mail addresses [183].

3.13.3. Coverage of on-line Survey

The target population that is the population for which the results are required are some Irish manufacturing and United Kingdom companies within plastic industry sector. In order to ensure that the survey was easy to complete, a pilot study was undertaken in our department with how many participants. During the pilot testing phase, the average time to complete the on-line survey was about 10 minutes.

In order to ensure that the survey was easy to understand and complete by respondent. Fig.3.14 shows a snap shot of the online questioner and Fig.3.15 and 3.16 shows question page and thank page.

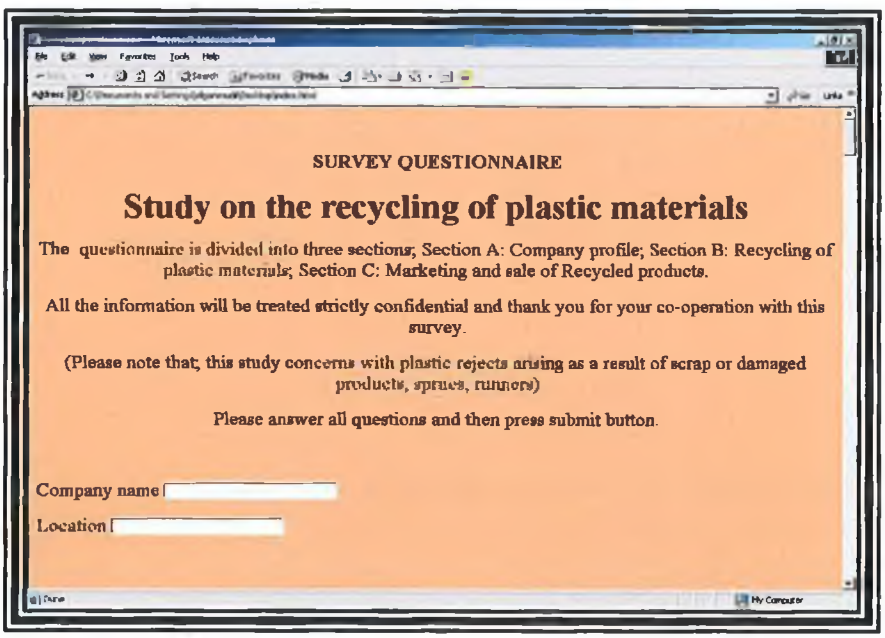


Fig.3.14: Snap shot view of online survey questionnaire.

This study used the <http://www.response-o-matic.com> website, which is a free time-saving form processor for html authors who want to add forms to their web pages. The link to the survey <http://student.dcu.ie/~elgamml2/> was sent to the respondents who were asked to complete the questionnaire on-line. Once the questionnaire was completed, the respondents clicked the submit button. Therefore, the contents of the questionnaire forms were directly sent to response-o-matic processing engine, which sends the answers to a specific email address.

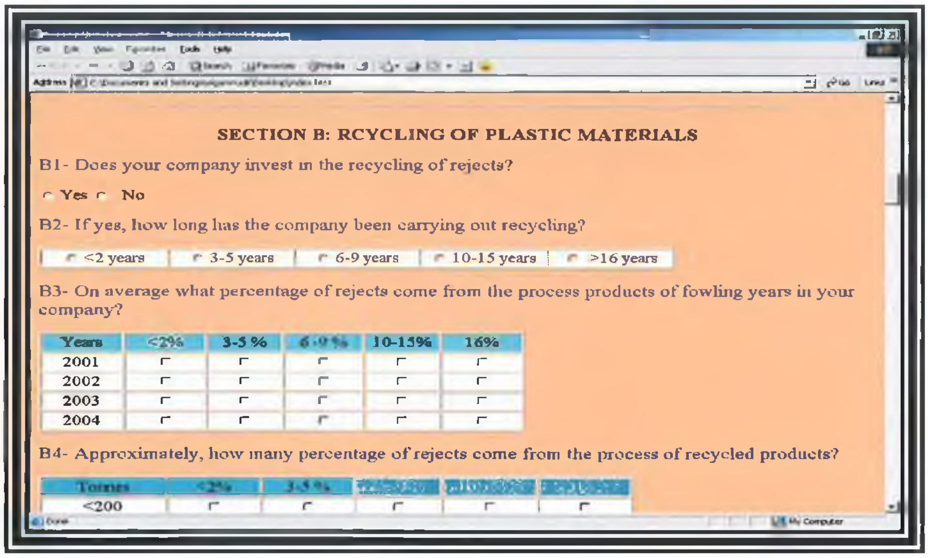


Fig.3.15: Snapshot view of question page.

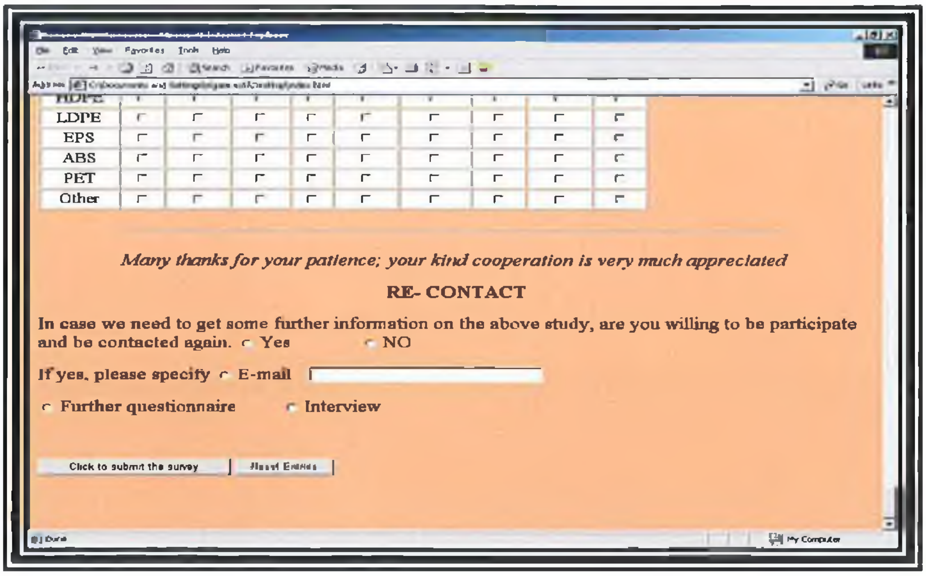


Fig.3.16: Snapshot view of thank you page.

Fig.3.17 and 3.18 shows the sector of the questionnaire related to the plastic industries in the republic of Ireland and United Kingdom.

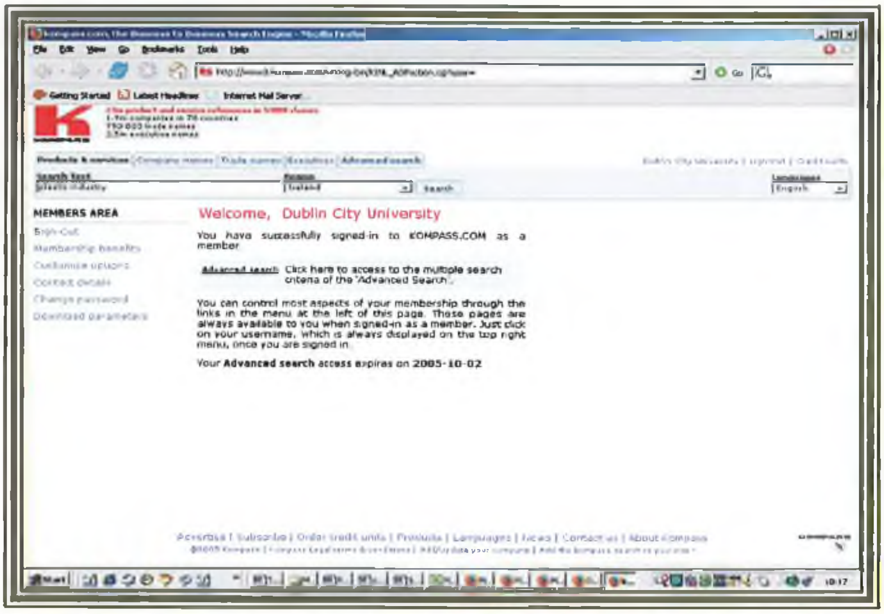


Fig.3.17: Snapshot view of kompass of plastic industrial in Ireland.

Fig.3.18: Snapshot view of kompass of plastic industrial in UK.

3.14. Experimental Procedure

3.14.1. Introduction

The present research investigates an innovative optimisation of the process input parameters to produce final products with good quality at minimal cost. In this work, injection mould machine HM7, was used to produce samples of raw and recycled polypropylene (PP) plastic materials. Several recycled stages were implemented. The material properties were evaluated in order to decide which recycling stage could achieve optimum properties of yield strength (Y) and ultimate tensile strength (UTS). The results obtained are used to compare the effects of the input process parameters on the output properties. There procedures used to compare different samples under various different conditions are outlined in the current chapter. The injection mould facility used in the current research is a manually controlled continuous process using various input parameters.

This chapter details the material, equipment and procedures which were used in the experimental and validation procedures, along with the parameters, the process and the characterisation equipment implemented the process parameters used in the experimental research is shown in Fig. 3.19. The injection mould (HM7) is described, along with the design of mechanical properties tested and analysed using Design of Experimental (DoE). A calibration test was performed of each recycling stage. In addition, evaluation of the input process parameters was performed using various measuring equipment. The procedure used to conduct these measurements is also presented.

In the present research, a detailed formulation was given of the simulation process of the injection moulding machine and reviews of the input process parameters along with the resultant property change of the plastic samples. These were conducted though eight tests in each recycled stage and second exponential at each recycled stage as shown in chapter six, conducted with the additional percentages of raw PP in the each stage. To optimise the response y and UTS; the ultimate goal is achieved through optimising the values of the three input parameters in each recycled stage.

3.14.2. Description of Injection Moulding HM7

A systematic of the injection-moulding machine, model HM7 used in the present research, is shown in Fig. 3.20 and 3.21. Table 3.4 shows the performance specifications for type HM7. This machine is equipped with a standard call-type liquid crystal control system and a parts feeder for moulding assembly lines using extra small products. This machine is the smallest-of-its-type. Table-top in-line injection moulding machine exhibits specific functions such as low-pressure mould closing, variable screw rotation and continuous hydraulic ejection; permitting its use for trial manufacture, as well as any other desired use specification to meet production requirements. The specific details of the above components of the injection-moulding machine will be described in the following sections. Fig. 3.22 and 3.23 shows typical mould HM7. And fig. 3.24 illustrates the barrel and nozzle temperature of the injection-moulding machine.

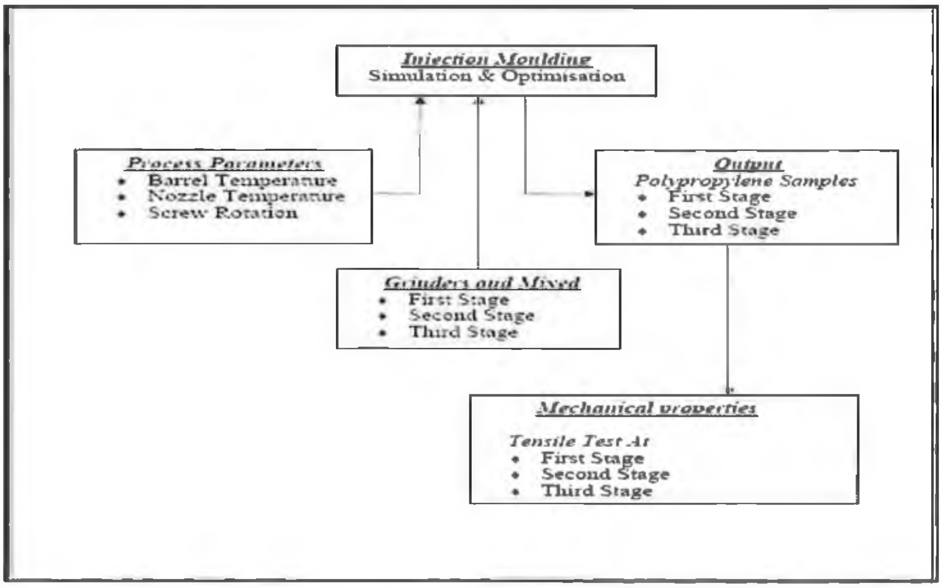


Fig. 3.19: Equipment and parameters used in the experimental phase of the research.

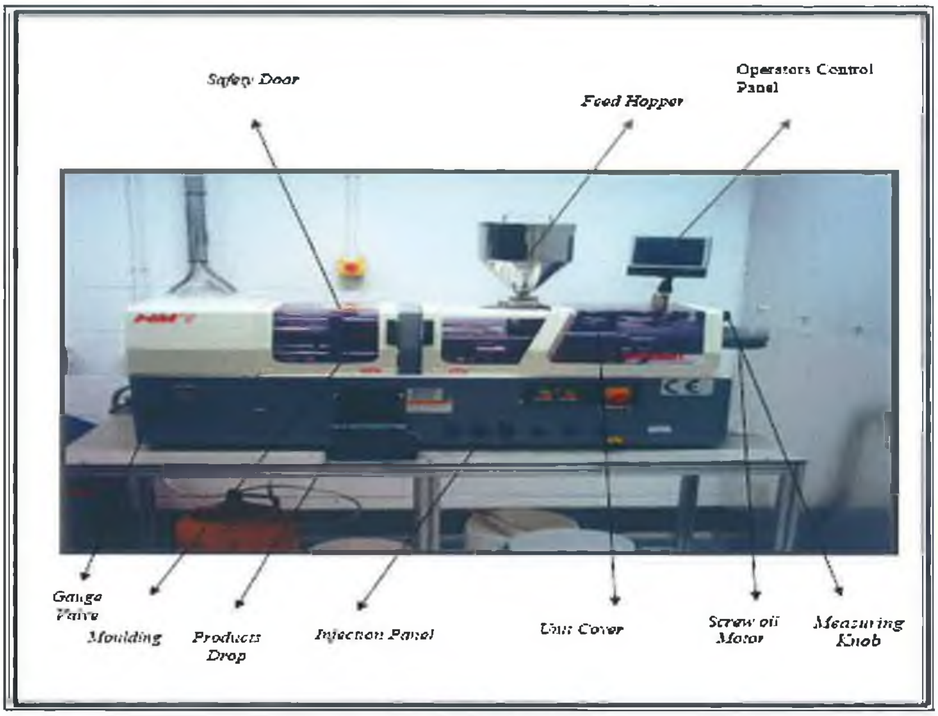


Fig. 3.20: HM7 injection moulding machine equipment.

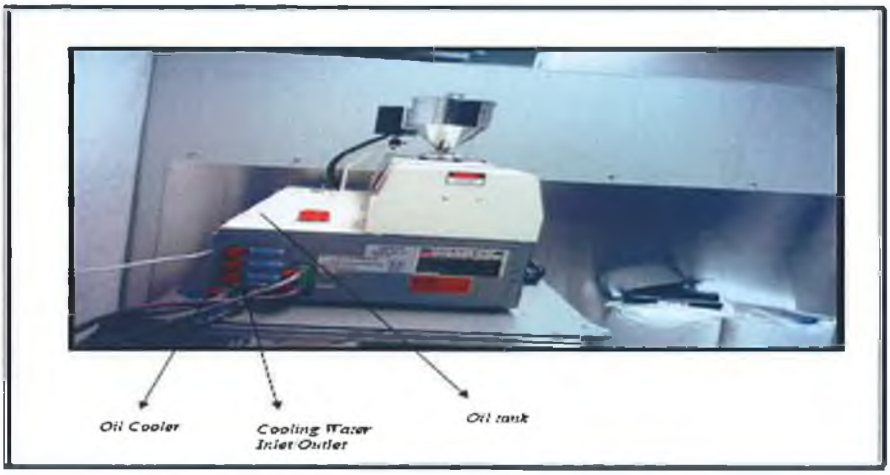


Fig. 3.21: HM7 moulding machine equipment.

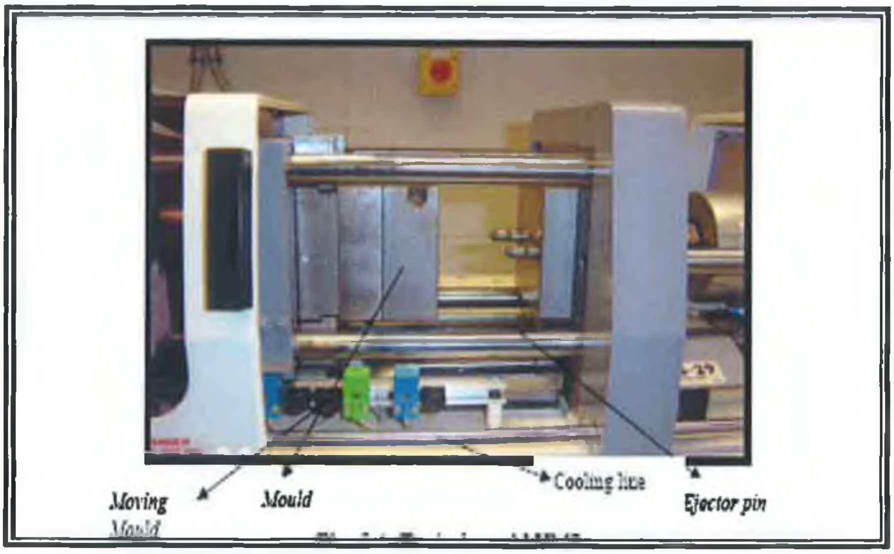


Fig. 3.22: Typical mould HM7.

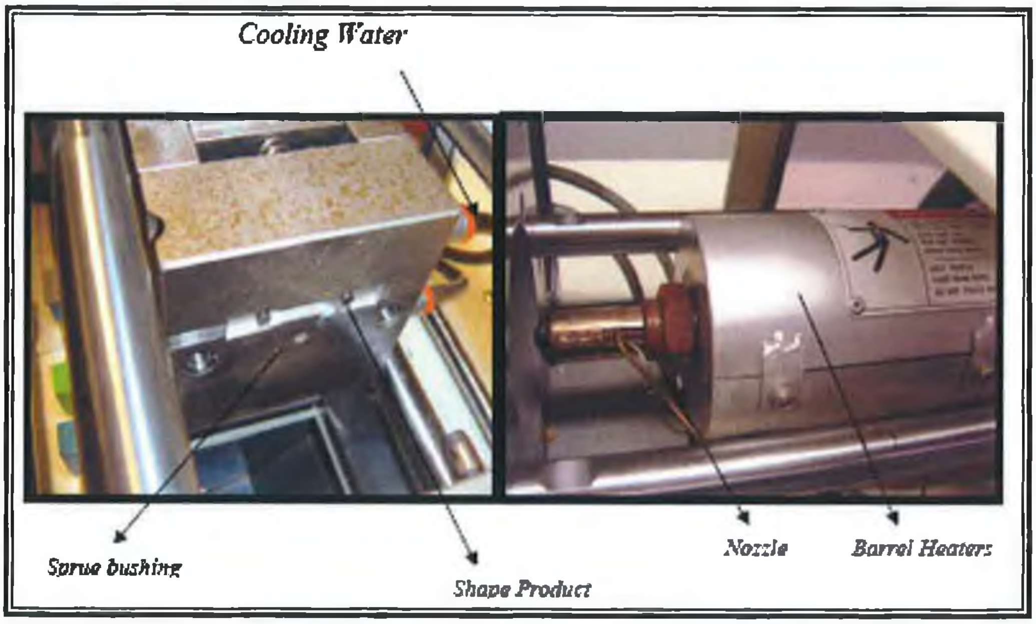


Fig. 3.23: Mould product shape. Fig. 3.24: Barrel and nozzle temperature.

Table 3.4: HM7 mould machine specification

NO	Model	Unit	NO	Model	Unit
1.	Machine Model	HM7	15.	Heater capacity-(coil tem) for barrel	760W
2.	Machine weight	280/ k g	16.	Nozzle temperature Max	400°C
3.	Machine electricity consumption (Motor - Heater)	1.5 k w/h 0.9/ kw	17.	Heater capacity- (coil tem) for nozzle	70W
4.	Oil heraldic price	€ 20/ litter 17	18.	Screw Cost	€2050
5.	Oil temperature	15 °C- 50 °C	19.	Nozzle cost	€330
6.	Mould thickness	110/mm	20.	Barrel cost	€1880
7.	Screw diameter	14/mm	21.	Maximum line Pressure	13.7 Mpa (140 kgf/cm^2)
8.	Injection capacity	6.2 /cm^3	22.	Maximum water pressure	0.98 Mpa (10 kgf/ cm^2)
9.	Tie bar clearance	102 x 102 /mm	23.	Voltage current lotor –Heater)	(400 v-230 v)
10.	Clamping stroke	110/mm	24.	Injection pressure	1785 kg/cm^2
11.	Pump motor rotated	20 kg/cm^2	25.	Clamping force	7 Tons
12.	Labour	400 € /Day	26.	Min mould thickness	110/ mm
13.	Screw Rotation 30 ,50 and 100rpm	Cycle Time (sec) 23, 18 and 15	27.	Max daylight opening	220/ mm
14.	Barrel temperature max	400°C	28.	Mould price	€ 2000

3.14.3. Materials Study and Method Description

3.14.3.1. Method description

The present study used an experimental approach in collecting and analysing data. A factorial design (FD) and analysis technique using DoE approach through Design Expert software Ver.7.0 to determine the relationship between the process input parameters and find product quality. The input parameters were screw rotation, barrel temperature and nozzle temperature. DoE techniques were used to evaluate critical responses and identify the optimum process parameters for improvement in the product quality.

3.14.3.2. Materials preparation

The present research involved raw, first, second and third stage recycling with selected Polypropylene (PP)-(EP540P). Fig. 3.25 and 3.26 show the raw material PP and recycled PP, which has been used to produces products by using the injection-moulding machine HM7. Fig 3.27 shows the tensile sample of PP produced by HM7 machine. Fig.3.28 and 3.29 shows samples of the raw and recycled PP after preparation. In the present research, grinding of the materials at different stages and moulding of the new products were tensile tested at each stage. Fig. 3.30 identifies sprue and runner. In the second experimental stage of this research, mixed raw material with the recycled material PP was used at different percentages and in optimising the final optimum product quality at several stages by observing the effects of adding different percentages of raw materials to produces products with optimum quality.

Fig. 3.25: Raw material PP. Fig. 3.26: Recycled material PP.

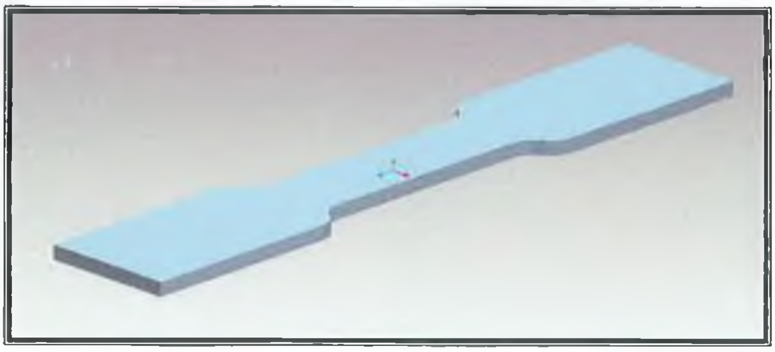


Fig. 3.27: Plastic sample of PP.

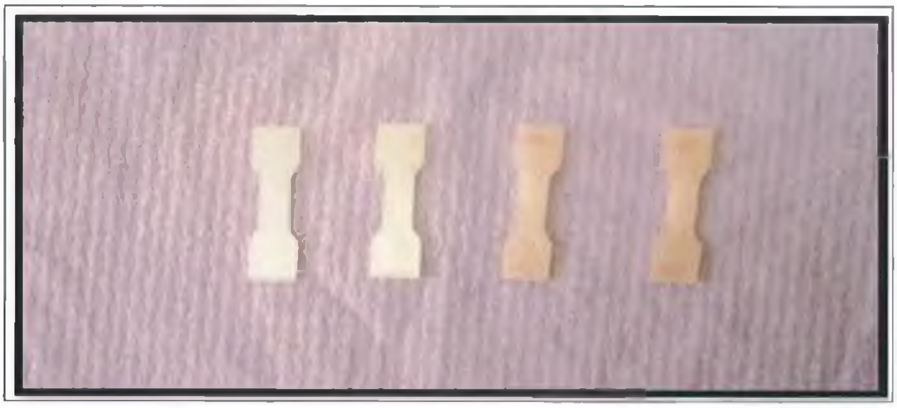


Fig. 3.28: Several recycle samples of plastic material PP, (1) raw material, (2) first recycle, (3) second recycle and (4) third recycle.

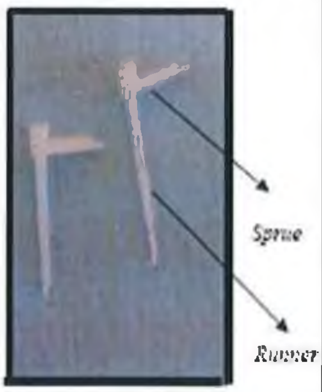


Fig. 3.29: Third recycle samples.

Fig. 3.30: Sprue and runner.

3.14.3.3. Sample dimension

The sample size used in the present research is shown in Fig. 3. 31, outlining the dimension of the standard specimen sample produced from the injection mould machine HM7. These dimensions include gauge length (19mm), width (5.9mm) and thickness (2mm), while the weight of each plastic sample is (0.8g). Fig. 3.32 shows the grinder machine, which has been used, for grinding samples at different recycling stages. Fig. 3.33 shows the different PP specimens used with different percentages of raw PP.

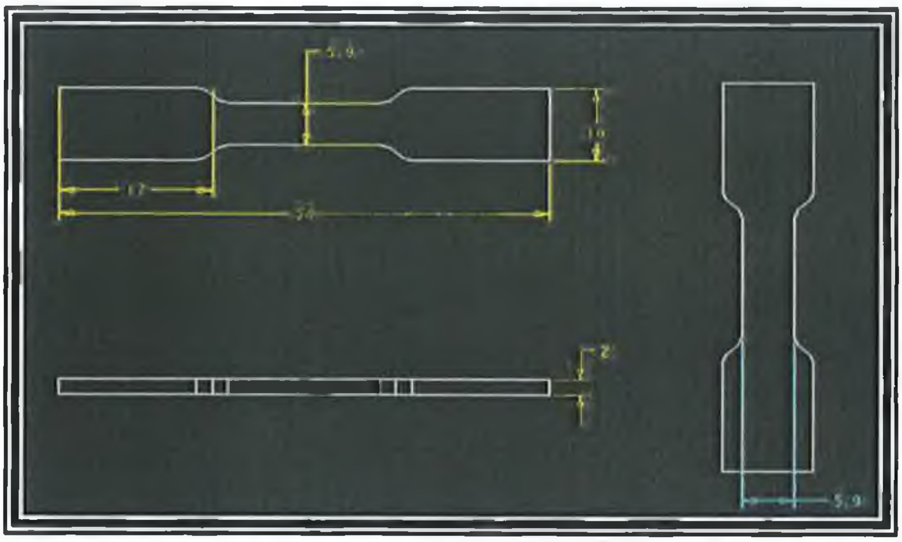


Fig. 3.31: Schematic diagrams showing the dimensions of the standard subsize tensile specimen.

Fig. 3.32: Plastic grinder machine.

Fig. 3.33: Several of add percentages raw PP with the recycled material PP, (1) first recycle, (2) second recycle and (3) third recycle.

3.14.3.4. Mechanical properties

3.14.3.4.1. Tensile testing

In the present research, mechanical testing was carried out by using tensile test machine model "Housfield (HZOK-W)", tensile test was determine in using speed 40mm/min, performed at room temperature (20 °C). PP plastic material was recycled to evaluate the raw, first, second and a third samples were applied for testing the tensile strength. Fig. 3.34 shows the tensile machine model housfield (HZOK-W). The yield strength (Y) and ultimate tensile strength (UTS) were measured as shows Fig. 3.35.

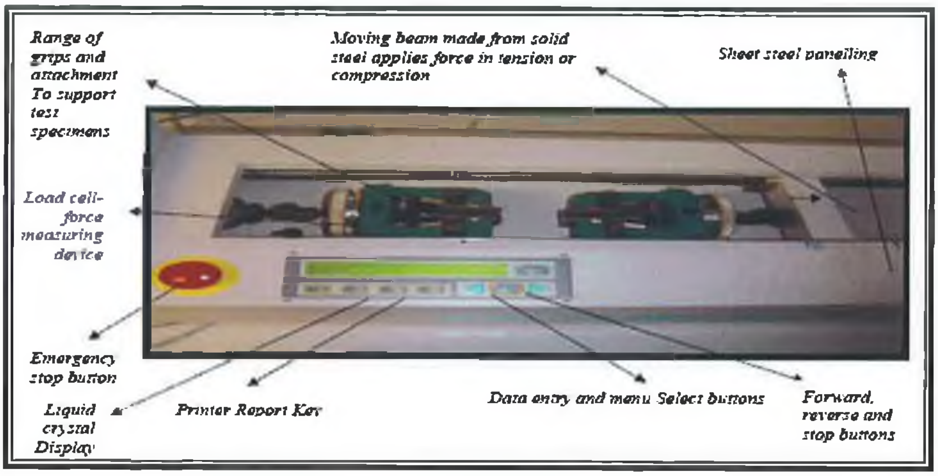


Fig. 3.34: Schematic of tensile machine model housfield (HZOK-W).

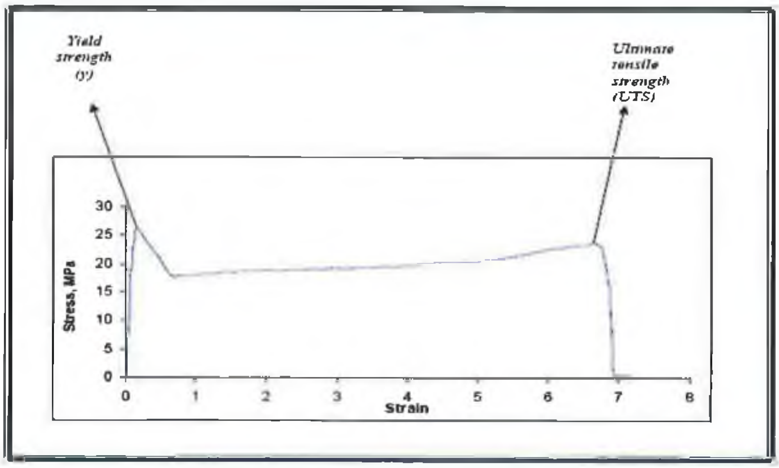


Fig. 3.35: Schematic of stress-strain curve plastic PP.

3.14.3.5. Pilot test

The ranges of factors have been determined by running a pilot test, at which the factor have been changed one at a time. An absence of visual defects was the criterion for choosing the factor ranges. Table 3.5 show the pilot test range of mould process factors. It is acknowledged that by its nature, the experimental methodology selected to carry out this fact-finding or collection of information to administer the behaviour of material affected by the inputs factors to be considered in carrying out sound mould plastic samples at several stages. Thus, in accordance with standard practice of professional testing bodies and due to its wide use in research experimental, pilot test experiment is carefully carried out in this research. The purpose of conducting a pilot test was to test the samples before embarking on the complete study. A pilot study was made to access content validity, where few test were administered to leading, which range factor were administered significant quality such as barrel temperature was using "five level", nozzle temperature "five level" and screw rotation "three level".

Tensile strength data has been collected for each stage, average of four samples was produced as data reading for each case. Mould temperature was monitored by reading temperature as assistance response results.

Within the framework of the general principles and guidelines for administrating a sound experiment, pilot test are a necessary prerequisite. In order to be sure that the factors ranges are understandable, to get any suggestion for improvement, otherwise were decided to selecte the factor range in general , which was not found that in literature review as present research has been used three percentage at each stage with the PP produced products by HM7. Using FD method, eight sets of main experiments were applied with a combination of parameters in the first element of experimental work has been used three factors and two levels, which were expected to identify the variables having most significant effect on production variables. Considered for the experimental design (Y) and (UTS), in second element experimental has used four factors and three levels has been applied in DoE, with fifty four sets mixture raw material at different percentages, excepted nozzle temperature was using two level.

Table 3.5: Pilot test of factors using by injection moulding.

No.	Barrel Temperature	Screw Rotation	Nozzle Temperature	Mould Temperature	Cycle Time (sec)	Parts Sample
1.	270°C	30 rpm	270°C	20°C	23	30
2.	260°C	100 rpm	260°C	26°C	16.5	30
3.	225°C	50 rpm	225°C	22°C	18	30
4.	190°C	30 rpm	190°C	19°C	22	30
5.	180°C	100 rpm	180°C	25 °C	16	30

FD was applied using three levels and three variables. Each independent variable was investigated at a high (+1) and a low (1) level. Table 3.6 shows actual and coded values of the factorial design of the pilot test.

Table 3.6: Actual and coded values of the factorial design of the pilot test by using PP.

No.	Variable	Unit	Low level (-1)	High level (+1)
1.	Barrel Temp	°C	180	270
2.	Screw Rotation	RPM	30	100
3.	Nozzle Temp	°C	180	270

Analysis of the pilot test results of the mould products, using HM7 injection mould indicates that the processing parameters, such as, screw rotation have significant affect on the resulting time cycle for producing recycled products. Fig. 3.36 shows that a screw rotation at 100 rpm minimises the product time cycle; a screw rotation at 50rpm has an increased effect on cycle time while 30 rpm maximizes the cycle time. This suggests that a screw rotation at (100 rpm) is appropriate range to produce products with minimum cycle time.

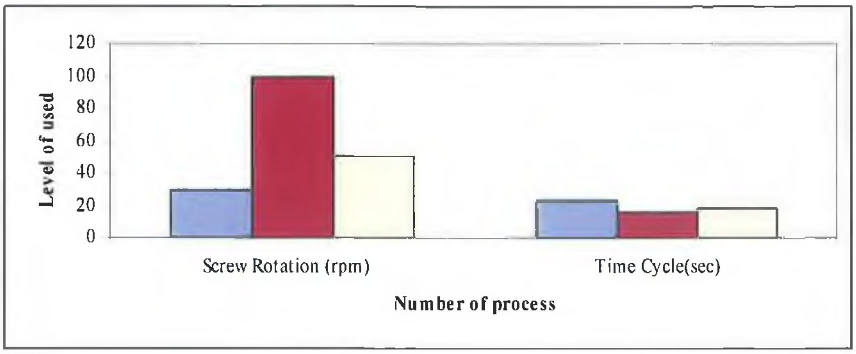


Fig. 3.36: Time cycle of produce mould products by HM7 machine.

Table 3.7 and Table 3.8 show the moulding setting and the percentage of row material used for the pilot test or to produce 2000 samples in order to obtain recycled material. Table 3.8 presents the actual values of the variables and their level for each stage for second experiment. Table 3.9 shows the actual values and level for all variables used in the factorial design.

Table 3.7: Actual values of the pilot test in the second experiment.

N0.	Variable	Unit	Level
1.	Barrel Temp	°C	260
2.	Screw Rotation	RPM	95
3.	Nozzle Temp	°C	150

Table 3.8: Actual values % of raw PP for the pilot test in the second experiment.

No.	first stage		second stage		third stage	
	% of raw material	Cycle Time (sec)	% of raw material	Cycle Time (sec)	% of raw material	Cycle Time (sec)
1.	10%	15	20%	29	30%	19.6
2.	20%	11	30%	13	40%	13.3
3.	30%	16	40%	12.5	50%	11.1

Table 3.9: Actual values/levels for the variables of the second experiment.

Variable	Stage/level		
	1^{st}	2^{nd}	3^{rd}
% of raw material	5-20-35	10-25-40	20-35-50
Barrel Temp °C	180, 225 & 270		
Screw Rotation rpm	30, 65 & 100		
Nozzle Temp °C	160 and 270		

Fig. 3.37 and 3.38 show several weight samples of each recycling stage. The results were indifferent with respect to raw and controlled percentage weight products, which indicated that sample weight has no significant affect on the final recycled product.

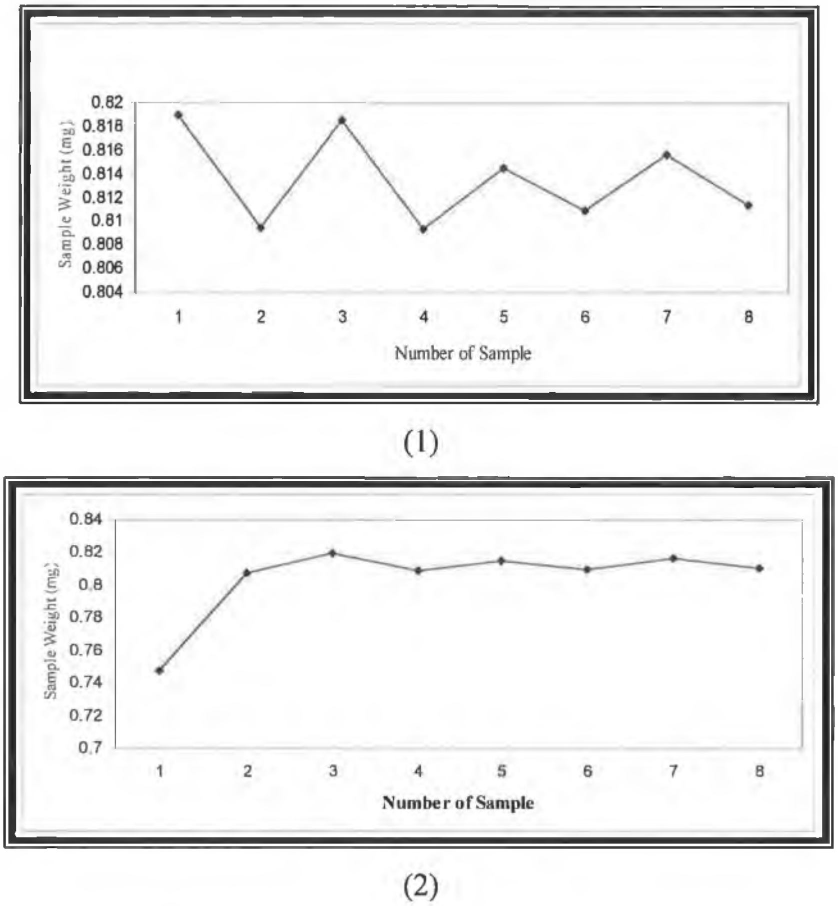
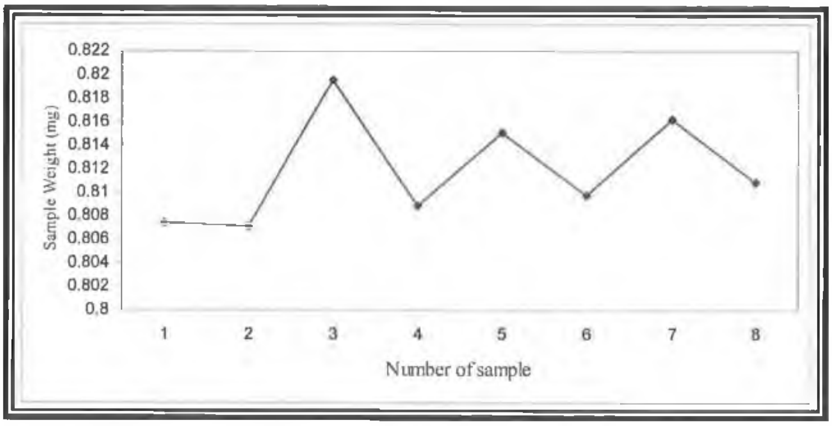
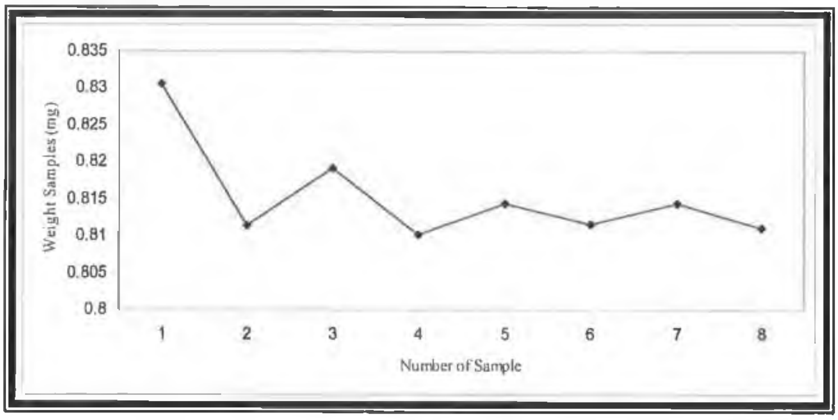


Fig. 3 .37: Schematic diagram of several weight samples in each stage, (1) raw material, (2) first stage.



(1)



(2)

Fig. 3 .38: Schematic diagram of several weight samples in each stage, (1) second stage , (2) third stage.

3. 15. Chapter Summary

This chapter outlined the overview of research methodologies and a justification for the selection of appropriate methodologies used in this study to address the objectives of the research. The chapter starts with an overview of research in general and a description of research philosophies and a description of certain terms related to research methodology. The chapter then presented the research methodology chosen that is, questionnaire survey research, in elaborating the survey questionnaire design and process, as well as the statistical analytical tools and tests used in this study. It also described the justification of research method chosen in this study. This is followed by describing the survey instrument used which covers the survey coverage, method of data collection, questionnaire design, response scaling and questionnaire content and the survey process steps including pre-testing and pilot test and main survey.

It also outlined the steps taken to ensure that the general principles and guidelines according to the standard practice of professional survey bodies are followed for administering a sound survey. At the end, this chapter presented an overview of SPSS software package and the statistical procedures contained in SPSS as well as the test results, which are used in this study. The research approach and design discussed in this chapter then are employed to obtain the empirical data, which will be presented in the chapters – results and discussion. The chapter also describes the rationale behind each question used in the survey and ends by explaining the scoring system adopted for the study. Finally presented are discretion methods of online survey.

The next phase of the research work will be the selection of reviewing of the analysis of the results obtained from the survey, as would be shown in the body of research efforts reviewed on presentation of the descriptive statistics tool used in SPSS such as, frequency distributions, cross-tabulations and correlation, analysis as well as the comparison study between the each recycling stage the result of hypotheses testing is discussed also, which will be addressed in chapter five.

Also, the chapter presented an overview of the research equipment and procedures for the selection of injection moulding HM7 process parameters used in this study to address the objectives of the research. The chapter starts with technical specification of the injection moulding, HM7, and a method description related to the research methodology. It also described the materials investigated study and sample dimension, of the plastic materials polypropylene. This is followed by describing the mechanical properties used which covers the coverage, method of data collection, experimental design, process steps including pilot test and main experimentally. The chapter then presented the second research methodology chosen i.e. experimental, in elaborating the experimental work design and process in each stage, as well as the statistical analytical tools and tests used in this research.

CHAPTER 4
SURVEY RESULTS AND ANALYSIS

4. Survey Results and Analysis

4.1. Introduction

This chapter covers the analysis of the results obtained from the survey. The main software used in this task is the Statistical Package for the Social Sciences (SPSS) version 11.0, which is a data management and analysis product produced by "SPSS" [1]. SPSS is considered one of the leading statistical software applications. The integration of the graphics model to the base with excellent interface is just one example of the status of this software. Also "SPSS" has a command language, which is very easy to understand [1]. The process parameter input used in the survey would be used as evidence to carry out applied experimental work to compare and determine which inputs process parameters affect greatly the quality of recycling plastic products in each recycle stage. Survey methods have been used in the three recycling stages and each stage has selected three optional answers. This chapter presents the survey analysis using statistical and technical methods to provide analysis of data collection from the plastic industry.

This chapter depicts the results of the survey carried out and their discussions divided into two main sections; survey results and discussions. In the first section, section 5.2, the results and analysis of the data from the survey findings on the current implementation, the stage of used recycled materials, processing methods, process inputs parameter and the sale of recycled products is presented. It consists of a presentation of the descriptive statistics, frequency distributions, cross-tabulations and correlation, analysis as well as the comparison study between the each recycling stage. In the second section section 5.3, discussions take place that will further elaborate and evaluate the information from the findings of the results and analysis. The result of the hypotheses and its testing is discussed in this section also. For each hypothesis there is a discussion of the empirical findings in order to facilitate the analysis in relation to the aims of this study.

4.2. Results and Data Analysis of Survey

This study covers the analysis of the results obtained from the survey. To indicate which input parameters are statistically significant; several statistical tools have been implemented, such as Frequency, Cross –Tabulation and Correlations to analyses data obtained from the plastic industry and identify which variables are most affected in the recycling plastic industry.

4.3. Frequency Analyses and Cross –Tabulation

4.3.1. General information

A survey conducted indicates that the majority of companies' surveyed shows 74% are local While 7% are mixed and 19 % foreign company (see Fig. 4.1).

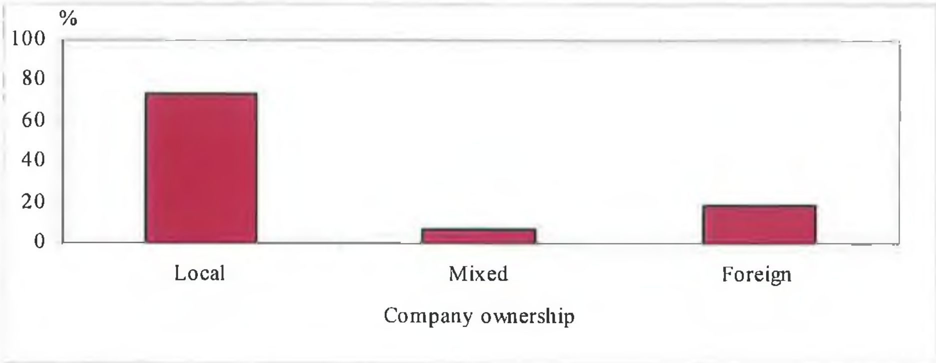


Fig. 4.1: Identification of current company ownership.

The results indicated that the majority of companies' surveyed les then fifty employees (see Fig. 4.2).

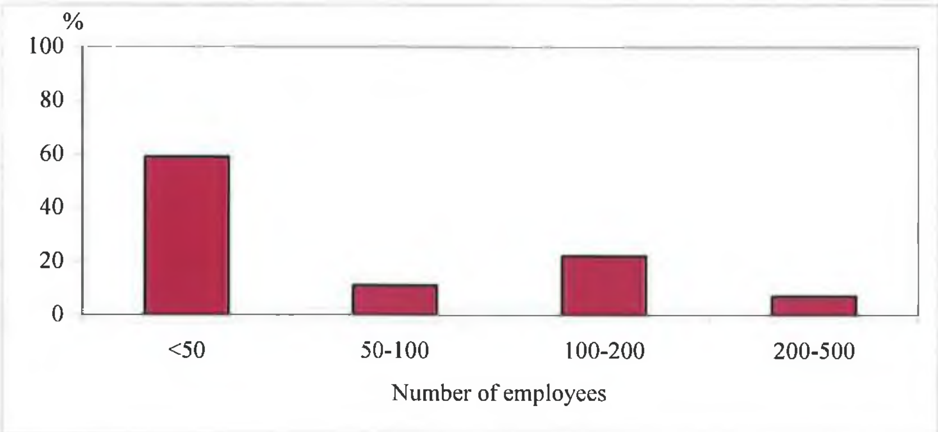


Fig. 4.2: The number of employees for current recycling companies.

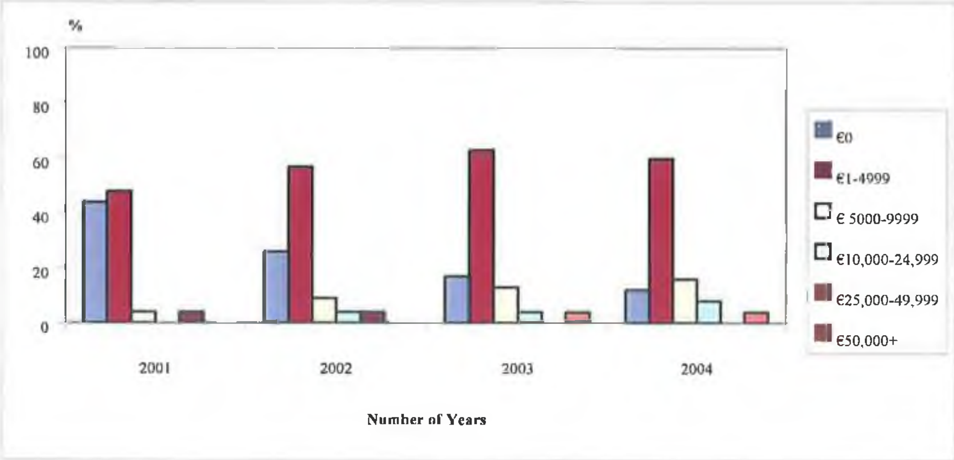


Fig. 4.3 highlights the company spend on staff from 2001 to 2004.

The results presented on Fig. 4.4 indicates that the majority of companies surveyed are using injection moulding.

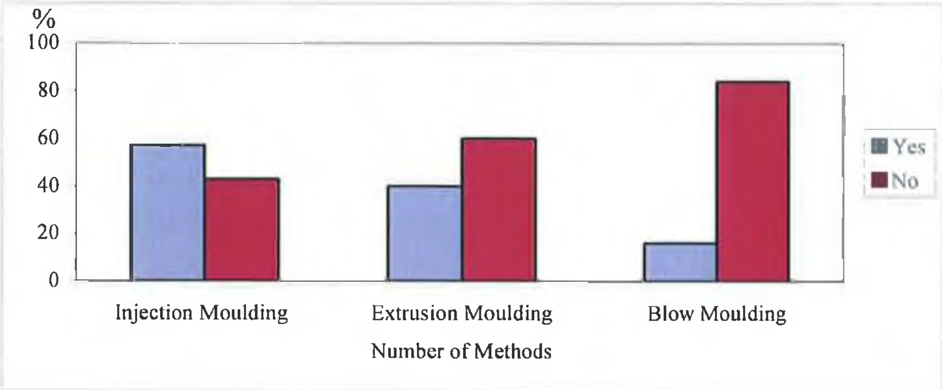


Fig. 4.4: The processing methods presented by recycling companies.

Fig. 4.5 indicates that majority of plastic companies (38%) have been in existences for a period of greater then 16 years, 23% for 6-9 years, 19% for 10-15 years, 12% for 3-5 years and 8% for les than 2 years.

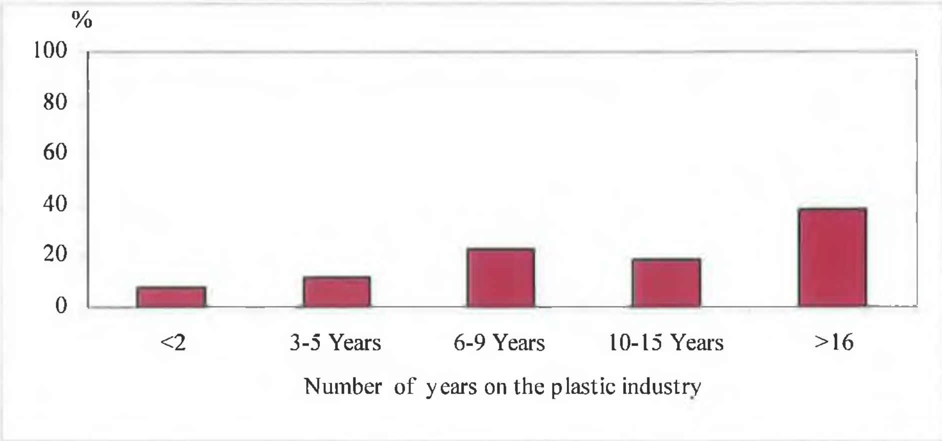


Fig. 4.5: Number of years of manufacturing for the plastic industry.

Fig. 4.6 shows that 3-5% of companies have a significant percentage of rejects coming from the processed products for the following years.

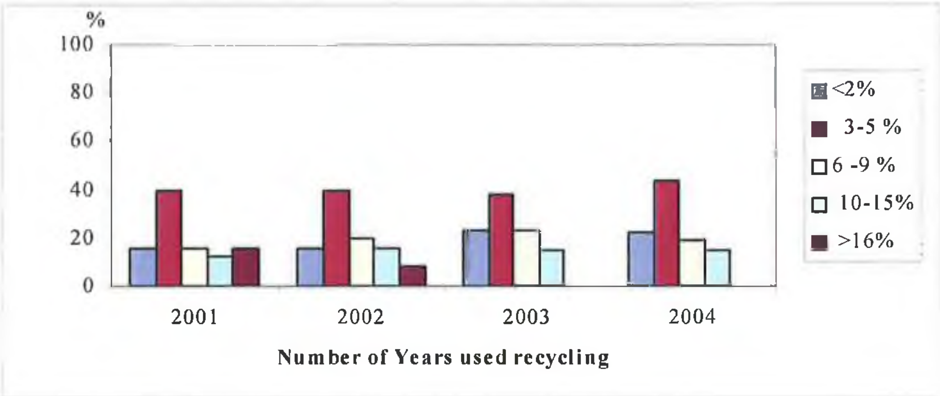


Fig. 4.6: The average percentage of rejects on an annual basis.

4.3.2. Stage of used recycled materials

The survey indicates that the majority of companies' surveyed shows that 89% are using recycled materials, while 11% are not (see Fig. 4.7).

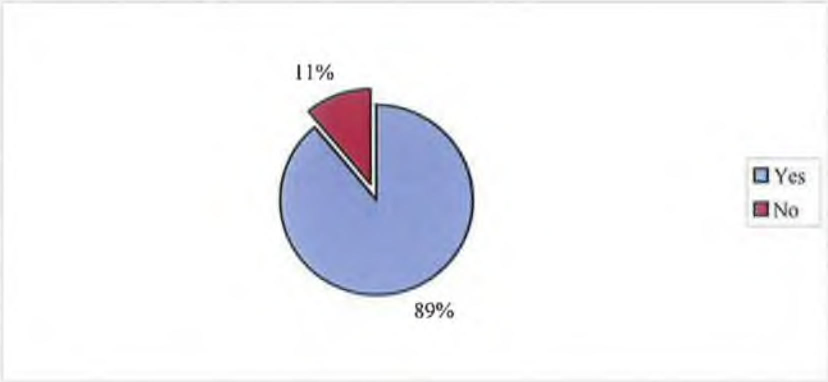


Fig. 4.7: Implementation of recycling of plastic materials within industry.

Fig. 4.8 shows that the 63% of companies have used first stage recycling in their plant 24% are planning to use second stage recycling, while 8% of companies already use third stage recycling in their plants and 5% are using additional stages of recycling in their process.

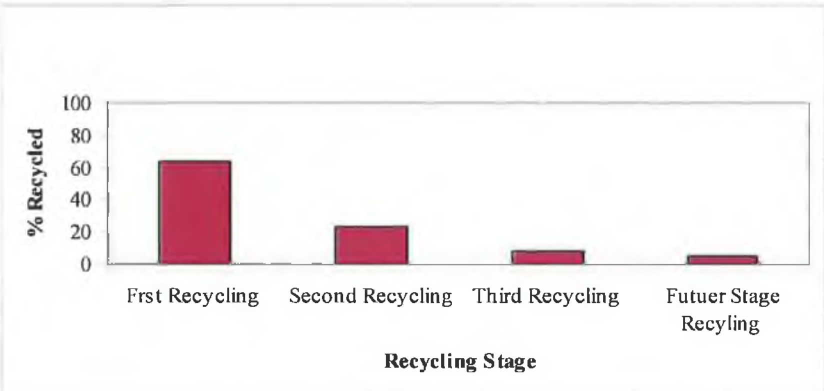


Fig. 4.8: Stages of recycling.

Table 5.1 shows the findings relating to the rejects, which result from the different recycling stages. The majority of rejects come from first recycling stage and this result indicates that companies have main use for the first recycling stage.

Table 4.1: The percentages by Cross –Tabulation of rejects, which come from process producing less than200 tonnes in the different recycling stages.

Approximately ,what Percentage of rejects Come from the process of recycled products	How many time does your company recycle the plastic materials			Total
	First Recycling	Second Recycling	Third Recycling	
<2%	36.1%	9.5%	9.5%	57.1%
3-5%	23.6%	NB	NB	23.8%
6-9%	48%	NB	NB	4.8%
10-15%	14.3%	NB	NB	14.3%
Total	81%	9.5%	9.5%	100%

Table 4.2 shows the findings of reduced process costs in the recycling process. The majority of companies (76.2%) surveyed used recycling of rejects of the years 2001.

Table 4.2: The percentages of reduced process costs from 2001-2004.

Does your company invest in the recycling of rejects	Reduce process cost				Total
	2001	2002	2003	2004	
Yes	76.2%	4.6%	4.8%	4.8%	90.5%
No	4.8%	4.7%	NB	NB	9.5%
Total	81%	9.3%	4.8%	4.8%	100%

Table 4.3 shows the findings of maximum profits obtained as a result of 4 years the recycling process. The majority of companies surveyed (75%) maximized profits in 2001.

Table 4.3: The percentages Cross –Tabulation of maximizes profits from 2001-2004.

Does your company invest in the recycling of rejects	Maximizes profits				Total
	2001	2002	2003	2004	
Yes	75%	5%	10%	5%	95%
No	5%	NB	NB	NB	5%
Total	80%	5%	10%	5%	100%

4.3.3. Inputs process parameters

4.3.3.1. External process

The results reviewed recycling to the external process conducted for the moulding process used within plastics companies, highlights that process parameters and personal skill were the major factors affecting the quality of the products at different stage. As presented in the figures bellow. Figs 5.10 to 5.12 graphically illustrates these representatives:

a) Fig 5.10 factor attesting first-stage recycling.

b) Fig 5.11 factor attesting second-stage recycling.

c) Fig 5.12 factor attesting third-stage recycling.

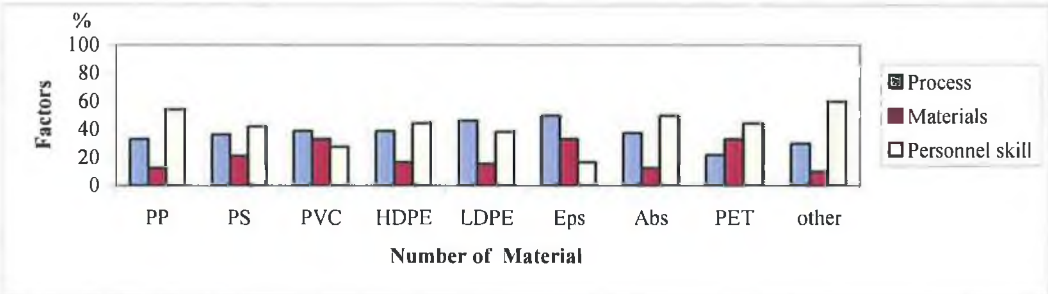


Fig. 4.10: First stag.

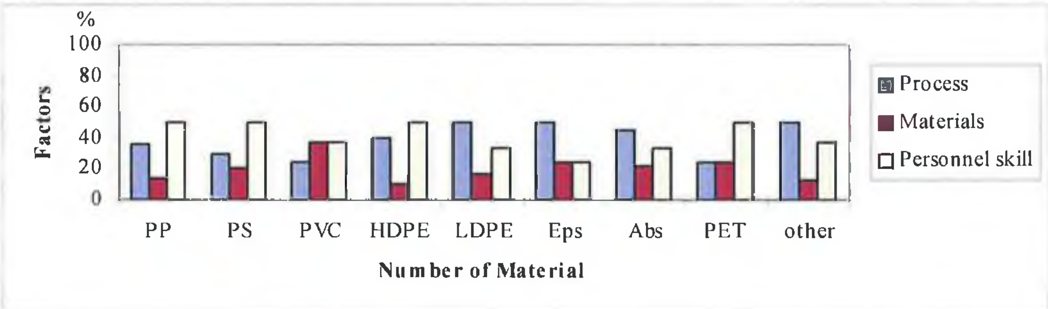


Fig. 4.11: Second recycle.

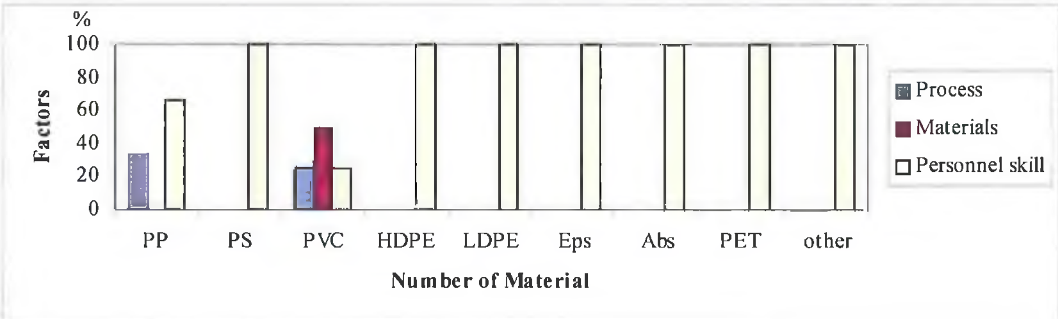


Fig. 4.12: Third recycle.

4.3.3.2. Internal process

The results reviewed relating to the internal process conducted for the moulding process used within plastics companies, indicated that process parameters; such as screw rotation, barrel temperature and nozzle temperature had major affect on the quality of the products at different recycling stage. These results are shown in Fig. 4.13.

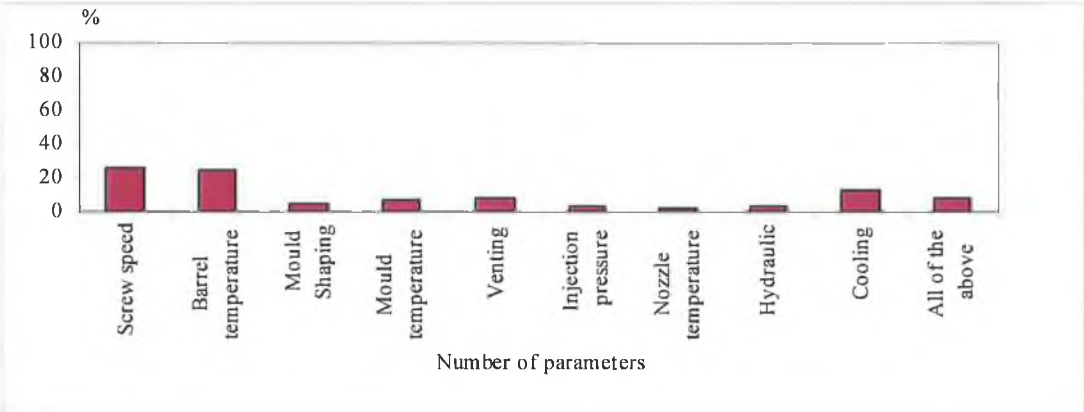


Fig. 4.13: Internal parameters affecting the mould process.

The survey conducted also indicates that the majority of companies' surveyed stated that screw rotation and barrel temperature passed the greatest effect on the recycled materials at different recycling stage. This is presented in Fig 5.14-5.16.

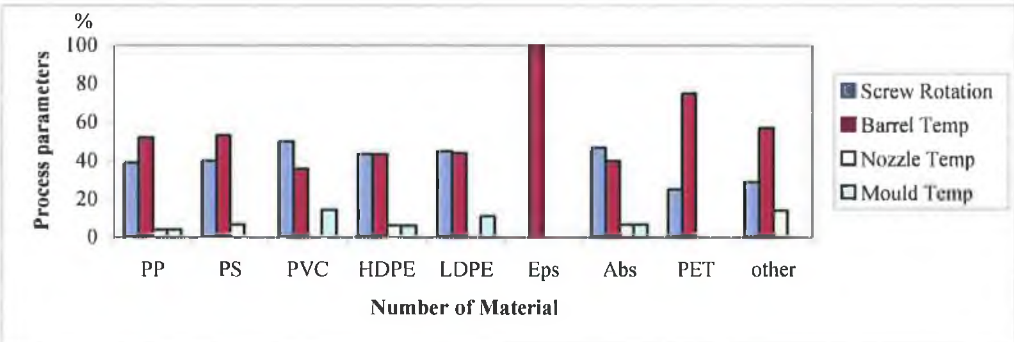


Fig. 4.14: The effect of the inputs process parameters on the first recycling stage.

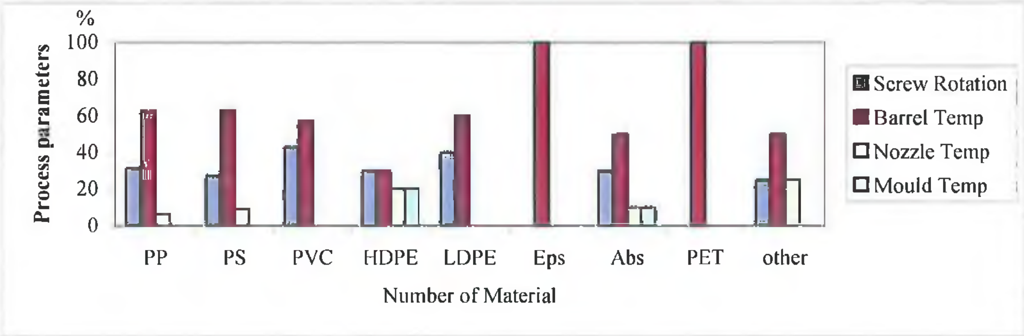


Fig. 4.15: The effect of the inputs process parameters on the second recycling stage.

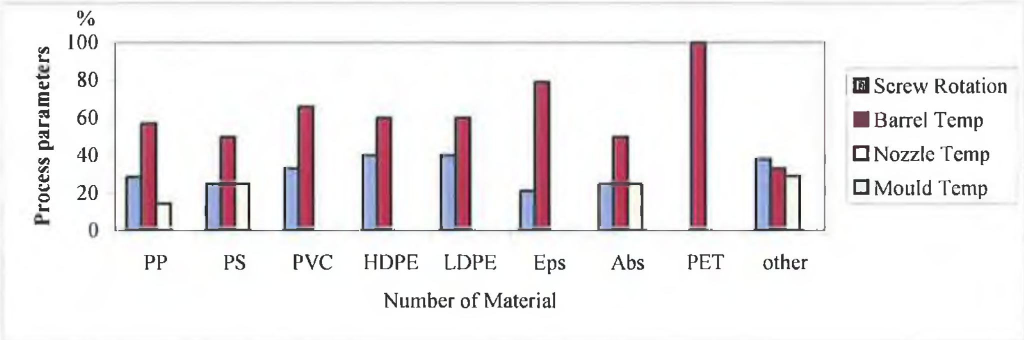


Fig. 4.16: The effect of frequency of the inputs process parameters on the third stage.

4.3.3.3. Quality of recycled products

The results indicate that the majority of plastic companies' surveyed show that the quality of plastic materials is affected at different stages. These results are presented in Figs 5.17 to 5.19.

- *First Recycling*

The results indicate that the majority of plastic materials do no change their quality after the first recycling stage (see Fig. 4.17).

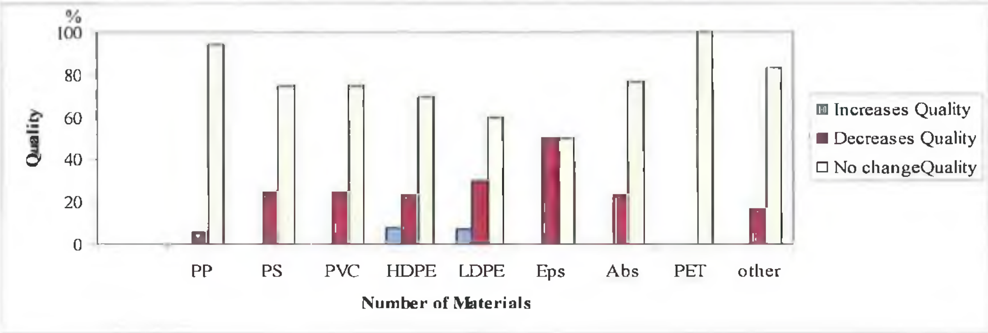


Fig. 4.17: First recycle.

- *Second Recycling*

The analysis of second recycling indicates that the majority of the quality in plastic materials decreases (see Fig. 4.18).

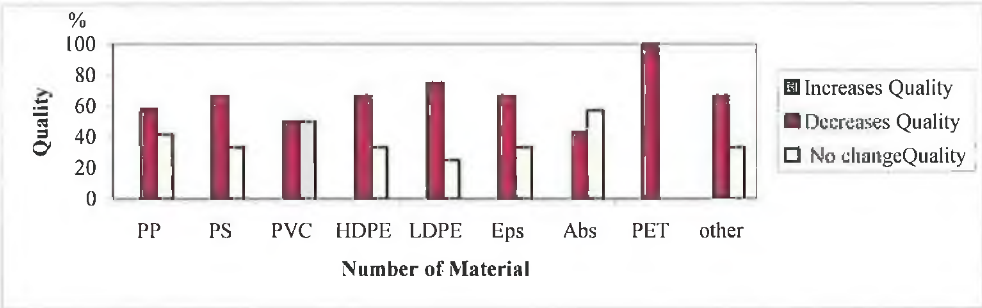


Fig. 4.18: Second recycle.

- *Third Recycling*

The results indicate that the majority of the quality in plastic materials decreases after the third recycling (see Fig. 4.19).

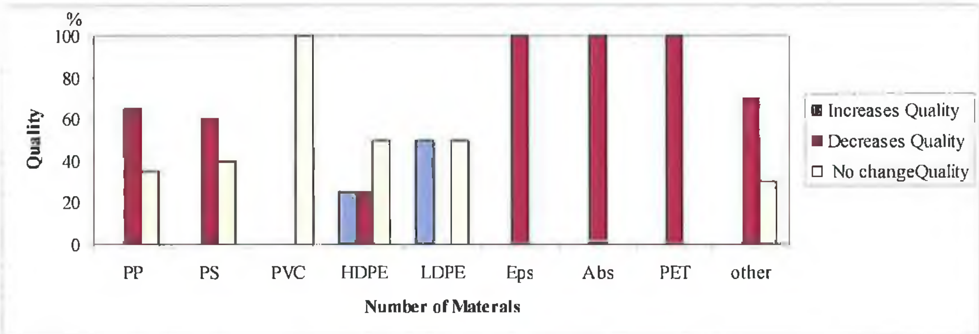


Fig. 4.19: Third recycle.

4.3.3.4. Cost estimation

The results obtained from the plastic industries surveyed, indicate that the majority of companies' note a decreased cost throughout the several recycling stages as presented in Figs 5.20 to5.22.

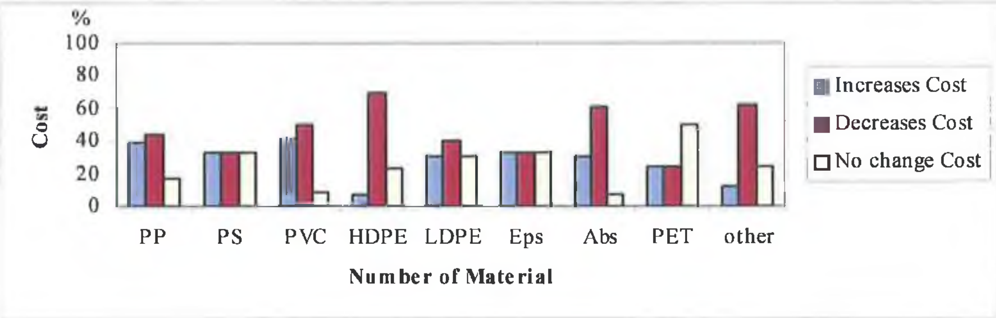


Fig. 4.20: Cost estimation for first stage recycling.

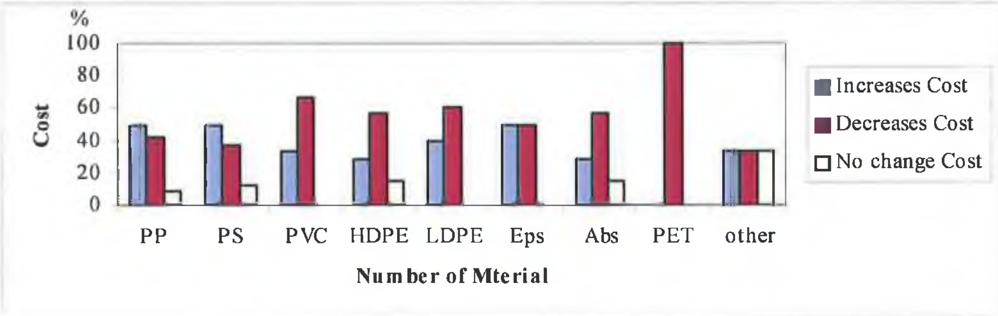


Fig. 4.21: Cost estimation for second stage recycling.

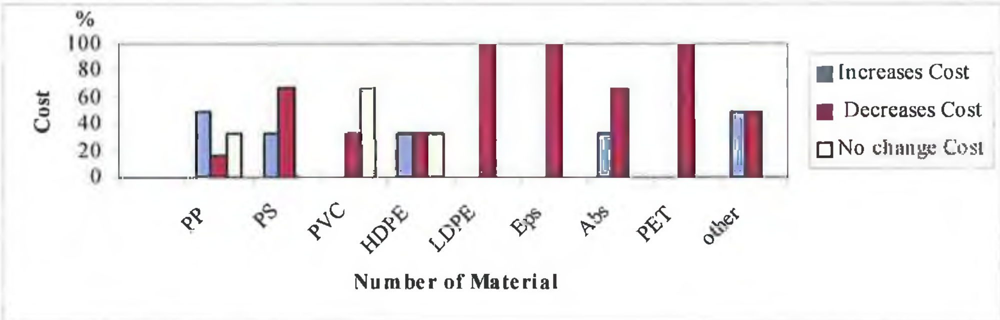


Fig. 4.22: Cost estimation for third stage recycling.

4.3.4. Sale of recycled product

4.3.4.1. Involved in the sale of recycled products

The results indicate that 58% of the companies surveyed sell recycled products where as 42%, do not. Fig. 4.23 shows the percentage sale of recycled plastic products.

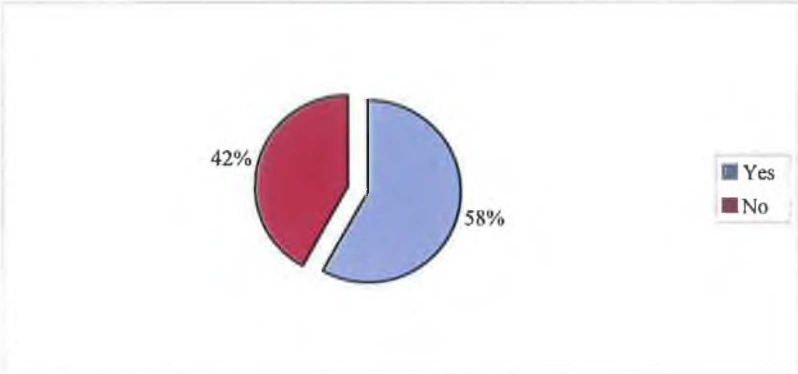


Fig. 4.23: Percentage sale of recycled plastic.

Fig. 4.24 indicates that 14% of the companies surveyed sell recycled plastic products for less than 2 years, 21% since 3-5 years, 22% since 6-9 years, 14% since 10-15 years, and more than 29% have sold recycled plastic products for more than 16 years.

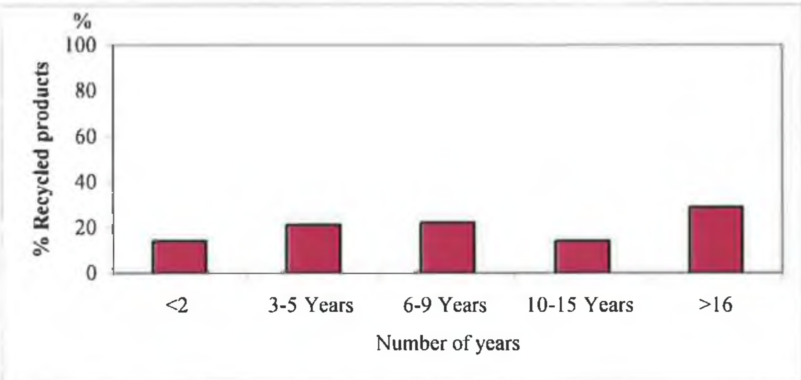


Fig. 4.24: Number of years used on the sell of recycling plastic.

Table 4.4 shows the findings of the sale of the recycled products. Local ownerships majority of (75%) accounts for the companies selling recycled products.

Table 4.4: The percentages Cross –Tabulation of the sale of recycled products with respect/regards company ownership.

Ownership	Does your company sell recycled products		Total
	Yes	No	
Local	44.5 %	30.5%	75%
Mixed	8.3%	NB	8.3%
Foreign	5.2%	11.5%	16.7%
Total	58%	42%	100%

Table 4.5 shows the percentages by Cross –Tabulation of the sale of recycled products and also years operating recycling methods. It can be clearly noticed that the majority of the companies surveyed have been selling products recycled for 21 to 30 years.

Table 4.5: The percentages Cross –Tabulation of the sale of recycled products within manufacturing plastic companies.

How many years has your company been manufacturing plastic products	Does your company sell recycled products		Total
	Yes	No	
<5	NB	4.2 %	4.2 %
6-9 years	20 %	9 %	29%
10-20 years	17 %	8%	25%
21-30 years	21 %	12.3 %	33.3%
>30 years	NB	8.5%	8.5%
Total	58%	42%	100%

Table 4.6 shows the information gathered interpreting the profits coming from the sale of recycling materials. The majority of companies surveyed obtained 2% of their profits over the years of though selling recycled materials and 5% of profits for companies operating greater than 16 years.

Table 4.6: The percentages Cross –Tabulation of profits to results the sale of recycled products.

If yes, how long has the company been involved in the sale	On average what percentage of profits come from the sale of recycled products			Total
	2%	5%	10%	
<2 Years	14.3%	NB	NB	14.3%
3-5Years	14.3%	7.1%	NB	21.4%
6-9 Years	14.3%	7.1%	NB	21.4%
10-15Years	7.1%	7.1%	NB	14.3%
> 16 Years	7.1%	14.3%	7.1%	26.6%
Total	57.1%	35.7%	7.1%	100%

Fig. 4.25 indicates that the sale of recycled plastic products materials increased in 2001 for all various plastic materials and products.

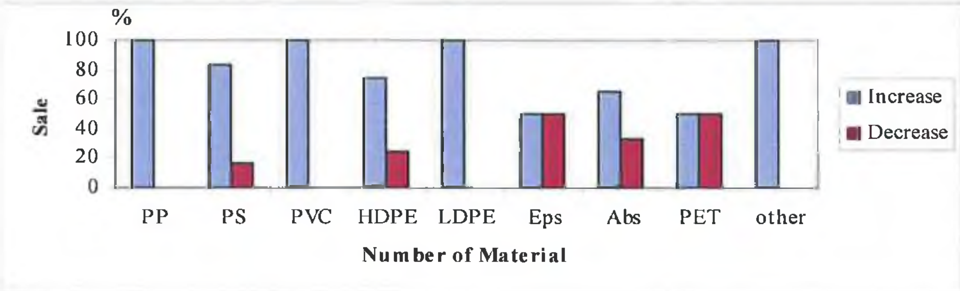


Fig. 4.25: The trend for sale of plastic recycled products in 2001.

Fig. 4.26 indicates that the sales of various recycled of plastic material products increased in the 2002.

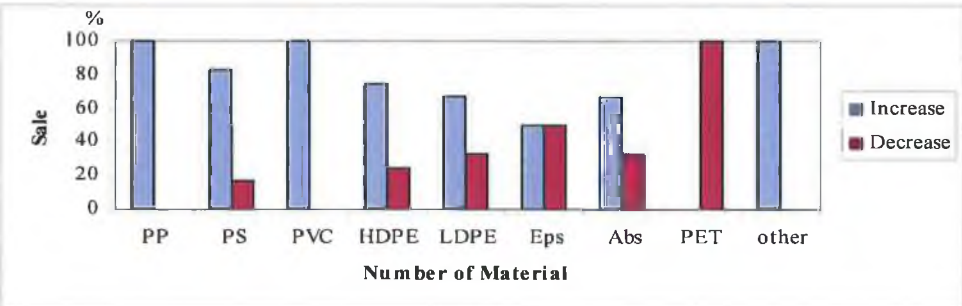


Fig. 4 .26: The trend for sale of plastic recycled products in 2002.

Fig. 4.27 indicates that the sales of the majority of various recycled plastic materials products decreased in the 2003.

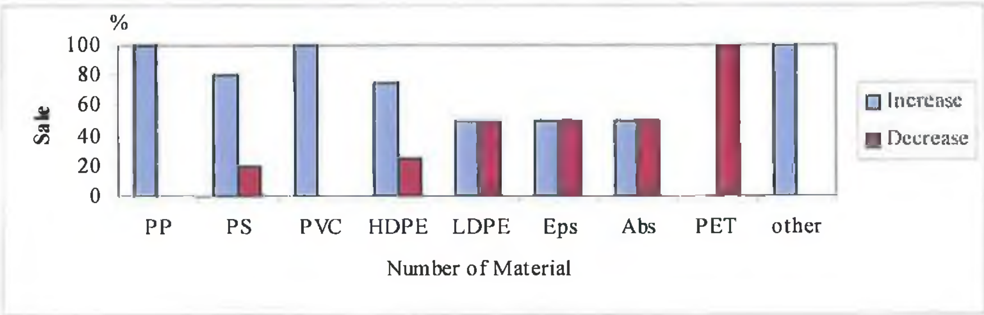


Fig. 4.27: The trend for sale of plastic recycled products in 2003.

The results indicate that the sale of recycled plastic materials products decreased again for the year 2004. Fig. 4.28 shows the sale of recycled plastic parts in 2004.

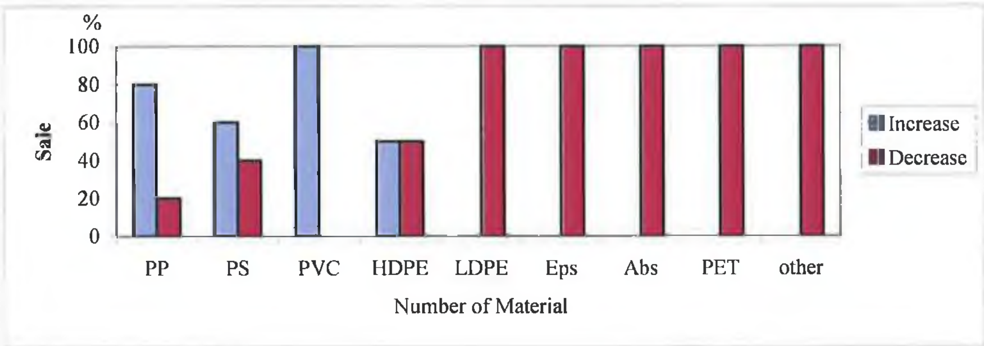


Fig. 4.28: The trend for sale of plastic recycled products in 2004.

4.3.4.2. Price of recycled products

The results indicate that the majority of recycled plastic materials products are set to a medium price during the first to second, while third stage recycled products are set to a low price as presented in Figs 5.29 to5.31.

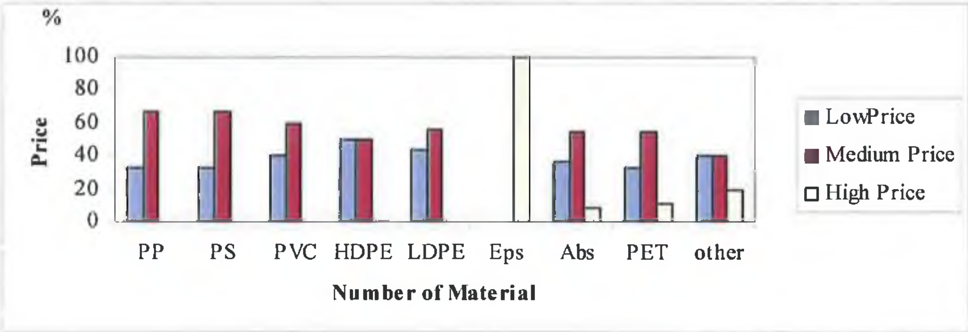


Fig. 4.29: Price of plastic recycled products produced from first stage recycling.

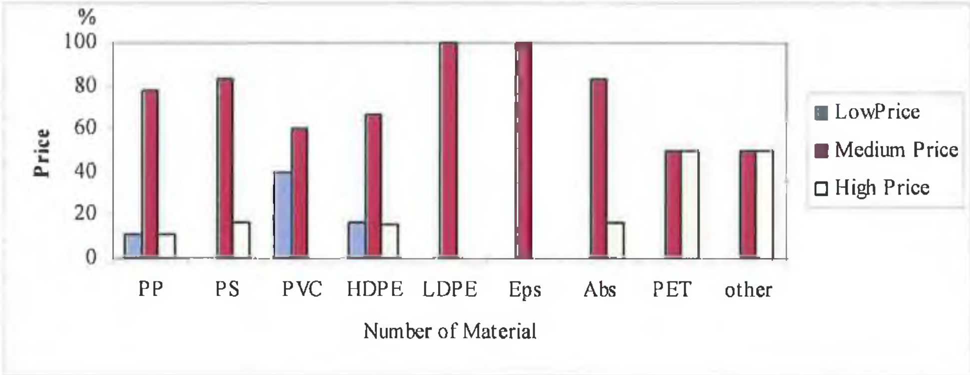


Fig. 4.30: Price of plastic recycled products produced from second stage recycling.

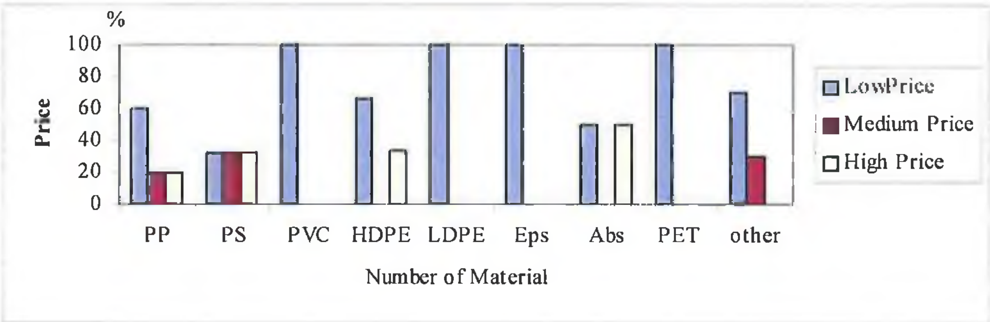


Fig. 4.31: Price of plastic recycled products produced from third stage recycling.

4.4. Results and Discussions of Survey Results

4.4.1. Testing hypothesis

This study has provided information on the implementation of recycled plastic materials and it's marketing of plastic industry in both countries. Statistics from the survey have shown factors, which have an effect on the product quality. The survey has also shown several stages, which have an effect on the marketing and price of recycled product.

This section further elaborates and evaluates the information from the results reported in the previous sections. It consists of data interpretation and evaluation from the descriptive statistics, frequency distributions, cross-tabulations and correlations, analysis as well as the comparison from both quality and sell of recycled products at each recycle stage. The statistical analysis was carried out using SPSS software to determine the correlation between the variables (X_1, X_2 and X_3), with the (Y), as the depended variable of the study, where: (X_1 quality product, X_2 inputs process parameters, X_3 sell of recycled products and Y recycle process), as well as the significant of the independent variables on the dependent variable by using ANOVA test. Finally the research model will be presented by a regression equation by using DoE software and analysis by the ANOVA test at each recycle stage. As for the hypotheses testing, for each hypothesis there is a discussion of the empirical results in order to facilitate the analysis in relation to the aims of this study. Research hypothesis are presented below:

- **<u>Hypothesis 1</u>**

H_0: There was no significant relationship between recycled process and quality of the products at each recycling stage.

H_1: There was significant relationship between recycled process and quality of the products at each recycling stage.

- **Hypothesis 2**

H_0: Input process parameters have no interaction effect on the quality products at each recycling stage.

H_2: Input process parameters have interaction effect on the quality products at each recycling stage.

- **Hypothesis 3**

H_0: There was no significant relationship between sells of recycled products and recycles performance products at each recycling stage.

H_3: There was significant relationships between sell of recycled products and recycle performance products at each recycling stage.

4.4.2. Company background

The results of the sample survey, as shown above in Fig. 4.1 demonstrate that 74 % of the respondents are local business companies and they are using first recycling stage only. Also, the results of the analyses of cross –tabulation show that these local companies are selling products produced by first recycled material. On the other hand, most of the companies in both countries have less than 50 employees as shown in Fig. 4.2. Also Fig.5.3 shows that the human resource development is a vital component in human resource management. Furthermore, the survey consists of a question, which analyzes the companies training policy. For both countries, the results of the survey prove that recycling business companies usually spend on human training between €1 and € 4999. It was found that the major obstacle is the lack of competencies technicians' skill. A high investment in training and development can lead to more effective and utilized high technology and higher skill levels.

This statement is supported by the result of the correlation analysis, which indicates the positive relationship between training planning and numbers of employees as presented in Appendix B. It can be noted that the training staff are the most appropriate and efficient approaches for the skilled personnel to increase their knowledge and competencies in performing the recycled process.

Three different types of moulded products used in plastic companies. The frequency results show that the majority of companies surveyed are using injection-moulding process. In terms of the number of years in operation, the comparison between two countries shows that the majority of the respondents in Ireland and UK have been in plastic business for more than16 years as shown in Fig. 4.5. The results indicate that the main benefits occurred from the implementation of the recycling process as the majority of responded results indicate is maximizes sales and profits as presented in Appendix B.

4.4.3. Quality of the recycled products

The majority of plastics companies using the first and second recycling stages only as shown in Fig. 4.8. The third recycling stage is not often used due to the decrease in the product quality it can be recommended to avoid to use third recycling stage unless raw material is being added to improve the quality. For that, the first hypothesis (H1) was formulated to address this aspect, and will be tested as follows:

- **Testing Hypothesis 1:**

Hypothesis H_1: There was significant relationship between recycled process and quality of products at each recycling stage.

From the results, the recycling phases could be classified into three stages: First recycle stage, which are quite extensively used. Second and third recycled which are quite moderately used

To test this hypothesis, a relationship between the products quality (X_1) and recycle process (Y) at each stage was examined using correlation and frequency analysis techniques, for this hypothesis there is a discussion of the empirical findings in order to using survey question such as B13, The frequency analysis indicate that the quality of the recycled products were decreased from first stage to third stage. As reported in Figs. 5.17 to 5.19.

- In this research, correlation were analysed between two variables products quality and recycling process for each stage. The results indicate that the correlation - coefficient in first stage was statistically significant for this stage. For the second and third stages were statistically not significant as presented in Appendix B.

- To analyse the quality performance versus the product cost, Figs. 5.20 to 5.22 show that the first stage for PP has less cost, while, the second and the third stages have higher cost. The corr-coefficient for the third stage is statistically significant with a positive relationship, as presented in Appendix B.
- On the other hand, to analyse the quality performance versus the productivity, the frequency results indicated that the majority of plastic materials such as PP, PS, PVC, etc have high productivity in the first and second stages and no change in the productivity in third stage as presented in Appendix B.

Therefore, the first hypothesis (H_1) is accepted and (H_0) refused. The results and correlation matrix shows that there was a high relationship between X_1 and dependent variable Y. The hypothesis (H_2) was formulated to address this aspect and will be tested as follows:

■ **Testing Hypothesis 2:**

Hypothesis H2: Inputs process parameters have interaction effect on the products quality at each recycling stage.

To test this hypothesis, a relationship between the inputs process parameters (X_2) and product quality (X_1) at each stage, was examined using frequency analysis. The frequency results shown that the barrel temperature and screw rotation have highly significant effects on the final product quality, as shown in Figs. 5.14 to 5.16. Therefore, the second hypothesis (H_2) is accepted and refused (H_0). The results and correlation matrix show that there was relationship between X_1 and independent variable X_2.

4.4.4. Selling of recycled products

The results indicate that the majority of company surveyed have been sold of recycled products over 16 years. The results indicate that the third stage has low price, and they recommend to reject it. While, the first and second stage have medium price and this demonstrates that the first and second stages have effective marketing.

Furthermore, cross –tabulation results show the sale profits of recycled products have 2 %. The result shows significant relation and viable affect between recycled processes and sale products in each stage. In order to examine the hypothesis (H3), it was formulated and will be tested as follows:

■ **Testing Hypothesis 3:**

Hypothesis H3: There was significant relationship between sell recycled products and recycle performance products at each recycling stage.

To test this hypothesis, a relationship between the sell-recycled products (X_3) and recycle process (Y) was examined using correlation techniques and frequency analysis in the research survey. The survey questions C4, C6 were used to exam the hypothesis (H3), the results indicate that there is a significant relations between recycle and selling of recycled products in each stage. The correlation analysis between two variables recycle and competitive were tested. The corr-coefficient was positive relation, which means a statistically significant, as presented in refer Appendix B. Therefore, the third hypothesis (H_3) is accepted and refused (H_0). The results and correlation matrix shows that there was a high relationship between X_3 and dependent variable Y.

4.6. Chapter Summary

This chapter has reported and analysed the results obtained from survey in Republic of Ireland and UK for plastic companies. This chapter also identified several statistically techniques to analyse the different hypothesises. It presents also discussions on the information from the results from the descriptive statistics.

A discussion on the general questions and also the analysis of the results in this chapter would help as a guide in the experimental work. Finally, based on the results and discussions, it summarizes the key findings related to the recycle practice and approaches, which linked to the development of products quality.

CHAPTER 5
EXPERIMENTAL DESIGN

5. Experimental Design results

5.1. Introduction

Designs of Experiment (DoE) have been utilized in many disciplines such as biological, pharmaceutical, engineering etc. In the last two decades, the use of DoE has grown rapidly and been customized for many process in industry such as machining, chemical mixing and recycle to find out the optimal conditions. This chapter provides details on the results of experimental design that been provide by Design-Expert software V7. Also, the desirability approach was used in conjunction with FD to find out the optimal combination of the recycling process parameters to achieve the required recycle quality at low cost. In addition percentages of raw material has been investigated of the recycled joints in order to study the effect of injection mould conditions on the mechanical properties namely, yield strength (Y) and ultimate tensile strength (UTS) for three recycling stages. In this chapter, detailed information was given on factorial design (FD) and the selection of the inputs process parameters along with the resulted properties of the PP plastic samples during the eight sets of main experiments.

5.2. Experimental design and data analysis

In this research, factorial design has been used to study the effects of each processing parameter on the mechanical properties. Injection-moulding machine HM7 was used to produce the specimens. The experimental data tests were analyzed using statistical software. Three parameters at two levels were selected. The process parameters are screw rotation rate (S), barrel temperature (B) and nozzle temperature (N), the investigation was carried out in order to determine which process parameters would affect the material properties after the injection-moulding process.

5.2.1. Factorial design

Factorial design is one of the optimisation techniques currently in widespread usage to describe the performance of the recycling process and find the optimum of the responses of interest. FD is a set of mathematical and statistical techniques that are useful for modelling and predicting the response of interest affected by several inputs variables with the aim of optimising this response [185]. This approach was applied to optimise the mould process. The two-level factorial part of the design consists of all possible combinations of the +1 and -1 levels of the factors. For the two factors case there are four design points: (-1,-1) (+1,-1) (-1, +1) (+1, +1) as shown in Fig. 5.1. In general, the number of factorial points is equal to 2^k. Three factors were investigated; the melting temperature, nozzle temperature and screw rotation the design contains eight experiments and fifty four as shown in tables below; the performance of the synthesis was evaluated by analysing two responses; (Y, UTS). In this work the essential process factors were determined from the past literatures. Design-Experimental V7 software was used to code the data, develop the design matrix and analyse the case , the limits for each factor were coded via this relationship; $X_l = 2(2x - (X_{max} + X_{min}))/ (X_{max} + X_{min})$. Where: X_l is the required coded value, X is any value of the factor which wanted to be coded and X_{max}, X_{min} are the upper and lower limit of the factor being coded respectively.

In this study the tensile strength and yield strength were evaluated for all the setting. Finally the results were compared with the tensile strength of the raw material. Fig. 5.2 shows a flowchart for the analysis steps. DoE techniques were used to evaluate responses and identify the optimum process inputs parameters and to make suggestions for improvement in this study.

Statistical analyses are extremely important to study basic mechanisms in complex situations, thus providing better process control and understanding. The main objective of FD is to determine the optimum operational conditions for the system or to determine a region that satisfies the operating specifications. In this study, the effect of eight experiment and fifty-four process parameters was examined with the aid of experimental design in the presence of nutrients feeding. Regression analysis and the statistical analysis of main and interaction effects were quantified by analysis of variance (ANOVA). To optimise the response (Y) and (UTS), it is necessary to find an appropriate approximation for the true functional relationship between the independent variables and the responses. A second order polynomial model shown in Eq 5.1 was used to describe the relationships between responses and experimental factors.

$$Y = b_0 + \sum_{i=1}^{n} b_i x_i + \sum^{i \neq j} b_{ij} x_i x_j + \sum^{i \neq j \neq k} b_{ijk} x_i x_j x_k \qquad (5.1)$$

Where y is the response, b_0 is the constant coefficient, X_i, X_j and X_k are the variables, b_is are the linear coefficients, b_{ij} are interaction coefficients and b_{ijk} is the three-interaction coefficient. This polynomial model was fitted to the two responses. The value of the coefficients can be calculated using regression analysis.

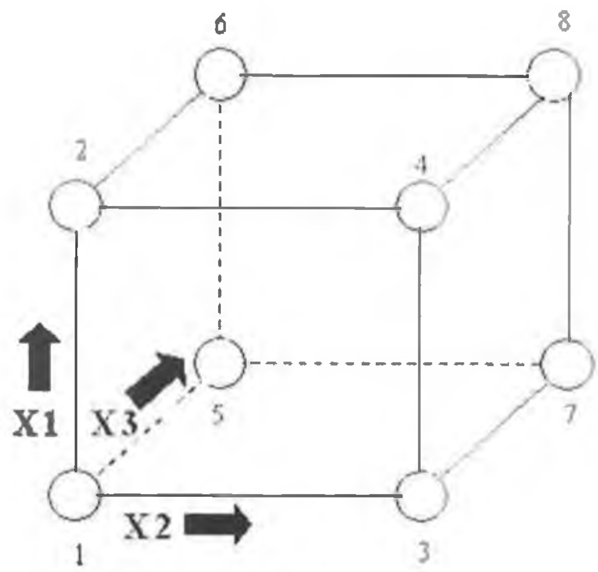


Fig. 5.1: A 2^3 two-level, full factorial design; factors X1, X2, X3 [185].

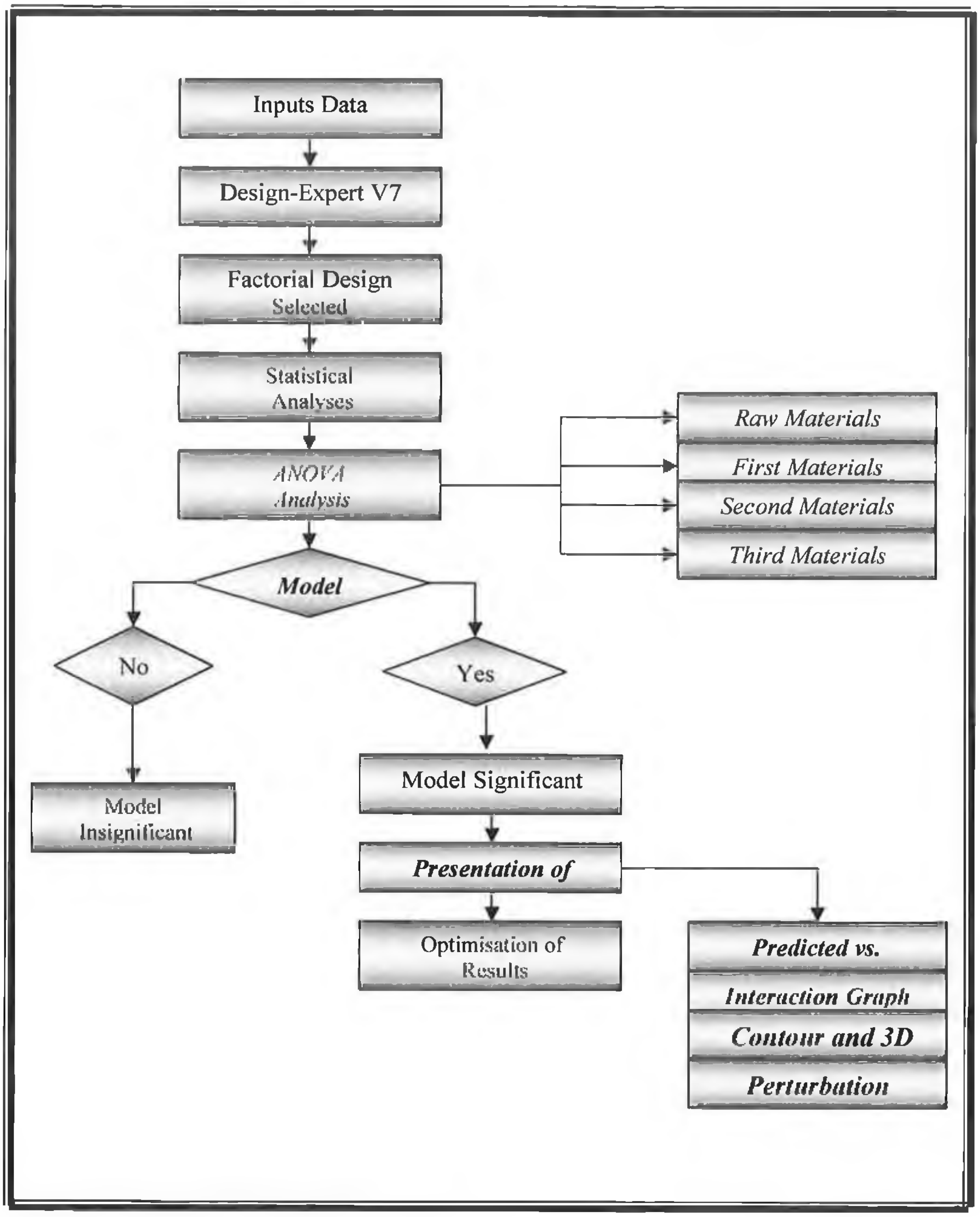


Fig. 5.2: Flowchart shows the building and using the factorial design model.

5.2.1.2. Development of the mathematical model

The functional relationship representing any response of interest can be expressed as y = f(A, B, C and D) and Eq .5.2 becomes as follows.

$$Y= b_0+ b_1A+ b_2B + b_3C+ b_{12}AB + b_{13}AC + b_{23}BC + b_{123}ABC \qquad (5.2)$$

5.2.1.3. Testing the adequacy of the models developed

The analysis of variance (ANOVA) was used to test the adequacy of the models developed. The statistical significance of the models developed and each term in the egression equation were examined using the sequential F-test, and other adequacy measures (i. e. R^2, Adj- R^2, Ped.R^2 and Adeq precision ratio). The Prob>F (sometimes it called P-value) of the model and of each term in the model can be computed by means of ANOVA. If the Prob>F of the model and of each term in the model does not exceed the level of significance (say $\alpha = 0.05$) then the model may be considered adequate within the confidence interval of $(1- \alpha)$. Table 5.1 below is a summary of the ANOVA table.

Table 5.1: ANOVA table for full model:

Source	SS	df	MS	F_{cal}- Value	p-value or Prob > F
Model	SS_M	p	Each SS divided by its df	Each MS divided by MS_E	From table or software library
A	SS_1	1			
B	SS_2	1			
C	SS_3	1			
AB	SS_{12}	1			
AC	SS_{13}	1			
BC	SS_{23}	1			
ABC	SS_{123}	1			
Residual	SS_R	N-p-1			-
Cor Total	SS_T	N - 1	-	-	-

Where:

P: Number of coefficients in the model
N: Total number of runs
SS: Sum of squares
df: Degree of freedom
MS: Mean square

5.2.1.4. Development of the final reduced model

The model contains only the significant terms and the terms that are necessary to maintain hierarch. Also, a reduced quadratic ANOVA table can be produced.

5.2.1.5. Post analysis

When the final model has been tested and checked and found to be adequate, then the response at any midpoints can be predicted using this adequate model. Also, producing some important plots, such as 3D graphs, contours and perturbation plots, to present the factors effect and how they contribute to the response. Moreover it is now possible to employ the developed model to find the mould setting at which the process could be optimized.

5.2.2. Optimisation

5.2.2.1. Desirability approach

There are many statistical techniques for solving multiple response problem, such overlaying the contours plots for each response, constrained optimisation problem and desirability approach. The common statistical software packages, such as SPSS, NEMROD and Design-Expert, include a multiple response optimisation techniques. The desirability method is recommended due to its simplicity, availability in the software and it's also provides flexibility in recycling and giving importance to individual responses. Solving such multiple response optimisation problems using this technique consists of using a technique for combining multiple responses into a dimensionless measure of performance called the overall desirability function.

5. 2.2. 2. Optimization approach in Design-Expert software

The optimisation part in Design-expert software V7 searches for a combination of factor levels that simultaneously satisfy the requirements placed (i.e. optimisation criteria) on each one of the responses and process factors (i.e. multiple response optimisation). Numerical and graphical optimisation methods were used in this work by choosing the desired goals for each factor and response. The numerical optimisation feature in the design expert software packages finds appoint or more in the factors domain that would maximize this objective function. In a graphical optimisation with multiple responses, the software defines regions where requirements simultaneously meet the proposed criteria. Superimposing or overlaying critical response contours on a contour plot. Then, a visual search for best compromise becomes possible. In the case of dealing with many responses, it is recommended to do numerical optimisation first; otherwise it could be impossible to uncover a feasible region. The graphical optimisation displays the area of feasible response values in the factor space. Regions that do not fit the optimisation criteria are shaded [186]. Fig. 5.3 shows flow chart of the optimisation steps in the design-expert software.

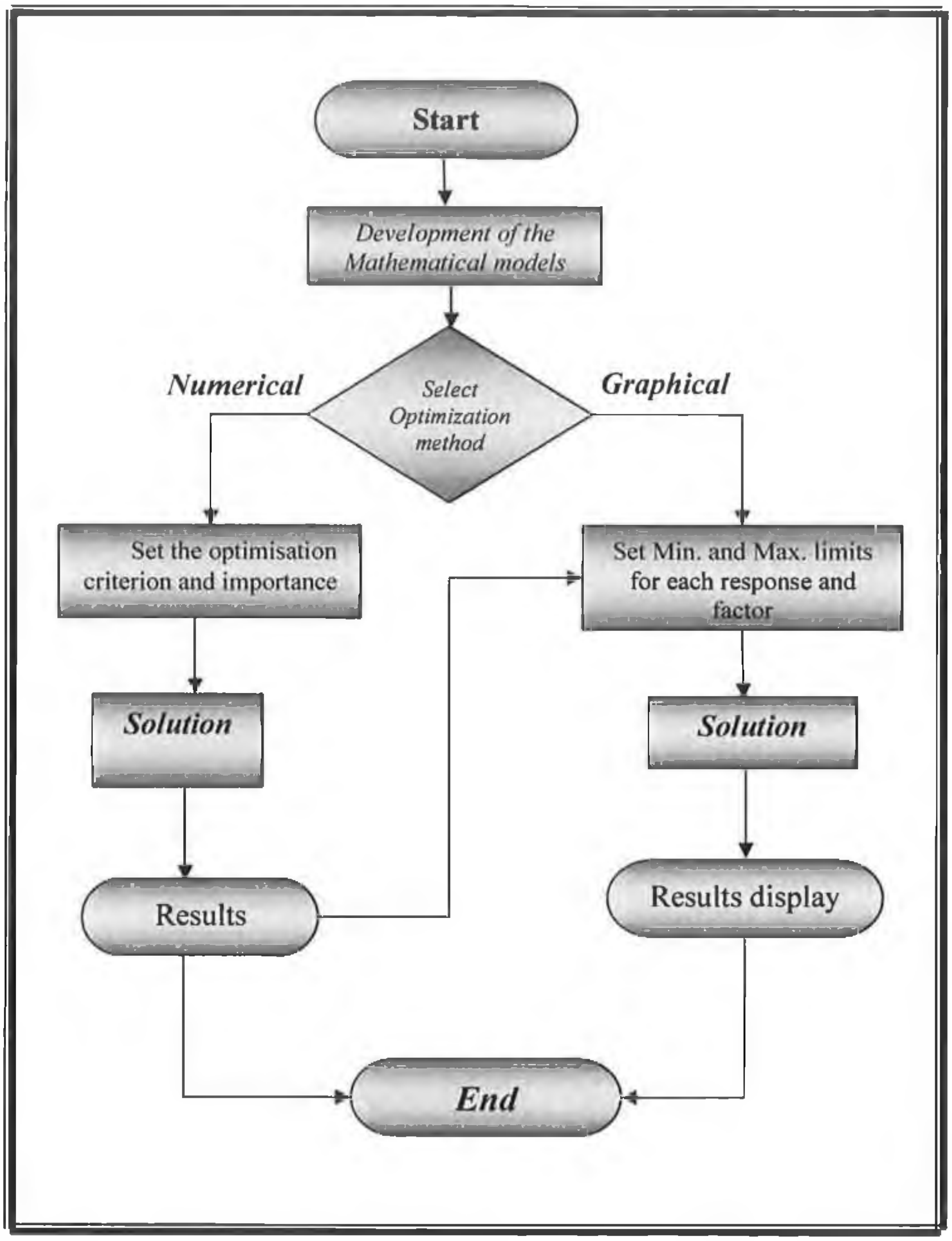


Fig. 5.3: Flowchart shows the optimisation steps [187].

5.3 Results and discussion

In this chapter, the experimental design used, the range of each process parameters and experimental layout are presented for each recycling stage. This chapter also shows the results for all the stages investigated in this work, in terms of ANOVA analysis of each response, and the validation experiments. The effects of process parameters on each response are described and discussed. Further, the results of the operating cost are illustrated and discussed to distinguish the effects of the process parameters on the cost estimation at each stage. All the variables used in this research with ANOVA table were abbreviated as follows:

A= Barrel Temp

B= Screw Rotation

C= Nozzle Temp

AB= Barrel Temp *Screw Rotation

AC= Barrel Temp * Nozzle Temp

ABC= Barrel Temp * Screw Rotation * Nozzle Temp

5.4. Recycling process with no mixture of raw material PP

These experiments were carried out without addition of raw material PP, the design levels, input variables and experimental design levels used for this material in each stage are shown in table below. The yield strengths were measured as quality criteria for the different injection mould conditions in order to identify which factors are having significant effects on the Y. Three mathematical models were developed successfully to predict the responses as follows:

5.4.1. Development of raw material PP

In this stage, the experiment was designed based on three process factors A,B,C and two levels to working range of each variable. Table 5.2 shows the mould inputs variables and experimental design levels used for this stage. The experiment was carried out according to the design matrix of the FD method. Eight sets of experiments were performed and the mechanical properties were measured for each experiment. Table 5.3 shows the experiment layout and the measured responses. For this stage the mathematical models were developed successfully to predict the following response; yield strength (Y). The percentages of reduction in the yield strength were measured for each experiment by using Eq .5.3 to come up with an idea about how good is the number of recycling stage is and there impact on the quality of the final product.

$$\% = \frac{A - E}{A} \times 100 \tag{5.3}$$

Where:

%: percentage of reduction in the yield strength.

A: Expected value

E: Measured value

Table 5.2: Actual and coded values of the three factors.

Code	Variables	Unit	Low level (-1)	High level (+1)
A	Barrel Temp	°C	180	270
B	Screw Rotation	RPM	30	100
C	Nozzle Temp	°C	160	270

Table 5.3: The experiment layout and the measured responses.

Exp. No.	Run	Factors			Responses	
		A: Barrel Temp °C	B: Screw Rotation, (rpm)	C: Nozzle Temp °C	(y) Raw MPa	% of reduced
1	17	180	30	160	30.89	0.35
2	5	270	30	160	29.4	5.44
3	15	180	100	160	29.6	4.72
4	4	270	100	160	28.2	9.92
5	16	180	30	270	31.56	-1.77
6	8	270	30	270	29.83	3.92
7	18	180	100	270	29.83	3.92
8	19	270	100	270	29.77	4.13

5.4.1.1. Effects of A, B and C on the % of reduction in Y of the raw PP

Fig 5.4 shows the cycle time in eight sets of raw material PP. The results indicated that the screw rotation at 100 rpm were appears effectible to produced samples within less time than 65 and 30 rpm for example barrel temperature at 180 °C, screw rotation 100 rpm and nozzle temperature 160 °C. Which were appears effectives and economically for this range. Table 5.4 presents the ANOVA results for the parentage of reduction of the yield strength of the raw material. It indicates that the response can be described well by polynomial models with a good coefficient of determination (R^2). In this research the main three process factors effect of (A, B and C), two interaction effects of (AB) and

(AC), were significant model terms. It is evident from Table 5.4 that the model is significant since the "Prob>F" is less than 0.05. The adequacy measures considered herein are R^2 of 0.999, Adj- R^2 of 0.991, Pred- R^2 of 0.915, all these measures are in reasonable agreement and confirm that the model is adequate. Also the adequate precision ratio 35.033 is greater than 4, which indicates a desirable model. Fig. 5.5, it is a contours graph showing the effect of two factors (A and C) and (A and B) on the reduction percentage of tensile strenght. From Fig. 5.5a it is evident that less percentage of reduction can be obtained as the nozzle temperature decreased and the barrel temperature increased. From Fig. 5.6b, it is evident that as the screw rotation increase and the barrel temperature increased the percentage of reduction increases. Fig. 5.6 perturbation graph shows the relationship between the three factors and the percentage of reduction of raw PP, it is evident that the percentage of reduction in the yield strength increases as the barrel temperature and screw rotation increased and nozzle temperature decreased which can yield poor properties. Also, from this graph A and B is the most important variable that affects the response, while C has less affecte. Furthermore, Fig. 5.7 shows the relationship between the actual and predicted values of the three variable inputs (A, B and C). This Figure indicates that the developed models are adequate because the residuals in prediction of response are tiny, as the residuals tend to be close to the diagonal line to indicate good relationship between the experimental and predicted value of response in recycling the raw material of PP. The (ANOVA) test indicated that the main factor affecting the yield strength was (B) which is the most important factor influencing on the recycle of raw PP. Also, the two factors (A) and (C) have strong effect on the (Y). The final mathematical models in terms of coded factors as determined by the design-expert V7 software can be expressed as follows Eq .5.4:

$$\%\ \text{of reduction of raw} = 3.996 + 1.488\,A + 2.125\,B - 0.770\,C - 1.109\,AB - 0.843\,AC - 1.036\,ABC \qquad (5.4)$$

Table 5.4: ANOVA for reduced quadratic mode of the % of reduction of raw material.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	82.691	6	13.782	125.986	0.0681	Significant
A- Barrel Temp	17.711	1	17.711	161.904	0.0499	
B-Screw rotation	36.125	1	36.125	330.237	0.0350	
C-Nozzle Temp.	4.745	1	4.745	43.378	0.0959	
AB	9.837	1	9.837	89.923	0.0669	
AC	5.682	1	5.682	51.939	0.0878	
ABC	8.591	1	8.591	78.536	0.0715	
Residual	0.109	1	0.109			
Cor Total	82.800	7				
$R^2 = 0.999$				Adj. R^2=0.991		
Pred. $R^2 = 0.915$				Adeq .Precision= 35.033		

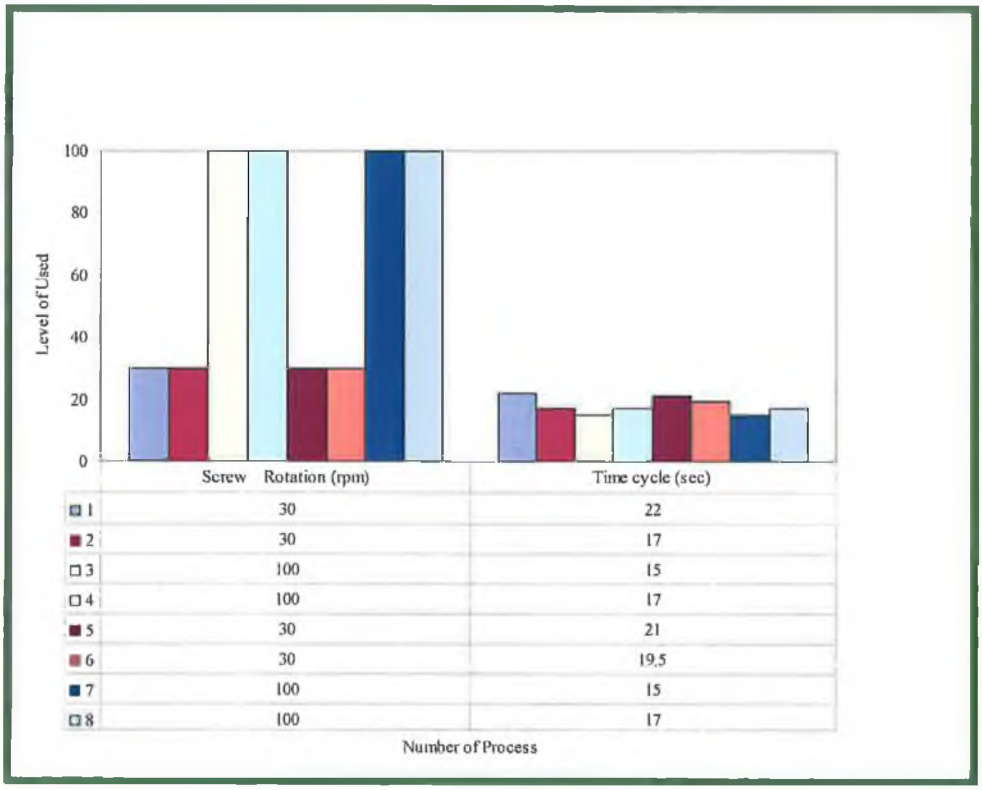
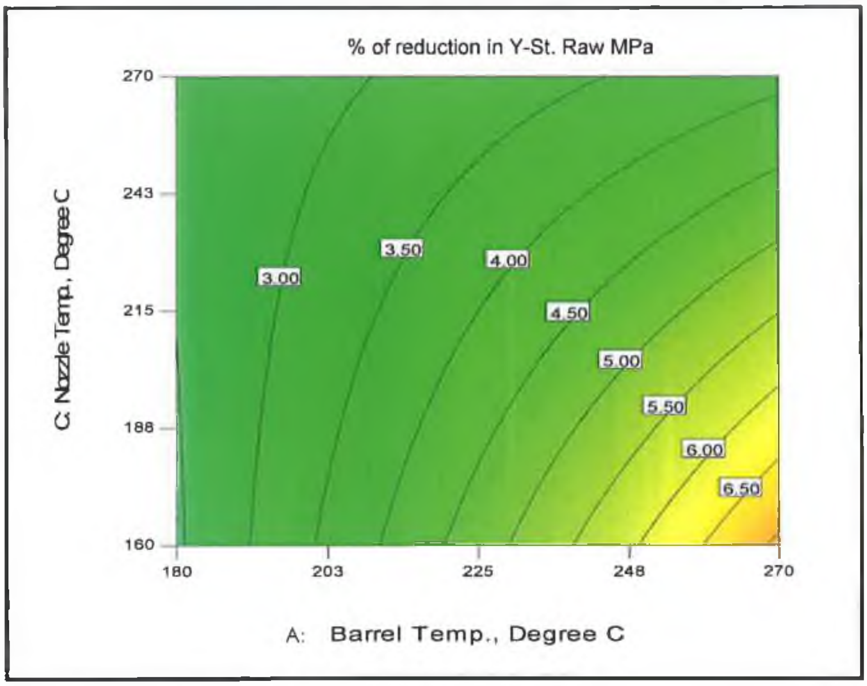
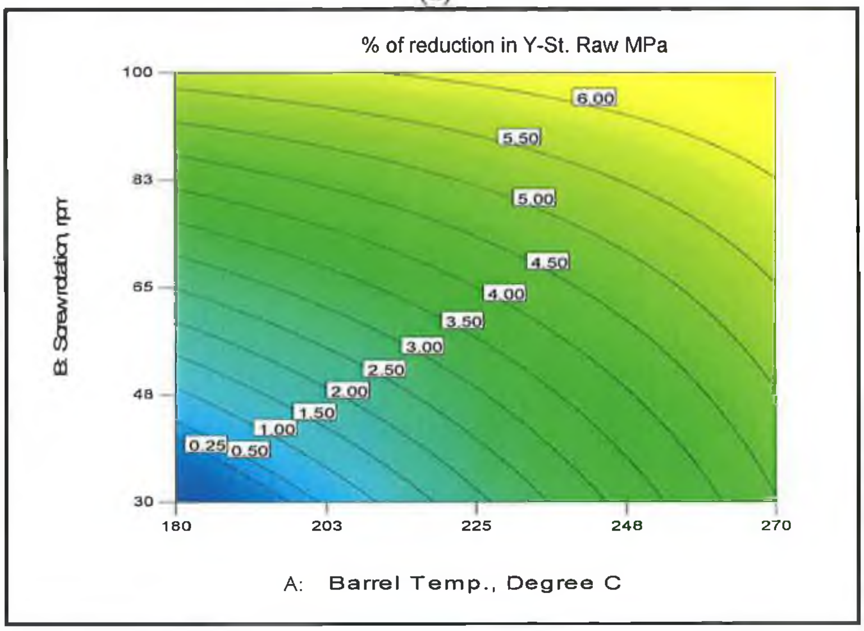


Fig. 5.4: Cycle time for raw material.



(a)



(b)

Fig. 5.5: Contour graphs of the effects of three variables on the % of reduction of the yield strength for the raw PP.

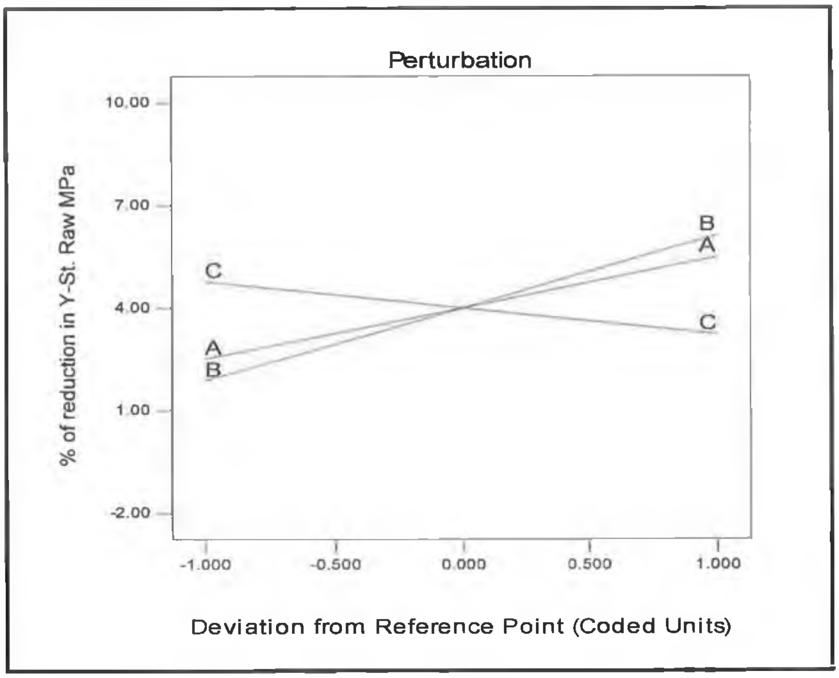


Fig. 5.6: Perturbation graph shows the relationship between the three factors and the percentage of reduction for raw PP.

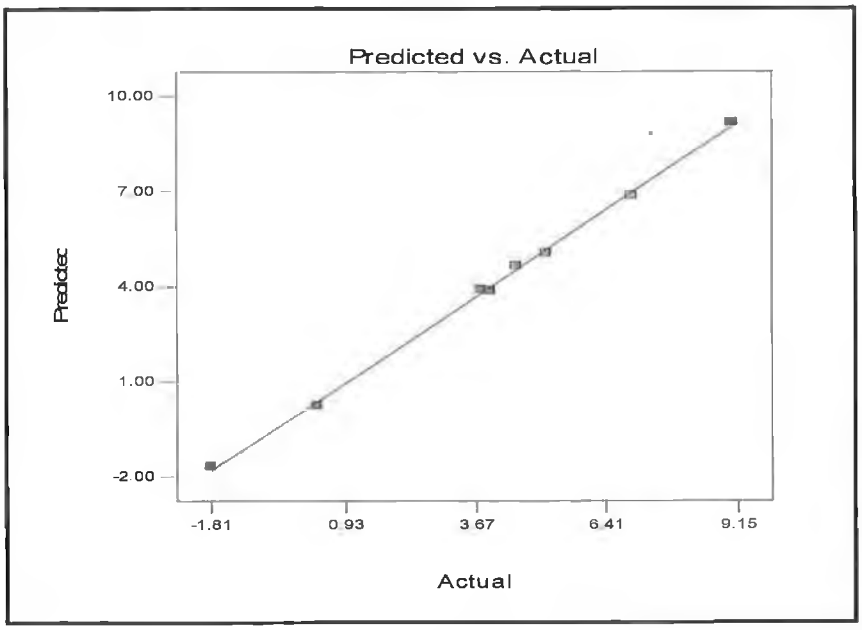


Fig. 5.7: Scatter diagram.

5.4.2. Development of the first recycling model

For the first stage, the experiment was designed based on three factors and two levels. Table 5.5 shows the mould inputs variables and experimental design levels used for this stage. The experiment was carried out according to the design matrix. Eight sets of experiments were applied with a combination of parameters, which expected to determine the variables having most significant effect on the response. Table 5.6 shows the process variables and experimental design levels used. For this stage the mathematical model was developed successfully to predict the following response the percentages of reduction.

Table 5.5: The experiment layout and the measured responses for 1st recycling.

Exp. No.	Run	Factors			Responses	
		A: Barrel Temp °C	B: Screw Rotation Rpm	C: Nozzle Temp °C	(y)First MPa	% of reduced
1	17	180	30	160	28.20	9.92
2	5	270	30	160	28.28	9.61
3	15	180	100	160	28.87	7.37
4	4	270	100	160	27.73	11.79
5	16	180	30	270	29.94	3.54
6	8	270	30	270	29.03	6.78
7	18	180	100	270	28.32	9.46
8	19	270	100	270	28.46	8.92

Table 5.6: Actual and coded values of the three factors for 1st recycling.

	Variables	Unit	Low level (-1)	High level (+1)
A	Barrel Temp	°C	180	270
B	Screw Rotation	rpm	30	100
C	Nozzle Temp	°C	160	270

5.4.2.1. Effects of A, B and C on the % of reduction of the yield strength of 1st recycling

In this case the effect of (A, B and C), two interaction effects of (BC) are significant model terms. The results of the ANOVA test, is summarised in Table 5.7. It is evident from Table 5.7 that the model is significant since the "Prob>F" is less than 0.05. The adequacy measures considered herein are R^2 of 0.996, Adj- R^2 of 0.984, Pred- R^2 of 0.929, all these measure are in reasonable agreement and confirm that the model is adequate. Also the adequate precision ratio 30.366 is greater than 4, which indicates a desirable model. Fig. 5.8 scatter diagram shows the relationship between the actual and predicted values of the three variables. This Figure indicates that the developed models are adequate because the residuals in prediction of response are minor, as the residuals tend to be close to the diagonal line. Fig. 5.9a and b are contour graphs that show the effect of the factors (A, C) and (B, C) on the percentage of reduction in tensile strength of the recycling first stage. From Fig. 5.9a, it is evident that as the nozzle temperature increases and the barrel temperature decreases and a good quality can be obtained. While, from Fig. 5.9b the good quality product can be achieved as the screw rotation decreases and the nozzle temperature increases. The results of ANOVA test indicated that the main factors affecting the yield strength is nozzle temperature (C) is the most important factor influencing on the recycle of first recycle PP. Furthermore, (B) and (A) have significant effects on the response, where the effect of (B) was stronger than the effect of (A). The Final mathematical models for percentage of reduction in the yield strength of the first recycling in terms of coded factors as determined by the Design-Expert are shown in Eq .5.5.

$$\% \text{ of reduction in yield strength of } 1^{st} \text{ recycling} = 7.730 + 0.738\,A + 0.835B - 1.07C + 0.931BC - 0.915\,ABC \quad (5.5)$$

Table 5.7: ANOVA for reduced quadratic mode of the % of reduction of 1st stage.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	32.846	5	6.569	89.387	0.0111	Significant
A-Parrel Temp.	4.356	1	4.356	59.273	0.0165	
B-Screw rotation	5.573	1	5.573	75.839	0.0129	
C-Nozzle Temp.	9.273	1	9.273	126.175	0.0078	
BC	6.941	1	6.941	94.444	0.0104	
ABC	6.703	1	6.703	91.202	0.0108	
Residual	0.147	2	0.073			
Cor Total	32.993	7				
$R^2 = 0.996$				Adj . R^2 =0.984		
Pred . $R^2 = 0.929$				Adeq .Precision =30.366		

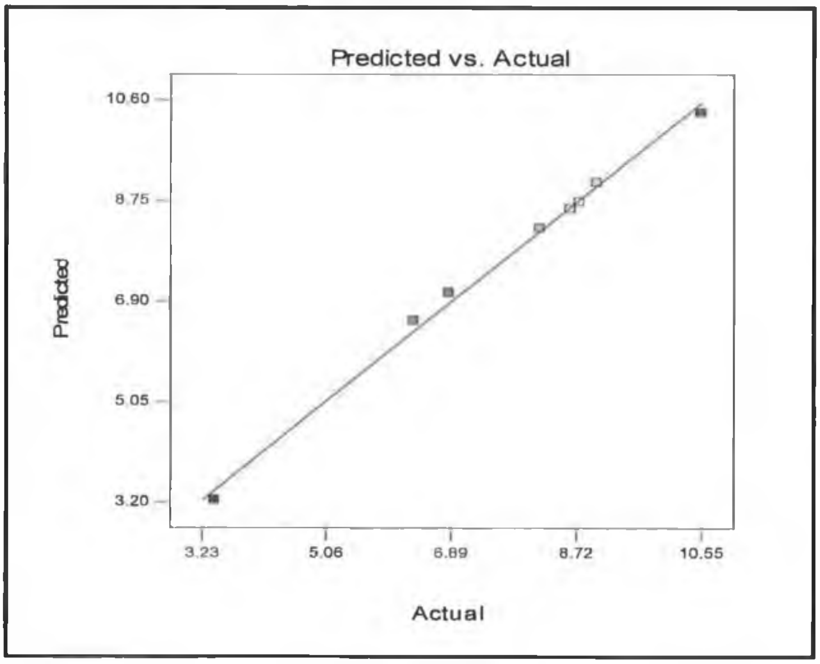
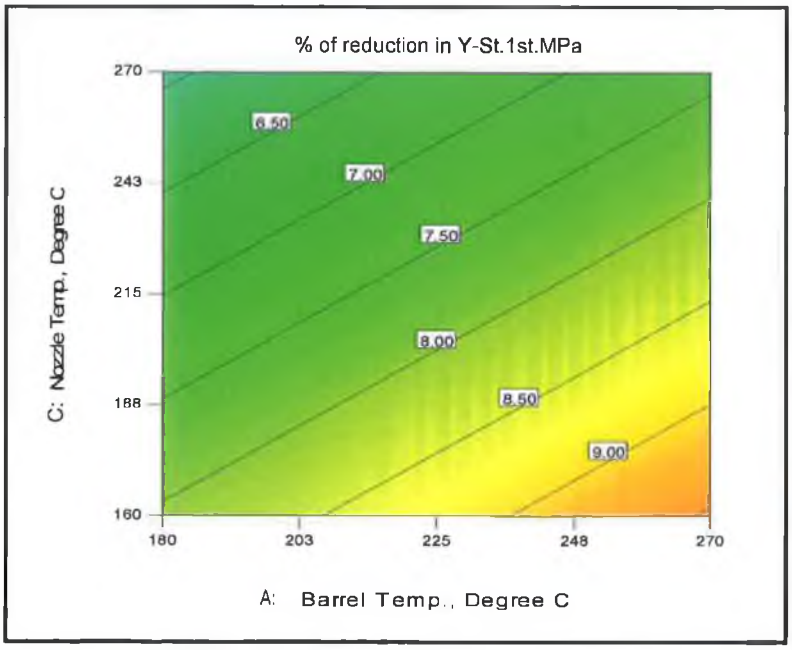
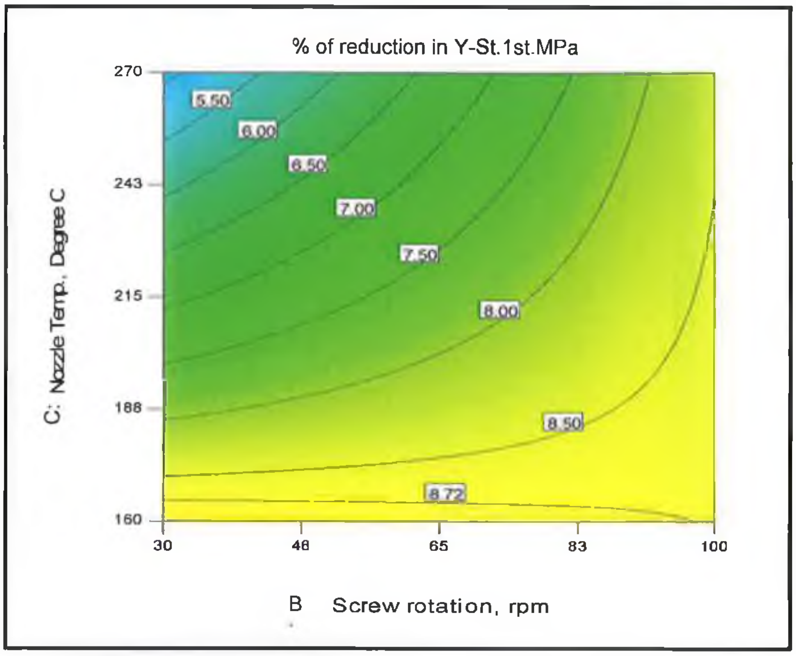


Fig. 5.8: Scatter diagram for 1st recycling.



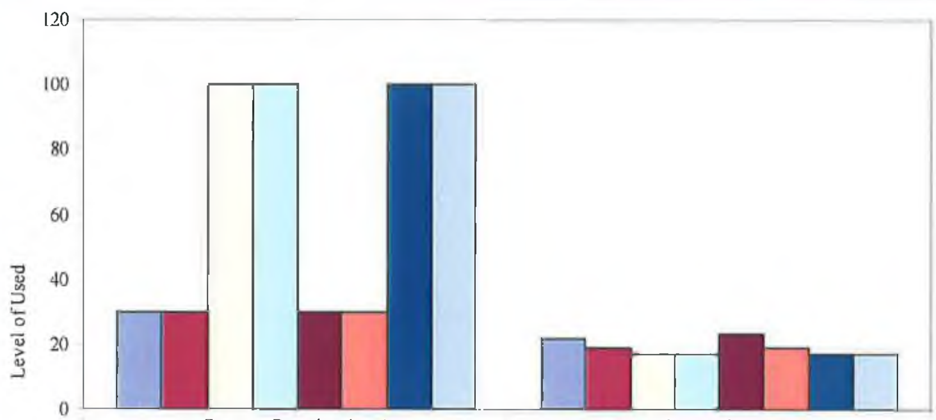
(a)



(b)

Fig. 5.9: Contour graphs of the effects of three variables on the % of reduction of the first recycling.

Fig 6.10 shows the cycle time for the eight sets of the first recycling. The results indicated that the screw rotation at 100 rpm were effectible to produce samples within less time than 65 and 30 rpm for example barrel temperature at 270 °C, screw rotation 100 rpm and nozzle temperature 160 °C. Which appears effective and economically for this range.



	Screw Rotation (rpm)	Time cycle (sec)
1	30	22
2	30	19
3	100	17.1
4	100	17
5	30	23.4
6	30	19
7	100	17
8	100	17

Number of Process

Fig. 5.10: Cycle time for first stage.

5.4.3. Development of second recycling model

For the second stage, the experiment was designed based on three factors and two levels. Table 5.8 shows the mould inputs variables and experimental design levels used for this stage. The experiential was carried out according to the design matrix. Eight sets of experiments were applied with a combination of parameters, which were expected to identify the variables having most significant effect on response. Table 5.9 presents the process variables and experimental design levels used. For this stage the mathematical model was developed successfully to predict the % of reduction in yield strength.

Table 5.8: The experiment layout and the measured responses for 2nd recycling.

Exp. No.	Run	Factors			Response	
		A: Barrel Temp °C	B: Screw Rotation Rpm	C: Nozzle Temp °C	(y) Second MPa	% of reduction
1	17	180	30	160	27.36	13.30
2	5	270	30	160	27.15	14.18
3	15	180	100	160	27.55	12.52
4	4	270	100	160	26.38	17.51
5	16	180	30	270	28.95	7.08
6	8	270	30	270	28.35	9.34
7	18	180	100	270	27.05	14.60
8	19	270	100	270	26.22	18.23

Table 5.9: Actual and coded values of the three factors for 2nd recycling.

Code	Variables	Unit	Low level (-1)	High level (+1)
A	Barrel Temp	°C	180	270
B	Screw Rotation	rpm	30	100
C	Nozzle Temp	°C	160	270

5.4.3.1. Effects of A, B and C on the % of reduction in the yield strength for the second recycling

In this case the effect of (A, B and C), two interaction effects of (AB) and two factors interaction effect (BC) are significant model terms. The results of the ANOVA test is summarised in Table 5.10. It is evident from Table 5.10. That the model is significant since the "Prob>F" is less than 0.05. The adequacy measures considered herein are R^2 of 0.989, Adj- R^2 of 0.961, Pred- R^2 of 0.820, all these measures are in reasonable agreement and confirm that the model is adequate. Also the adequate precision ratio 17.154 is greater than 4, which indicates a desirable model. Fig. 5.11 scatter diagram shows the relationship between the actual and predicted values of the response. This Figure indicates that the developed models are adequate because the residuals in prediction of response are small, as the residuals tend to be close to the diagonal line. Fig. 5.12a and b are contour graphs that show the effect of the three factors (A, B) and (B, C) on the response for second recycled PP. From Fig. 5.12a it is evident that as both the screw rotation and barrel temperature decreases superior quality products can be obtained as the percentage of reduction decreases. From Fig. 5.12b it is clear that as the screw rotation decreases and the nozzle temperature increases the desirable products could be achieved. The results of ANOVA test indicated that the main factor affecting the response is screw rotation (B), also (A) have strong effect on the response and (C). The Final mathematical model in terms of coded factors as determined by the Design-Expert is shown in Eq .5.6:

$$\%\text{ of reduction in Y for } 2^{nd}\text{ recycling} = 11.690 + 1.133\,A + 1.859B - 0.859\,C + 0.480\,AB + 1.391\,BC \quad (5.6)$$

Table 5.10: ANOVA for reduced quadratic mode of the % of reduction of 2^{nd} stage.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	61.139	5	12.228	35.117	0.0279	Significant
A-Barrel Temp.	10.271	1	10.271	29.496	0.0323	
B-Screw rotation	27.643	1	27.643	79.388	0.0124	
C-Nozzle Temp.	5.901	1	5.901	16.948	0.0542	
AB	1.842	1	1.842	5.290	0.1482	
BC	15.482	1	15.482	44.462	0.0218	
Residual	0.696	2	0.348			
Cor Total	61.835	7				
R^2 =0.989				Adj. R^2 =0.961		
Pred. R^2 = 0.820				Adeq .Precision= 17.154		

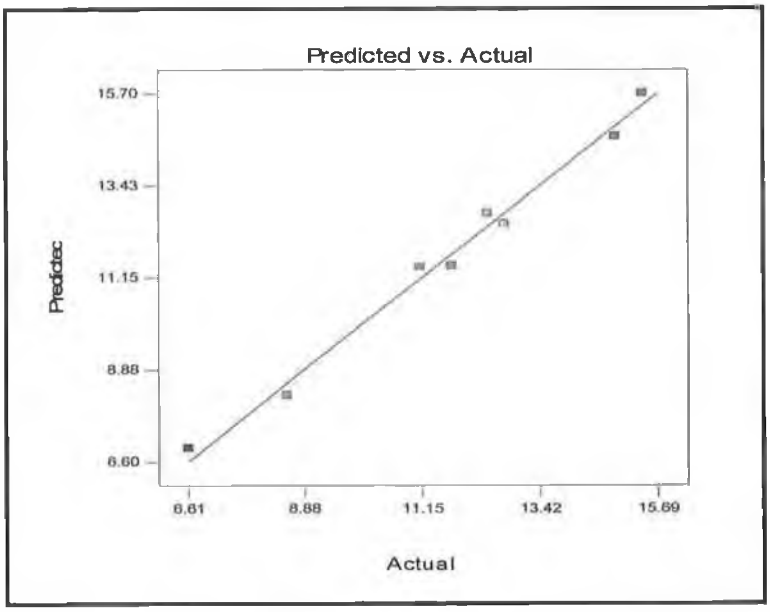
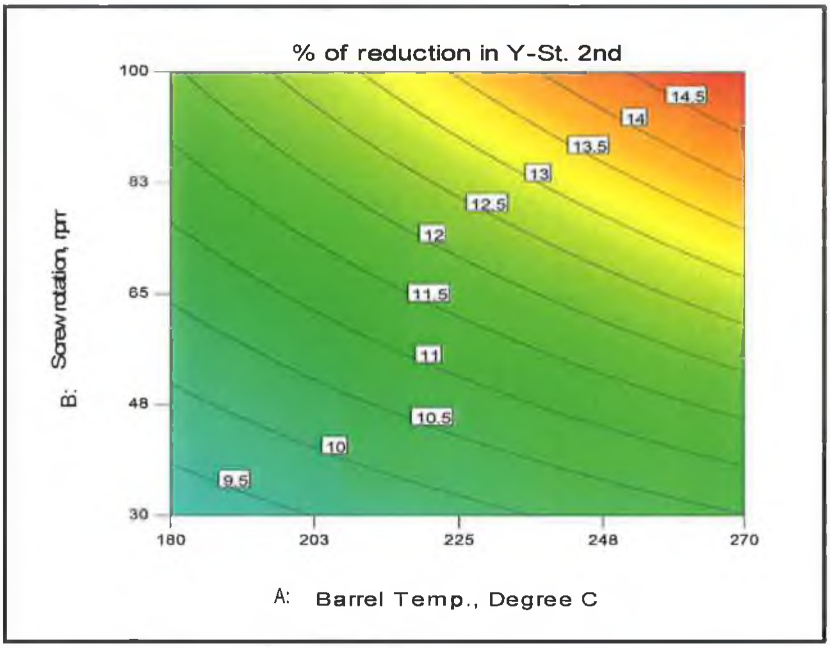
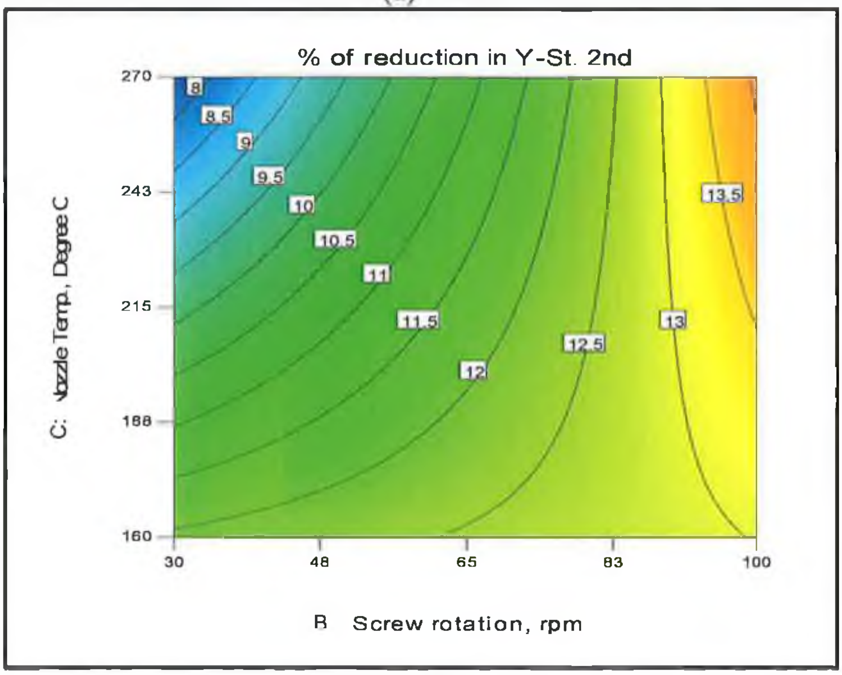


Fig. 5.11: Scatter diagram.



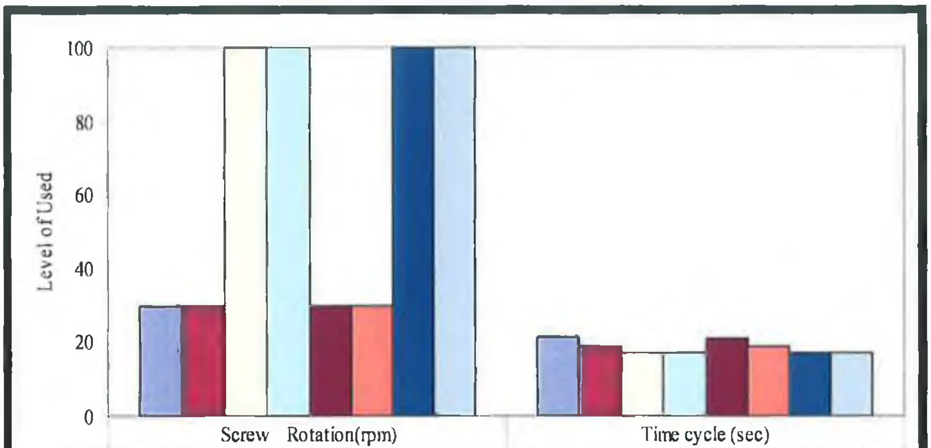
(a)



(b)

Fig. 5.12: Contour graphs of the effects of the three variables on the % of reduction in (Y) of the second recycling PP.

Fig 5.13 shows the cycle time for the eight sets of second recycled PP. The results indicated that the screw rotation at 100 rpm which appears effectible to produced samples within less time than 65 and 30 rpm for example barrel temperature at 180 °C, screw rotation 100 rpm and nozzle temperature 270 °C. Which appears effectives and economically for this range.



	Screw Rotation(rpm)	Time cycle (sec)
1	30	21.3
2	30	19
3	100	17.3
4	100	17
5	30	21.2
6	30	19
7	100	17
8	100	17

Number of Process

Fig. 5.13: Cycle time for second stage.

5.4.4. Development of third recycling

For the third stage, the experiment was designed based on three factors and two levels. Table 5.11 shows the mould inputs variables and experimental design levels used for this stage. The experiential was carried out according to the design matrix. The eight sets of experiments were carried out to identify the variables having most significant effect on response. Table 5.12 shows the process variables and experimental design levels used. For this stage the mathematical model was developed successfully to predict the percentages of reduction in the yield strength of the thirdly recycled pp.

Table 5.11: The experiment layout and the measured responses for 3rd recycling.

Exp. No.	Run	Factors			Responses	
		A: Barrel Temp °C	B :Screw Rotation Rpm	C :Nozzle Temp °C	(Y) third MPa	% of reduced
1	17	180	30	160	24.15	28.36
2	5	270	30	160	23.87	29.87
3	15	180	100	160	24.63	25.86
4	4	270	100	160	23.47	32.08
5	16	180	30	270	27.03	14.68
6	8	270	30	270	25.87	19.82
7	18	180	100	270	25.87	19.82
8	19	270	100	270	23.56	31.57

Table 5.12: Actual and coded values of the three factors for 3rd recycling.

Code	Variables	Unit	Low level (-1)	High level (+1)
A	Barrel Temp	°C	180	270
B	Screw Rotation	rpm	30	100
C	Nozzle Temp	°C	160	270

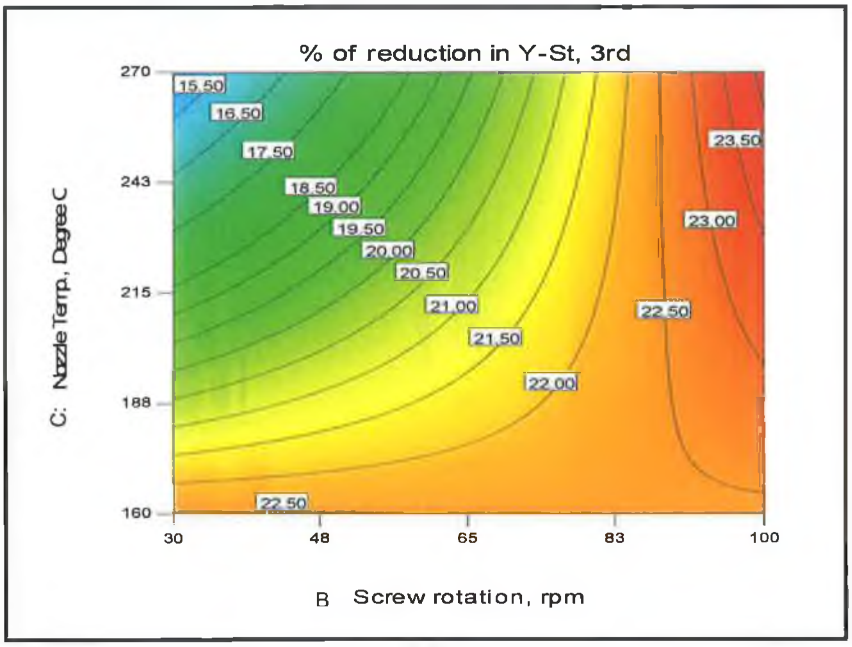
5.4.4.1. Effects of A, B and C on the % of reduction of the yield strength of the third recycling

In this case, the effect of (A, B and C), two factors interaction (BC), and three factors interaction effect (ABC) are significant model terms. The results of the ANOVA test is summarised in Table 5.13. It is evident from Table 5.13 that the model is significant since the "Prob>F" is less than 0.05. The adequacy measures considered herein are R^2 0.997, Adj- R^2 0.990, Pred- R^2 0.954, all these measures are in reasonable agreement and confirm that the model is adequate. Also the adequate precision ratio 31.446 is greater than 4, which indicates a desirable model. Fig. 5.14 a scatter plot shows the relationship between the actual and predicted values of the response. This figure indicates that the developed models are adequate because the residuals in prediction of response are tiny and the residuals tend to be close to the diagonal line. Contour graphs Fig. 5.15a and b a showing the effects of the three factors (A, B) and (B, C) on the response of the third recycled PP. From Fig. 5.15a it is evident that as the nozzle temperature increases and the screw rotation decreases a good property of the product is produced from third recycled PP. From Fig. 5.15b it is evident that as both the screw rotation and the barrel temperature decrease good property could be achieved. While, the desired quality could be achieved also as the nozzle temperature increased and the barrel temperature decreases as can be seen in Fig. 5.16. The Final mathematical model for this response in terms of coded factors as determined by the software is presented in Eq .5.7:

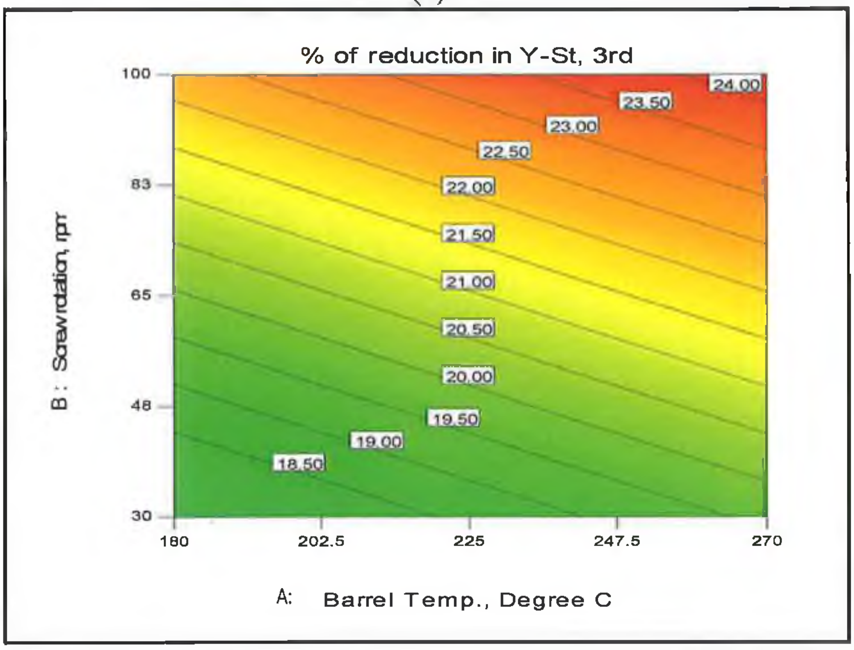
$$\% \text{ of reduction in Y of the third stage} = 20.948 + 1.012\,A + 2.335\,B - 1.536\,C + 2.399\,C - 0.859\,ABC \qquad (5.7)$$

Table 5.13: ANOVA for reduced quadratic mode of the % of reduction of 3rd stage.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	122.632	5	24.526	137.735	0.0072	Significant
A-Barrel Temp.	8.195	1	8.195	46.020	0.0210	
B-Screw rotation	43.606	1	43.606	244.880	0.0041	
C-Nozzle Temp.	18.882	1	18.882	106.034	0.0093	
BC	46.049	1	46.049	258.601	0.0038	
ABC	5.901	1	5.901	33.140	0.0289	
Residual	0.356	2	0.178			
Cor Total	122.988	7				
$R^2 = 0.997$				Adj. $R^2 = 0.990$		
Pred. $R^2 = 0.954$				Adeq. Precision= 31.446		



(a)



(b)

Fig. 5.15: Contours graph showing the effects of three variables on the % of reduction in (y) of the third recycling PP.

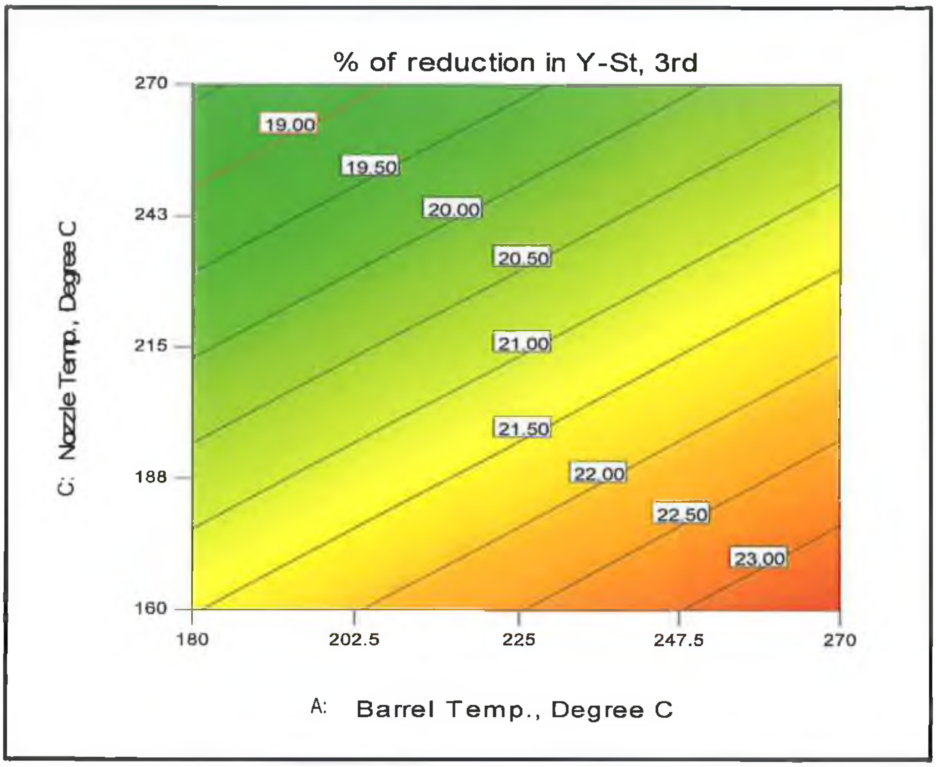
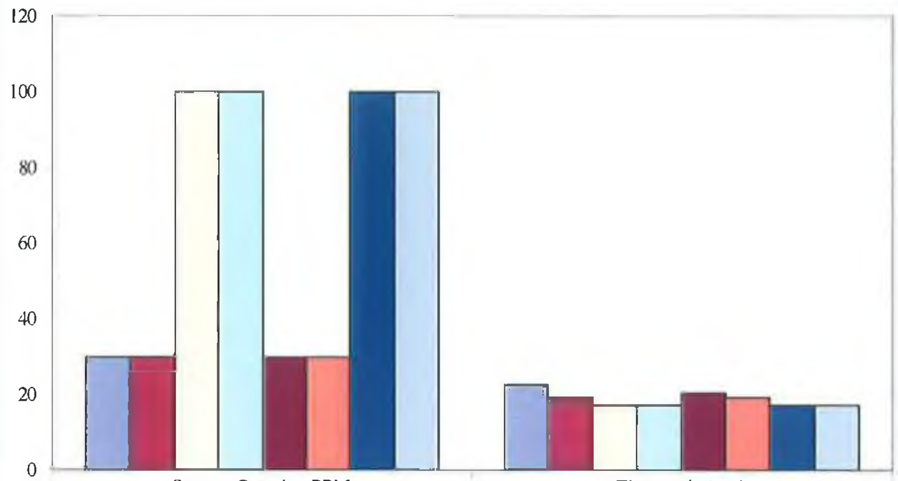


Fig. 5.16: Contours graph shows the effects of the nozzle temperature and barrel temperature on the response of the third recycled PP.

Fig 5.17 shows the cycle time in eight set of third recycled. The results indicated that the screw rotation at 100 rpm which appears effectible to produced samples within less time than 65 and 30 rpm for example barrel temperature at 270 °C, screw rotation 100 rpm and nozzle temperature 160°C. Which appears effectives and economically for this range.



	Screw Rotation RPM	Time cycle (sec)
1	30	22.4
2	30	19.1
3	100	17.1
4	100	17
5	30	20.4
6	30	19.1
7	100	17
8	100	17

Fig. 5.17: Cycle time in third stage.

5.5. Recycling process of mixture raw material PP

In This experiment, the recycled material was mixed with raw material with different percentages in order to enhance the quality of the final product. Table 5.14 shows the input variables, percentage of raw material and the experimental design levels used for this stage. Fifty-four different experiments for each stage were carried out and specimens of tensile strength were produced for each experiment in each stage. The responses which been considered herein are Y, UTS and operating cost per 500 samples (OC), at each stage. The experiments for each stage were designed based on four factors factorial design with three factors with three levels (the barrel temperature, screw rotation and percentage of raw material) as well as one factor with two levels (nozzle temperature).

5.5.1. Development of first recycling

For the first recycling stage, Table 5.14 shows the process variables and experimental design levels used. Table 5.15 and Table 5.16 show the mould inputs variables used for this stage and the responses values corresponding to each experiment.

Table 5.14: Process variables and experimental design levels used.

Code	Variables	Unit	Limits coded/actual		
			-1	0	+1
A	Barrel temp.	°C	180	225	270
B	Nozzle Temp	°C	160	-	270
C	Screw Rotation	rpm	30	65	100
D	% of RM.	%	5	20	35

Table 5.15: Experimental layout for first recycled material.

No.	Run	A	B	C	D	No.	Run	A	B	C	D
1	39	270	160	100	35	**28**	5	270	270	65	20
2	18	225	160	100	35	**29**	8	225	270	65	20
3	52	180	160	100	35	**30**	13	180	270	65	20
4	16	270	270	100	35	**31**	20	270	160	30	20
5	47	225	270	100	35	**32**	4	225	160	30	20
6	38	180	270	100	35	**33**	22	180	160	30	20
7	30	270	160	65	35	**34**	15	270	270	30	20
8	19	225	160	65	35	**35**	33	225	270	30	20
9	31	180	160	65	35	**36**	14	180	270	30	20
10	42	270	270	65	35	**37**	35	270	160	100	5
11	24	225	270	65	35	**38**	9	225	160	100	5
12	2	180	270	65	35	**39**	17	180	160	100	5
13	13	270	160	30	35	**40**	40	270	270	100	5
14	20	225	160	30	35	**41**	10	225	270	100	5
15	4	180	160	30	35	**42**	34	180	270	100	5
16	22	270	270	30	35	**43**	49	270	160	65	5
17	15	225	270	30	35	**44**	50	225	160	65	5
18	33	180	270	30	35	**45**	5	180	160	65	5
19	14	270	160	100	20	**46**	8	270	270	65	5
20	35	225	160	100	20	**47**	13	225	270	65	5
21	9	180	160	100	20	**48**	20	180	270	65	5
22	17	270	270	100	20	**49**	4	270	160	30	5
23	40	225	270	100	20	**50**	22	225	160	30	5
24	10	180	270	100	20	**51**	15	180	160	30	5
25	34	270	160	65	20	**52**	33	270	270	30	5
26	49	225	160	65	20	**53**	14	225	270	30	5
27	50	180	160	65	20	**54**	35	180	270	30	5

Table 5.16: Responses values corresponding to each experiment.

No.	Run	Y	UTS	OC	No.	Run	Y	UTS	OC
1	39	349.00	265.55	0.6654	**28**	5	350.56	254.11	0.7536
2	18	336.11	252.67	0.6457	**29**	8	340.33	243.44	0.7314
3	52	352.33	264.11	0.6259	**30**	13	348.78	259.44	0.7092
4	16	336.78	255.33	0.6699	**31**	20	342.56	250.78	0.9566
5	47	334.78	265.00	0.6501	**32**	4	344.89	249.44	0.9282
6	38	335.11	258.44	0.6304	**33**	22	350.33	255.00	0.8998
7	30	333.33	244.33	0.7486	**34**	15	340.67	261.22	0.9630
8	19	336.00	257.00	0.7264	**35**	33	352.67	260.33	0.9346
9	31	351.78	261.89	0.7042	**36**	14	351.22	266.11	0.9062
10	42	341.33	283.33	0.7536	**37**	35	337.67	275.33	0.6654
11	24	369.11	286.00	0.7314	**38**	9	347.11	251.78	0.6457
12	2	367.44	276.67	0.7092	**39**	17	355.33	259.22	0.6259
13	13	352.56	267.33	0.9566	**40**	40	334.00	233.00	0.6699
14	20	382.89	282.56	0.9282	**41**	10	348.33	257.22	0.6501
15	4	350.33	252.00	0.8998	**42**	34	343.78	250.56	0.6304
16	22	359.11	280.78	0.9630	**43**	49	346.89	268.33	0.7486
17	15	340.33	271.78	0.9346	**44**	50	351.33	256.00	0.7264
18	33	356.78	265.67	0.9062	**45**	5	357.78	257.11	0.7042
19	14	348.56	268.44	0.6654	**46**	8	351.56	270.78	0.7536
20	35	360.44	260.89	0.6457	**47**	13	337.11	265.00	0.7314
21	9	349.78	253.22	0.6259	**48**	20	345.11	257.89	0.7092
22	17	346.78	252.89	0.6699	**49**	4	339.22	246.89	0.9566
23	40	349.22	259.33	0.6501	**50**	22	338.67	252.11	0.9282
24	10	336.89	252.33	0.6304	**51**	15	348.78	250.67	0.8998
25	34	351.11	266.89	0.7486	**52**	33	310.78	255.78	0.9630
26	49	346.33	282.11	0.7264	**53**	14	337.11	266.00	0.9346
27	50	317.67	252.00	0.7042	**54**	35	339.67	260.00	0.9062

5.5.1.1. Effects of C, D on the yield strength in the first recycling

In this case, the main effect of the two factors C and D and their interaction effect are significant model terms. The results of the ANOVA test is summarised in Table 5.17. It is evident from Table 5.17, that the model is significant since the "Prob>F" is less than 0.05. The adequacy measures considered herein are R^2 of 0.193, Adj- R^2 of 0.144, Pred-

R^2 of 0.054, all these measure are in reasonable agreement and confirm that the model is adequate. Also the adequate precaution ratio 6.557 is greater than 4, which indicates a desirable model. Fig. 5.18 is an interaction graph shows the relationship between the two factors C and D on response (Y), it is evident that as the percentage of raw material (D) increased higher yield strength can be achieved Fig. 5.19 is a perturbation graph show the effect of two factors C and D on response, it is evident that as the screw rotation increased, poor yield strength will result despite the addition of raw material this can be notched from Fig. 5.18 as well. Furthermore, the graph indicated also that when the percentage of raw material is being increased this would result in higher tensile strength. The results indicate good relationship between the experimental and predicted values of (Y) of the first recycled PP. The results of (ANOVA) test indicated that the factor (D) - percentage of RM. is the most significant factor affecting this response. The Final mathematical models for this response in terms of coded factors as determined by the Design-Expert are shown in Eq.5.8. While, the final mathematical models in terms of actual factors are presented in Eqs. 5.9:

$$\text{Y-Strength First} = 346.0019 - 1.01541C + 3.19138D - 6.24537\,CD \quad (5.8)$$

$$\text{Y-Strength First} = 328.1678 + 0.208907\ \text{Screw Rotation} + 0.985996\ \%\ \text{of RM.} - 0.0119\ \text{Screw Rotation} * \%\ \text{RM.} \quad (5.9)$$

Table 5.17: ANOVA analysis for (Y) with the model in the first stage mixture material.

Source	Sum of Squares	Df	Mean Square	F Value	Prob > F	
Model	1339.887	3	446.629	3.993	0.0126	Significant
C-Screw rotation	37.117	1	37.117	0.331	0.5671	
D-% of RM.	366.656	1	366.656	3.278	0.0762	
CD	936.113	1	936.113	8.370	0.0056	
Residual	5591.871	50	111.837			
Cor Total	6931.759	53				
$R^2 = 0.193$				Adj. R^2=0.144		
Pred. $R^2 = 0.054$				Adeq .Precision= 6.557		

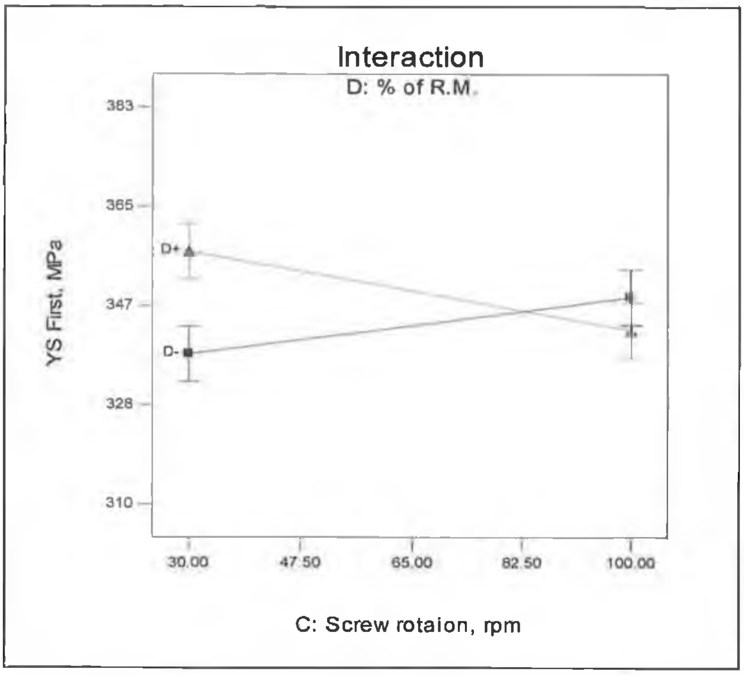


Fig. 5.18: Interaction graph shows the effect of C and D on Y for the first stage.

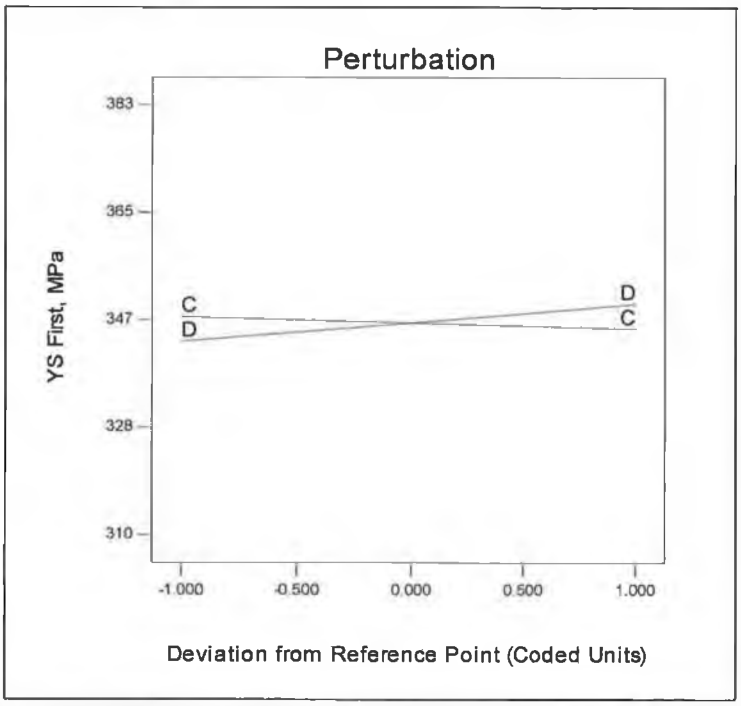


Fig. 5.19: Perturbation graph shows the effect C and D on Y for the first stage.

5.5.1.2. Effects of B, C and D on the ultimate tensile strength in the first recycling

In this case of the first stage, the main factor effect of (B, C and D), two interaction effects of (BC) and three factors interaction effect (BCD) are significant model terms. The results of the ANOVA test are summarised in Table 5.18. It is evident from Table 5.18 that the model is significant since the "Prob>F" is less than 0.05. The adequacy measures considered herein are R^2 of 0.234, Adj- R^2 of 0.171, Pred- R^2 of 0.088, all these measure are in reasonable agreement and confirm that the model is adequate. Also the adequate precision ratio of 6.717 is greater than 4, which indicates a desirable model. Fig. 5.20 shows contours graph, which presented the effects of two variables (B and C) on the UTS of the first recycled PP; it is evident that as the screw rotation increases and nozzle temperature increases the UTS would increase. Fig.5.21 Contours graph shows the effects of C and D on UTS, it is evident that as the screw rotation decreases and percentage of raw material increased the UTS enhances. Fig.5.22 presented 3D graph which shows the effect of C and A on the UTS, it is evident that as the barrel temperature increased and screw rotation increased the UTS would decrease. Fig.5.23 is a Perturbation graph shows the effect of the three factors B, C and D on UTS for the first recycling stage, it is evident that as the nozzle temperature and percentage of raw material increase this would result in increasing the UTS. Furthermore, the graph indicated that when the screw rotation increased this would reduce the UTS. The results of (ANOVA) test indicated that the factor (D)-% of Raw material is the most significant factor that would affect the product quality of first recycling stage. Table 5.18 shows the ANOVA results for UTS of the first stage mixture material PP. The final mathematical model for UTS of the first recycling in terms of coded factors as determined by the Design-Expert is shown in Eq .5.10. While, the final mathematical model in terms of actual factors is presented in Eqs. 5.11:

$$\text{UTS- First} = 260.5945 + 1.199623B - 1.642C + 4.354917D - 4.11109BC \quad (5.10)$$

$$\text{UTS- First} = 223.3025 + 0.160627 \text{ Nozzle Temp} + 0.412247 \text{ Screw Rotation} + 0.290328 \text{ \% RM.} - 0.00214 \text{ Nozzle Temp} * \text{Screw Rotation} \quad (5.11)$$

Table 5.18: Presents ANOVA analysis for UTS with the model in the first stage mixture material.

Source	Sum of Squares	df	Mean Square	F Value	Prob > F	
Model	1465.963	4	366.490	3.747	0.0097	Significant
B-Nozzle Temp	77.711	1	77.711	0.794	0.3771	
C-Screw Rotation	97.061	1	97.061	0.992	0.3240	
D-% of R.M.	682.750	1	682.750	6.980	0.0110	
BC	608.439	1	608.438	6.221	0.0160	
Residual	4792.377	49	97.803			
Cor Total	6258.34	53				
$R^2 = 0.234$			Adj. $R^2 = 0.171$			
Pred. $R^2 = 0.088$			Adeq .Precision= 6.717			

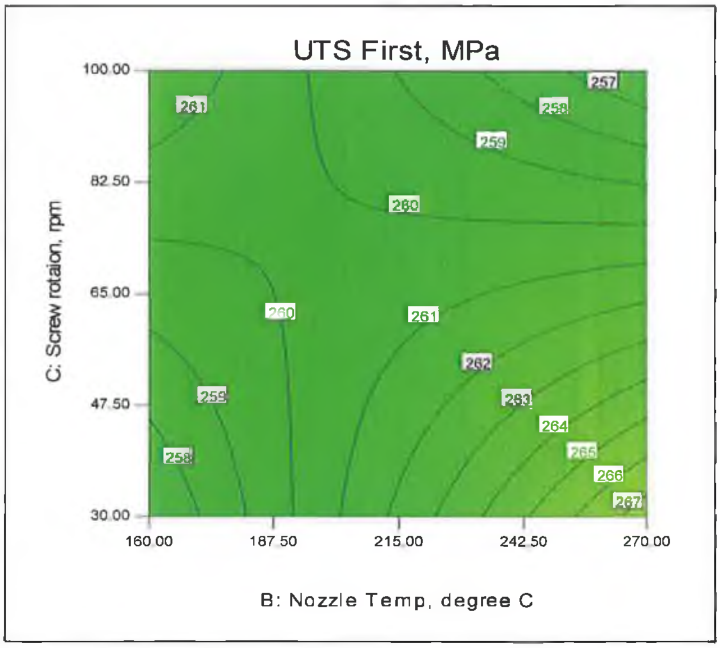


Fig.5.20: Contours graph shows the effects of C and B on UTS at the first stage.

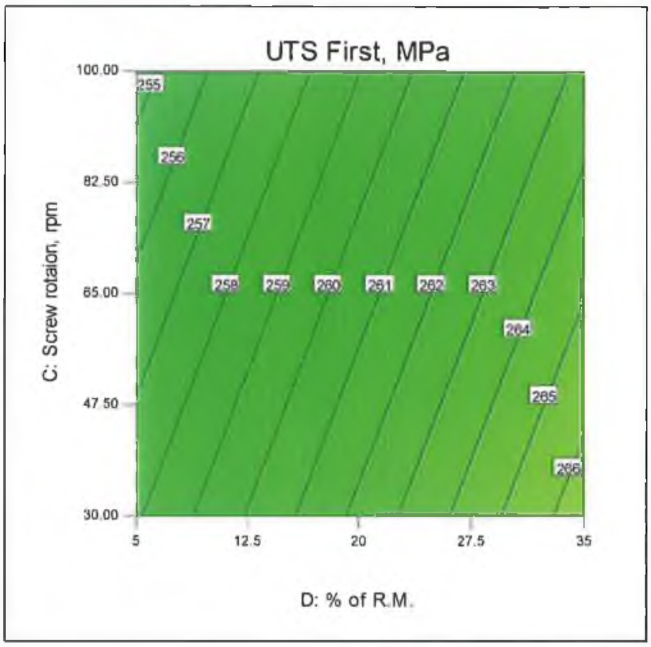


Fig.5.21: Contours graph shows the effects of C and D on UTS at the first stage.

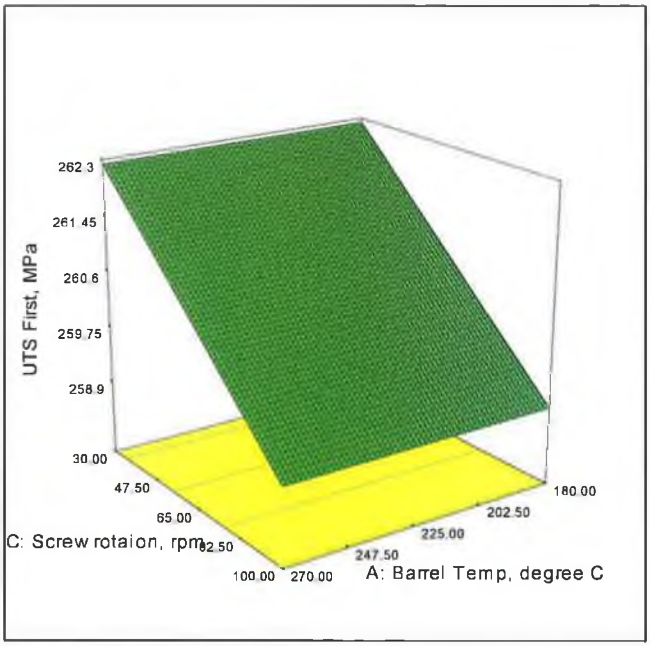


Fig.5.22: 3D graph show the effect of C and A on UTS at first stage.

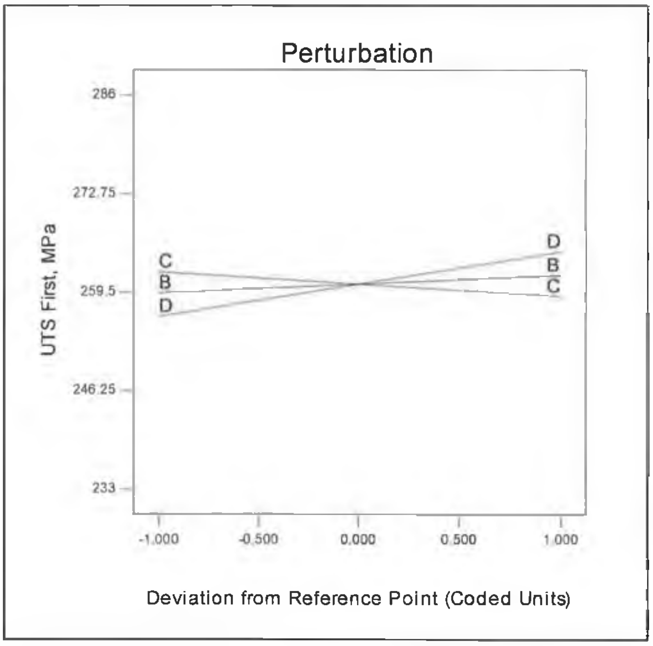


Fig.5.23: Perturbation graph show the effect of B, C and D on UTS at first stage.

5.5.2. Development of second recycling

For the second recycling stage, Table 5.19 shows the process variables and experimental design levels used. Table 5.20 and Table 5.21 present the mould inputs variables used for this recycling stage.

Table 5.19: Process variables and experimental design levels used.

Code	Variables	Unit	Limits coded/actual		
			-1	0	+1
A	Barrel temp.	°C	180	225	270
B	Nozzle Temp	°C	160	-	270
C	Screw Rotation	Rpm	30	65	100
D	% of RM.	%	10	25	40

Table 5.20: Experimental layout for second recycled material.

No.	Run	A	B	C	D	No.	Run	A	B	C	D
1	39	270	160	100	40	**28**	8	225	270	65	25
2	18	225	160	100	40	**29**	11	180	270	65	25
3	52	180	160	100	40	**30**	37	270	160	30	25
4	16	270	270	100	40	**31**	44	225	160	30	25
5	47	225	270	100	40	**32**	**8**	225	270	65	25
6	38	180	270	100	40	**33**	36	180	160	30	25
7	30	270	160	65	40	**34**	41	270	270	30	25
8	19	225	160	65	40	**35**	3	225	270	30	25
9	31	180	160	65	40	**36**	26	180	270	30	25
10	42	270	270	65	40	**37**	32	270	160	100	10
11	24	225	270	65	40	**38**	51	225	160	100	10
12	2	180	270	65	40	**39**	29	180	160	100	10
13	13	270	160	30	40	**40**	45	270	270	100	10
14	20	225	160	30	40	**41**	12	225	270	100	10
15	4	180	160	30	40	**42**	21	180	270	100	10
16	22	270	270	30	40	**43**	25	270	160	65	10
17	15	225	270	30	40	**44**	28	225	160	65	10
18	33	180	270	30	40	**45**	23	180	160	65	10
19	14	270	160	100	25	**46**	53	270	270	65	10
20	35	225	160	100	25	**47**	6	225	270	65	10
21	9	180	160	100	25	**48**	27	180	270	65	10
22	17	270	270	100	25	**49**	1	270	160	30	10
23	40	225	270	100	25	**50**	48	225	160	30	10
24	10	180	270	100	25	**51**	7	180	160	30	10
25	34	270	160	65	25	**52**	43	270	270	30	10
26	49	225	160	65	25	**53**	46	225	270	30	10
27	50	180	160	65	25	**54**	54	180	270	30	10

Table 5.21: Responses values corresponding to each experiment for 2nd.

No.	Run	Y	UTS	OC	No.	Run	Y	UTS	OC
1	39	334.00	247.44	0.6654	**28**	5	348.67	267.22	0.7536
2	18	345.11	244.67	0.6457	**29**	8	343.00	255.11	0.7314
3	52	360.00	252.44	0.6259	**30**	13	359.67	261.67	0.7092
4	16	353.67	241.56	0.6699	**31**	20	338.33	250.00	0.9566
5	47	347.67	266.00	0.6501	**32**	4	339.22	249.67	0.9282
6	38	357.00	273.11	0.6304	**33**	22	354.56	259.22	0.8998
7	30	348.56	254.11	0.7486	**34**	15	349.56	254.11	0.9630
8	19	354.56	261.33	0.7264	**35**	33	341.00	251.44	0.9346
9	31	363.56	266.00	0.7042	**36**	14	346.89	262.44	0.9062
10	42	344.44	270.78	0.7536	**37**	35	337.11	246.11	0.6654
11	24	353.22	256.78	0.7314	**38**	9	349.67	244.11	0.6457
12	2	352.56	268.11	0.7092	**39**	17	347.44	255.22	0.6259
13	13	335.78	243.11	0.9566	**40**	40	338.78	255.67	0.6699
14	20	336.78	253.78	0.9282	**41**	10	339.78	246.78	0.6501
15	4	352.44	264.33	0.8998	**42**	34	344.89	242.00	0.6304
16	22	347.89	263.00	0.9630	**43**	49	340.44	248.89	0.7486
17	15	348.56	259.89	0.9346	**44**	50	342.22	248.33	0.7264
18	33	357.00	275.00	0.9062	**45**	5	354.89	260.44	0.7042
19	14	348.00	247.44	0.6654	**46**	8	343.78	257.11	0.7536
20	35	346.44	255.00	0.6457	**47**	13	334.44	259.11	0.7314
21	9	367.11	267.67	0.6259	**48**	20	348.33	249.78	0.7092
22	17	349.78	252.78	0.6699	**49**	4	330.00	236.33	0.9566
23	40	337.67	249.67	0.6501	**50**	22	350.78	256.33	0.9282
24	10	351.11	331.67	0.6304	**51**	15	353.78	258.56	0.8998
25	34	347.33	248.11	0.7486	**52**	33	345.33	268.44	0.9630
26	49	350.78	253.44	0.7264	**53**	14	341.67	239.78	0.9346
27	50	360.78	261.11	0.7042	**54**	35	339.89	251.44	0.9062

5.5.2.1. Effects of A, B, C and D on the yield strength in the second recycling

In this case, the main factors effect of (A, B and C), two interaction effects of (AB) and three factors interaction effect (ABC) are significant model terms. The results of the ANOVA test is summarised in Table 5.22. It is evident from Table 5.22, that the model is significant since the "Prob>F" is less than 0.05. The adequacy measures considered herein are R^2 of 0.552, Adj- R^2 of 0.506, Pred- R^2 0.442, all of these measure are in reasonable agreement and confirm that the model is adequate. Also the adequate precaution ratio 10.708 is greater than 4, which indicates a desirable model. Fig. 5.24 is a contours graph shows the effect of the two factors A and B on the response (Y), it is obvious that as both the barrel temperature and nozzle temperature are decrease, the response would improve. Fig. 5.25 contours graph shows the effects of B ad D on Y. It is clear for low amount of raw material, that as percentage of raw material increases and the nozzle temperature decreases the desired quality can be achieved, but at high percentage of raw material the desired quality can be achieved by using high nozzle temperature. It is evident Fig. 5.25 that as the nozzle temperature and percentage of raw material increased good properties can be obtained. Furthermore, the graph indicated that the screw rotation increased it can obtained decreased UTS. The results of ANOVA test indicate that the barrel temp (A) is most major factor affecting the product quality for second recycling. Table 5.22 shows the ANOVA analysis for (Y) for the second stage. The Final mathematical model for the yield strength of the second recycling in terms of the coded factors as determined by the software is shown in Eq .5.12. While, the final mathematical model in terms of actual factors is presented in Eqs. 5.13:

$$\text{Y-Strength second} = 347.3311 - 5.29014\,A - 0.43415\,B + 3.043194 + 3.320972\,AB + 1.685176\,BD \quad (5.12)$$

$$\text{Y-Strength second} = 446.2961 - 0.40605 * \text{Barrel Temp} - 0.36087 * \text{Nozzle Temp} - 0.23629\ \%\ \text{R. M} + 0.001342\ \text{Barrel Temp} * \text{Nozzle Temp} + 0.002043\ \text{Nozzle Temp} * \%\ \text{of RM} \quad (5.13)$$

Table 5.22: ANOVA analysis for Y with the model in the 2nd stage mixed material.

Source	Sum of Squares	df	Mean Square	F Value	Prob > F	
Model	1850.328	5	370.065	11.861	< 0.0001	Significant
A-Barrel Temp	1007.481	1	1007.481	32.292	< 0.0001	
B-Nozzle Temp	10.17817	1	10.178	0.326	0.5705	
D-% of R. M.	333.397	1	333.397	10.686	0.0020	
AB	397.038	1	397.038	12.726	0.0008	
BD	102.233	1	102.233	3.276	0.0765	
Residual	1497.517	48	31.198			
Cor Total	3347.845	53				
$R^2 = 0.552$				Adj. $R^2 = 0.506$		
Pred. $R^2 = 0.442$				Adeq .Precision= 10.708		

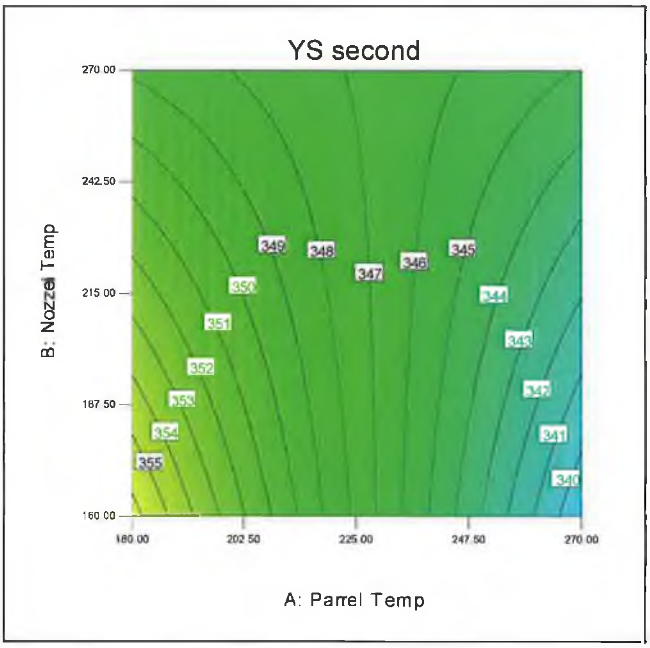


Fig. 5.24: Contours graph shows the effects of A and B on Y for second stage.

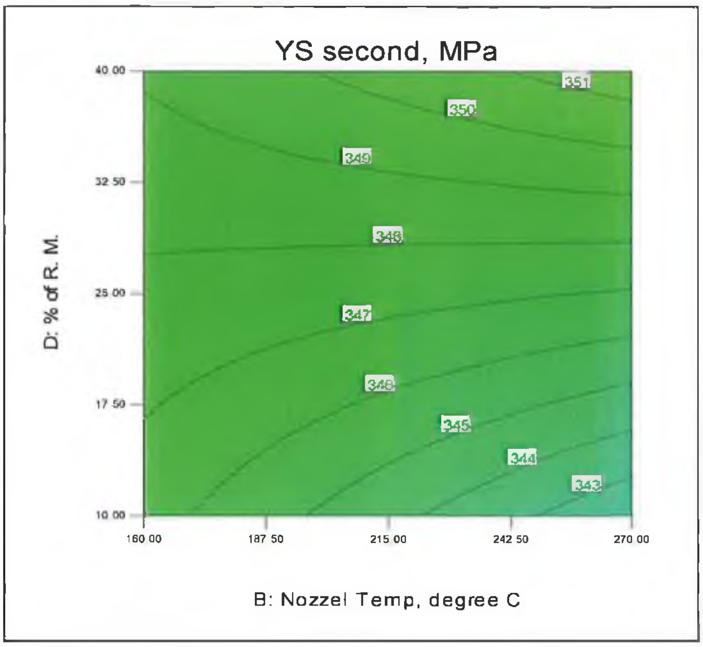


Fig. 5.25: Contours graph shows the effects of B ad D on Y for the second stage.

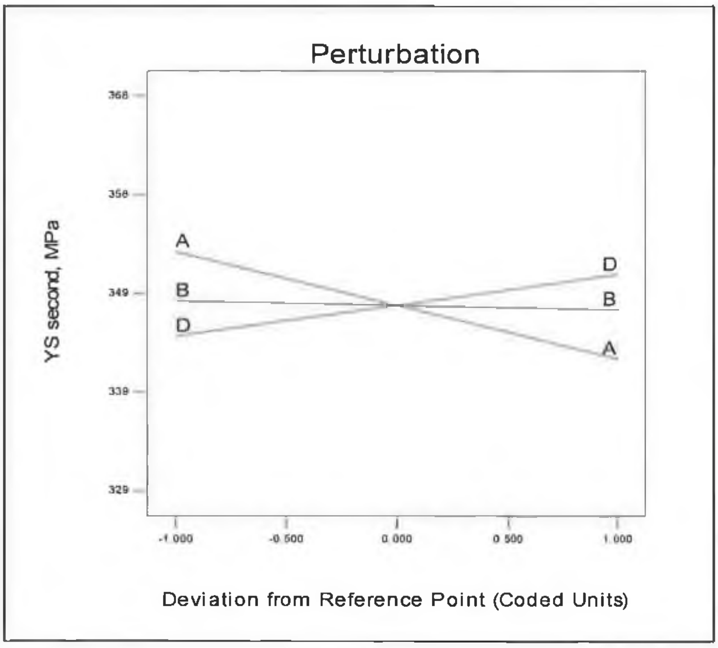


Fig. 5.26: Perturbation graph show the effect A, B and D on Y for the second stage.

5.5.2.2. Effects of A, B and D on the UTS of the second recycling

In this case, the main effects of the three factor effects (A, B and D) are significant model terms. The results of the ANOVA test are summarised in Table 5.23. It is evident from Table 5.23, that the model is significant since the "Prob>F" is less than 0.05. The adequacy measures considered herein are R^2 of 0.247, Adj- R^2 of 0.202, Pred- R^2 of 0.127, all these measure are in reasonable agreement and confirm that the model is adequate. Also the adequate precaution ratio 7.978 is greater than 4, which indicates a desirable model. Fig. 5.27 contours graph shows the effects of A and B on UTS, it is clear that as the nozzle temperature increases and the barrel temperature decreases the desirable quality could be reached. Fig. 5.28 contours graph shows the effects of C and D on UTS, it is evident that the screw rotation (C) has no significant effect, but as the percentage of raw material increases the UTS of the second stage improves. The results of ANOVA test indicate that the barrel temperature (A) is the most important factor affecting the product quality of second recycling stage. The Final mathematical model for ultimate tensile strength for the second recycling in terms of coded factors as determined by the Design-Expert is shown in Eq.5.14. Whilst, the final mathematical models in terms of actual factors are presented in Eqs. 5.15:

$$\text{UTS -Second recycle} = 256.7345 - 5.77778A + 3.652253B + 3.805574D \qquad (5.14)$$

$$\text{UTS -Second recycle} = 265.0038 - 0.1284 * \text{Barrel Temp} + 0.066405 * \text{Nozzle Temp} + 0.253705 * \%\ \text{RM}. \qquad (5.15)$$

Table 5.23: ANOVA analysis for UTS with the model in the 2nd stage mixed material.

Source	Sum of Squares	df	Mean Square	F Value	Prob > F	
Model	2443.447	3	814.482	5.480	0.0025	Significant
A-Barrel Temp	1201.778	1	1201.778	8.086	0.0064	
B-Nozzle Temp	720.303	1	720.303	4.846	0.0323	
D-% of R. M.	521.366	1	521.366	3.508	0.0669	
Residual	7430.614	50	148.612			
Cor Total	9874.061	53				
$R^2 = 0.247$				Adj. $R^2 = 0.202$		
Pred. $R^2 = 0.127$				Adeq .Precision= 7.978		

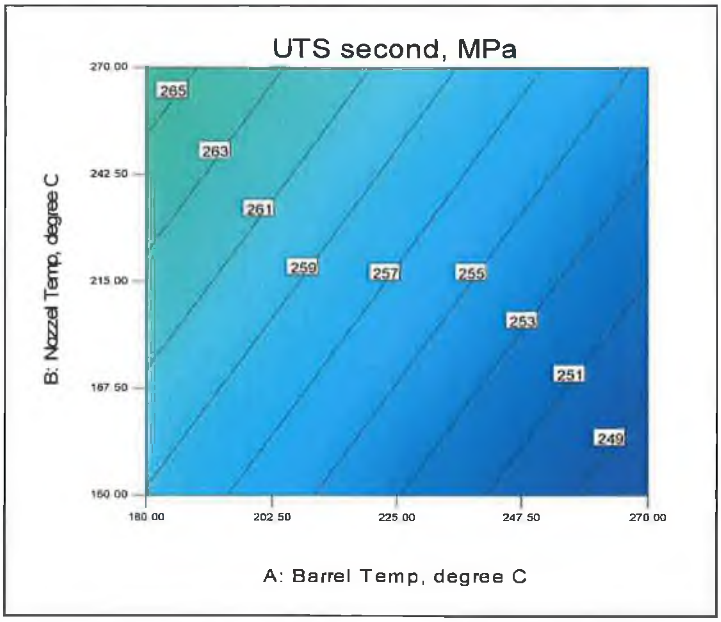


Fig. 5.27: Contours graph shows the effects of A and B on the UTS for the second stage.

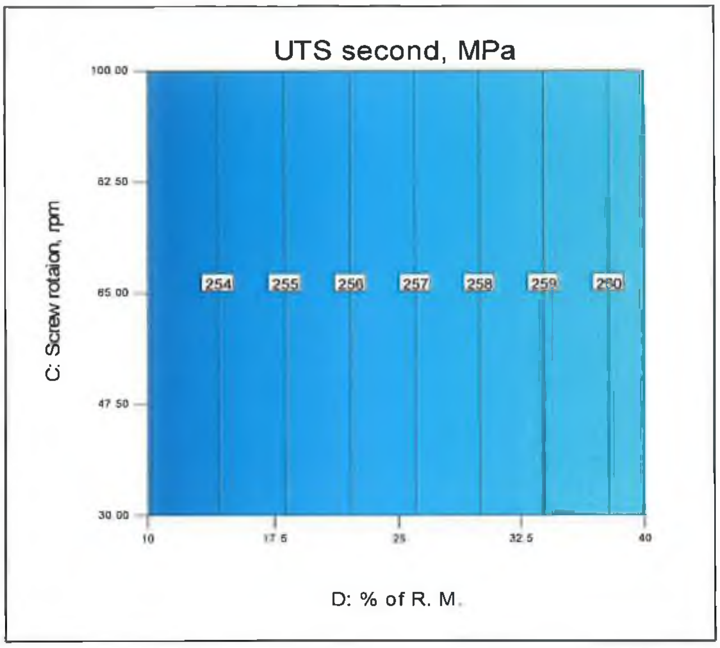


Fig. 5.28: Contours graph shows the effects of C and D on the UTS for the second stage.

5.5.3. Development of third recycling

For the third recycling stage, Table 5.24 illustrates the process variables and experimental design levels used. Table 5.25 and Table 5.26 show the mould inputs variables and the responses values corresponding to each experiment.

Table5.24: Process variables and experimental design levels used.

Code	Variables	Unit	Limits coded/actual		
			-1	0	+1
A	Barrel temp.	°C	180	225	270
B	Nozzle Temp	°C	160	-	270
C	Screw Rotation	rpm	30	65	100
D	% of RM.	%	20	35	50

Table 5.25: Experimental layout for third recycled material.

No.	Run	A	B	C	D	No.	Run	A	B	C	D
1	39	270	160	100	50	**28**	5	270	270	65	35
2	18	225	160	100	50	**29**	8	225	270	65	35
3	52	180	160	100	50	**30**	11	180	270	65	35
4	16	270	270	100	50	**31**	37	270	160	30	35
5	47	225	270	100	50	**32**	44	225	160	30	35
6	38	180	270	100	50	**33**	36	180	160	30	35
7	30	270	160	65	50	**34**	41	270	270	30	35
8	19	225	160	65	50	**35**	3	225	270	30	35
9	31	180	160	65	50	**36**	26	180	270	30	35
10	42	270	270	65	50	**37**	32	270	160	100	20
11	24	225	270	65	50	**38**	51	225	160	100	20
12	2	180	270	65	50	**39**	29	180	160	100	20
13	13	270	160	30	50	**40**	45	270	270	100	20
14	20	225	160	30	50	**41**	12	225	270	100	20
15	4	180	160	30	50	**42**	21	180	270	100	20
16	22	270	270	30	50	**43**	25	270	160	65	20
17	15	225	270	30	50	**44**	28	225	160	65	20
18	33	180	270	30	50	**45**	23	180	160	65	20
19	14	270	160	100	35	**46**	53	270	270	65	20
20	35	225	160	100	35	**47**	6	225	270	65	20
21	9	180	160	100	35	**48**	27	180	270	65	20
22	17	270	270	100	35	**49**	1	270	160	30	20
23	40	225	270	100	35	**50**	48	225	160	30	20
24	10	180	270	100	35	**51**	7	180	160	30	20
25	34	270	160	65	35	**52**	43	270	270	30	20
26	49	225	160	65	35	**53**	46	225	270	30	20
27	50	180	160	65	35	**54**	54	180	270	30	20

Table 5.26: Responses values corresponding to each experiment for 3nd.

No.	Run	Y	UTS	OC	No.	Run	Y	UTS	OC
1	39	347.44	253.11	0.6654	**28**	5	351.11	237.33	0.7536
2	18	353.56	250.78	0.6457	**29**	8	356.00	247.56	0.7314
3	52	357.78	263.11	0.6259	**30**	11	348.78	256.00	0.7092
4	16	336.22	242.22	0.6699	**31**	37	355.78	252.11	0.9566
5	47	349.11	245.00	0.6501	**32**	44	347.11	247.44	0.9282
6	38	356.44	253.11	0.6304	**33**	36	352.78	251.78	0.8998
7	30	350.11	247.67	0.7486	**34**	41	329.78	243.78	0.9630
8	19	340.67	249.33	0.7264	**35**	3	339.11	242.67	0.9346
9	31	356.00	254.22	0.7042	**36**	26	340.67	249.22	0.9062
10	42	352.33	256.78	0.7536	**37**	32	335.00	236.78	0.6654
11	24	345.11	243.33	0.7314	**38**	51	339.00	245.67	0.6457
12	2	349.78	254.11	0.7092	**39**	29	349.44	259.33	0.6259
13	13	345.78	246.00	0.9566	**40**	45	338.00	251.89	0.6699
14	20	354.89	256.22	0.9282	**41**	12	335.78	243.56	0.6501
15	4	361.11	260.78	0.8998	**42**	21	344.22	257.33	0.6304
16	22	350.11	259.89	0.9630	**43**	25	335.00	251.33	0.7486
17	15	360.22	265.78	0.9346	**44**	28	344.67	253.22	0.7264
18	33	362.00	264.67	0.9062	**45**	23	347.78	251.33	0.7042
19	14	344.00	245.67	0.6654	**46**	53	342.67	266.33	0.7536
20	35	353.67	251.33	0.6457	**47**	6	341.56	251.22	0.7314
21	9	356.22	248.67	0.6259	**48**	27	350.89	262.11	0.7092
22	17	346.89	256.56	0.6699	**49**	1	335.67	237.44	0.9566
23	40	343.78	247.56	0.6501	**50**	48	343.11	249.78	0.9282
24	10	346.78	263.56	0.6304	**51**	7	348.44	252.00	0.8998
25	34	348.00	256.44	0.7486	**52**	43	347.44	248.33	0.9630
26	49	354.89	253.11	0.7264	**53**	46	338.44	268.78	0.9346
27	50	355.11	257.78	0.7042	**54**	54	339.89	257.89	0.9062

5.5.3.1. Effects of A, B and D on the yield strength in the third recycling

In this case the main effects of the three factors (A, B and D) are significant model terms. The results of the ANOVA test are summarised in Table 5.27. It is evident from Table 5.27, that the model is significant since the "Prob>F" is less than 0.05. The adequacy measures considered herein are R^2 of 0.465, Adj- R^2 of 0.433, Pred- R^2 of 0.380, all these measure are in reasonable agreement and confirm that the model is

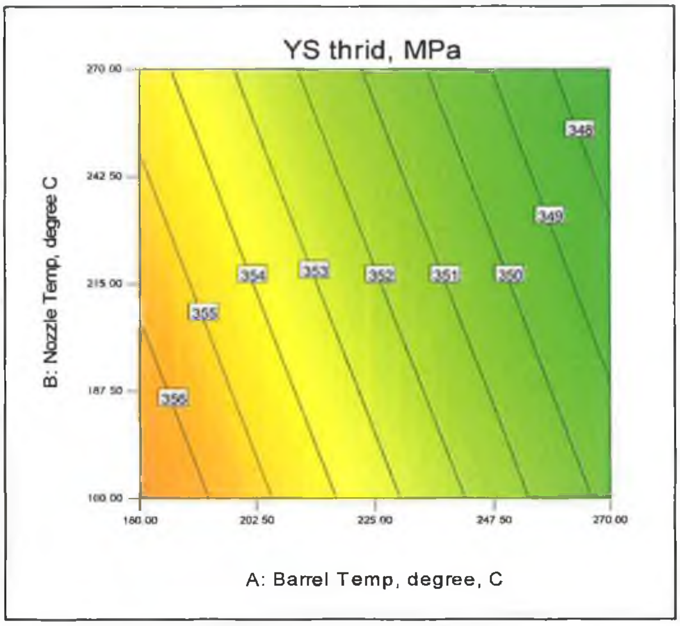


Fig. 5.29: Contours graph shows the effects of A and B on Y for the third stage.

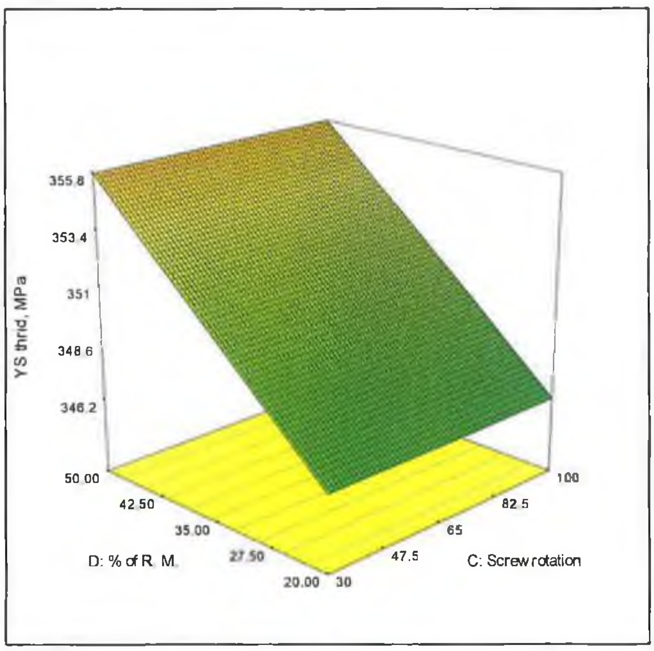


Fig. 5.30: 3D graph shows the effects of C and D on Y for the third stage.

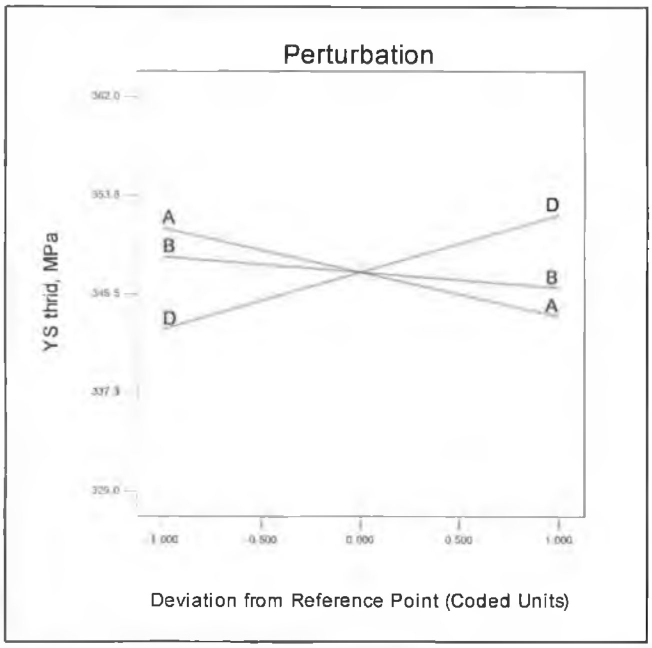


Fig. 5.31: Perturbation graph shows the effects of A, B and D on Y for the third stage.

5.5.3.2. Effects of A on the ultimate tensile strength of the third recycling

In this case, the main factor effect of (A) is significant model term. The results of the ANOVA test are summarised in Table 5.28. It is evident from Table 5.28, that the model is significant since the “Prob>F” is less than 0.05. The adequacy measures considered herein are R^2 of 0.153, Adj- R^2 of 0.136, Pred- R^2 of 0.087, all these measure are in fair agreement and confirm that the model is adequate. Also the adequate precision ratio 5.309 is greater than 4, which indicates a desirable model. Fig. 5.32 one factor effect grape shows the effect of (A) on UTS. It is evident that as the barrel temperature (A) increased the (UTS) decreases for the third stage. The final mathematical model for the ultimate tensile strength - third recycling in terms of coded factors as determined by the Design-Expert is shown in Eq.5.18. While, the final mathematical model in terms of actual factors is presented in Eqs. 5.19: Table 5.29 shows cycle time of first, second and third recycling stage with mixed raw PP.

UTS- Third = 252.2036 – 0.53704 A (5.18)

UTS- Third= 269.8888 - 0.0786 * Barrel Temp (5.19)

Table 5.28: ANOVA analysis for UTS of the model in the 3rd stage mixed material.

Source	Sum of Squares	Df	Mean Square	F Value	Prob > F	
Model	450.382	1	450.382	9.395	0.0034	Significant
A-Barrel Temp	450.382	1	450.382	9.395	0.0034	
Residual	2492.641	52	47.935			
Cor Total	2943.024	53				
$R^2 = 0.153$				Adj. $R^2 = 0.136$		
Pred. $R^2 = 0.087$				Adeq .Precision= 5.309		

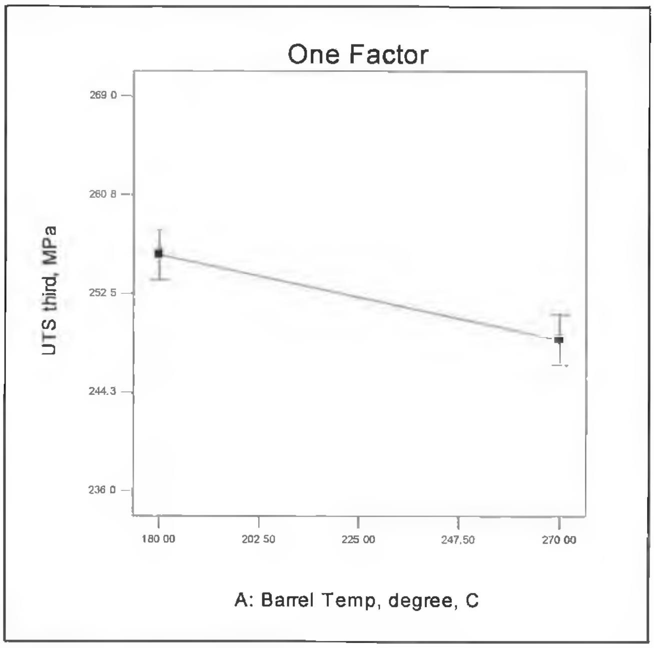


Fig. 5.32: Interaction grape show the effect of C on UTS at third stage.

Table 5.29: Cycle time of first, second and third recycling stage with mixed raw PP.

No.	Cycle time First Recycling	Cycle time Second Recycling	Cycle time third Recycling
1	15	15	15
2	15.1	15.1	15
3	15.2	15.2	15.1
4	14.8	14.9	15
5	15	15	15
6	15	15.1	15.2
7	15.1	15	15.1
8	15.7	15.3	15.3
9	16.3	17.3	18.1
10	14.8	15.1	15.5
11	15.5	15.5	15.3
12	16.7	17.9	18.2
13	21.5	20.9	22.4
14	21.7	22	23.5
15	24.2	25.2	25.1
16	20.5	21.4	21
17	20.6	22	22.7
18	23	26	24.2
19	14.9	15	14.9
20	14.9	15.1	14.8
21	15	14.9	15
22	14.8	15	15
23	15	14.9	14.8
24	14.9	14.8	15
25	15.5	15.4	15.2
26	15.3	15.4	15.5
27	15.8	16.7	17
28	15.3	15	15
29	14.9	15.4	15.4
30	16.2	17.2	17
31	19.9	21	22.5
32	22.4	20.8	22.7
33	22.3	23.3	24
34	21.1	20.5	22
35	22.2	23.1	22
36	24.1	24.6	23.5
37	14.8	14.8	14.8
38	15.1	14.8	14.5
39	15.1	14.9	14.9
40	14.9	15	15
41	14.9	15.1	14.8
42	15.1	14.8	15
43	15.1	14.8	15.5
44	15.2	15.1	15.5
45	17.2	16.1	16
46	15.2	15.5	15
47	15.1	15	15
48	17.3	16.8	16
49	24.3	22.1	22
50	22.9	25.8	21
51	24	25.2	23
52	21.3	21	22.4
53	21.7	21.1	22
54	24	24.4	23

5.6. Operating cost calculation

Recycling operating cost can be estimated as Euro per hour or Euro per sample for particular injection moulding machine type HM7, The barrel and nozzle- changed after 10 years, barrel temperature max 400°C, nozzle temperature max 400°C. Also oil heraldic uses 17 litres changed after three years or after 1,000,000 samples as mention in Table 5.1 chapter 5. The total approximated operating cost per hour or per sample as a function of the output power can be estimated by Eq.5. 20 and Eq.5.21. Table 5. 30 show the elements of operating costs of the injection moulding HM7.

Table 5.30: Operating costs break down.

No.	Elements of cost	Calculations	Operating cost €/h
1	Machine power cost	1.5 [kW]*€ 0.104/[kWh]	0.15600
2	Barrel	0.76 [kWh]* (€ 0.104/[kWh])* Tb/400	0.0001976*Tb
3	Nozzle	0.07 [kWh]* (€ 0.104/[kWh])* Tn/400	0.0000182*Tn
4	Replacing the screw	€ 2050/ 10 years*52 w/y*5days/w*24h/day	0.03285
5	Replacing the barrel	€ 1880/ 10 years*52 w/y*5days/w*24h/day	0.03013
6	Replacing the nozzle	€ 330/ 10 years*52 w/y*5days/w*24h/day	0.00481
7	Labour cost	(8h/62400h) *€ 400/8h	0.00641
8	Oil heraldic price	(€ 20/litre)*17litre/(3y*52w/y*7*days/w*24h/day)	0.01297
9	Mould Cost	€ 2000/(1000000 sample* t h/sample)	0.002 * t

$$OC\ [€/h] = (0.24317 + 0.0001976*Tb + 0.0000182*Tn + 0.002 * t) \quad (5.20)$$

$$OC\ [€/sample] = (0.24317 + 0.0001976*Tb + 0.0000182*Tn + 0.002 * t)*t \quad (5.21)$$

Where:

Tb- is the barrel temperature.

Tn- is the nozzle temperature.

5.6.1. Effects of A, B and C on the operating cost

In this case the main three factor effect of (A, B and C), are significant model terms. The results of the ANOVA test are summarised in Table 5.31. It is obvious from Table 5.31, that the model is significant since the "Prob>F" is less than 0.05. The adequacy measures considered herein are R^2 of 0.996, Adj- R^2 of 0.939, Pred- R^2 of 0.934 all these measure are in reasonable agreement and confirm that the model is adequate. Also the adequate precaution ratio 41.221 is greater than 4, which indicates a desirable model. Fig. 5.33 contours graph shows the effects of A and C on (OC), it is evident that as the barrel temperature increases and the screw rotation decreases the operating cost increases. Fig. 5.34 contours graph shows the effects of B and C on (OC), it is clear that as the screw rotation decreases and the nozzle temperature increase the operating cost increases. Fig. 5.35 perturbation graph shows the effects of three factors A, B and C on the (OC), it is evident that as the screw rotation increases the operating cost decreases sharply. The Final mathematical model for the operating cost in terms of coded factors as determined by the Design-Expert is shown in Eq.5.22. While, the final mathematical model in terms of actual factors is presented in Eqs. 5.23:

$$OC = 0.769378 + 0.023465\ A + 0.002642\ B - 0.14173\ C \quad (5.22)$$

$$OC = 0.904945 + 0.000521\ \text{Barrel Temp} + 4.8E-05\ \text{Nozzle Temp} - 0.00405\ \text{Screw rotation} \quad (5.23)$$

Table 5.31: ANOVA analysis for operating.

Source	Sum of Squares	df	Mean Square	F Value	Prob > F	
A-Barrel Temp	0.7433	3	0.2477	276.7871	< 0.0001	Significant
B-Nozzle Temp	0.0198	1	0.0198	22.1413	< 0.0001	
C-Screw rotation	0.0003	1	0.0003	0.4208	0.5195	
Residual	0.7231	1	0.7231	807.799	< 0.0001	
Cor Total	0.0447	50	0.0008			
	0.7881	53				
$R^2 = 0.943$				Adj. $R^2 = 0.939$		
Pred. $R^2 = 0.934$				Adeq. Precision= 41.221		

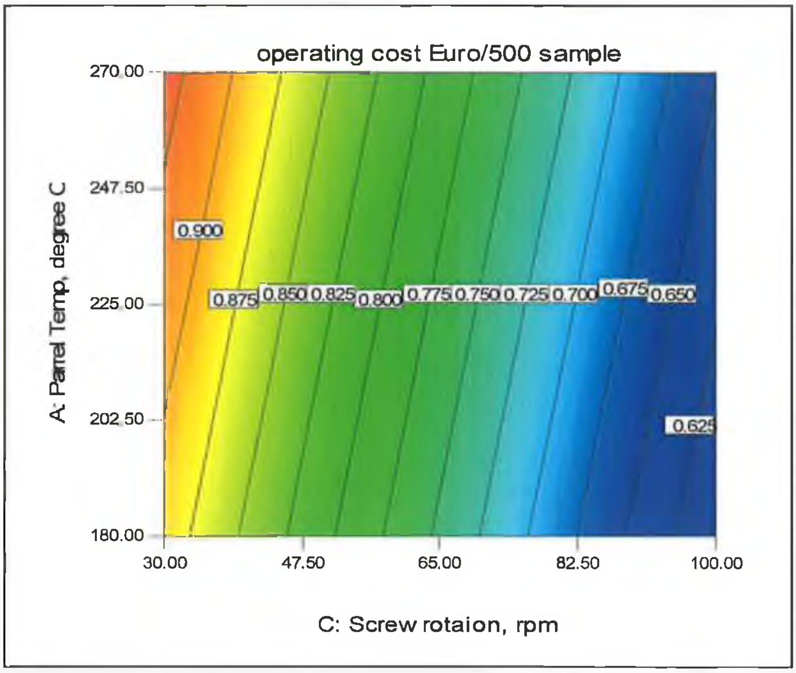


Fig.5.33: Contours graph shows the effects of A and C on OC.

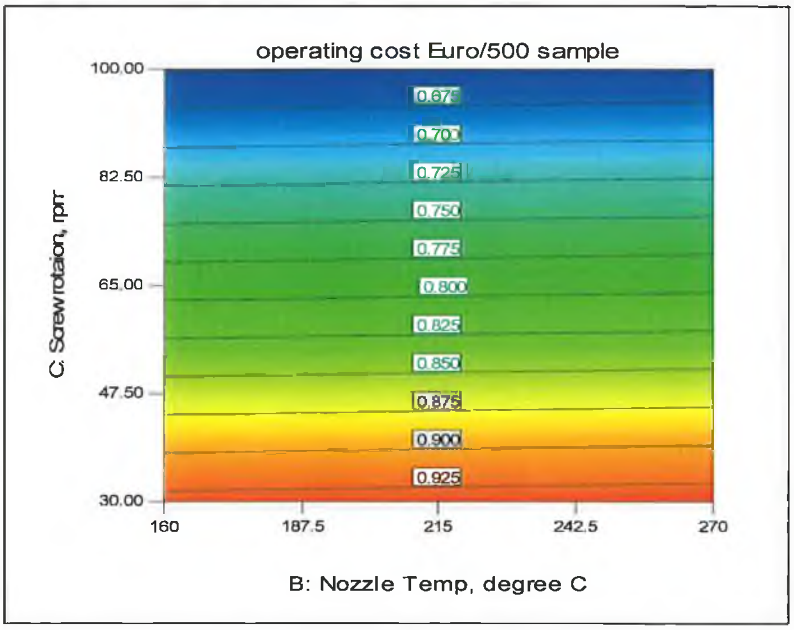


Fig. 5.34: Contours graph shows the effects of B and C on OC.

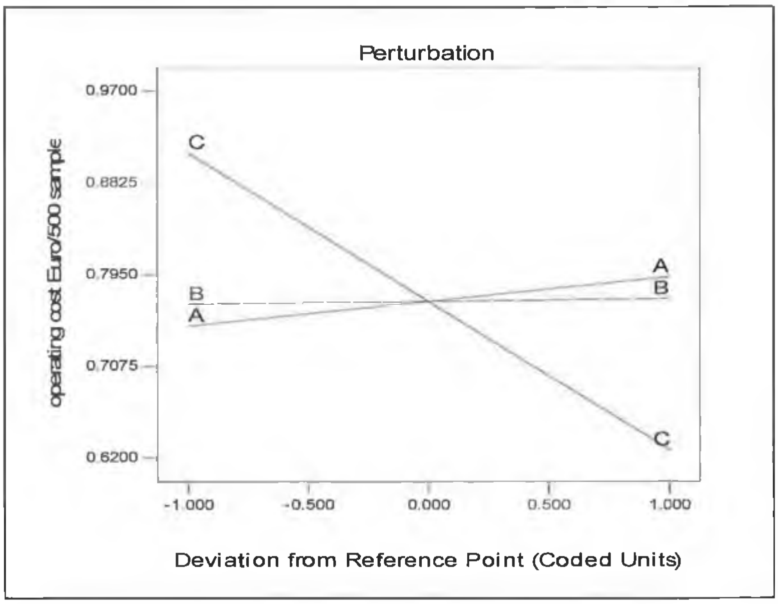


Fig. 5.35: Perturbation graph shows the effects of A, B and C on OC.

5.7. Optimisation

5.7.1. First recycling

5.7.1.1. Numerical Optimisation

In the numerical optimisation of PP plastic material for this stage, two optimization criteria were implemented to produce sound recycling products at relatively low operating cost as presented in Table 5.32. The first criterion goal is to reach maximum yield strength and ultimate tensile strength at relatively low operating cost by using the limitation listed in Table 5.32. Table 5.33 presents the optimal moulding conditions the desirable optimal conditions would be achieved for second stage. However, for the first criterion the barrel temperature has to be set between 180.02 and 184.24 °C with screw rotation between 93.99 and 94.53 rpm, while the nozzle temperature has to be set to between 160 and 161.54 °C and the percentage of raw material has to be around 35% to achieve the maximum yield strength and ultimate tensile strength. Implementing these moulding conditions would result in excellent mechanical properties of the first recycled material, as presented in Table 5.33. Table 5.34 presents the optimal solution based second optimisation criteria. The optimisation results clearly demonstrate that, the barrel temperature has to be around 180 °C; the nozzle temperature has to be around 160 °C, the screw rotation of about 100 rpm and raw material of 5% to achieve the maximum yield strength and ultimate tensile strength. To optimise the yield strength and ultimate tensile strength to be of about 343 MPa and 266 MPa respectively in the first criterion the operating cost would be of about € 0.6259 per 500 samples as can seen in Table 5.32. While, maximise the responses to be of about 348 MPa and 257 MPa respectively in the second criterion the operating cost should be around € 0.6015 per 500 samples as can seen in Table 5.34.

5.7.1.2. Graphical Optimisation

In the graphical optimisation, the range of each response has been selected from the numerical optimisation results. The ranges obtained from the two criteria which were proposed in the numerical optimisation were brought into graphical optimisation as well. The green area on overly plot Fig. 5.36 and Fig. 5.37, which are the region that meet the first and the second criterion of the first recycling at D= 35% of raw material for the first criteria and for the second criteria D= 5% of raw material respectively.

Table 5.32: Optimisation criteria used for the first stage.

Parameter or Response	Limits		Importance	First criterion	Second criterion
	Lower	Upper			
Barrel Temp	180	270	3	Is in range	minimise
Nozzle Temp	160	270	3	Is in range	is in range
Screw rotation	30	100	3	Is in range	maximise
% of RM.	5	35	3	Is in range	minimise
Y First	310.778	382.888	5	maximize	maximise
UTS First	233	286	5	maximize	maximise
OC for 500 samples	0.6259	0.9629	5	minimize	Minimise

Table 5.33: Optimal bases on the first criterion for the first stage.

No.	Barrel Temp	Nozzle Temp	Screw rotation	% of RM.	Y First	UTS First	OC for 500 samples	Desirability
1	180.04	160.01	93.99	34.99	343.18	265.79	0.625908	0.6526
2	180.55	160	94.06	35	343.17	265.80	0.625897	0.6526
3	180.89	160	94.1	35	343.16	265.80	0.625910	0.6525
4	181.65	160	94.19	35	343.14	265.81	0.625910	0.6524
5	180.02	160.25	93.99	34.83	343.20	265.74	0.625911	0.6524
6	180.17	160.98	94.01	35	343.17	265.76	0.625910	0.6523
7	183.05	160	94.37	35	343.10	265.82	0.625908	0.6523
8	180.03	161.54	94	35	343.18	265.73	0.625911	0.6522
9	183.82	160	94.47	35	343.08	265.83	0.625909	0.6522
10	184.24	160.16	94.53	34.98	343.07	265.82	0.625906	0.6521

Table 5.34: Optimal solution bases on the second criterion for the first stage.

No.	Barrel Temp	Nozzle Temp	Screw rotation	% of RM.	Y First	UTS First	OC for 500 samples	Desirability
1	180	160.03	100	5	348.04	257.51	0.601541	0.7421
2	180	160.08	99.99	5.21	348.00	257.56	0.601593	0.7416
3	180.44	160	100	5.14	348.01	257.55	0.601770	0.7413
4	180.01	160	99.67	5.03	347.99	257.49	0.602898	0.7412
5	180.9	160	100	5	348.04	257.51	0.602010	0.7411
6	180	160	100	5.61	347.92	257.69	0.601548	0.7408
7	180	165.31	100	5	348.04	257.23	0.601794	0.7403
8	181.79	160	99.98	5	348.04	257.51	0.602537	0.7402
9	180.01	160	99.13	5	347.91	257.45	0.605059	0.7400
10	180.01	160	100	6.02	347.83	257.81	0.601548	0.7399

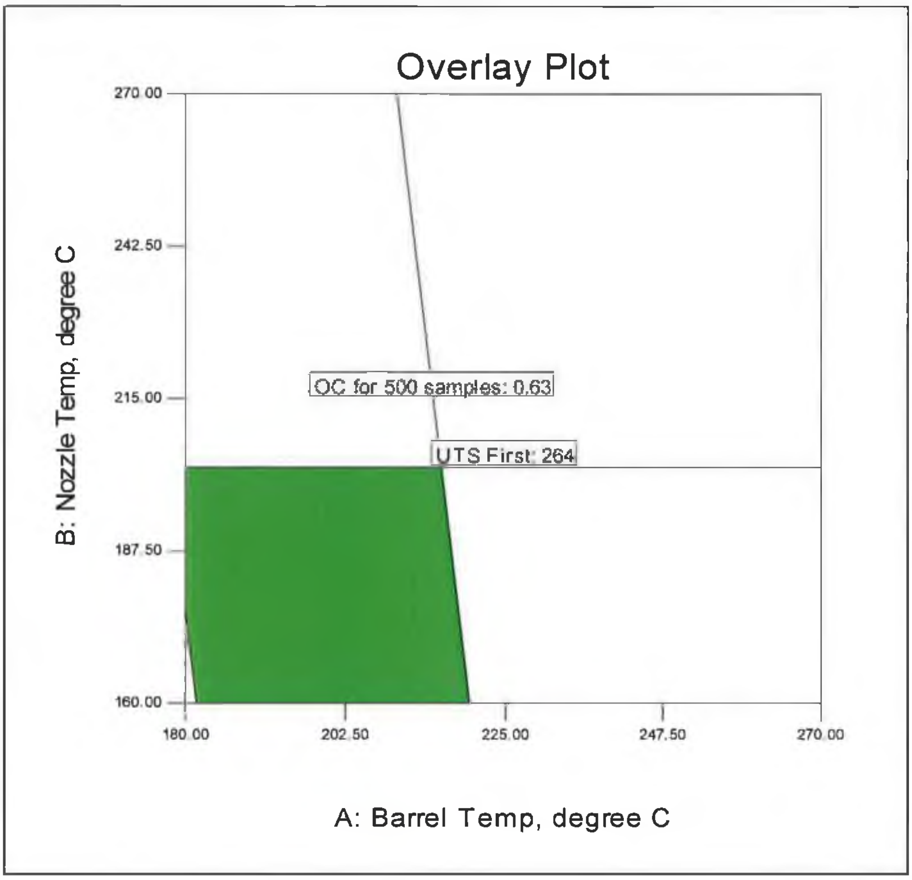


Fig. 5.36: Overlay plot shows the optimal conditions according to the first criterion at D = 35% of RM.

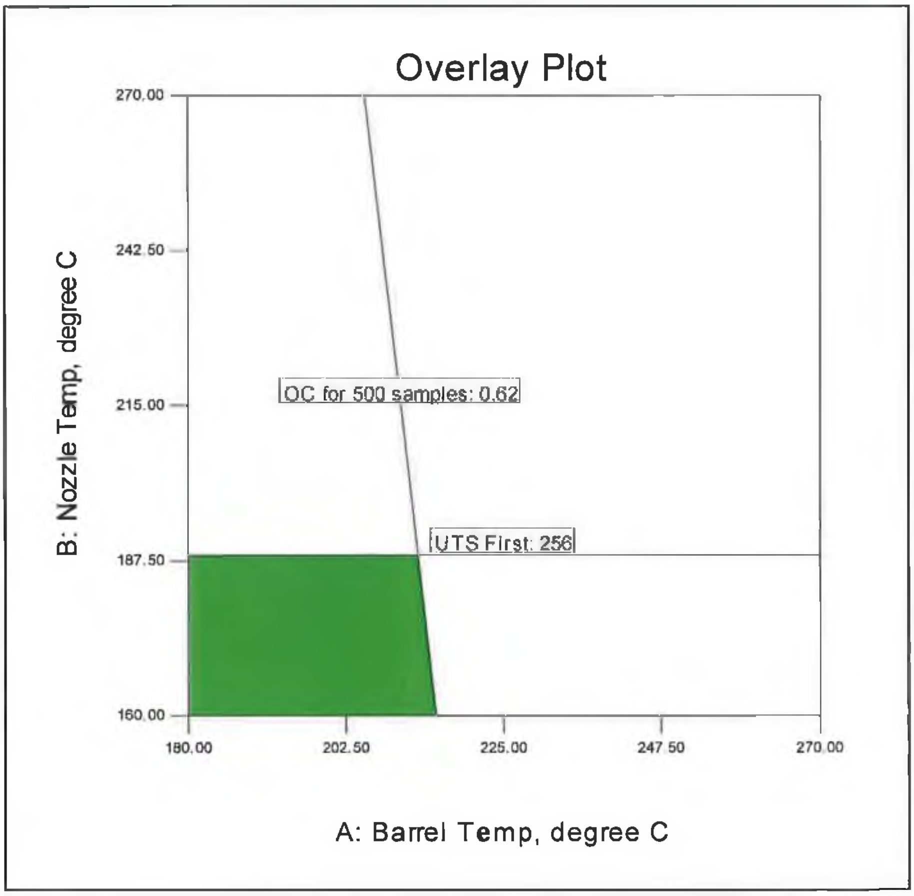


Fig. 5.37: Overlay plot shows the optimal conditions according to the second criterion at D = 5% of RM.

5.7.2. Second recycling

5.7.2.1. Numerical Optimisation

In the numerical optimisation of PP plastic material for this stage, two optimization criteria were implemented to produce sound recycling products at relatively low operating cost as presented in Table 5.35. The first criterion goal is to reach maximum yield strength and ultimate tensile strength at relatively low operating cost by using the limitation listed in Table 5.36. Table 5.37 presents the optimal moulding conditions the desirable optimal conditions would be achieved for second stage. However, according to the first creation for this stage the barrel temperature has to be set to 180 °C with screw rotation between 94.63 to 99.88 rpm, while the nozzle temperature has to be set between 209.71 and 214.23 °C and the percentage of raw material has to be of about 30 % to achieve the maximum yield strength and ultimate tensile strength. Implementing these moulding conditions would result in excellent mechanical properties of the second recycled, as presented in Table 5.36. Table 5.37 presents the optimal solution based second optimisation criteria. The optimisation results clearly demonstrate that, the barrel temperature has to be around 180 °C; the nozzle temperature has to be around 160 °C and the screw rotation of about 100 rpm and percentage of raw material of around 20 % to achieve the maximum yield strength and ultimate tensile strength. To optimise the yield strength and ultimate tensile strength to be of about 354 MPa and 263 MPa respectively in the first criterion the operating cost would be of about € 0.6250 per 500 samples as can seen in Table 5.36. While, maximise the responses to be of about 356 MPa and 257 MPa respectively in the second criterion the operating cost should be around € 0.6042 per 500 samples as can seen in Table 5.37.

5.7.2.2. Graphical optimisation

In the graphical optimisation, the range of each response has been selected from the numerical optimisation results. The ranges obtained from the two criteria, which were proposed in the numerical optimisation, were brought into graphical optimisation as well. Fig.5. 38 and Fig 5.39 show the green areas on overly plot, which are the region that meet the first and the second criterion respectively of second recycling at D= 30% for the first criteria and for the second criteria D= 20%.

Table 5.35: Optimisation criteria used for second stage.

Parameter or Response	Limits		Importance	First criterion	Second criterion
	Lower	Upper			
Barrel Temp	180	270	3	is in range	minimise
Nozzle Temp	160	270	3	is in range	minimise
Screw rotation	30	100	3	is in range	maximise
% of RM.	20	30	3	is in range	minimise
Y First	329.999	367.111	5	Maximize	maximise
UTS First	236.333	331.666	5	Maximize	maximise
OC per 500 samples	0.6259	0.9629	5	Minimize	minimise

Table 5.36: Optimal solution based on the first criterion for second stage.

No.	Barrel Temp	Nozzle Temp	Screw rotation	% of RM.	Y Second	UTS Second	OC for 500 samples	Desirability
1	180	211.85	94.63	30	353.82	263.57	0.625907	0.5681
2	180	211.44	96.54	30	353.84	263.54	0.618196	0.5681
3	180	212.51	96.61	30	353.78	263.62	0.617922	0.5681
4	180	213	94.84	30	353.75	263.65	0.625068	0.5681
5	180	212.89	99.88	30	353.76	263.64	0.604661	0.5681
6	180	210.8	96.42	30	353.88	263.50	0.618692	0.5681
7	180	213.53	94.74	30	353.72	263.68	0.625480	0.5681
8	180	209.71	95.74	30	353.94	263.43	0.621421	0.5681
9	180	213.98	94.67	30	353.70	263.71	0.625758	0.5681
10	180	214.23	98.74	30	353.68	263.73	0.609280	0.5681

Table 5.37: Optimal solution based on the second criterion for second stage.

No.	Barrel Temp	Nozzle Temp	Screw rotation	% of RM.	Y Second	UTS Second	OC for 500 samples	Desirability
1	180.01	160	100	20	355.92	257.59	0.60418	0.7086
2	180	160	99.54	20	355.92	257.59	0.606050	0.7081
3	180.01	161.16	100	20	355.83	257.67	0.604188	0.7078
4	180.36	160.04	100	20	355.85	257.55	0.604371	0.7077
5	180.29	160.55	100	20	355.83	257.59	0.604330	0.7075
6	180	161.48	99.05	20.01	355.81	257.69	0.608029	0.7065
7	180.68	160.72	99.97	20	355.74	257.55	0.604663	0.7063
8	180	160	97.72	20	355.92	257.59	0.613412	0.7060
9	180.12	160	100	20.38	355.94	257.67	0.604245	0.7060
10	181.01	160.17	100	20	355.72	257.47	0.604707	0.7059

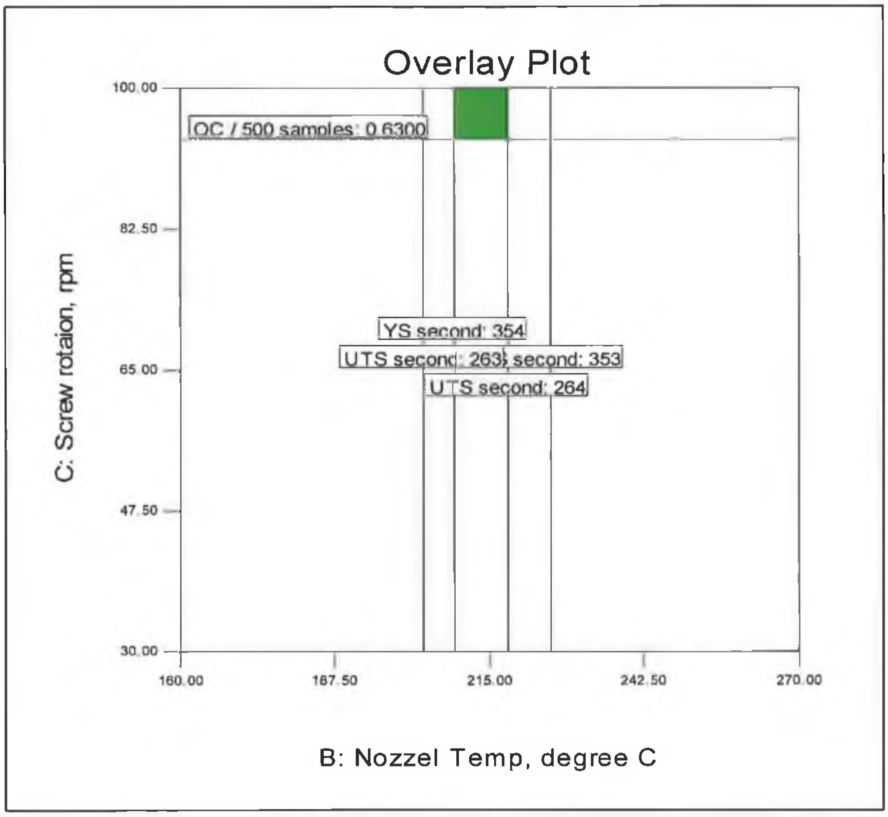


Fig. 5.38: Overlay plot shows the optimal according to the first criterion of the second stage at D= 30% of RM.

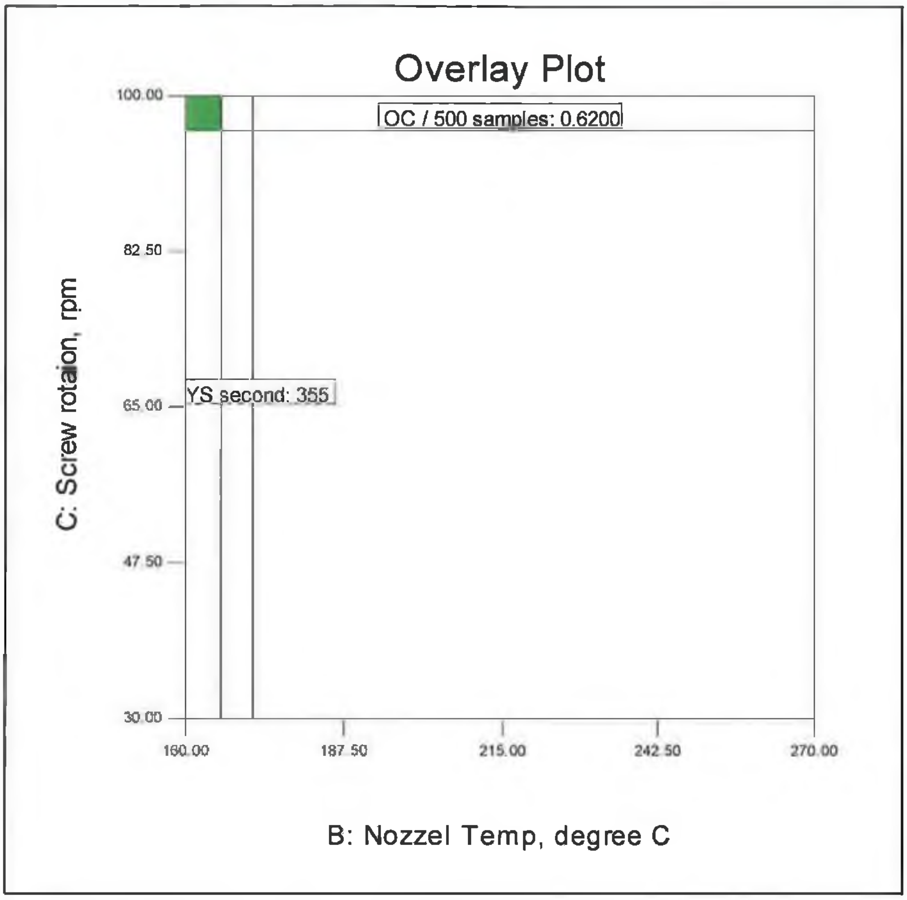


Fig. 5.39: Overlay plot shows the optimal according to the second criterion for second recycling at D = 20% of RM.

5.7.3. Third recycling

5.7.3.1. Numerical Optimisation

In the numerical optimisation of PP plastic material for this stage, two optimization criteria were implemented to produce sound recycling products at relatively low operating cost as presented in Table 5.38. The first criterion goal is to reach maximum yield strength and ultimate tensile strength at relatively low operating cost by using the limitation listed in Table 5.39. Table 5.40 presents the optimal moulding conditions the desirable optimal conditions would be achieved for third stage. However, according to the first creation for this stage the barrel temperature has to be set to 180 °C with screw rotation between 94.67 to 99.48 rpm, while the nozzle temperature has to be set of about 160 °C and percentage of raw material of about 50 % to achieve the maximum yield strength and ultimate tensile strength. Implementing these moulding conditions would result in excellent mechanical properties of the third recycled, as presented in Table 5.39. Table 5.40 presents the optimal solution based second optimisation criteria. The optimisation results clearly demonstrate that, the barrel temperature has to be around 180 °C; the nozzle temperature has to be around 160 °C and the screw rotation of about 100 rpm and percentage of raw material of about 20 % to achieve the maximum yield strength and ultimate tensile strength. To optimise the yield strength and ultimate tensile strength to be of about 357 MPa and 255 MPa respectively in the first criterion the operating cost would be of about € 0.8129 per 500 samples as can seen in Table 5.39. While, maximise the responses to be of about 347 MPa and 255 MPa respectively in the second criterion the operating cost should be around € 0.8129 per 500 samples as can seen in Table 5.40.

5.7.3.2. Graphical Optimisation

In the graphical optimisation, the range of each response has been selected from the numerical optimisation results. The ranges obtained from the two criteria, which were proposed in the numerical optimisation, were brought into graphical optimisation as well. Fig.5.40 and Fig 5.41 show the green/ shaded area on overly plot, which are the region that meet the first and the second criterion respectively of third recycling at D= 50% for the first criteria and for the second criteria D= 21%.

Table 5.39: Optimisation criteria used in the third stage.

Parameter or Response	Limits		Importance	First criterion	Second criterion
	Lower	Upper			
Barrel Temp	180	270	3	is in range	minimise
Nozzle Temp	160	270	3	is in range	minimise
Screw rotation	30	100	3	is in range	maximise
% of RM.	20	50	3	is in range	minimise
Y First	329.777	362	5	Maximise	maximise
UTS First	236.777	268.777	5	Maximise	Maximise
OC for 500 samples	0.6259	0.9629	5	minimise	Minimise

Table 5.40: Optimal solution based on the first criterion for third stage.

No.	Barrel Temp	Nozzle Temp	Screw rotation	% of RM.	Y Third	UTS Third	OC for 500 samples	Desirability
1	180	160	98.07	50	357.09	255.74	0.61199	0.7948
2	180	160	95.85	50	357.09	255.74	0.620996	0.7948
3	180	160	94.67	50	357.09	255.74	0.625773	0.7948
4	180	160	99.16	50	357.09	255.74	0.607595	0.7948
5	180.01	160	97.59	50	357.09	255.74	0.613954	0.7948
6	180	160	95.52	49.98	357.08	255.74	0.622321	0.7948
7	180	160	98.48	49.97	357.08	255.74	0.61033	0.7947
8	180.01	160.7	98.69	50	357.07	255.74	0.609480	0.7947
9	180	160.9	99.48	50	357.07	255.74	0.606273	0.7946
10	180	161.12	96.88	50	357.06	255.74	0.616809	0.7946

Table 5.41: Optimal solution based on the second criterion for third stage.

No.	Barrel Temp	Nozzle Temp	Screw rotation	% of RM.	Y Third	UTS Third	OC for 500 samples	Desirability
1	180	160	99.98	20.02	347.55	255.74	0.604259	0.8129
2	180	160	100	20.27	347.63	255.74	0.604181	0.8128
3	180	160	99.99	20.66	347.75	255.74	0.604205	0.8126
4	180	160	99.91	20.78	347.79	255.74	0.604542	0.8125
5	180.04	160	100	20.92	347.83	255.73	0.604201	0.8124
6	180	160.03	100	21.07	347.88	255.74	0.604181	0.8124
7	180	160.52	99.96	20	347.53	255.74	0.604346	0.8123
8	180	160.02	100	21.51	348.02	255.74	0.604181	0.8122
9	180.01	160	99.41	20	347.54	255.74	0.606563	0.8121
10	180.37	160	100	20.04	347.53	255.71	0.604372	0.8120

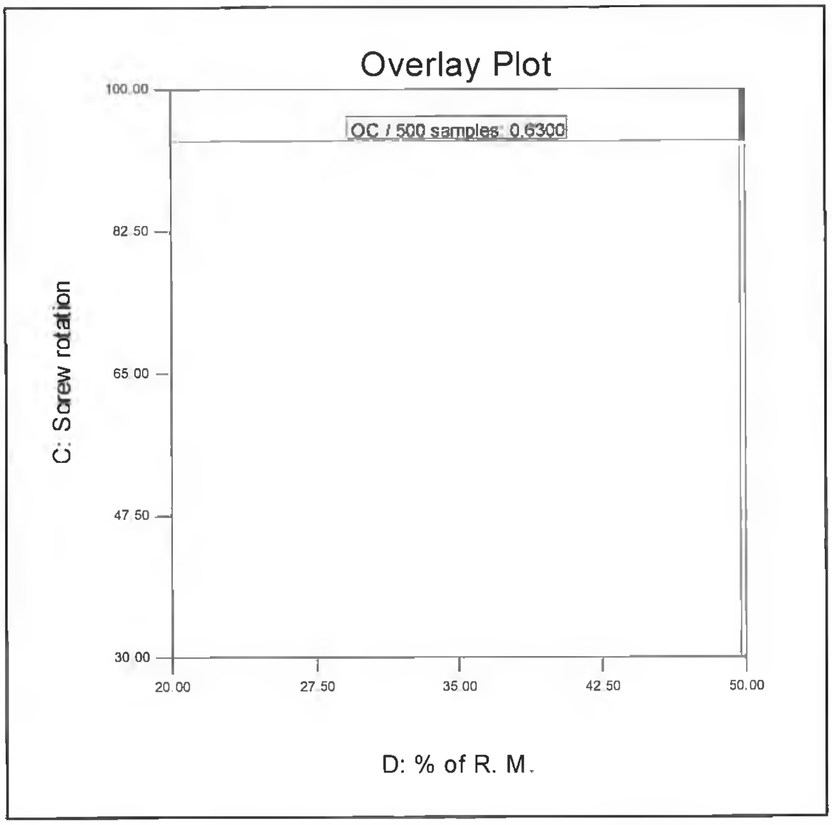


Fig. 5.40: Overlay plot shows the optimal according to the first criterion for the third stage at D= 50% of RM.

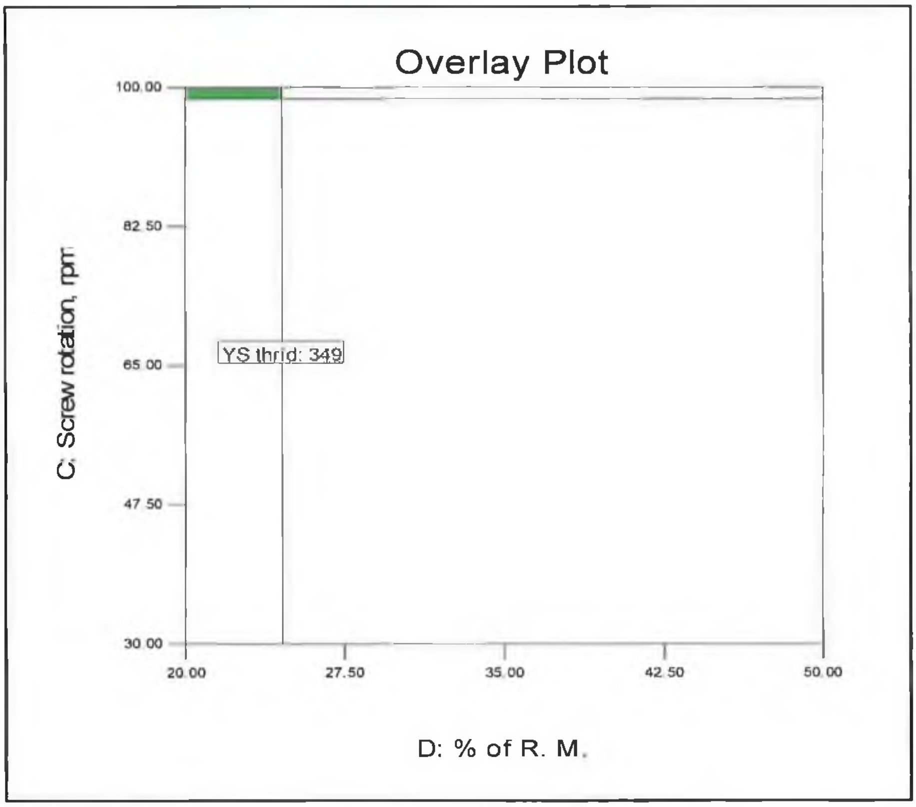


Fig. 5.41: Overlay plot shows the optimal according to the second criterion for the third recycling at D= 21% of RM.

5.8. Validation of the developed models

In order to validate the model developed for the three recycling stages with mixing raw material, some experiments were carried out using molding conditions selected from the optimization results for each stage. These optimal conditions are within the range of this experiment. An average of at least three experiments was calculated for each confirmation test and compared with the predicted value by computing the percentage of error in prediction.

5.8.1 First stage

Table 5.42 presents the measured responses, predicted responses and the (OC). The mathematical models for first recycling clearly demonstrate an outstanding agreement between measured and estimated values of the mentioned response since the maximum error in prediction is 5.428% as can be seen in Table 5.42.

Table 5.42: Confirmation experiments for first stage.

Exp. No.	Barrel Temp	Nozzle Temp	Screw rotation	% of RM.		Y First	UTS First	OC for 500 samples
1	180.04	160.01	93.99	34.99	Actual	343.18	265.79	0.625908
					Predicted	336.44	262.66	0.625908
					Error %	1.964	1.178	0
2	180.01	160	99.67	5.03	Actual	347.99	257.49	0.625913
					Predicted	329.10	260.22	0.602899
					Error %	5.428	-1.060	3.677

5.8.2 Second stage

The results of the confirmation experiments for the second stage are presented in Table 5.43. It is clear that the models can explain the responses within the factors domain, as the maximum error in prediction is 11.280 %, which indicates fair agreement.

Table 5.43: Confirmation experiments for second stage.

Exp. No.	Barrel Temp	Nozzle Temp	Screw rotation	% of RM.		Y Second	UTS Second	OC for 500 samples
1	180	211.44	96.54	30	Actual	353.84	263.54	0.627989
					Predicted	318.66	258.44	0.618197
					Error %	9.942	1.935	1.560
2	180.01	160	100	20	Actual	355.92	257.59	0.625913
					Predicted	315.77	246.22	0.604188
					Error %	11.280	4.414	3.471

5.8.3 Third stage

The results of the confirmation experiments for the third stage are presented in Table 5.44. It is clear that the models can effectively explain responses within the factors domain, as the maximum error in prediction is 8.833 %, which indicates good agreement.

Table 5.44: Confirmation experiments for third stage.

Exp. No.	Barrel Temp	Nozzle Temp	Screw rotation	% of RM.		Y Third	UTS Third	OC for 500 samples
1	180	160	98.07	50	Actual	357.09	255.74	0.625909
					Predicted	325.55	259.55	0.611996
					Error %	8.833	-1.490	2.222
2	180	160	99.98	20.02	Actual	347.55	255.74	0.625909
					Predicted	322.44	244.66	0.604259
					Error %	7.224	4.333	3.460

5.9. Chapter Summary

In this chapter, the author has emphasised the importance of commitment of the FD in realising the success of recycling process and has highlighted the importance of linkage of the recycled process in the frame work of response (Y) and (UTS), measurement as quality criteria at each recycling stages and also he estimated the operating cost at each stage. Based on the elements of the recycled by the injection mould HM7, the author has formulated the recycle process which is a combination of recycled PP with raw material in three stages all aspects of each recycling stage has three different percentages raw PP give the direction for optimum quality and achieving its objective. The empirical data findings were carrying out in this research by Design-Expert V7 software. The results show significant models at each stage. The optimisation was used different ranges of each response. Finally, the developed mathematical models and the optimal solutions are validated in each recycling stages by selected some moulding setting from the numerical optimisation.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6. Conclusions and Recommendations for Future Work

6.1 Introduction

The principal findings of the research and the proposed recommendations are summarised in this chapter, followed by the thesis contribution and the recommendations for future work. The following conclusions were drawn from the results obtained and are applicable for the polypropylene plastic material investigated in this work. The developed mathematical models and the optimal solutions are valid in the moulding parameters ranges that were used for developing them.

6.2 Conclusions for Survey Results

A comprehensive questions survey study has been presented on aspects of use recycling plastic materials implementation in the plastic companies in republic of Ireland and United Kingdom. There has been little or no substantial research carried out in the aspect of recycle process in the plastic industries in Ireland and United Kingdom. This is therefore important as it addresses the need for this kind of research in the plastics recycles process. The results indicate that in both countries, the higher recycle level using, the more sophisticated mould technologies are associated with recycled process. As such, more comprehensive injection mould should be implemented, so that the improvement of performance in the quality products can be achieved. The results also indicate that in both countries the major problem encountered by the quality product is related to the issue of process parameters, which are due to the lack of knowledge, competencies and motivation. These can be overcome through the employee development approach that leads to the improvement of quality products of the plant availability and performance. These are up-to-date information to the body of knowledge and can provide new insight to current situation and guideline for the recycle process department as far as Ireland and UK plastic industries are concerned. In general, this study has contributed in the following manner:

1. Through this research, a comparative study between three recycling stages in the manufacturing plastic industry has been carried out in Ireland and United Kingdom.
2. The study on the implementation of recycle process in the plastic companies in both countries has been presented in this thesis. This study has presented the relationship between recycling process and products quality. Furthermore, most of recycling plastic is of the minimum and medium employed level. A diversity of mould process has been used and higher sales of recycled products also were mould.
3. The results show in both countries that the recycle process effort contributes in good percentage in the improvement of sale products.
4. The recycle personnel team should consist of multi-skill personnel who are able to solve the problems according to the plastic materials and process used in the production plant. This requirement can be achieved by manpower development, conducting an appropriate training and continuous education to improve skills and recycled knowledge.
5. The first and second stages are very important in realizing the success of recycle implementation.
6. The sales of recycled products for different plastic materials for a period of four years were increased.
7. In the first recycling stage quality of the product could be maintained, however, for the second and third stage the quality could be decreased.
8. For third stage a reduction in the price of the products would occur. However, majority of companies used the sale of recycling products over 16 years.
9. The profits coming from the sale of recycled products in the majority of companies' equals 2 % from the company involved the sale from less than 2 years to over 16 years. However, the first recycling stage is the most reliable to produce a profit.

6.3 Conclusions for Experimental Design

The result of this study would contribute greatly to the understanding for the development of recycling process in each stage. In general, this study has contributed in the following manner:

1. The third stage of recycling often results in poor quality. However, in the second experiment both material properties (Y and UTS) were enhanced by the additional of raw polypropylene.
2. The main factors affecting the responses (Y) and (UTS) are the barrel temperature and screw rotation. While, the nozzle temperature has slight effect on the response.
3. The main and interactions effect of the three process parameters were determined.
4. Good agreement between the measured and estimated values of the response.
5. The optimal temperatures what ever the optimisation criteria are barrel temperature around 180 °C and nozzle temperature of about 160 °C apart form the one of the 2nd recycling stage with no restriction which is ranged between 209.71 and 214.23 °C.
6. The optimal moulding conditions that would lead to the best products quality in terms of its mechanical properties and at relatively low operating cost for each stage are:

   a. For the 1st stage, the percentage of raw material is 5 %, barrel temperature of about 180°C, nozzle temperature of about 160°C, screw rotation 100 rpm and the operating cost is € 0.6015 per 500 samples.
   b. For the 2nd stage, the percentage of raw material is 20 %, barrel temperature of about 180°C, nozzle temperature of about 160°C,

screw rotation of about 100 rpm and the operating cost is € 0.6042 per 500 samples.

c. For the 3rd stage, the percentage of raw material is 20 % Barrel temperature about of 180°C, nozzle temperature of about 160°C, screw rotation 100 rpm and the operating cost is € 0.6043 per 500 samples.

6.4 Recommendation for Future Work

The results of this study point to some further opportunities for research. Some suggestions for future work are listed as follows:

1. Some fairly strong relationships were found between various parameters, this study does not include the contribution of all process parameters. Further investigation can be carried out on the recommended approach for recycle process of PP in injection moulding, which will integrate the interest and the needs of quality criteria.
2. It can be suggested to investigate mixing PP with other type of recycled plastic materials to introduce the effect of percentage of recycled material on the final product quality at different stages of recycling process and determine which inputs parameters would affect the responses.
3. Apply this technique to optimise other plastic materials with different percentage of raw materials PP.
4. Extend this investigation and study more mechanical properties, at various plastic material and processes of mould parameters.

Publications Arising From This work

Conference Papers:

1- A study Effect of Recycling Process on the Productivity of Plastic Materials, 22nd International Manufacturing Conference (IMC-22),31st August-2nd September 2005, Institute of Technology Tallaght, Dublin ,Ireland.

2- The Relation Between Recycling Process and Products Quality of Plastic Materials. The 16th International Conference on Flexible Automation and Intelligent Manufacturing 26th –28th June 2006, University of Limerick, Ireland .

3- Effects of The Recycling Process on the Marketing of Plastic Materials Product, 23rd International Manufacturing Conference, 30th August to 1st September 2006, Belfast, UK.

4- Optimisation of the Moulding Process of Recycled Plastic, Material Dvances in Materials and Processing Technologies (AMPT 2006), 30th July to 3th August 2006, Las Vages, USA.

5- Effect of Moulding Parameters on Mechanical Properties of Polypropylene Plastic Materials, Materials Energy Design (MED 2006), 14th –17th March 2006, Institute of Technology, Dublin, Ireland.

6- Effects of Recycling Stages and Moulding Parameters on Yield Strength of Polypropylene, 24th International Manufacturing conference (IMC-22), 29th to 31st August, 2007, Institute of Technology Waterford, Dublin, Ireland.

Journals:

1- Application of Factorial Design in Mixing the Virgin and Recycled Polypropylene for Injection-Moulding, submitted to Journal of Advances in Engineering Software, 2007.

2- Effects of Injection Moulding Conditions on the Mechanical Properties of Polypropylene Plastic Material, submitted to Journal of Simulation Modelling Practice and Theory, 2007.

REFERENCE

[1] M.I.B. Tavares and C.G. Mothe, Material Characterisation Sold State Carbon-13 NMR, Study of Structural Polymeric Industrial Rejects, Journal of Polymer Testing, 1998, Vol 17, PP 289-295.

[2] T. Goldman, Recycling as Economic Development: Toward a Framework for Strategic Materials Planning, Masters Thesis, Department of City and Regional Planning, University of California, Berkeley. January 1997.

[3] Information on Plastic and the Environment, American plastic council, March, 2004. Available online: http://www.Plasticsresource.com/s_plasticseresource/sec.asp.

[4] T.A. Vilhena and C.A Hemais, Reciprocal of rejects plastics, Brazil – aspects economics", 3 Congress Brassiere de Polymers, Rio de Janeiro, 1995, pp702-7 20.

[5] M .A. Martins, C.G Mothe and M.I.B Tavares, Journal of Polymer Testing, 1996, Vol 15, PP91-97.

[6] Reprocessing-Recycling and Transport of Nuclear Material, General Director for Energy and Raw Materials Sub-directorate of Nuclear Industry, June 2006. Available online: http://www.industrie.gouv.fr/energie/anglais/pdf/fiche.pdf.

[7] Information on the plastic and environmental, September 2003. Available online: http:// www.plasticsresourece.com/s_plasticresource/index.asp.

[8] M .Bevis, Secondary Recycling of Plastics, Journal of Materials in Engineering, Vol 3, 1982, PP 344-349.

[9] Plastics recycling information sheet, May, 2004. Available online: http:// www.wasteonline.org.uk/resources/informationsheets/plastics.htm.

[10] Information on the history of plastic, September 2003. Available online: http:// www.americanplasticscouncil.org/s_apc/index.asp .

[11] Introduction to Thermoplastic, Injection Moulding, December 2003. Available online: http:/www.crclarke.Co.UK.

[12] S. Slater and J. Naver, Competitive Environment Moderate the Market Orientation-Performance Relationship, Journal of Marketing, January 1994, pp 46-55.

[13] T. Pepelnjak, G.Gantar and K.K.uzman, Numerical Simulations in Optimisation of Products and forming Process, Journal of Materials Processing Technology, 2001, pp122-126.

[14] F. P. L. Mantia and J.L .Gardette, Improvement of the Mechanical Properties of Photo-Oxidized film after Recycling, Journal of Polymer Degradation and Stability, Vol 75, 2002, PP 1-7.

[15] T.K. Boguski ,H .R. William ,General Mathematical Models for LCI Recycling Resources, Journal of Conservation and Recycling, 1994, Vol 12, pp147-163.

[16] M. Patel, V.N. Thienen and E. Jochem, Recycling of Plastic in Germany Resources, Journal of Conservation and Recycling, 2000, PP 25-90.

[17] General Directorate for Energy and Raw Materials Sub-Directorate of Nuclear Industry, Reprocessing- recycling and transport of nuclear material, France, July 2001.

[18] C.G. Mothe and M.I .B. Tavares, Study of Recycling and Biodegradability of Ethylene –Co-Vinyl Acetate Rejects by Thermal Analysis, Journal of Polymer Degradation an Stability, 1997, Vol 57, PP 183-186.

[19] C.G. Mothe and S.M. Castor, Recycling of polymers, 1995, pp1-35.

[20] G. R. Adams and J. D. Schvaneveldt, "Understanding research methods", (2nd Edition), 1991, New York, Longman.

[21] B. Blumberg, D. R. Cooper and P. S. Schindler, "Business Research Methods", MC Graw Hill, Beckshire, 2005, UK.

[22] K. F. Punch, "Introduction to Social Research – Quantitative & Qualitative approach", Sage Publication, 1998, London.

[23] S. Sarantakos, "Social research", Macmillan Press Ltd, 1993, London.

[24] Introduction of Recycle Plastic, October, 2003. Available online: http://web.info.com/infocom.us2/search/web.

[25] Introduction to Environmental and Recycling Programme (Honk Kong), November, 2003 Available online: http://www.epd.gov.hk/epd/eindex.html.

[26] R. J.Murphy, Florida Centre of Solid and Hazardous Waste Management, 1990, Florida, USA.

[27] Plastics Division of the American Chemistry Council (ACC), May, 2003. Availableonline:http://www.americanplasticscouncil.org/benefits/about_plastics/history.html , September .

[28] L. Kunstoffe, German plastic, Germany, 1978, pp 266-280.

[29] E.G.Leverkusen, Hydrolysis of Plastic Waste, 1999, pp 281-284.

[30] T. Czvikovszky and T. Czigány, Harmonization of Plastics and the Environment in the 21-st century Budapest University of Technology and Economics, Department of Polymer Engineering, 2001.

[31] Introduction of Recycling of Polymers, April, 2004. Available online: http://www.pcn.org/Technical%20Notes%20-%20Recycle1.htm.

[32] Plastics Recycling Background and Information on Municipal Recycling Programs, June 2005. Available online: http://www.plasticsresource.com/s_plasticsresource/doc.asp.

[33] R.D .Deanin, A. Amran, R. Saraogi and N. Matani, Recycle of Polystirene. Journal of Polymer Preprints 1983, Vol 2, pp 430–431.

[34] D.A .Hoffman, Antec'94 Conference Proceedings, 1994, Vol 1, pp 883–883.

[35] B.Vosshenrich, Higher proportions of recycled material can beused. Journal of Kunststoffe Synthetics, 1993, Vol 5, pp15–18.

[36] C. Voute , Recycling Council Annual Seminer Birmingham, 1994.

[37] T. Goldman, Recycling as Economic Development, Toward a Framework for Strategic Materials Planning, California at Berkeley, January 1997.

[38] PACIA, National Plastics Recycling Survey 2003 Main Survey Report, Australia, September, 2003.

[39] Report to the U.S. Environmental Protection Agency and the Plastic Redesign Project, Solid Waste Research Program, August 2004. Available online: http:/ www.plasticredesign .org/files/phasetworeport.html .

[40] D. Bryce, Plastic Injection Moulding-Materials Selection and Product Design Fundamentals –Fundamentals of Injection Moulding Series, Society of Manufacturing Engineers, USA, 1996.

[41] D .Bryce, Plastic Injection Moulding-Materials Selection and Product Design Fundamentals –Fundamentals of Injection Moulding Series, Society of Manufacturing Engineers,USA,1996.

[42] R.J Crawford, Plastics Engineering, Butterworth Heinmann, 1998.

[43] V.J. Stokes, Thermoplastics as Engineering Materials, Journal of Materials Design Processing, Vol 117, 1995, pp 448-455.

[44] M. Crum, N. Buckley and C .Bucnall, Principles of Polymer Engineering, Oxford University Press, 1997.

[45] J. White, The Injection Moulding Process, 1983, pp 86-109.

[46] Information Service of Recycling Plastics, May, 2004. Available online: http://www.itdg.org/docs/technical_.

[47] T.A. Osswald , L.S. Turng and P.J. Gramann, "Injection Molding Handbook", 2002, USA

[48] B.R. Duffy , Injection Mouldig ,Design System, Theses of MSc, University College Dublin Ireland, Augest, 1994.

[49] R.J. Crawford, Plastics Engineering, 2nd Edition, Pergamon Press, Oxford, 1989

[50] Information to Mould Products, July, 2005. Available online:

http://www.alibaba.com/productsearch/Mould.html.

[51] Different type of Mould Products, July, 2005. Available online: http://hengshenli.en.alibaba.com.

[52] American Society Testing and Materials, standard Classification System for Carbon Blacks Used in Rubber Oroducts, 1999.

[53] T. Osswald, L. Turng and P. Gramann, Injection Moulding Handbook, Hanser, 2002.

[54] Manual Book of Injection Moulding Machine, Type HM7, Mechanical Engineering Workshop, Dublin City University, Ireland, 2005.

[55] N. Moran , Computer Aide Engineering for Injection Mould cooling System Desgin, Theses of MSc , School of Mechanical and Manufacturing Engineering in Dublin City University, Ireland , August, 1998.

[56] D. Bryce, Plastic Injection Moulding –Manufacturing Process Fundamental, Vol 1, Fundamental of Injection Moulding Series, Society of Manufacturing Engineering, USA, 1996.

[57] M. Stevens, Polymer Chemistry University Press, 1990.

[58] C. Austin, Filling of Mould Cavities, Computer Aided Engineering for Injection Moulding, Edited by E. Bernhardt, Hanser Publications, 1983, pp 276-324.

[59] J. Chabot, the Development of Plastic Processing Machinery and Methods, John Wiley&Sons, 1992.

[60] K. Singh, Mold Cooling, Computer Aide Engineering for Injection Moulding, Edited by E. Bernhard, Hanser Publications, 1983, pp326-347.

[61] T. Kwon, Mold Cooling system Design using Boundary Element, 1988, Vol 110, pp 384-394.

[62] A. J. Parker, the Economics of Technological Innovation in Recycling, October, 1999.

[63] Contains information about Bennet, August 2004. Available online: http:/ www.bennet_europe.nl/bennet.html.

[64] O. Murakami, Technology for Recycling Plastic Materials, 2000.

[65] L .Mantia and F.P. Basic, Recycling of PVC and Mixed plastic waste , ChemTec Publishing, Toronto, 1996.

[66] J .C. Anderson, K.D. Leaver, R.D. Rawlings and J.M. Alexander, Materials Science an No strand Reinhold (UK), Molly Millars Lane, Wokingham, Berkshire, England, 1985 .

[67] Introduction of Polystyrene, January 2003. Available online: http://www.dow.com/styron/design/guide/mechanical.htm.

[68] N.T. Dintcheva, F.P.LaMantia, R.Scaffaro, M.Paci, D.Acierno and G.Camino, Reprocessing and Restabilization of Greenhouse Films, Journal of Polymer Degradation and Stability, Vol 75, July 2002, pp 459-464.

[69] C. Javierre, I. Clavera, L.Ponz, J.Aisa and A.Fernandez, Influence of the Recycling Materal Percentage on the Rheological Behavour of HDPE for Injection Moulding Process, Waste Management, 2006.

[70] M .H.Martins and M.A.De paoli, Polypropylnee Compounding with Post-Consumer Material Reprocessing, Journal of Polymer Degradation and Stability, 2002, Vol 78, PP 491-495.

[71] A .K. Agrawal, and S .A.Utreja , Effects of Hydroperoxid Decomposer and Slipping Agent on Recycling of Polypropylene, Journal of Applied Polymer Science ,Vol 92, 2004, PP 3247-3251.

[72] J. Aurrekoetxea, MA. Sarrionandia and I. Urrutibeascoa, Fracture Behaviour of Virgin an Recycled Isotactic Polypropylene, Materials Science Journal, Vol 36,2001, pp 5073-5078.

[73] L. Incarnato, P.Scarfato, G.Gorrasi, V.Vittoria and D.Acierno, Structural Modifications Induced by Recycling of Polypropylene, Journal of Polymer Engineering and Science, 1999, Vol 39, P9.

[74] S .Tall, Aa.C.albertsson and S .Karlsson, Enhanced Rigidity of Recycled Polypropylene from Packaging Waste by compounding With Talc and High-Crystallinity Polypropylene, Polymer for Advaced Technologies Journal,2001,Vol 12 , PP 279-284.

[75] C.J.Tsenoglou, C.N. Kartalis and C.D.Papaspyrides, Restabilization of Recycled Caco3-filled Polypropylene :Assessment of Reprocessing Induced Modifications and

processing Stabilizer Effectiveness, Advances in Polymer Technology Journal, 2002,Vol 21, PP 260-267.

[76] A. Espert, W.Camacho and S. Karlson, Termal and Thermo mechanical Properties of Biocomposites Made from Modified recycled Cellulose and Recycled polypropylene, Journal of Applied Polym3er Science, 2003, Vol 89, pp 2353-2360.

[77] B. E Tiganis , R. A. Shanks and Y. Long, Effects of processing on the microstructure, melting behavior, and equilibrium melting temperature of polypropylene, Journal of applied polymer science,1996, Vol 59, pp 663-671.

[78] M. H. Martins and M.A .De Paoli, Polypropylene Compounding with Recycled Material, Statistical response surface analysis, Polymer Degradation and Stability Journal, Vol 71, 2001, pp 293-298.

[79] M.C.Bonelli, A.F. Martins, E .B. Mano and C .L.Beatty, Effects of Recycled Polypropylene on polypropylene/High Density Polyethylene Blends, Journal of Applied Polymer Science,2001, Vol 80, pp1305-1311.

[80] P. Phinyocheep, F.H. Axtell and T. Laosee, Influence of Compatibilizers on Mechanical Properties, Crystallization and Morphology of Polyoproplene/Scrap Rubber Dust Blends, Journal of Applied Polymer Science, 2002, Vol 86, pp 148-159.

[81] S. Ross and D. Evans, The Environmental Effect of Reusing and Recycling a Plastic – Based Packaging System, Journal of Cleaner Production ,2003, Vol 11, pp 561–571.

[82] A .Oromiehie and A. Mamizadeh, Recycling PET Beverage Bottles and Improving Properties, Journal of Polymer International, 2004, Vol 53 , pp 72-732.

[83] S. Bertin and J.J.Blends, Study and Characterization of Virgin and Recycled LDPE/PP Blends, European Polymer, 2002, Vol 38, pp 2255-2264.

[84] H.P. Blom and A.Rudin, PP/PE Blends .IV. Characterization and compatibilization of Blends of Post Consumer Resin With Virgin PP and HDPE, Journal of Applied Polymer Science, 1998, Vol 70, pp 2081-2095.

[85] N.T. Dintcheva, F.P.La Mantia, D. Acierno, L.D Maio, G Camino, F. Trotta, M.P.Luda, and M.Paci, Characterization and Reprocessing of Greenhouse Film, Polymer Degradation and Stability, 2001, Vol 72, pp141-146.

[86] T. Kallel, V.M.Nageotte, M.Jaziri and J.F.Gerard, Compatibilzation of PE/PS and P/PP Beland .I .Effect of rocessing Coditions and Formulation , Applied Polymer Science ,Vol 90,2003,PP 2475-2484.

[87] J.K. Kim, S.H. Lee and S.H. Hwang, Study on the Thermoplastic Vulcanizate Sing Ultrasonically Treated Rubber Powder, Journal of Applied Polymer Sciencech, 2003, Vol 90, pp 2503-2507.

[88] P. Rachtanapun, S. E. M. Selke and L. M. Matuana, Effect of the High-Density Polyethylene Melt Index on the Microcellular Foaming of High-Density Polyethylene/Polypropylene Blends, Journal of Applied Polymer science , 2004, Vol 93, pp 364-371.

[89] S.H. Chang, H. Dongpark and W. Jei Cho, Recycling of Commingled Plastics by Cellulosic Reinforcement. Journal of Applied Polymer Science, 1999, Vol. 74, pp 1531–1538.

[90] A.S.F. Santos, J.A.M. Agnelli, D.W. Trevisan and S.Manrich, Degradation and Stabilization of Polyolefins from Municipal Plastic Waste During Multiple Extrusions under Different Reprocessing Conditions, Polymer Degradation and Stability Journal , 2002, Vol 77, pp 441-447.

[91] G. Ragosta, P .Musto, e.Martuscellp and P. Russo,Recycling of Plastic Car Components, The Case of Amultilayer Item Based on Polypropylene, Materials Science , 2000, Vol 35, pp 3741-3751.

[92] M. Mehrabzadeh and F .Faramand, Recycling of Commingled Plastic waste Containing Polypropylene, Polyethylene, and Paper, Journal of Applied Polymer Science, 2001, Vol 80, pp 2573-2577.

[93] M. Arroyo and M.Bell, Morphology Behavior Relationship and Recyclability of Composites Based on PP/EPDM Blends and Short Aramid Filbers, Journal of Applied Polymer Science, 2002, V ol 83, pp 2474-2484.

[94] P. Santos and S.H.Pezzin, Mechanical Propertis of Polypropylene Reinforced with Recycled –Pet fibers, Materials Processing Technology, 2003, Vol 143, PP 517-520.

[95] N. Kukaleva, G.P.Simon and E.Kosior, Binary and Ternary Blends of Recycled High –Density polyethylene Contaiing Polypropylenes, Journal of Polymer Engineering and Science, 2003, Vol 43P2.

[96] C. Albano and G .Sanchez , Study of the Mechanical, thermal, and Thermodegraative Properties of Virgin PP with Recyled and Non-Recycled HDPE, Journal of Polymer Engineering and Science, 1999, Vol 39, P8.

[97] H. Ismail and Suryadiansyah , Thermopolis Elastomers based on polypropylene/ Natural Rubber and Polypropylene /Recycle Rubber Blends, Polymer Testing Journal, 2002, Vol 21, pp 389-395.

[98] J. Kuk, H.L. Sung and S. H. Hwang, Experimental Investigation of the Morphology Development and Mechancal Properties of Waste Ethylene Propylene Diene Monomer/ Polypropylene Blend in Modular Intermeshing Corotating Twin-Screw Extruder, Journal of Applied Polymer Science, 2002, Vol 85, pp 2276-2282.

[99] E .Vaccaro N .T.Dibenedetto and S .J.Huang, Yield Strength of Low –Density Polyethylene Belnds , Polymer programme Journal ,University of Connecticut John ,1997.

[100] S.Tall, A .C.Albertsson and S. Karlsson, Recycling of Mixed Plastic Fractions : Mechanical Proopertes of Multicomponent Extruded Polyolefin Blends Using Response Surface Methodology, Experimental Investigation, Journal of Applied Polymer Scienceh, 1998, Vol 70, pp 2381-2390.

[101] H.P. Blom and A .Rudin, PP/PE Blends.IV.Characterizaion and Compatibilization of Blends of Postconsumer Resin with Virgin PP and HDPE, 1998,Vol 70, pp 2081-2095.

[102] C. Hsien and W.J. Liang, Effects of Geometry and Injection-Molding Parameters on Weld-Line Strenght, Journal of Polymer Engineering and Science, 2005, pp 1022-1030.

[103] Y. Wyers, Y. Leterrier and J.A.E.Manson, Effect of Inclusions and Blendng on the Mechancal Performance of Recycled Multilayer PP/PET/So Films, Experimental Investigation, Journal of Applied Polymer Science, 2000, Vol 78, pp 910-918.

[104] E. Susan and M.Selke, Relationshi Between Cell Morphology and Impact Strength of Microcellular Foamed High-Density Polyethlene/Polypropylene Blends, 2004, Vol 44, p8.

[105] N.T .Z. Dintcheva, F.P.LaMantia, R.Scaffaro, M.Paci, D.Acierno and G.Camino, Reprocessing and Restabilization of Greenhouse Films, 2002, Vol 75, pp 459-464.

[106] P.D C. Jacob, A.K. Bhowmick and S.K.De, Recycling of EPDM Waste, Replacement of Virgin Rubber by Ground EPDM Vulcanizate in EPDM/PP Thermoplastic Elastomeric Compostion, Journal of Applied Polymer Science, 2001, Vol 82, pp 3304-3312.

[107] S. H. Chang, H. Dong Park and W.J. Cho, Compatibilizers for Rrecycling of the Plastic Mixure Wastes. The Effect of a Compatibilizer for Binary Blends on the Properties of Ternary Blends, Journal of Applied Polymer Science, 2000, Vol 76, pp 1048-1053.

[108] M. Ruth, Campomans Santaa Manrich, Studies on Morphology and Mechanical Properties of Plypropylene/ High-Impact Plystyrene Blends from Postconsumer Plastic Waste, Journal of Applied Polymer Science, 2003, Vol 88, pp 2861-2867.

[109] P .D. Marco,F.Charles and K.Eubanks,Compatibility Analysis of Product design for Recyclability and reuse,Columbus, February ,1994.

[110] J.K. Kim, S.H.Lee and S.H.Hwang, Study on the Thermoplastic Vulcanizate sing Ultrasonically Treated Rubber Powder, Journal of Applied Polymer Scienceh, 2003, Vol 90, pp 2503-2507.

[111] P. Santos and S.H.Pezzin, Mechanical Propertis of Polypropylene reinforced with Recycled –Pet fibers, Journal of Materials Processing Technology, 2003, Vol 143, pp 517-520.

[112] H. Guang Leu, and H.L. Sheng, Cost–benefit Analysis of Resource Material Recycling, Resources Conservation and Recycling, 1998, Vol 23, pp 183–192.

[113] K. Palmer and M, Walls, The Cost of Reducing Municipal Solid Waste, Environmental Economics and Management, 1997, Vol 33, pp128-150.

[114] K.S. Rebeiz and A.P. Craft , Conservation and Recycling Plastic Waste Management in Construction: Technological and Institutional Issues, Journal of Resources, Conservation and Recycling, 1995, Vol 15, pp 245-257.

[115] B. Hallberg , K. Aquilonius , Y. Lechon , H. Cabal and R.M. Sa´ez , Schneider c, S. Lepicard c, D. Ward d, T. Hamacher e, R. Korhonen , Studsvik Eco and Safety AB, External Costs of Material Recycling Strategies for Fusion Power Plants, Fusion Engineering and Design Journal , 2003, Vol 69, pp 699- 703.

[116] W. Reid Lea, Plastic Incineration Versus Recycling: a Comparison of Energy and Landfill Cost savings, Experimental Investigation Hazardous Materials, 1996 Vol 47,pp 295-302.

[117] E. Diamadopoulos, Y. Koutsantonakis and V. Zaglara, Conservation and Recycling Optimal Design of Municipal Solid Waste Recycling Systems, Resources, Conservation and Recycling Journal, 1995, Vol 14, pp 21-34.

[118] H. M. Raymond and D.C. Montgomery, Response Surface Methodology :Process and Product Optimization using Desigied Experment, Blacksburge Virginia Tempc ,Arizon ,July ,1995.

[119] N.N. Nawani and B.P. Kapadnis ,Optimization of Chitinase Production Using Statistics Based Experimental Designs, Experimental Investigation Process Biochemistry , 2005, Vol 40, pp 651-660.

[120] E.P George, Empirical Model Boilding and Response Surfaces (Wiley Series in Probability and Statistics), Canada, John, 1987.

[121] R .J. Whitman, Surveys for Starters an Introduction to Designing and Conducting Management Survey, Survey Tools Corporation, USA, 2002.

[122] F. P. L. Mantia and J.L. Gardette, Improvement of the Mechanical Properties of Photo-Oxidized film after Recycling, Polymer Degradation and Stability, 2002, Vol 75, pp 1-7.

[123] B. Blumberg, D. R. Cooper and P. S. Schindler, "Business Research Methods", MC Graw Hill, Beckshire, 2005, UK.

[124] S. Sarantakos, "Social research", 1993, Macmillan Press Ltd, London.

[125] K. F. Punch, "Introduction to Social Research – Quantitative & Qualitative Approach", 1998, Sage Publication, London.

[126] M. Easterby-Smith, R. Thrope and A. Lowe, "Management research: An introduction", Sage, 1991, London.

[127] B. B. Flynn, S. Sakakibara, R. G. Schroeder, K. A. Bates and E. J. Flynn, "Empirical Research Mmethods in Operation Management", Journal of Operations Management, 1990, Vol 9, p 2.

[128] H. F. Wolcott, "Posturing in qualitative inquiry", in M.D. LeCompte, W.L. Millroy and J. Preissle (eds), "Handbook of Qualitative Research in Education", San Diego, CA, Academic Press, 1992, pp 3-52.

[129] M. Hammersley, "Deconstructing the Qualitative-Quantitative Divide", in J. Brannen , "Mixing methods: Qualitative and Quantitative Research", Aldershot: Avebury, 1992, pp 39-55.

[130] J. Brewer and A. Hunter, "Multimethod research: A synthesis of styles", Newbury Park, CA, Sage,1989.

[131] Marshall, Catherine and B. Gretchen and Rossman , Designig Qualitative Research, 1995, California, Sage Publications.

[132] Ryan, Bob, W. Robert , Scapens and M. Theobald,1992, Research Method and Methodology in Finance and Accounting, London ,Academic Press.

[133] Press and Roy, Starting Research: An Introduction to Academic Research and Dissertation Writing, 1994, London: Printer Publishers.

[134] A. J. Maxwell, 1996, Qualitative Research design: An interactive Approach, California: Sage Publication.

[135] A. Pinsonneault and K. L. Kraemer, "Survey Research Methodology in Management Information System: An assessment", Journal of Management Information System, 1993, Vol 10, p 75-105.

[136] A. Bryman , Quantity and Quality in Social Research , 1998, London: Unwin Hyman.

[137] R.G. Burgess, In the Field, 1984, London: Allen &Unwin.

[138] Denzin and K.Norman.,The Research act, New Jersey:Prentice-Hall.

[139] A. Simon, A. Sohal and A. Brown, Generative and case study research in quality management: part 1: Theoretical Considerations. Introduction Journal of Quality and Reliability Management, 1996, Vol 13, pp 32-43.

[140] F. N. Kerlinger, "Foundation of behavioral research", 3rd Edition, 1986, New York: Holt, Rinehart and Winston.

[141] M. J. Baker, "Selecting a research methodology", The marketing review, 2001, Vol 1, pp 373-397.

[142] S. Hart, "The Use of the Survey in Industrial Market Research", Journal of Marketing Management, 1987, Vol 3, pp 25-38.

[143] P. L. Alreck and R. B. Settle, "The Survey Research Handbook", 1985, Homewood III.

[144] K.G. Diem, "Choosing a data Collection Method for Survey Research", The State University of New Jersey, Desktop Publishing by RCE/Resource Centre Revised: February 2002.

[145] C. Moser and G. Kalton, Survey Methods in Social Investigation, 1971, Heinemann Educational.

[146] F. J. Fowler, "Survey Research Methods", Beverly Hills, 1984, Sage Publication, Inc.

[147] Kompass Ireland, the Market Leader in Irish Business Databases, December 2003. Available online: http://www.kompass.ie/about-kompass/marketplace.html.

[148] Ireland and UK Business Companies, "KOMPASS" database Available online: http:// http://www.library.dcu.ie/ .

[149] D. H. T. Walker, "Choosing an Appropriate Research Methodology", Construction Management and Economy, 1997, p 149-159.

[150] R. Czaja and J. Blair, "Designing survey", Pine Forge Press, 1996.

[150] S. Sudman, "Asking Questions", San Fracisco, Jossey-Bass Publishers, 1982.

[152] A. Fink, "How to Ask Survey Questions, 1995, London, Sage Publications, Inc.

[153] M.Y. Ismail, "Implementation of Quality Management in the Manufacturing Industry", Phd Thesis, School of Mechanical and Manufacturing Engineering in Dublin City University, Ireland, 1998.

[154] E.E Adam, P. M Swamidass, "Assessing Operations Management From A strategic Perspective", Journal of Management, 1989, Vol 15, pp. 181-203

[155] S.K .Vickery, C. Droge and R.E. Markland, "Production Competence and Business Strategy: do they Affect Business Performance", Decision Sciences, 1993, Vol 24, pp 435-455.

[156] B. M. Deros, S. M. Yusof, and A. M. Salleh, A survey on Benchmarking Perceptions of Importance and Practices in Malaysian Companies", ICAMT 2005 Proceedings, May 2004, Kuala Lumpur.

[157] G.S. Dangayacha and S.G. Deshmukhb, "An exploratory Study of Manufacturing Strategy Practices of Machinery Manufacturing Companies in India", Omega, Article in press - available Online 25 December 2004.

[158] I. Miller and J.E. Freund, Probability and Statistics for Engineers, Franklin Institute 1965, Vol 279, PP 474-475.

[159] W. L. Neuman, "Social Research Methods: Quantitative and Qualitative approaches", 2nd edition, Boston: Allyn and Bacon, 1994.

[160] R.A. Zeller, "Validity" in J.P. Keeves (ed), Educational Research, Methodology and Measurement: An International Handbook, 2nd Edition, Oxford: Elsevier, 1997, pp 822-829.

[161] Introduction to SPSS "Applied Technologies for Learning in the Arts & Sciences (ATLAS) (Revised September,)", 2002, Available online: http://www.atlas.uiuc.edu/Stats/News%20and%20Resources/documents/SPSS-Fl02b.pdf.

[162] R. R. Pagano, "Understanding Statistics in the Behavioural Sciences", Fourth Edition, 1994, USA, West Publishing Company.

[163] C.C Ragin, "Constructing Social Research", Thousnaf Oaks, CA: Pine Forge,1994.

[164] P. Kline, "An easy Guide to Factor Analysis", Routledge Publisher, 1994, London

[165] Module 24: C ross-Tabulation of Quantitative Data, March 2005. Available online: http://www.idrc.ca/en/ev-56452-201-1-DO_TOPIC.html.

[166 J.V Saraph, P.G Benson and R.G. Schroeder, "An Instrumant for measuring the critical factors of quality management", Decision Science, 1989, Vol 20, pp 810-829

[167] S. Rahman, "A comparative Study of TQM Practice and Organisational Performance of SMEs with and Without ISO 9000 Certification", International Journal of Quality and Reliability Management, 2001, Vol 18, pp 35-49.

[168] D. George and P. Mallery, SPSS/PC step by step: A simple Guide and Reference, Wadsworth Publishing Co, 1995.

[169] J. Reilly, "Understanding Statistics and its Applications in Business, Science and Engineering", 1997, Ireland, Folen Publisher.

[170] H. N. Norman, C. H. Hull, J. G. Jenkings, K. Steinbrenner and D. H. Bent, "Statistical Package for the Social Sciences (SPSS)", McGraw-Hill, Inc,1975.

[171] SPSS version 11 Course Tutorial Software, 2003.

[172] H.J. Motulsky, "Analysing Data with GraphPad Prism", GraphPad Software Inc, San Diego CA, 1999, pp. 135-153.

[173] J. Cohen, and P. Cohen, "Applied Multiple Regression/Correlation Analysis for the Behavioural Sciences", Second Edition, Lawrence Erlbaum Associates (LEA), Publishers Hillsdale, New Jersey London, 1983, pp 25 – 79.

[174] H. McDonald and S. Adam, A comparison of Online and Postal Data Collection Methodsin Marketing Research , Marketing Intelligence& Planning , 2003, Vol 21, pp 85-5.

[175] R. Mctronic and E. Sivadas, "Comparing Response Rate and Response Content in Mail Versus Electronic Mail Survey", Journal of Market Research Society , 1995,Vol 37, pp 29-39.

[176] D. Bachmann and J. Elfrink, Tracking the Progress of E-mail Versus Snal-Mail, Marketing Research, 1996, Vol 8, pp31-35.

[177] G. Keith and Diem, "Choosing a Dta Collection Method for Survey Research", 2002.

[178] D.Shannon, E. Johnson, S.Searchy and A.Lott, Using Electronic Survey: Advice Form Ssurvey Professionals, 2002.

[179] Introduction to the Application of Web-Based Survey, June 2004. Available on http//tps.dpi.state.nc.us/ncd/surveyweb/introduction on the application .htm..

[180] M. Carbonaro, J. Bainbridge and B. Wolodko,"Using Internet Survey to Gather Data From Teachers:rials and Triblations", Journal of Educational Tchnology, Australian, 2002, Vol 18, pp 275-292.

[181] L.Parker, "Collecting Data the E-Mail Way" Training and Development, 1992, pp52-54.

[182] Y.Zhang, "Using the Internet for Survey Research: A Case Study", Journal of the American Society for Information Science, 2002, Vol5, pp 57-68.

[183] Matthis ,"Conducting Research Survey via E-mail and the Web", 2001.

[184] Introduction in "SPSS", November 2003. Available on: http://www.utexas.edu/cc/stat/software/spss/.

[185] D.C.Montgomery, Desgin and Anlysis of Experiments.2nd Edition, John Wiley&Sons, New York, 1984.

[186] Design-Expert Sofwer, V7, Users Guide, Technical Manual, Stat-Ease Inc, Minneapolis, MN, 2005.

[187] K. Y. Benyounis, Prediction And Optimization of Residual Stresses- Laser Weld, Thesis of PhD, School of Mechanical and Manufacturing Engineering in Dublin City University, Ireland, February 2007.

APPENDIX

SIN NO:

SURVEY QUESTIONNAIRE

Study on the recycling of plastic materials

This questionnaire is divided into three sections; Section A: Company profile; Section B: Recycling of plastic materials; Section C: Marketing and resale of Recycled products.
All the information will be treated strictly confidential and thank you for your co-operation with this survey.

- (Please note that ; this study concerns with plastic rejects arising as a result of scrap or damaged products, sprues, runners)

SECTION A: COMPANY PROFILE

A1- Ownership. (Tick as applicable). 1. ☐Local 2. ☐ Mixed 3. ☐ Foreign

A2-How many years has your company been manufacturing plastic products. (Tick)

☐<5	☐6 -9years	☐10-20 years	☐21-30years	☐>30

A3- Number of employees on site. (Tick)

☐<50	☐50-100	☐100-200	☐200-500	☐500-1000	☐ Over

A4- Approximately, how much did you spend training staff in recycling in recent years? (Tick as applicable).

N.	Years	€ 0	€1-4999	€ 5000-9999	€10,000-24,999	€25,000-49,999	€50,000+
1.	2001	☐	☐	☐	☐	☐	☐
2.	2002	☐	☐	☐	☐	☐	☐
3.	2003	☐	☐	☐	☐	☐	☐
4.	2004	☐	☐	☐	☐	☐	☐

A5-Which of the following methods of processing plastics, are used in your company?

		Core Business	
		Yes	No
1.	Injection Moulding	☐	☐
2.	Extrusion Moulding	☐	☐
3.	Blow Moulding	☐	☐
4.	Others	☐	☐

✍ SECTION B: RCYCLING OF PLASTIC MATERIALS

B1- Does your company invest in the recycling of rejects. (Tick as applicable)

□Yes □No

B2- If yes, how long has the company been carrying out recycling? (Tick as applicable)

□<2	□3-5 years	□6-9 years	10-15years	>16

B3- On average what percentage of rejects come from the process products of fowling years in your company? (Tick as applicable)

N.	Years	<2%	3-5 %	6 -9 %	10-15%	>16%
1.	2001	□	□	□	□	□
2.	2002	□	□	□	□	□
3.	2003	□	□	□	□	□
4.	2004	□	□	□	□	□

B4- Approximately, how many percentage of rejects come from the process of recycled products? (Tick as applicable)

N.	Ton	<2%	3-5 %	6 -9 %	10-15%	>16%
1.	<200	□	□	□	□	□
2.	200-800	□	□	□	□	□
3.	800-1500	□	□	□	□	□
4.	1500-3000	□	□	□	□	□
5.	Over 3000	□	□	□	□	□

B5- In which year was recycling introduced for the following plastic materials? (Tick as applicable).

[Scale: 1= None Recycled, 2= Recycled]

N.	**Plastic Material**	**2001**		**2002**		**2003**		**2004**	
		1	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1.	PP	□	□	□	□	□	□	□	□
2.	PS	□	□	□	□	□	□	□	□
3.	PVC	□	□	□	□	□	□	□	□
4.	HDPE	□	□	□	□	□	□	□	□
5.	LDPE	□	□	□	□	□	□	□	□
6.	EPS	□	□	□	□	□	□	□	□
7.	ABS	□	□	□	□	□	□	□	□
8.	PET	□	□	□	□	□	□	□	□
9.	Other	□	□	□	□	□	□	□	□

B6- How many times does your company recycle the plastic materials? (Tick as applicable)

1.□First Recycling 3. □ Third Recycling
2.□ Second Recycling 4.□More Recycling

B7- On average, in your company what percentage of each plastic material is recycled? (Please tick for each recycling stage).

[Scale: 1=0%, 2=1-5%, 3=6-9%, 4=10-15%, 5= >16%]

N.	Plastic Material	First Recycling					Second Recycling					Third Recycling				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1.	PP	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2.	PS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3.	PVC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4.	HDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5.	LDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6.	EPS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7.	ABS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8.	PET	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9.	Other	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

B8- In your opinion, which of the following input <u>parameters</u> reduce the quality of recycled products in your company? (Please tick for each recycling stage).

[Scale: 1= Process, 2= Materials, 3= Personnel skill]

N.	Plastic Material	First Recycling			Second Recycling			Third Recycling		
		1	2	3	1	2	3	1	2	3
1.	PP	☐	☐	☐	☐	☐	☐	☐	☐	☐
2.	PS	☐	☐	☐	☐	☐	☐	☐	☐	☐
3.	PVC	☐	☐	☐	☐	☐	☐	☐	☐	☐
4.	HDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐
5.	LDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐
6.	EPS	☐	☐	☐	☐	☐	☐	☐	☐	☐
7.	ABS	☐	☐	☐	☐	☐	☐	☐	☐	☐
8.	PET	☐	☐	☐	☐	☐	☐	☐	☐	☐
9.	Other	☐	☐	☐	☐	☐	☐	☐	☐	☐

B9-Please choose the specific reason(s) why recycling was not used in each year. (Where applicable).

N.	Reason(s)	200	2002	2003	2004
1.	Cost of recycling process	☐	☐	☐	☐
2.	Inadequate personnel skills	☐	☐	☐	☐
3.	Cheap Raw material	☐	☐	☐	☐
4.	Inability to distribution marketing	☐	☐	☐	☐
5.	Reduction in quality	☐	☐	☐	☐
6.	Low price sales	☐	☐	☐	☐
7.	Decreased market in recycled products	☐	☐	☐	☐
8.	Decrease quantity of productivity	☐	☐	☐	☐
9.	Others	☐	☐	☐	☐

B10- In your opinion what are the economic benefits of recycling plastic materials in your company. (For each year as appropriate).

N.	Economic Benefits	2001	2002	2003	2004
1.	Increased productivity	☐	☐	☐	☐
2.	Maximizes Sales	☐	☐	☐	☐
3.	Reduce process cost	☐	☐	☐	☐
4.	Low cost products	☐	☐	☐	☐
5.	Maximizes profits	☐	☐	☐	☐
6.	More Competitive	☐	☐	☐	☐
7.	Others	☐	☐	☐	☐

B11- For each plastic material, how is <u>Cost</u> affected by the recycling process? (Please tick for each recycling stage).

[Scale: 1=Increased Cost, 2= Decreases Cost, 3= No change Cost]

N.	Plastic Material	First recycling			Second recycling			Third recycling		
		1	2	3	1	2	3	1	2	3
1.	PP	☐	☐	☐	☐	☐	☐	☐	☐	☐
2.	PS	☐	☐	☐	☐	☐	☐	☐	☐	☐
3.	PVC	☐	☐	☐	☐	☐	☐	☐	☐	☐
4.	HDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐
5.	LDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐
6.	EPS	☐	☐	☐	☐	☐	☐	☐	☐	☐
7.	ABS	☐	☐	☐	☐	☐	☐	☐	☐	☐
8.	PET	☐	☐	☐	☐	☐	☐	☐	☐	☐
9.	Other	☐	☐	☐	☐	☐	☐	☐	☐	☐

B12- For each plastic material, how is <u>Productivity</u> affected by the recycling process? (Please tick for each recycling stage).

[Scale: 1= Increase Productivity, 2= Decrease Productivity]

N.	Plastic Material	First recycling		Second recycling		Third recycling	
		1	2	1	2	1	2
1.	PP	☐	☐	☐	☐	☐	☐
2.	PS	☐	☐	☐	☐	☐	☐
3.	PVC	☐	☐	☐	☐	☐	☐
4.	HDPE	☐	☐	☐	☐	☐	☐
5.	LDPE	☐	☐	☐	☐	☐	☐
6.	EPS	☐	☐	☐	☐	☐	☐
7.	ABS	☐	☐	☐	☐	☐	☐
8.	PET	☐	☐	☐	☐	☐	☐
9.	Other	☐	☐	☐	☐	☐	☐

B13- For each plastic material, how is <u>Quality</u> affected by the recycling process? (Please tick for each recycling stage).

[Scale: 1= Increases Quality, 2= Decreases Quality, 3= No Change Quality]

N.	Plastic Material	First recycling			Second recycling			Third recycling		
		1	2	3	1	2	3	1	2	3
1.	PP	☐	☐	☐	☐	☐	☐	☐	☐	☐
2.	PS	☐	☐	☐	☐	☐	☐	☐	☐	☐
3.	PVC	☐	☐	☐	☐	☐	☐	☐	☐	☐
4.	HDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐
5.	LDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐
6.	EPS	☐	☐	☐	☐	☐	☐	☐	☐	☐
7.	ABS	☐	☐	☐	☐	☐	☐	☐	☐	☐
8.	PET	☐	☐	☐	☐	☐	☐	☐	☐	☐
9.	Other	☐	☐	☐	☐	☐	☐	☐	☐	☐

B14- When choosing a process, which one of the following has an impact on your choice? (Tick as applicable).

1.	☐ Screw speed	5.	☐ Venting	9.	☐ Cooling
2.	☐ Barrel temperature	6.	☐ Injection pressure	10.	☐ Moving piston rod
3.	☐ Mould Shaping	7.	☐ Nozzle temperature	11.	☐ All of the above
4.	☐ Mould temperature	8.	☐ Hydraulic		

B15- In your opinion, which of process <u>parameters</u> reduces the quality of recycled products in your company. (Please tick for each recycling stage).

[Scale: 1= Screw Speed, 2= Barrel Temperature, 3= Mould Temperature]

N.	Plastic Material	First recycling				Second recycling				Third recycling			
		1	2	3	4	1	2	3	4	1	2	3	4
1.	PP	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2.	PS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3.	PVC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4.	HDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5.	LDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6.	EPS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7.	ABS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8.	PET	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9.	Other	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

SECTION C: MARKETING AND SALE OF RECYCLED PRODUCTS

C1-Does your company sell recycled products. (Tick as applicable)

☐Yes ☐No

C2- If yes, how long has the company been involved in the sale of products. (Tick as applicable)

☐<2	☐3-5 years	☐6 -9 years	☐ 10-15years	☐ >16

C3- On average what percentage of profits come from the sale of recycled products? (Tick as applicable)

☐2%	☐5%	☐10%	☐15%	☐30%	☐45%	☐ More

C4- How has the sale of recycled plastic materials affected sales, during the following years in your company. (For each year as appropriate).

[Scale: 1= Increase, 2= Decrease]

N.	Plastic Material	2001		2002		2003		2004	
		1	2	1	2	1	2	1	2
1.	PP	☐	☐	☐	☐	☐	☐	☐	☐
2.	PS	☐	☐	☐	☐	☐	☐	☐	☐
3.	PVC	☐	☐	☐	☐	☐	☐	☐	☐
4.	HDPE	☐	☐	☐	☐	☐	☐	☐	☐
5.	LDPE	☐	☐	☐	☐	☐	☐	☐	☐
6.	EPS	☐	☐	☐	☐	☐	☐	☐	☐
7.	ABS	☐	☐	☐	☐	☐	☐	☐	☐
8.	PET	☐	☐	☐	☐	☐	☐	☐	☐
9.	Other	☐	☐	☐	☐	☐	☐	☐	☐

C5-What are the market benefits of recycling in your company. (For each year as appropriate)

N.	Market Benefits	2001	2002	2003	2004
1.	Low price	☐	☐	☐	☐
2.	Consumer Satisfaction	☐	☐	☐	☐
3.	Increased Productivity	☐	☐	☐	☐
4.	Maximizes Sales	☐	☐	☐	☐
5.	Financial diversity	☐	☐	☐	☐
6.	Reduced process cost	☐	☐	☐	☐
7.	Maximize profits	☐	☐	☐	☐
8.	More Competitive	☐	☐	☐	☐
9.	Others	☐	☐	☐	☐

C6-How would you rate the cost of each recycling process?

[Scale: 1= Low Price, 2= Medium Price, 3= High Price]

Plastic Materials	First recycling			Second recycling			Third recycling		
	1	2	3	1	2	3	1	2	3
PP	☐	☐	☐	☐	☐	☐	☐	☐	☐
PVC	☐	☐	☐	☐	☐	☐	☐	☐	☐
HDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐
LDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐
EPS	☐	☐	☐	☐	☐	☐	☐	☐	☐
ABS	☐	☐	☐	☐	☐	☐	☐	☐	☐
PS	☐	☐	☐	☐	☐	☐	☐	☐	☐
PET	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐	☐	☐	☐	☐

Many thanks for your patience; your kind cooperation is very much appreciated.

RE- CONTACT

In case we need to get some further information on the above study, are you willing to be participate and be contacted again.

1☐.Yes 2☐. No

If yes, please specify.

1☐.E-mail-please specify____

2☐.Further questionnaire

3☐.Interview

Please add any further information you feel may be useful to this study in the space provided below ✐

____

____

____

____

____

Please return (using the pre-addressed and stamped envelope) **to:**

School of Mechanical and Manufacturing Engineering,
Dublin City University, Dublin 9, Ireland.

17 th Feb.2005

Dear Sir/Madam

Please find enclosed questionnaire for a recycling industry survey of plastic processing companies. The school of Mechanical and Manufacturing Engineering at Dublin City University is undertaking a study to determine the practice of recycling plastic rejects practices in the Manufacturing plastic industry.

I am studying the influence of investment incentives to promote the implementation of recycling manufacturing technology in the plastic industry in Ireland. It is for this reason this survey is directed to the manufacturing industry in Ireland. Your experience in recycling practices and contribute greatly to this research effort .we acknowledge that it is going to take some effort on your part to complete the whole questionnaire and in order to be sure that the questionnaire is understandable, to get any suggestion for improvements in this study or to avoid any difficulty and to observer that the instructions and question work as expected.

How to complete this questionnaire:

1- Most of the questions and simply which require a tick.

2-When you have completed the questionnaire just slip it into the envelope provided and mail it direct to.

Mr: Lutfi Elgammudi
School of Mechanical and Manufacturing Engineering
Dublin City University
Glasnevin, Dublin 9, Ireland

Please return it before 1st March.2005 if possible.

Thanking you in anticipation of your kind co-operation. Your support is greatly appreciated.

Yours faithfully

Prof. M.S.J. Hashmi

2nd .March.2005

Dear Sir/Madam

Please find enclosed questionnaire for a recycling industry survey of plastic processing companies. The school of Mechanical and Manufacturing Engineering at Dublin City University is undertaking a study to determine the practice of recycling plastic rejects practices in the Manufacturing plastic industry.

I am studying the influence of investment incentives to promote the implementation of recycling manufacturing technology in the plastic industry in Ireland; it is for this reason this survey is directed to the manufacturing industry in Ireland. Your experience in recycling practices and contribute greatly to this research effort .we acknowledge that it is going to take some effort on your part to complete the whole questionnaire.

How to complete this questionnaire:

1-Most of the questions simply require a tick.

2-When you have completed the questionnaire just slip it into the envelope provided and mail it direct to.

Mr: Lutfi Elgammudi
School of Mechanical and Manufacturing Engineering
Dublin City University
Glasnevin, Dublin 9,Ireland

Please return it before 31st March.2005 and automatically qualify for a:

Lucky Draw

1 st Prize 200 cash
2 nd Prize Dinner for two in a restaurant of your choice
3 rd Prize Dinner for one in a restaurant of your choice

Please enclose self-addressed envelope, which will be used to notify you should you become one of the lucky winners. Your response will be held in strict confidence. The five-digit code in the questionnaire will be computer generated and is used to ease our enormous administrative task.

Thanking you in anticipation of your kind co-operation. Your support is greatly appreciated.

Yours faithfully

____

Prof. M.S.J. Hashmi

15th June.2005

Dear Sir/Madam

This is just to remind you tat a survey questionnaire sent to you company on the 10th April 2005 may not have been addressed directly to you. If you have already completed the questionnaire and returned it to us we would like to thank you and please ignore this letter.

But if you have not done so yet owing to any reason, we would like to request you to kindly completed the questionnaire and return as to us soon as possible.

When you have completed the questionnaire just use the envelope provided and mail it direct to:

Mr: Lutfi Elgammudi
School of Mechanical and Manufacturing Engineering
Dublin City University
Glasnevin, Dublin 9, Ireland

I would like to emphasize that is very important project we have undertaken and its success will depend on good response from the industry.

We realize that we have nothing to offer you in return for our-operation other than our appreciation and free participation I a Prize Draw (Dinner for 2- € 150), which will be conducted by the middle of July 2005.

Your time and co-operation highly appreciated

Yours faithfully

____

Prof. M.S.J. Hashmi

Results of Survey

1- Alpha Test

Code	Questionnaire	No. of items	Alpha (α) value
B13	Quality effects by the recycled process (PP)at each stages.	3	.7500
B16	Process parameters reduce reduces the quality of recycled products (PP)at each stages.	3	1.0000
B12	Productivity affected by the recycling process(PP)at each stages.	3	.9265
A4	Percentage of rejects	4	.9117
B3	Spend training staff in recycling , (2001-2004).	4	.9668
B8	Input parameters reduce the quality of recycled products(PP)at each stages.	3	1.0000
C4	Sale of recycled plastic material affected sales(PP)at each stages.	3	.7500
C6	Rate the cost of (PP) at each stages.	3	.6818

2-Frequency

Table B3: Percentage of rejects come from the process products?

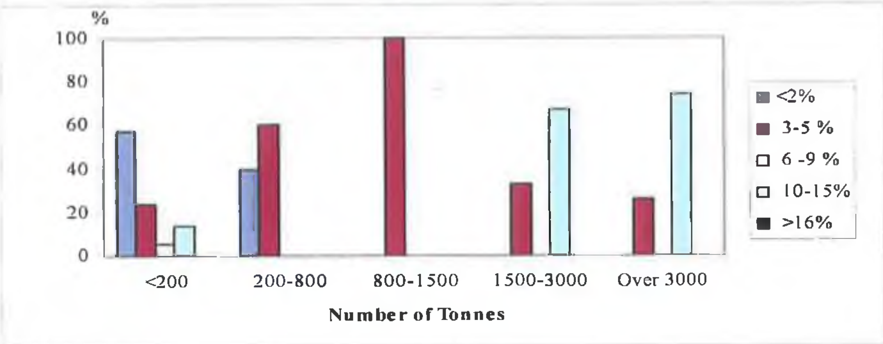
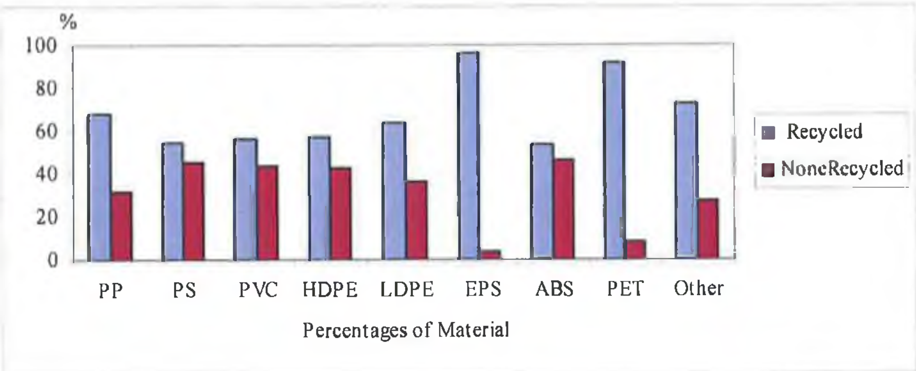
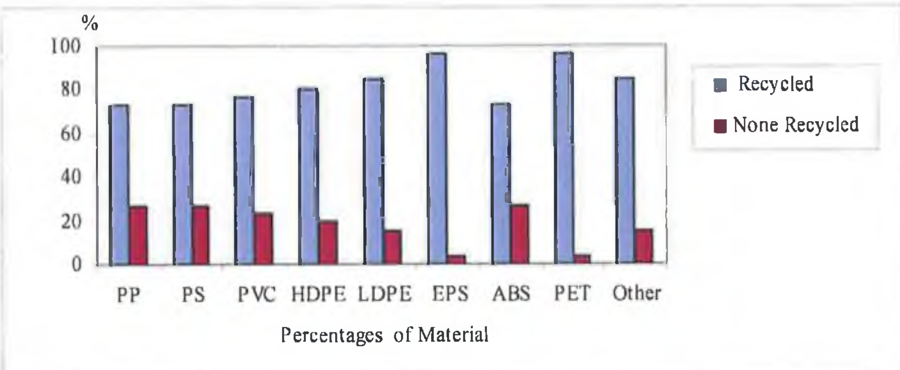


Table B5: recycling introduced for the following plastic materials?

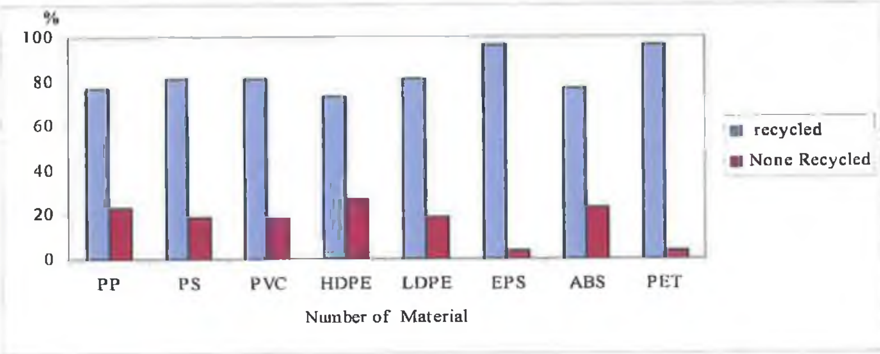
-2001



-2002



-2003



-2004

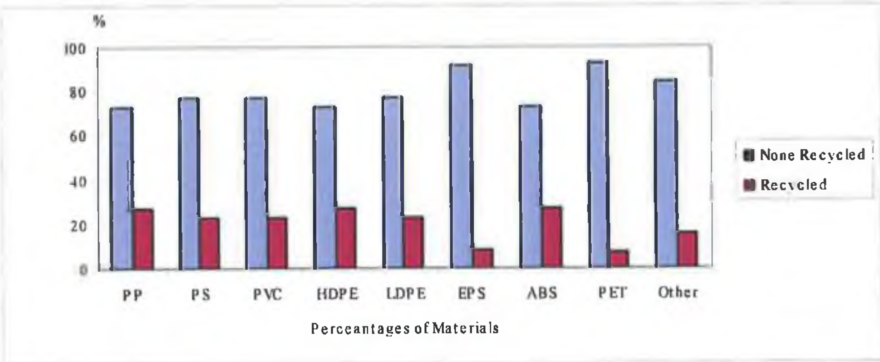


Table B7: Percentage of each plastic material is recycled?

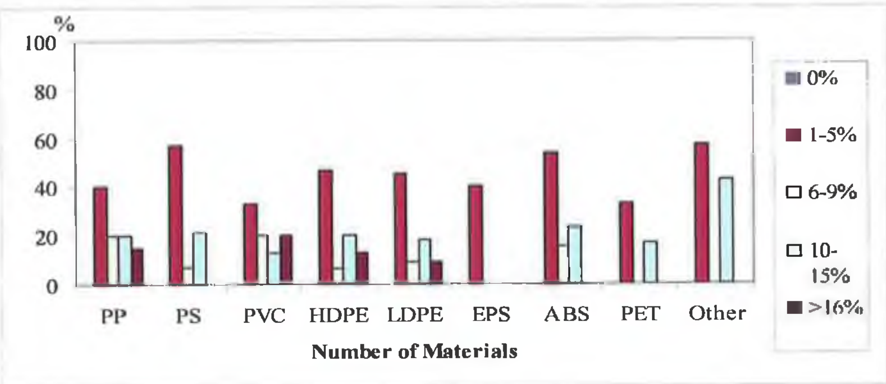


Table B9: Specific reason(s) why recycling was not used in each year.

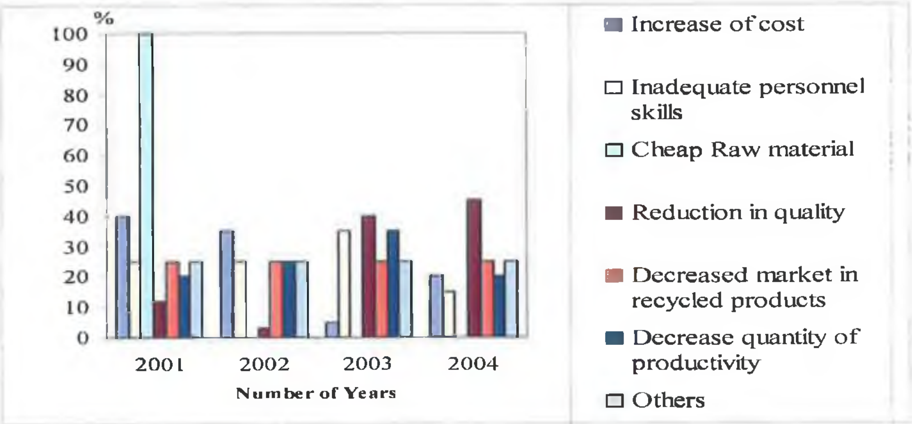


Table B10: Economic benefits of recycling plastic materials.

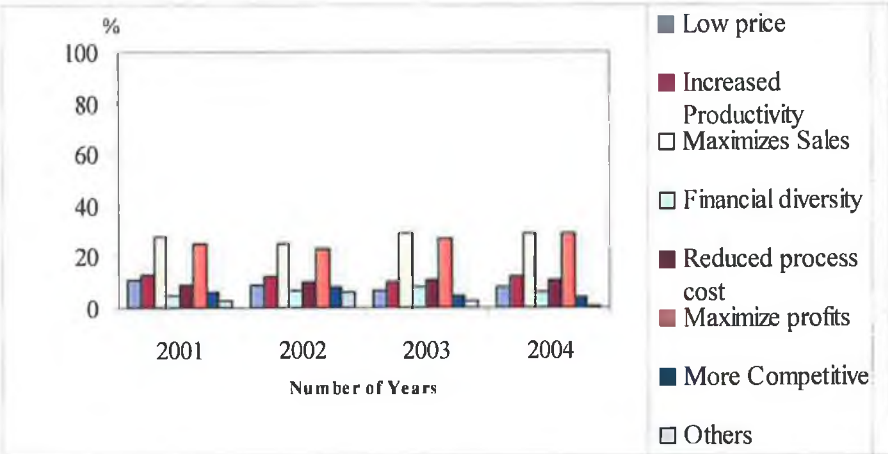
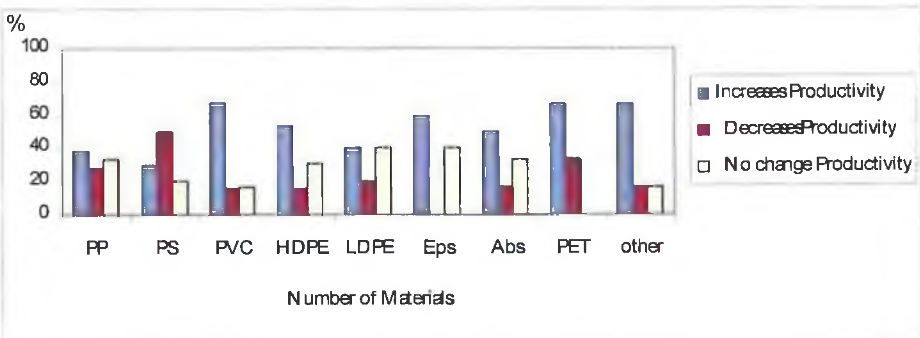
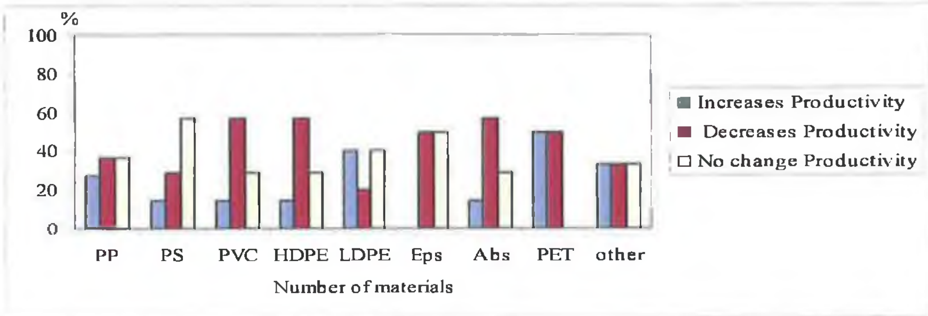


Table B12: Productivity affected by the recycling process?

- First Stage



-Second Stage



- Third Stage

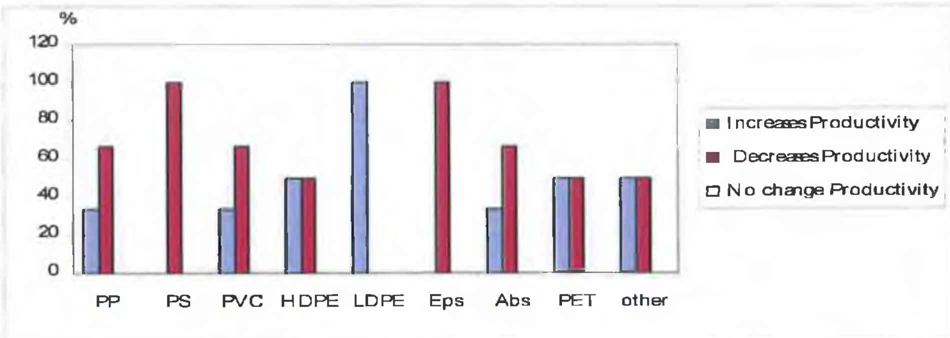


Table C3: profits come from the sale of recycled products?

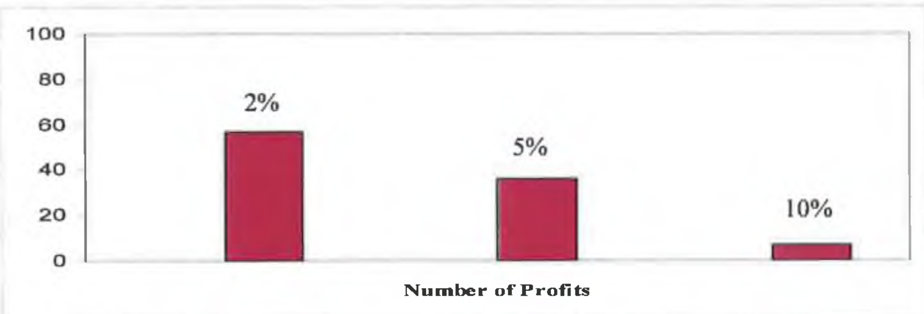
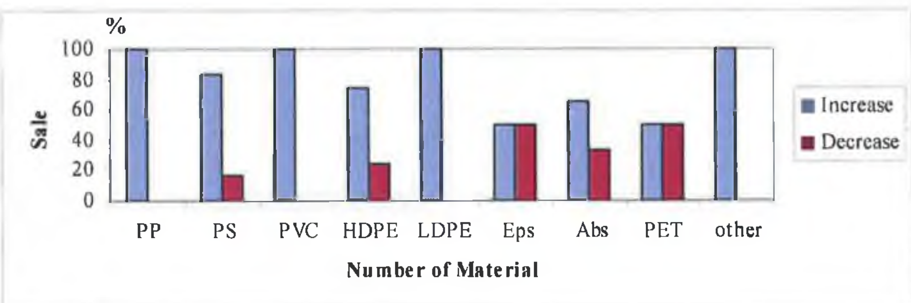
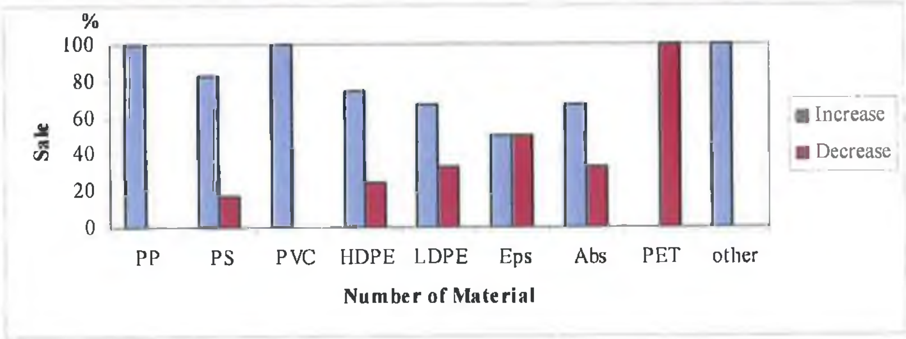


Table C4: Recycled plastic materials affected sales, during the following years.

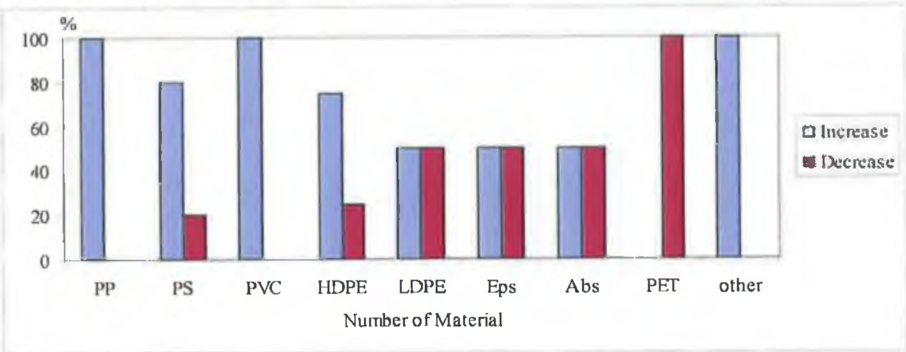
-2001



-2002



-2003



2004

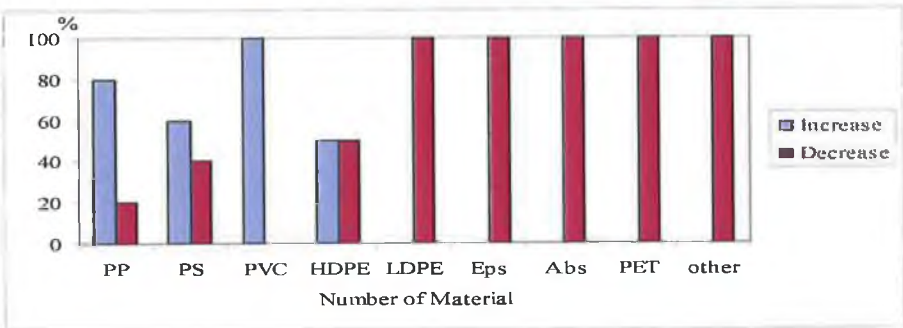
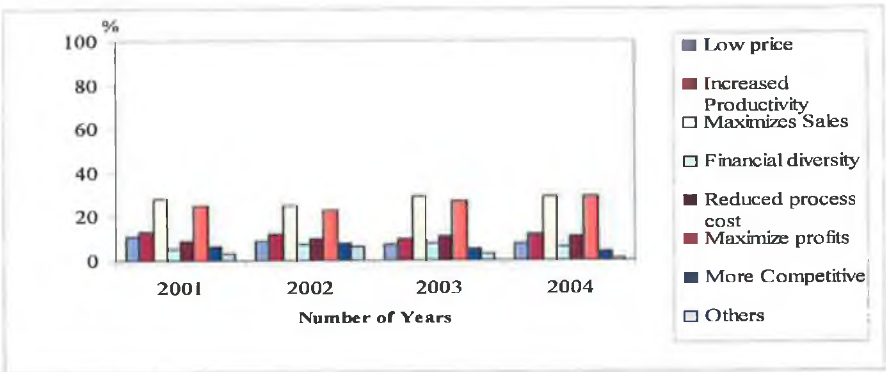


Table C5: Market benefits of recycling.



2-Cross Tabulation

			Does your company invest in the recycling of rejects		Total
			Yes	No	
Ownership	Local	% of Total	66.7%	7.4%	74.1%
	Mixed	% of Total	7.4%		7.4%
	Foreign	% of Total	14.8%	1 3.7%	18.5%
Total		% of Total	88.9%	11.1%	100.0%

			Does your companysell recycled products		Total
			Yes	No	
Ownership	Local	% of Total	37.5%	37.5%	75.0%
	Mixed	% of Total		8.3%	8.3%
	Foreign	% of Total	4.2%	12.5%	16.7%
Total		% of Total	41.7%	58.3%	100.0%

			How many time does yourcompany recycle the plastic materials			Total
			First Rcycling	Second Recycling	More Recycling	
Ownership	Local	% of Total	66.7%	7.4%		74.1%
	Mixed	% of Total	3.7%		3.7%	7.4%
	Foreign	% of Total	14.8%		3.7%	18.5%
Total		% of Total	85.2%	7.4%	7.4%	100.0%

			How many time does yourcompany recycle the plastic materials			
			First Rcycling	Second Recycling	More Recycling	Total
Approximately ,what percentage of rejects come from the process <200 of recycled products	<2%	% of Total	38.1%	9.5%	9.5%	57.1%
	3-5%	% of Total	23.8%			23.8%
	6-9%	% of Total	4.8%			4.8%
	10-15%	% of Total	14.3%			14.3%
Total		% of Total	81.0%	9.5%	9.5%	100.0%

			How much did yiu spend trainig staff in recycling,2001 years				
			€0	€1-4999	€5000-9999	€25,000-49,999	Total
Number of employees on site	<50	% of Total	36.0%	20.0%	4.0%		60.0%
	50-100	% of Total	4.0%	4.0%			8.0%
	100-200	% of Total		20.0%		4.0%	24.0%
	200-500	% of Total	4.0%	4.0%			8.0%
Total		% of Total	44.0%	48.0%	4.0%	4.0%	100.0%

			How much did yiu spend trainig staff in recycling,2002 years					
			€0	€1-4999	€5000-9999	€10,000-24,999	€25,000-49,999	Total
Number of employees on site	<50	% of Total	21.7%	26.1%	4.3%	4.3%		56.5%
	50-100	% of Total		8.7%				8.7%
	100-200	% of Total		17.4%	4.3%		4.3%	26.1%
	200-500	% of Total	4.3%	4.3%				8.7%
Total		% of Total	26.1%	56.5%	8.7%	4.3%	4.3%	100.0%

		How much did yiu spend trainig staff in recycling,2003 years					
		€0	€1-4999	€5000-9999	€10,000-24,999	€50,000+	Total
Number of employees on site	<50 % of Total	16.7%	33.3%	4.2%	4.2%		58.3%
	50-100 % of Total		8.3%				8.3%
	100-200 % of Total		16.7%	4.2%		4.2%	25.0%
	200-500 % of Total		4.2%	4.2%			8.3%
Total	% of Total	16.7%	62.5%	12.5%	4.2%	4.2%	100.0%

		How much did yiu spend trainig staff in recycling,2004 years					
		€0	€1-4999	€5000-9999	€10,000-24,999	€50,000+	Total
Number of employees on site	<50 % of Total	12.0%	36.0%	4.0%	4.0%		56.0%
	50-100 % of Total		8.0%		4.0%		12.0%
	100-200 % of Total		16.0%	4.0%		4.0%	24.0%
	200-500 % of Total			8.0%			8.0%
Total	% of Total	12.0%	60.0%	16.0%	8.0%	4.0%	100.0%

		On average ,what percentage of each plastic materials is recycled PP,first Recycling					
		0%	1-5%	6-9%	10-15%	>16%	Total
How many time does yourcompany recycle the plastic materials	First Rcycling % of Total	5.0%	40.0%	15.0%	20.0%	5.0%	85.0%
	Second Recycling % of Total			5.0%		5.0%	10.0%
	More Recycling % of Total					5.0%	5.0%
Total	% of Total	5.0%	40.0%	20.0%	20.0%	15.0%	100.0%

		How long has the company been carrying out recycling					
		<2	3-5 years	6-9 years	10-15 years	>16	Total
How many years has your company been manufacturing plastic products	<5 % of Total	3.8%					3.8%
	6-9 years % of Total			7.7%			7.7%
	10-20 years % of Total			3.8%	11.5%	7.7%	23.1%
	21-30 years % of Total	3.8%	7.7%	7.7%	3.8%	11.5%	34.6%
	>30 % of Total		3.8%	3.8%	3.8%	19.2%	30.8%
Total	% of Total	7.7%	11.5%	23.1%	19.2%	38.5%	100.0%

		Does your companysell recycled products		
		Yes	No	Total
How many years has your company been manufacturing plastic products	<5 % of Total		4.2%	4.2%
	6-9 years % of Total	8.3%		8.3%
	10-20 years % of Total	8.3%	16.7%	25.0%
	21-30 years % of Total	16.7%	16.7%	33.3%
	>30 % of Total	8.3%	20.8%	29.2%
Total	% of Total	41.7%	58.3%	100.0%

		On average waht percentage of profits come from the sale of recycled products			
		2%	5%	10%	Total
if yes ,how long has the company been involved inthe sale of	<2years % of Total	14.3%			14.3%
	3-5years % of Total	14.3%	7.1%		21.4%
	6-9years % of Total	14.3%	7.1%		21.4%
	10-15years % of Total	7.1%	7.1%		14.3%
	>16years % of Total	7.1%	14.3%	7.1%	28.6%
Total	% of Total	57.1%	35.7%	7.1%	100.0%

		Reduce process cost				
		2001	2002	2003	2004	Total
Does your company invest in the recycling of rejects	Yes % of Total	76.2%	4.8%	4.8%	4.8%	90.5%
	No % of Total	4.8%	4.8%			9.5%
Total	% of Total	81.0%	9.5%	4.8%	4.8%	100.0%

		Maximizes profits				
		2001	2002	2003	2004	Total
Does your company invest in the recycling of rejects	Yes % of Total	75.0%	5.0%	10.0%	5.0%	95.0%
	No % of Total	5.0%				5.0%
Total	% of Total	80.0%	5.0%	10.0%	5.0%	100.0%

3-Correlation

Correlations

			How many time does yourcompany recycle the plastic materials	Reduce process cost
Kendall's tau_b	How many time does yourcompany recycle the plastic materials	Correlation Coefficien	1.000	.386*
		Sig. (2-tailed)	.	.024
		N	38	29
	Reduce process cost	Correlation Coefficien	.386*	1.000
		Sig. (2-tailed)	.024	.
		N	29	63

*. Correlation is significant at the .05 level (2-tailed).

			How many time does yourcompany recycle the plastic materials	Maximizes profits
Spearman's rho	How many time does yourcompany recycle the plastic materials	Correlation Coefficient	1.000	.492**
		Sig. (2-tailed)	.	.009
		N	38	27
	Maximizes profits	Correlation Coefficient	.492**	1.000
		Sig. (2-tailed)	.009	.
		N	27	66

**. Correlation is significant at the .01 level (2-tailed).

			Does your company invest in the recycling of rejects	how is quality affectes by the recycling process
Spearman's rho	Does your company inves in the recycling of rejects	Correlation Coefficien	1.000	-1.000**
		Sig. (2-tailed)	.	.000
		N	27	17
	how is quality affectes by the recycling process	Correlation Coefficien	-1.000**	1.000
		Sig. (2-tailed)	.000	.
		N	17	18

**. Correlation is significant at the .01 level (2-tailed).

			Number of employees on site	How much did yiu spend trainig staff in recycling,2004 years
Spearman's rho	Number of employees on site	Correlation Coefficient	1.000	.445*
		Sig. (2-tailed)	.	.026
		N	27	25
	How much did yiu spend trainig staff in recycling,2004 years	Correlation Coefficient	.445*	1.000
		Sig. (2-tailed)	.026	.
		N	25	25

*. Correlation is significant at the .05 level (2-tailed).

Correlations

			Number of employees on site	How much did yiu spend trainig staff in recycling,2004 years
Kendall's tau_b	Number of employees on site	Correlation Coefficient	1.000	.395*
		Sig. (2-tailed)	.	.028
		N	27	25
	How much did yiu spend trainig staff in recycling,2004 years	Correlation Coefficient	.395*	1.000
		Sig. (2-tailed)	.028	.
		N	25	25

*. Correlation is significant at the .05 level (2-tailed).

			How many time does yourcompany recycle the plastic materials	More Competitive
Spearman's rho	How many time does yourcompany recycle the plastic materials	Correlation Coefficient	1.000	.606**
		Sig. (2-tailed)	.	.005
		N	38	20
	More Competitive	Correlation Coefficient	.606**	1.000
		Sig. (2-tailed)	.005	.
		N	20	47

**. Correlation is significant at the .01 level (2-tailed).

			How many time does yourcompany recycle the plastic materials	Reduce process cost
Spearman's rho	How many time does yourcompany recycle the plastic materials	Correlation Coefficient	1.000	.423*
		Sig. (2-tailed)	.	.022
		N	38	29
	Reduce process cost	Correlation Coefficient	.423*	1.000
		Sig. (2-tailed)	.022	.
		N	29	63

*. Correlation is significant at the .05 level (2-tailed).

1- **Wight of recycling samples**

Table 1: First recycle weighting

No.	Weight in g					Average Weight
	1	2	3	4	5	
1	0.79436	0.78721	0.7162	0.71995	0.72008	0.74756
2	0.80879	0.80996	0.79735	0.81029	0.80912	0.807102
3	0.81925	0.8198	0.81878	0.81973	0.81952	0.819416
4	0.80888	0.80872	0.80902	0.80867	0.8091	0.808878
5	0.81578	0.81533	0.81408	0.8153	0.8154	0.815178
6	0.81088	0.80856	0.80988	0.80976	0.80949	0.809714
7	0.81574	0.81646	0.81615	0.8162	0.81634	0.816178
8	0.8109	0.8105	0.81096	0.81145	0.81028	0.810818
9	0.81692	0.81637	0.81729	0.81759	0.81735	0.817104
10	0.81042	0.81061	0.81028	0.8106	0.81119	0.81062
11	0.80929	0.80874	0.81026	0.80969	0.81019	0.809634
12	0.81045	0.80994	0.81024	0.81002	0.80985	0.8101
13	0.8114	0.81122	0.8123	0.81143	0.8103	0.81133
14	0.80874	0.80805	0.8084	0.80847	0.80822	0.808376
15	0.81002	0.80955	0.80959	0.81014	0.81001	0.809862
16	0.81127	0.8275	0.81233	0.81192	0.8106	0.814724
17	0.81018	0.78983	0.81376	0.80889	0.78672	0.801876
18	0.81372	0.78235	0.81374	0.81328	0.81326	0.80727
19	0.81465	0.81397	0.81352	0.81401	0.81501	0.814232
20	0.81444	0.81493	0.81356	0.81346	0.81382	0.814042

Table 2: Second recycling weighting

No.	Weight in g					Average Weight
	1	2	3	4	5	
1	0.7945	0.7874	0.8161	0.8194	0.8201	0.8075
2	0.8087	0.8102	0.7972	0.8102	0.809	0.80706
3	0.8193	0.8195	0.8196	0.8199	0.8196	0.81958
4	0.809	0.8087	0.809	0.8087	0.8091	0.8089
5	0.8157	0.8153	0.8146	0.8151	0.8151	0.81516
6	0.8109	0.8087	0.8099	0.8096	0.8097	0.80976
7	0.8158	0.8165	0.8161	0.8161	0.8164	0.81618
8	0.8108	0.8104	0.8112	0.8115	0.8104	0.81086
9	0.8169	0.8165	0.8172	0.8177	0.8174	0.81714
10	0.8103	0.8105	0.8102	0.8105	0.8109	0.81048
11	0.8098	0.8103	0.8096	0.8098	0.8097	0.80984
12	0.8104	0.8099	0.808	0.8102	0.8093	0.80956
13	0.8112	0.8113	0.8123	0.8114	0.8101	0.81126
14	0.8088	0.808	0.8086	0.8083	0.808	0.80834
15	0.8099	0.8092	0.8097	0.8101	0.8099	0.80976
16	0.8113	0.7828	0.8124	0.812	0.8107	0.80584
17	0.8104	0.7897	0.8139	0.8091	0.7867	0.80196
18	0.8136	0.7824	0.8137	0.8132	0.8133	0.80724
19	0.8138	0.8137	0.8136	0.814	0.8149	0.814
20	0.8144	0.815	0.8136	0.8137	0.8139	0.81412

Table 3: Third recycle Weighting

No.	Weight in g					Average Weight
	1	2	3	4	5	
1	0.82032	0.81877	0.81226	0.88079	0.82074	0.8305756
2	0.81047	0.81145	0.81146	0.81108	0.81236	0.811364
3	0.81846	0.82092	0.82094	0.81781	0.81813	0.819252
4	0.81121	0.80974	0.81001	0.81063	0.80956	0.81023
5	0.81285	0.81279	0.81542	0.81608	0.81525	0.814478
6	0.81286	0.80341	0.81181	0.8177	0.81264	0.811684
7	0.81581	0.81377	0.81445	0.81471	0.81302	0.814352
8	0.81108	0.81081	0.81089	0.81185	0.81119	0.811164
9	0.81601	0.81627	0.81392	0.81266	0.81683	0.815138
10	0.81141	0.81124	0.81256	0.81241	0.81198	0.81192
11	0.81217	0.81212	0.81238	0.81228	0.80913	0.811616
12	0.81263	0.81166	0.81252	0.81111	0.81452	0.812488
13	0.81327	0.81292	0.81309	0.81441	0.81401	0.81354
14	0.81173	0.81024	0.81102	0.81142	0.81169	0.81122
15	0.81381	0.81345	0.81297	0.81368	0.81353	0.813488
16	0.81123	0.81301	0.81405	0.81375	0.81245	0.812898
17	0.81438	0.81385	0.81444	0.81407	0.81411	0.81417
18	0.81379	0.81098	0.81069	0.81101	0.81168	0.81163
19	0.81074	0.81358	0.81313	0.81333	0.81292	0.81274
20	0.81185	0.81347	0.81131	0.81321	0.81362	0.812692