INJECTION MOULDING THERMOPLASTIC COMPOSITES

by

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Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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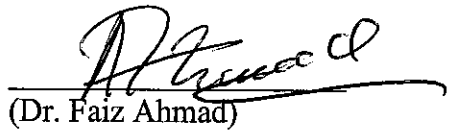
Approved by,



(Dr. Faiz Ahmad)

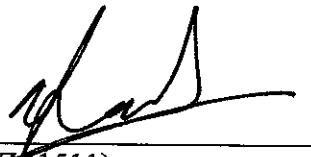
UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2004

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.



AHMAD FAIZ A.AZIZ (1511)

ABSTRACT

Injection molding process is well known for producing complex shape plastic components, manufacturing close dimensional tolerance and automatic production.

In the reports, the process was used for producing short glass fiber reinforced thermoplastic composites. A range of composites formulation was injection molded to optimize fiber contents. One of formulations was the result of the experimental work. The others were the discussion of the result obtained.

Molded specimens were tested mechanically and it was found that elongation, tensile strength and modulus were dependent on fiber weight fraction in the composite. An increase of fiber content in samples will increased the tensile strength and modulus of the samples. However, increasing fiber content will decrease the elongation value of the samples.

An impact test was done as well and it was found that the impact energy was dependent on fiber content and notching condition. For notched condition, it was found that increase fiber content in the samples will increase the impact energy for the samples.

Molding defects of the samples were identified using x-ray radiography and microscopy. For x-ray radiography, results show no evidence of micro voids and surface defects. But, for microscopy test, it was found that the surface of the molded specimens contain surface flaws. Furthermore, it was initiated that from microscopy test held, there were dimples and voids in the internal specimens.

ACKNOWLEDGEMENT

Alhamdullilah, after one year taken this project, I have completed the project within the due time. Not to forget, I would like to take this opportunity to thanks people who are directly or indirectly involved or be helping me in the project.

First of all, I would like to thank my parents because of their support for me from the first time I taken this project. And I would also want to say big thanks for my supervisor, Associate Professor, Dr. Faiz Ahmad for giving me chance to take this project. He has given me lots of guidance and information that I need in order to complete this project.

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Hope my dissertation of Final Year Project at UTP will contribute benefit to people who seek the researched related to this project. Last but not least, thanks to all.

CHAPTER 1

1.0 INTRODUCTION

1.1 Background

One of the common processing methods in manufacturing for processing of plastic is injection molding. The use of injection molding is well known all around the world. Its products are many and varied. The high costs of mould limits the process to component requiring relatively long production runs (Appendix I).

Rapid production rates can be achieved with little limitation on shape and size. Cycle times may be as low as 10 seconds for small components, being dependent on the time required to fill the mould and cooling time.

When thermoplastic containing short glass fiber were first introduced onto a market it was with the intention of producing a range of new materials possessing properties that were intermediate between the high tonnage commodity plastic and sophisticated continuous fiber reinforced composites.

The increase in stiffness and strength of the short fiber composite compared to the parent thermoplastic was modest but nevertheless sufficient to enable this class of material to penetrate into lightly stressed engineering applications. However, during the last few years, there has been some significance advanced. We have seen the emergence of thermoplastic together with a gradual reduction in the costs of the specialist fibers such carbon.

Material manufactures are now combining engineering thermoplastic with these more expensive fibers to produce a new range products having properties that are approaching those of the traditional long fiber composites. There are still long

ways to go, however, and significant improvements in materials design and fabrication technology are needed in order to optimize these developing reinforced thermoplastics.

The main objective of this present work is to investigate mechanical properties of reinforcement fiber thermoplastic composites in different volume fraction. In order to implement the objective, a range from 5% to 20% of volume fiber fraction of composite was produced. The test specimens were molded and tested mechanically. The results of the mechanical tests are given in result/discussion section. The final result will determined the most optimized mechanical properties depend on volume fraction of reinforced fiber.

1.2 Problem Statement

1.2.1 Problem Identification

Molding process is one of the most important processes in plastic manufacturing. A range of products in the market are manufactured by the injection molding process. The properties of composite material are strongly influenced by the proportions and properties of the matrix and the reinforcement. An increase in fiber volume fraction in the composite will affect the tensile strength, modulus and impact energy of the composite. Researches expected to have increased properties of composite.

1.2.2 Significance of the Project

The significant of the project is to prove a perfect reinforced fibers injection molded samples will increase the mechanical properties of the samples. A suitable process control of injection molding will lead to a perfect product. Increase fiber content in the product will affect the

mechanical properties of the samples. This volume content eventually play major role in determined optimum mechanical properties of the composite.

1.3 Objectives and Scope of Study

The project objective is to determine enhancement of mechanical properties as fiber is introduced in thermoplastics. Basically there are three objectives of the project:

i. To understand the injection-molding process for producing composite molding of different matrix/ reinforcement volume fraction by controlling different parameters

ii. To study the mechanical properties such as tensile strength, modulus and impact energy with different fiber volume content in composite.

iii. To carryout x-ray radiography and microscopy test to determine molding defects in the samples.

The scope of the study is to produce samples with different fiber volume proportion. Figure 1.3(a) shows the flow chart of the project.

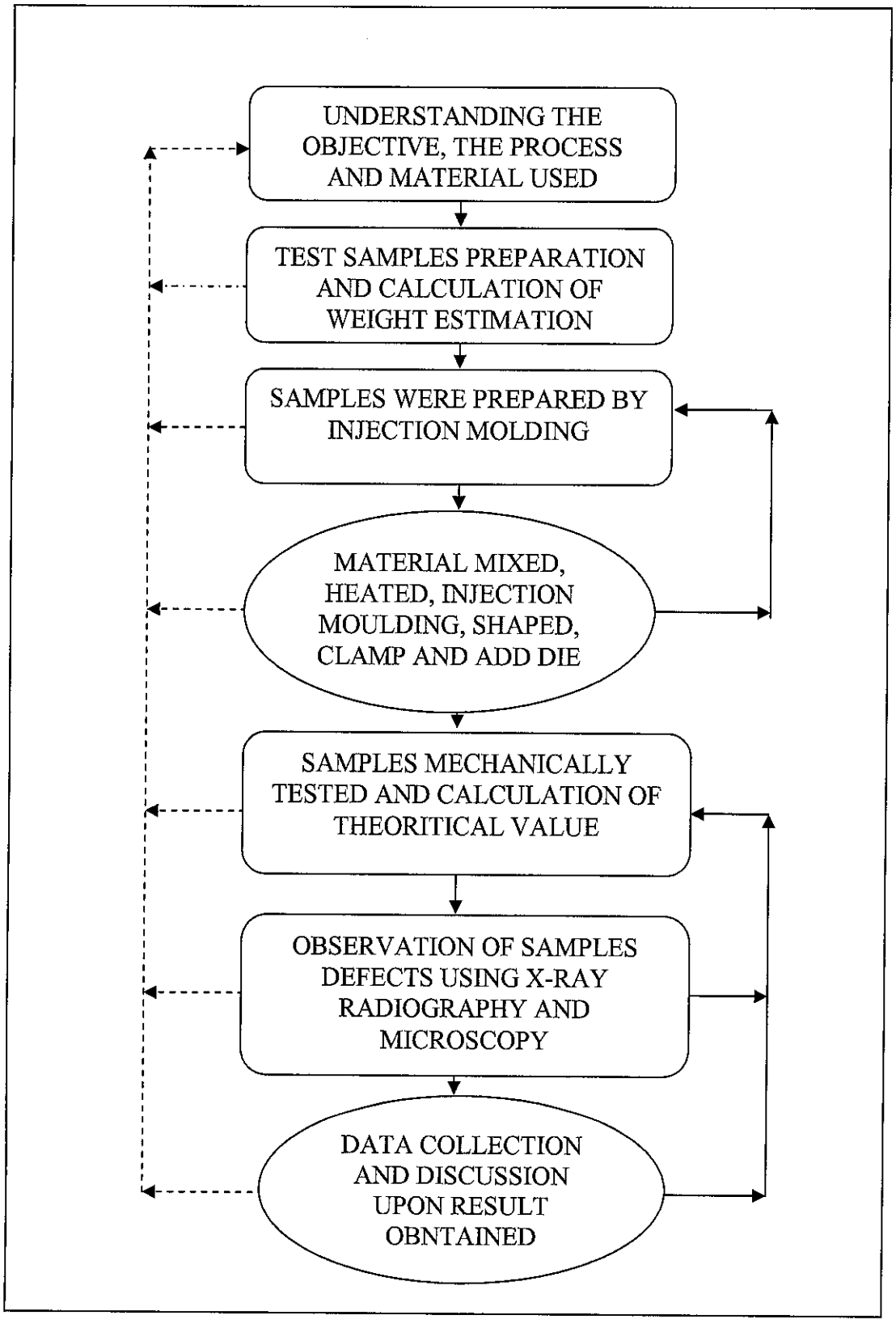

Figure 1.3(a): Projects' flow chart

1.3.1 The Relevancy of the Project

As per project undertaken, it is relevant to the author as the author himself have already taken majoring in manufacturing engineering. The project also involved with material selection, and the author also has already studies chemistry and material science subjects. As known, molding process is one of the popular processes in material manufacturing field. Thus, it is greatly benefit the author should the author specialized the process of the injection molding thermoplastic composites.

1.3.2 Feasibility of the Project within Time and Scope

The Gantt chart will be attached at the Appendix II. It will be a reference for the feasibility of the project within the scope and time. With having the Gantt chart, the author understands and plans the step that will be taken so as the project will be completed.

CHAPTER 2

2.0 LITERATURE REVIEW AND THEORY

2.1 Processing Condition

2.1.1 Injection Molding Process

One of the common processing methods in manufacturing for processing of plastic is injection molding. The use of injection molding is well known all around the world. However, the high cost of mould limits the process to component requiring relatively long production runs. This injection molding also can mould complex components.

The principal method used for the production of components in short fiber reinforced thermoplastic is injection molding. The normal molding cycle that is used for unfilled thermoplastic is also used for the reinforced material but the detail processing conditions employed may be rather different. Since the properties of short fiber reinforced thermoplastic are very dependent on composition, fiber length and orientation, it is important that both of these parameters can be controlled in the final molding, by an appropriate choice of processing condition.

The process involves the injection under pressure of a predetermined quantity of heated and plasticized material into a relatively cold mold. After the material solidifies it is allowed a further interval to cool before the mould is opened and the product removed. In some respects, the basic process is very similar to pressure die casting. The operations which make up a cycle of this basic process can be listed as below:

i. The measuring and feeding of a predetermined quantity of plastics, e.g. sufficient to fill the mould cavity or cavities, runners, etc, from the hopper to the heating or injection cylinder.

ii. The injection of this material (shot) but the use of plunger or ram into the heating cylinder, thus replacing the previous shot, now heated and softened, through the nozzle and into the mould cavity via sprue and runners (Figure 2.1.1(a)).

iii. Continued pressure of the ram and final cooling (Figure 2.1.1(b)).

iv. Opening of the mould and removing product (Figure 2.1.1(c)).

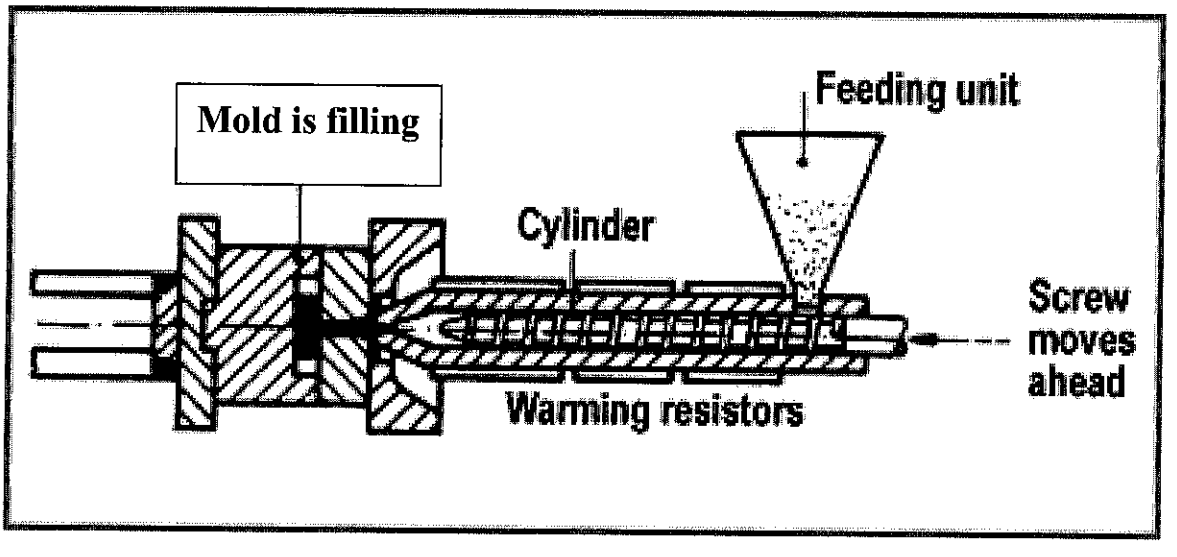

Figure 2.1.1(a): Feeding and injection phase

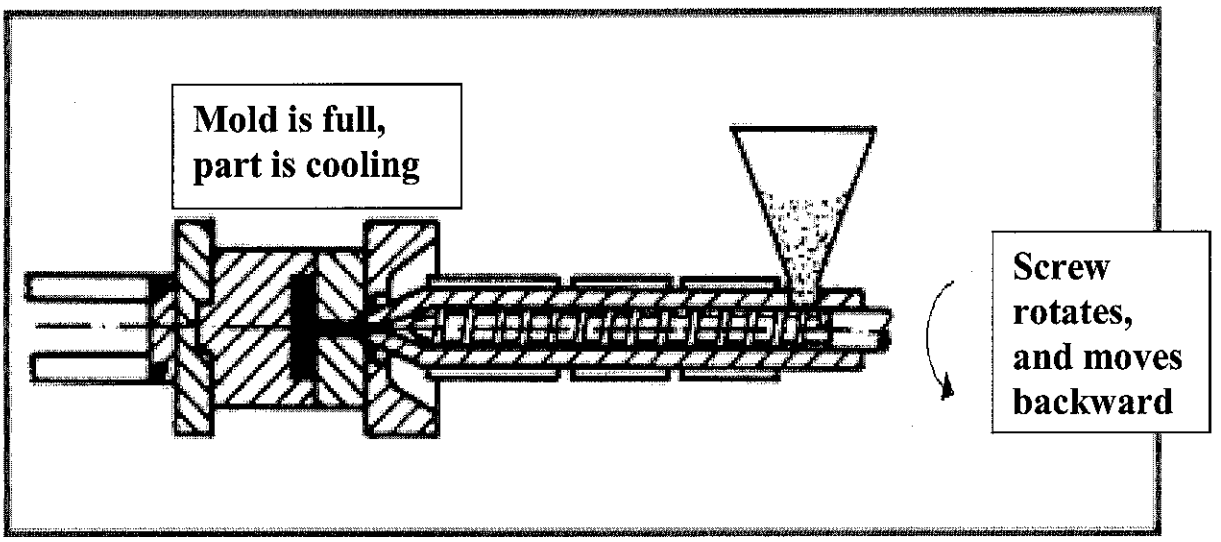

Figure 2.1.1(b): Holding and cooling phase

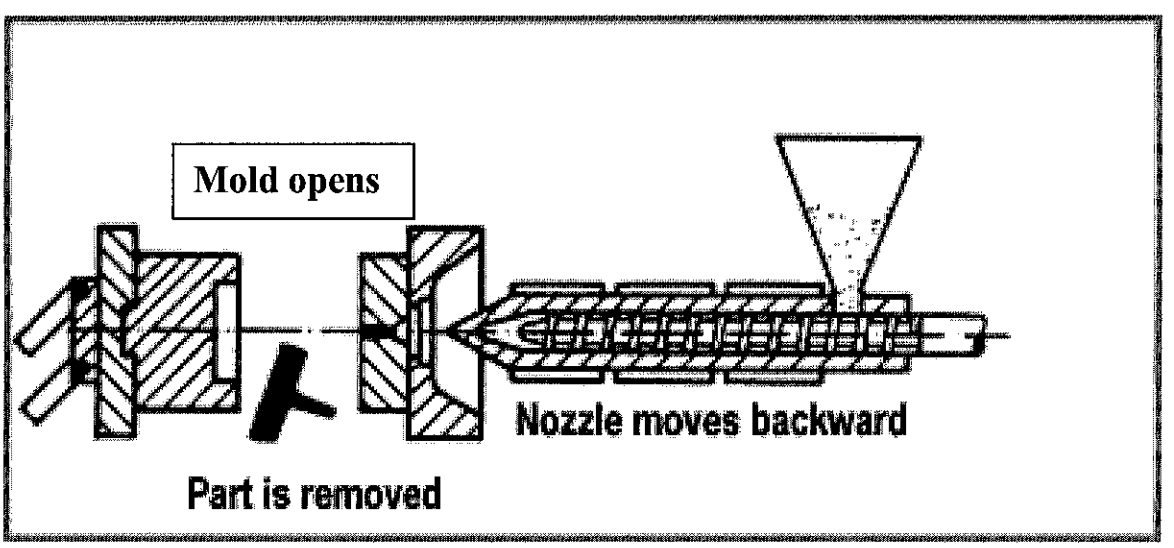

Figure 2.1.1(c): Removal phase

2.1.2 Effects of Injection Molding parameter

The principal method used for the production of components in short fiber reinforced thermoplastics is injection molding. The normal molding cycle that is used for unfilled thermoplastics is also used for reinforced material but the detailed processing conditions employed maybe rather different. Since the properties of a short fiber reinforced thermoplastics are very dependent on fiber length and orientation, not to

forget the existence of volume fiber in the composite. It is important that those parameters can be controlled to produce the final molding, by an appropriate choice of processing conditions.

During the molding of fiber reinforced thermoplastics, special processing conditions are recommend for the production of good quality parts. These are listed below:-

i. High injection speed should be used in order to achieve a good surface finish and to prevent premature solidification of the melt, either in the cavity or at the gate. However, a very high injection speed will cause a 'flash' condition; where the melt material leak out from the mold design. (Figure 4.1(a)).

ii. The screw speed and back pressure must be kept to a minimum, since although a homogenous melt is required, fiber breakage may become excessive.

iii. The melt temperature used for reinforced thermoplastics is usually at the upper end of the range recommend for the unfilled counterpart. This is chosen to reduce the viscosity of the melt and partly to assist in preventing premature solidification in the cavity.

iv. After the cavity is filled, a long hold time is required. This is needed, not to only to ensure that the molding dimensions are correct, but to minimize the ever present problem of voiding observed in the core of molded components. This is particularly important for reinforced thermoplastics, since the shrinkage that must necessarily take place in the core of the molding as it is cooling down cannot be accommodated by sinking of the surface layers, due to their inartistic stiffness. The maximum hold time is

determined by the onset of gate freezing and of course by the economic requirement of minimizing the overall cycle time.

v. Clamping force at the cavity and core also would effect the processing of the injection molding product. A necessary clamping force and pressure would produce a perfect molding.

Certain other factors should also be taken into account for the effective processing of reinforced thermoplastics. The wear and corrosion of the screw and barrel increased as if glass reinforced grades are being molded and so special alloys or hardened coatings should be used whenever possible. Also, the design of the mold is especially important for reinforced thermoplastics.

2.2 Material

2.2.1 Polypropylene

Among polyolefin, polypropylene (PP) is the most versatile polymer due to its good rigidity, low density, and high ductility. Despite these useful properties, polypropylene has lower modulus and impact strength as an engineering plastic to use in automotive, appliance, and other industrial goods. Blends of polypropylene with elastomers such as an ethylene-propylene copolymer, butyl rubber, styrene butadiene styrene copolymer, ethylene-propylene rubber, ethylene-propylene-diene copolymer have been investigate widely to improve the tensile and impact properties of polypropylene. Polypropylene in other words could be referred as matrix material for reinforced plastic. This matrix in reinforced plastics has three functions:

i. Support and transfer the stresses to the fibers, which carry most of the load.

ii. Protect and fibers against physical damage and the environment.

iii. Reduce propagation of cracks in the composite by virtue of the ductility and the toughness of the plastic matrix.

2.2.2 Short Glass Fiber

Glass fibers are mostly widely used and least expensive of all fibers. The composite material is called glass-fiber reinforced plastic (GFRP) and may contain between 30% and 60% glass fibers by volume. Glass fibers are made by drawing molten glass through small openings in a platinum die. There are two principal types of glass fibers:

i. The E type, a calcium aluminoborosilicate glass, which is used most; and

ii. The S type, a magnesia- aluminosilicate glass, which has higher strength and stiffness and is more expensive.

The mean diameter of fibers used in reinforced plastics is usually less than 0.01 mm (0.004 in). The fibers are very strong and rigid in tension. The reason is that the molecules in the fibers are oriented in longitudinal direction, and their cross sections are so small that the probability is low than any defects exist in the fiber. Glass fiber, for an example, can have tensile strength as high as 4600 MPa (650 ksi), whereas the strength of glass in bulk form is much lower. Thus glass fibers are stronger than steel.

Fibers are classified as short or long fibers, also called discontinuous or continuous fibers, respectively. Short fibers generally have an aspect ratio between 20 and 60, and long fibers from 200 to 500. The short and long fibers designations are, in general, based on the following observations. In a given fiber, if the mechanical properties improve as a result of increasing fiber length, then it is denoted as a short fiber. When no additional improvement in properties occurs, it is denoted as long fibers. In addition of this discrete fibers that we have described, reinforcements in composites may be in form of continuous roving (slightly twisted strand of fibers), woven fabric (similar to cloth), yarn (twisted strand), and mats of various combinations. Reinforcement elements may also be in the form of particle and flakes.

2.2.3 Reinforcement

Generally the reinforcement is harder, stiffer and stronger than the matrix. The function is to reinforce the mechanical properties of the matrix. The reinforcement used in the study is glass fiber. Glass fiber is based on silica (SiO_2). Fiber diameters normally range between 3μm and 20μm. Glass is use for fiber reinforcement material for some reasons.

i. It is easily drawn into high-strength fibers from the molten state.

ii. It is readily available and fabricated in a glass-reinforced plastic economically using a wide variety of composite-manufacturing techniques.

iii. It is relatively strong, and when embedded in plastic matrix, it produces a composite having a very high specific strength.

iv. When coupled with various plastics, it possesses a chemical inertness that renders the composite useful in variety of corrosive environment.

2.2.3.1 Properties

Reinforced plastics consist of fibers (the discontinuous or dispersed phase) in a plastic matrix (the continuous phase). Commonly used fibers are glass, graphite, aramids, and boron. These fibers are strong and stiff and have high specific strength (strength-to-weight-ratio) and specific modulus (stiffness-to-weight ratio). However they are generally brittle and abrasive and lack toughness. Thus fibers, by themselves, have little structure value. The plastic matrix is less strong and less stiff but tougher than the fibers. Thus reinforced plastics combine the advantage of each of two constitutes. When more than one type of fibers is used in reinforced plastic, the composite is called hybrid, which generally has even better properties.

In addition to high specific strength and specific modulus, reinforced plastic structures have improved fatigue resistance, greater toughness, and higher creep resistance than unreinforced plastic. These structures are relatively easy to design, fabricate and repair.

The percentage of fibers (by volume) in reinforced plastics usually ranges from 10% to 60%. Practically, the percentage of fiber in a matrix is limited by the average distance between adjacent fibers or particles. The highest practical fibers content is 65 percent, higher percentage generally result in diminished structural properties.

2.2.3.2 Surface Characteristic

The surface characteristics of glass fibers are extremely important because even minute surface flaws can deleteriously affect the tensile properties. Surface flaws are easily introduced by rubbing and abrading the surface with another hand material. Also, glass surface that have been exposed to the normal atmosphere for even short time periods generally have a weakened surface layer that interferes with bonding to the matrix. Newly drawn matrix is normally coated during drawing with a 'size' a thin layer of substance that protects the fiber surface from damage and undesirable environment interactions. This size is ordinarily removed prior to composite fabrication and replaced with 'coupling agent' or finish that promotes a better bond between the fiber and matrix.

2.2.3.3 Applications

Many fiberglass applications are familiar, automotive and marine bodies, plastic pipes, storage containers, and industrial floorings. The transportations industries are utilizing increasing amount of glass fiber reinforced plastics in an effort to decrease vehicle weight and boost fuel efficiencies. A host of new applications are being used or currently investigated by the automotive industries.

There are several limitations to this group of materials. In spite of having high strength, they are not very stiff and do not display rigidity that is necessarily for some application (e.g. structural members for airplanes and bridges). Most fiberglass material are limited to service temperature below 200°C (473°F); at higher

temperatures, most polymer begins to flow or to deteriorated. Service temperature ma be extended to approximately 300°C (573°F) by using high purity fused silica for the fibers and high temperature polymers such as polyimide resins.

2.3 Mechanical Testing

2.3.1 Tensile Strength

The tensile strength TS (MPa or psi) is the stress at the maximum on the engineering stress-strain curve (Figure 2.3.1(a)). This corresponds to the maximum stress that can be sustained by a structure in tension; if this stress is applied and maintained, fracture will result. All deformation up to this point is uniform throughout the narrow region of the tensile specimen. However, at this maximum stress, a small constriction or neck begins to form at some point, and all subsequent deformation is confined at this neck, as indicated by the schematic specimen insets. This phenomenon is termed "necking" and fracture ultimately occurs at the neck (Figure 2.3.1(a)).The fracture strength corresponds to the stress at the fracture.

Ordinarily, when the strength of a composite is cited for design purposes, the yield strength is used. This is because by the time a stress corresponding to the tensile strength has been applied, often a structure has experienced so much plastic deformation that is useless. Furthermore, fracture strengths are not normally specified for engineering design purposes.

For this experiment, we will see that fiber reinforced also will experience plastic deformation and fracture as well as other plastic. The reason behind this is because fiber reinforced also contain plastic (which polypropylene is used) in the composite.

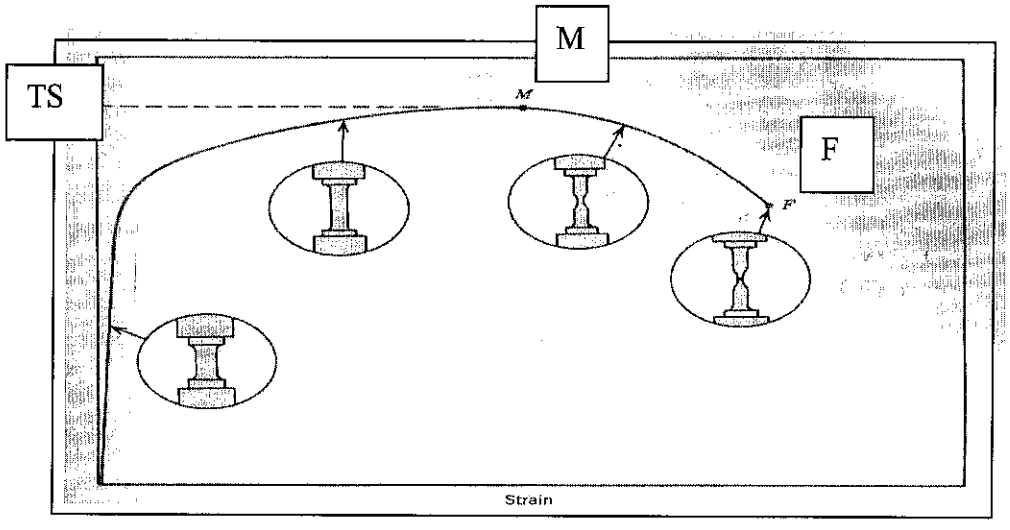

Figure 2.3.1(a): Typical engineering stress-strain behavior to fracture, point F. the tensile strength TS is indicated at point M. The circular insets represent the geometry of the deformed specimen at various points along the curve.

Reference: *Material Science and Engineering an Introduction, Fourth Edition, William D. Callister, Jr.*

A theoretical tensile strength value could be determined using the Kelly's equation as follow;

Shear strength of the interface;

$\tau_U = \sigma_M / 2$ ..... **Equation 2.3.1(a)**

Critical fiber length;

$l_C = (\sigma_F \times d) / (2 \times \tau_U)$ ..... **Equation 2.3.1(b)**

Tensile Strength

$\sigma_C = \sigma_F \times V \times [1-(l_C / 2l)] + [(1 - V) \times \sigma_M$ ..... **Equation 2.3.1(c)**

2.3.2 Impact Energy

Impact energy (notch toughness) is a measure of the energy absorbed during the fracture of specimen of standard dimensions and geometry subjected to very rapid (impact) loading. Charpy and Izod impact tests are used to measure this parameter, which is important in assessing the ductile-to-brittle behavior of material.

These two tests, the Charpy and Izod, were sometimes called as *notch toughness*. For both Charpy and Izod tests, the specimen is in the shape of a bar square cross section, into which a V-notch is machined. The load is applied as an impact blow from a weighted pendulum hammer that is released from a cocked position at a fixed height *h*. The specimen is positioned at the base as shown if figure 2.3.2(a). Upon release, a knife edge mounted in the pendulum strikes and fractures the specimen at the notch, which acts as a point of stress concentration for this high velocity impact blow. The pendulum continues its swing, rising to a maximum height *h'*, which is lower than *h*. The energy absorption computed from a difference h' and h, is a measure of impact energy. The primary difference between Charpy and Izod techniques lies in the manner of specimen support. The formula used to determine the impact energy is given by;

Impact energy = $mgh[\sin(\theta_1 - 90^\circ) + \cos\theta_2]$ ..... **Equation 2.3.2(a)**

m= mass of pendulum
g = free fall gravity
h= highest pendulum position
θ_1= highest angle before fracture
θ_2= highest angle after fracture

The interpretation of impact energy data as measured using pendulum method is still the centre of continuing debate even for unreinforced polymer. When short fiber reinforced thermoplastic are tested under impact conditions, the variation of impact energy versus fiber content is confused, in that for some polymers it increase with addition of fibers and decrease in others. As an example of complexity of the situation, figure 2.3.2(a) and 2.3.2(b) show the notched and unnotched impact strength for a number of short glass reinforced polymers. Nylon shows an increase in impact strength with fiber content, for both notched and unnotched specimens, but the behavior of reinforced polypropylene is very dependent on notching condition. Polypropylene shows increase in impact strength with fiber content for notched condition and shows decrease in impact strength with fiber content for unnotched condition.

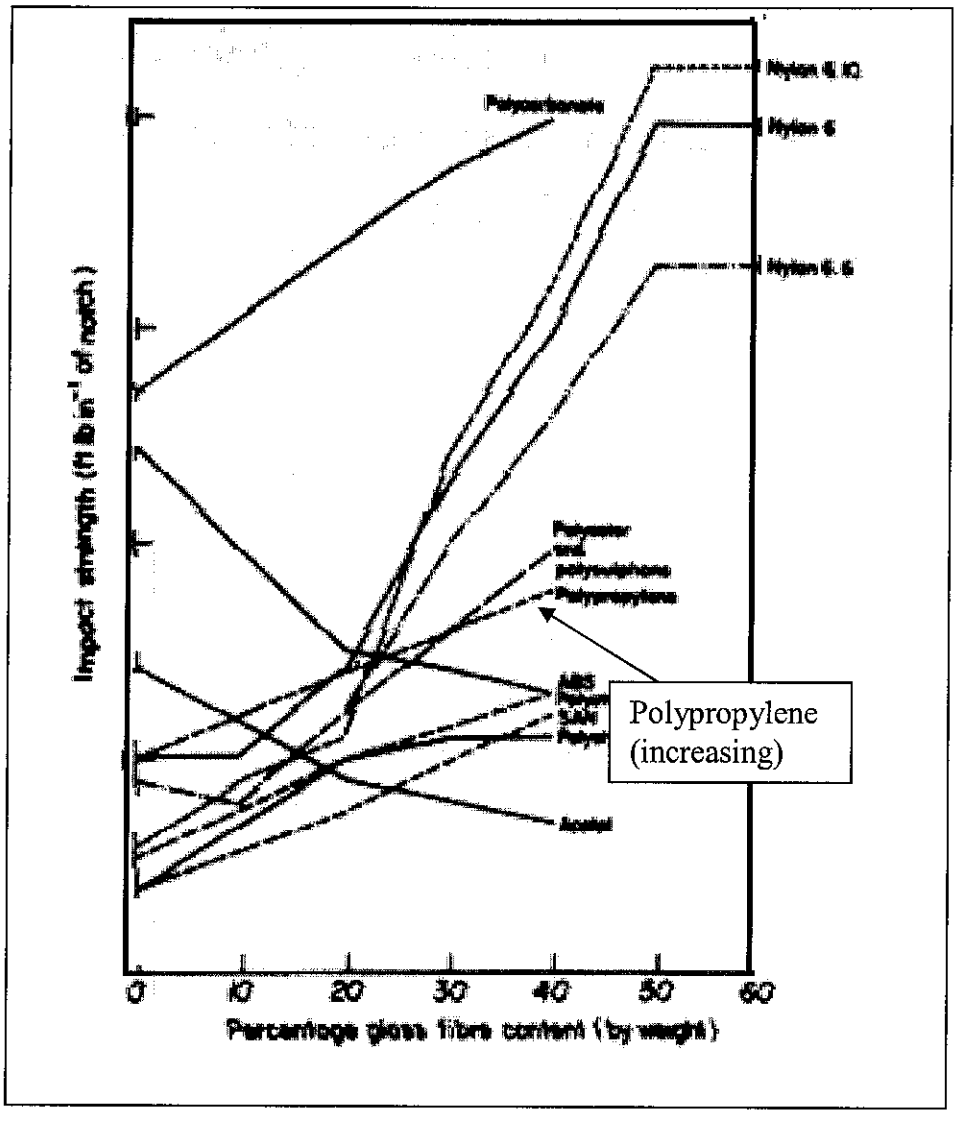

Figure 2.3.2(a): Notched Impact strength versus glass fiber content for a range of thermoplastic

Reference: *Short Fiber Reinforced Thermoplastics, M.J Folkes*

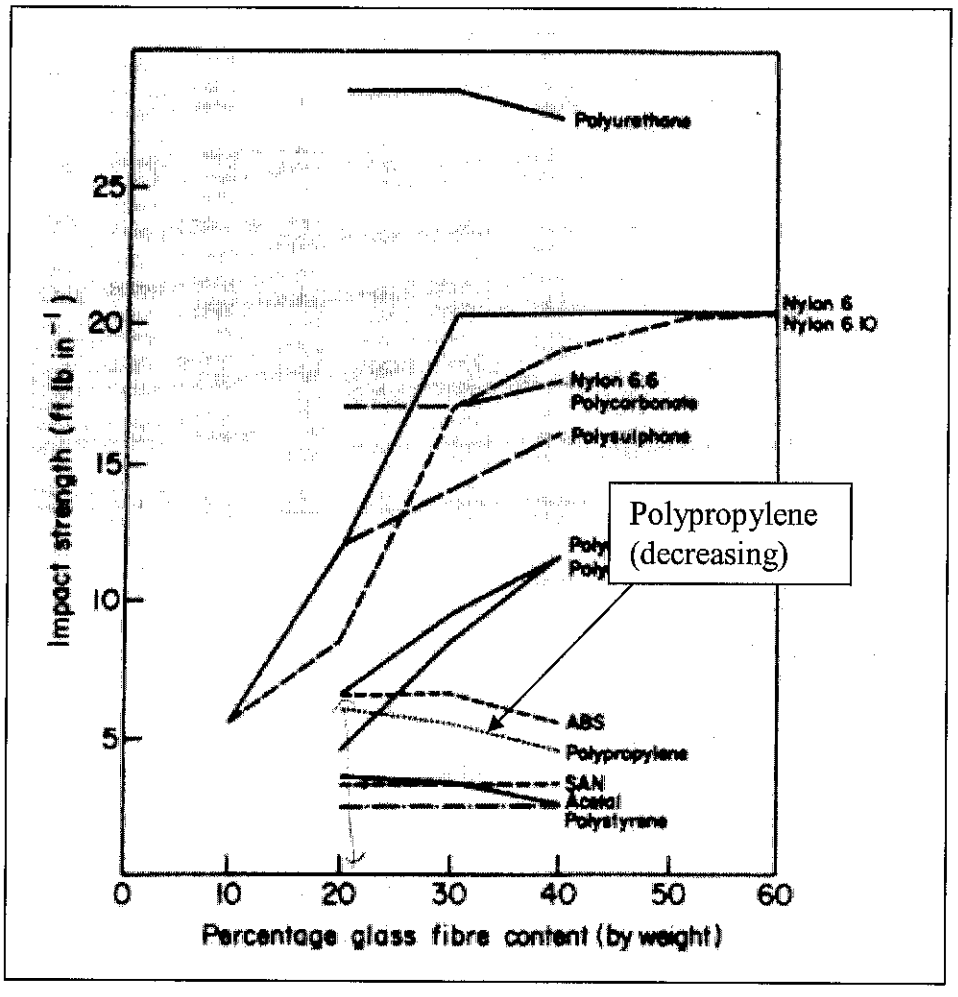

Figure 2.3.2(b): Un-notched Impact strength versus glass fiber content for a range of thermoplastic

Reference: *Short Fiber Reinforced Thermoplastics, M.J Folkes*

2.4 Examination of Microstructure

Here we will be concerned with some of the techniques that can be used to reveal the fiber orientation and defects in reinforced thermoplastics. In the experiment, the objective is to examine any defects occurred in reinforced thermoplastics.

2.4.1 X-ray Radiography

2.4.1.1 Macro- graph and Micro- graph

The use of x-rays for observing homogeneities in material e.g. crack in metal is well established in the non-Destructive Testing. The technique relies on a variation of X-ray absorption from one part of the sample to another and so, in principle, could be applied to fiber reinforced thermoplastics. It is a first class method for glass fiber reinforced thermoplastics. There are two methods of approach that may be used. One is referred to as macro-radiography and the other, micro-radiography. In the former, the molding itself is placed in contact with photographic plate and then exposed to a beam of x-rays. A typical macro-radiograph taken from a disc molding is shown in Figure 2.4.1(a):

It has been confirmed that the observed texture is primarily associated with fiber clump and that no really useful information is obtained on the well dispersed fiber. To improve the resolution of the technique, it is necessarily to use thin section (50-150μm) cut from a molding and a photographic plate of sufficiently high resolution to enable magnification of x 500 to be used. This is

referred to as micro-radiography and was original developing for use with biological materials. A contact micro-radiography obtained from a thin section glass fiber reinforced polypropylene is shown in Figure 2.4.1(b). The contrast between fibers and matrix is excellent and much better assessment of the fiber orientation distribution is possible compared to that using metallographic polishing.

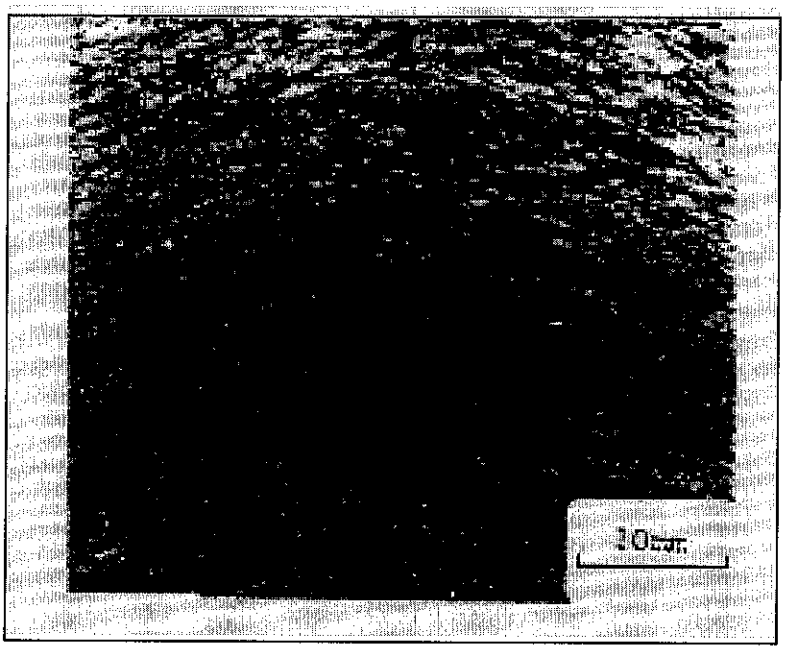

Figure 2.4.1(a): A typical macro-radiograph taken from a disc molding. Not very useful information for well dispersed fiber.

Reference: *Short Fiber Reinforced Thermoplastics, M.J Folkes*

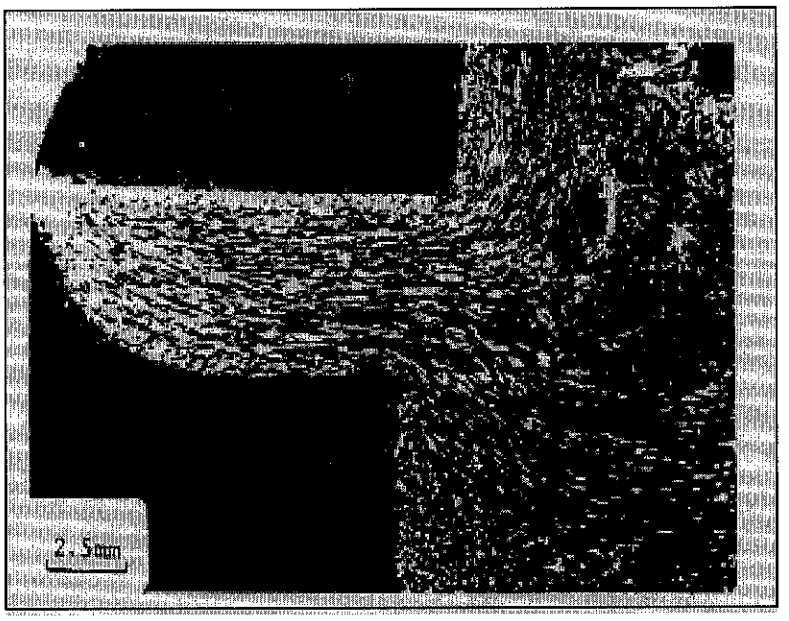

Figure 2.4.1(b): A contact micro-radiography obtained from a thin section glass fiber reinforced polypropylene

Reference: *Short Fiber Reinforced Thermoplastics, M.J Folkes*

2.4.2 Microscopy

This is one of earliest techniques used to access surface finish and defects in molded components. A part of the molding is has not been polished as usual, as the objective of the microscopy test is to investigate surface flaws of final molding. A polished molding will eliminate the surface flaws. The samples are observed in the optical microscope, using reflected light.

2.5 Supporting Information and References

2.5.1 Literature Review

i. Invicta plastic limited; V E Moore; Chapter 6

ii. Long fiber reinforced Thermoplastic; Hanser Publisher 1999

iii. Manufacturing process for engineering materials; 3rd edition; Serope Kalpakjian

2.5.2 Related Website

i. http://www.imhotepcomposites.co.uk/technology.html

ii. http://www.withersd.demon.co.uk/plasticsdex.htm

CHAPTER 3

3.0EXPERIMENTAL

3.1 Material

3.1.1 Material Properties

Below are the properties of composites used and fiber glass.

Glass Fiber Properties (E-Glass):		
Density (Mg/m^3)	-	2.56
Young's Modulus (Gpa)	-	70
Tensile Strength (Mpa)	-	2200
Melting Point (^oC)	-	550

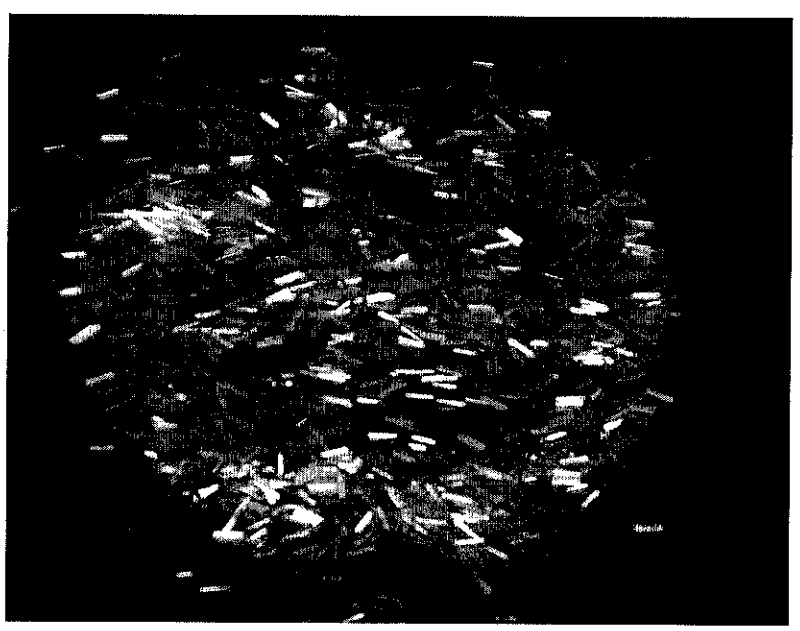

Figure 3.1.1(a): Short glass fiber

Polypropylene Properties:		
Density (Mg/m^3)	-	0.9
Young's Modulus (Gpa)	-	1.3-1.8
Tensile Strength (Mpa)	-	25-38
Melting Point (^oC)	-	165

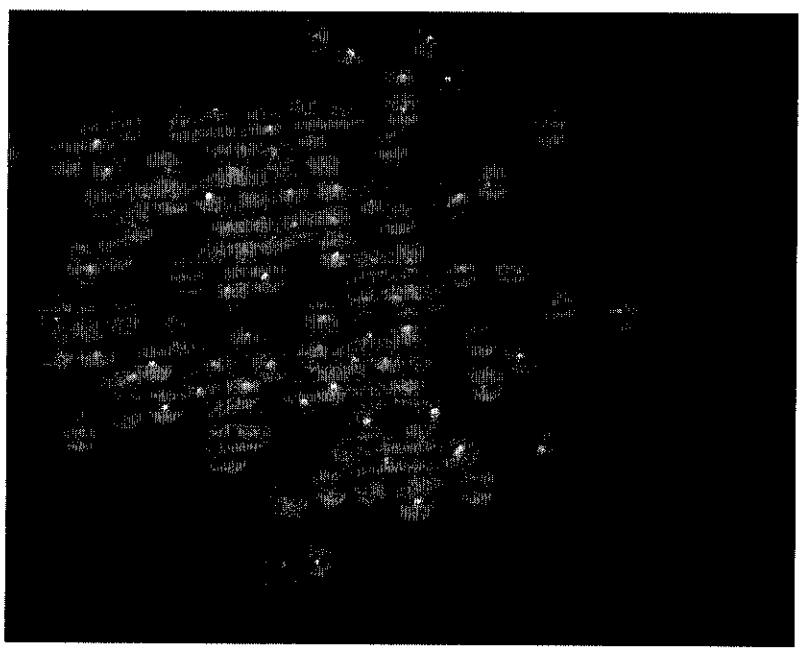

Figure 3.1.1(b): Granules of Polypropylene

3.1.2 Material Weight Estimation

Before begin the experimental project, materials weight estimation has to be done. This is the beginning of analyzing the volume fraction on mechanical properties of the composites. This materials weight estimation is compulsory as it will determine how much material will be used. The cost of the materials could be determined as well. Table 3.1.2(a) shows the density of materials used. Table 3.1.2(b) below shows the weight fraction estimation for polypropylene. The calculation made base on weight for

one batch is 5.0 kg. Figure 3.1.2(a) shows the weight device to determined calculated fiber weight.

Table 3.1.2(a): Density of materials used in the project

	Weight composite	5 kg
Density:	PP	900 kg/m^3
	Fiber Glass	2560 kg/m^3

Table 3.1.2(b): Weight estimation for polypropylene and glass fiber

Fiber Vol. Fraction	Wf(kg)	Wpp(kg)
5%	0.651	4.349
10%	1.201	3.799
15%	1.671	3.329
20%	2.078	2.922
25%	2.433	2.567

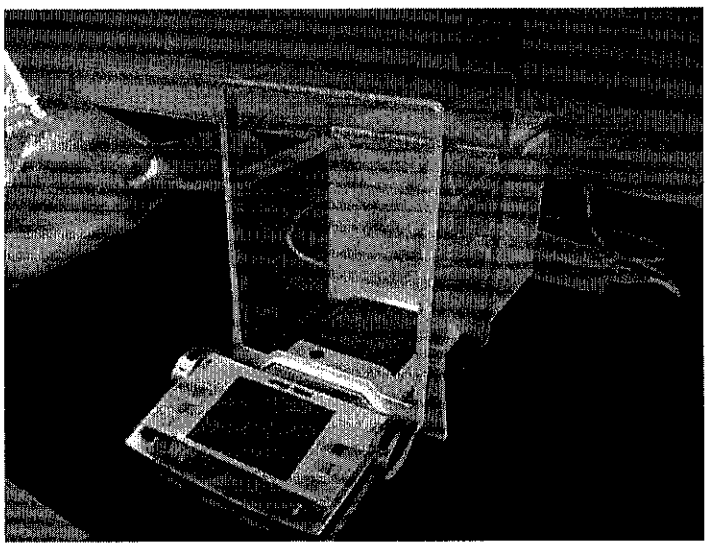

Figure 3.1.2(a): Weighting device for calculate amount of fiber and polypropylene needed

In order to calculate the weight of fiber and polypropylene need for one batch size (one batch= 5kg), equations below are used.

$W_f = [D_f \times V_f \times W_c] / [(D_f \times V_f) + D_{pp}(1-V_f)]$ ..... **Equation 3.1.2(a)**

$W_{pp} = W_c - W_f$ ..... **Equation 3.1.2(b)**

W_c = Weight of composite
W_f = Weight of short glass fiber
W_{pp} = Weight of polypropylene
D_f = Density of short glass fiber
D_{pp} = Density of polypropylene
V_f = Volume fraction of fiber

3.1.2.1 Samples of calculation

i. *For 5% fiber content*

$W_f = [D_f \times V_f \times W_c] / [(D_f \times V_f) + D_{pp}(1-V_f)]$

$$= \frac{[2560 kg/m3 \times 0.05 \times 5kg]}{[(2560 kg/m^3 \times 0.05) + 900 kg/m^3 (1-0.05)]}$$

$= \underline{0.651 \text{ kg}}$

$W_{pp} = W_c - W_f$

$= 5kg - 0.651kg$

$= \underline{4.349 \text{ kg}}$

ii. *For 10% fiber content*

$W_f = [D_f \times V_f \times W_c] / [(D_f \times V_f) + D_{pp}(1-Vf)]$

$$= \frac{[2560 kg/m3 \times 0.10 \times 5kg]}{[(2560 kg/m^3 \times 0.10) + 900 kg/m^3 (1-0.10)]}$$

$= \underline{1.201 \text{ kg}}$

$W_{pp} = W_c - W_f$

$= 5kg - 1.201kg$

$= \underline{3.799 \text{ kg}}$

iii. *For 15% fiber content*

$W_f = [D_f \times V_f \times W_c] / [(D_f \times V_f) + D_{pp}(1-V_f)]$

$$= \frac{[2560 kg/m3 \times 0.15 \times 5kg]}{[(2560 kg/m^3 \times 0.15) + 900 kg/m^3 (1-0.15)]}$$

$= 1.670$ kg

$W_{pp} = W_c - W_f$

$= 5kg - 1.670kg$

$= 3.329$ kg

iv. *For 20% fiber content*

$W_f = [D_f \times V_f \times W_c] / [(D_f \times V_f) + D_{pp}(1-V_f)]$

$$= \frac{[2560 kg/m3 \times 0.20 \times 5kg]}{[(2560 kg/m^3 \times 0.20) + 900 kg/m^3 (1-0.20)]}$$

$= 2.078$ kg

$W_{pp} = W_c - W_f$

$= 5kg - 2.078kg$

$= 2.922$ kg

v. *For 25% fiber content*

$W_f = [D_f \times V_f \times W_c] / [(D_f \times V_f) + D_{pp}(1-V_f)]$

$$= \frac{[2560kg/m3 \times 0.25 \times 5kg]}{[(2560kg/m^3 \times 0.25) + 900\ kg/m^3\ (1-0.25)]}$$

$= 2.433$ kg

$W_{pp} = W_c - W_f$

$= 5kg - 2.078kg$

$= 2.567$ kg

3.1.3 Final Product

The alternative taken is to use existing mould. The mould is used to produce specimens for tensile testing (figure 3.1.3(a)). As a result the specimens able to be tested with standard tensile testing machine and impact test therefore give more information on its mechanical properties such the strain rate.

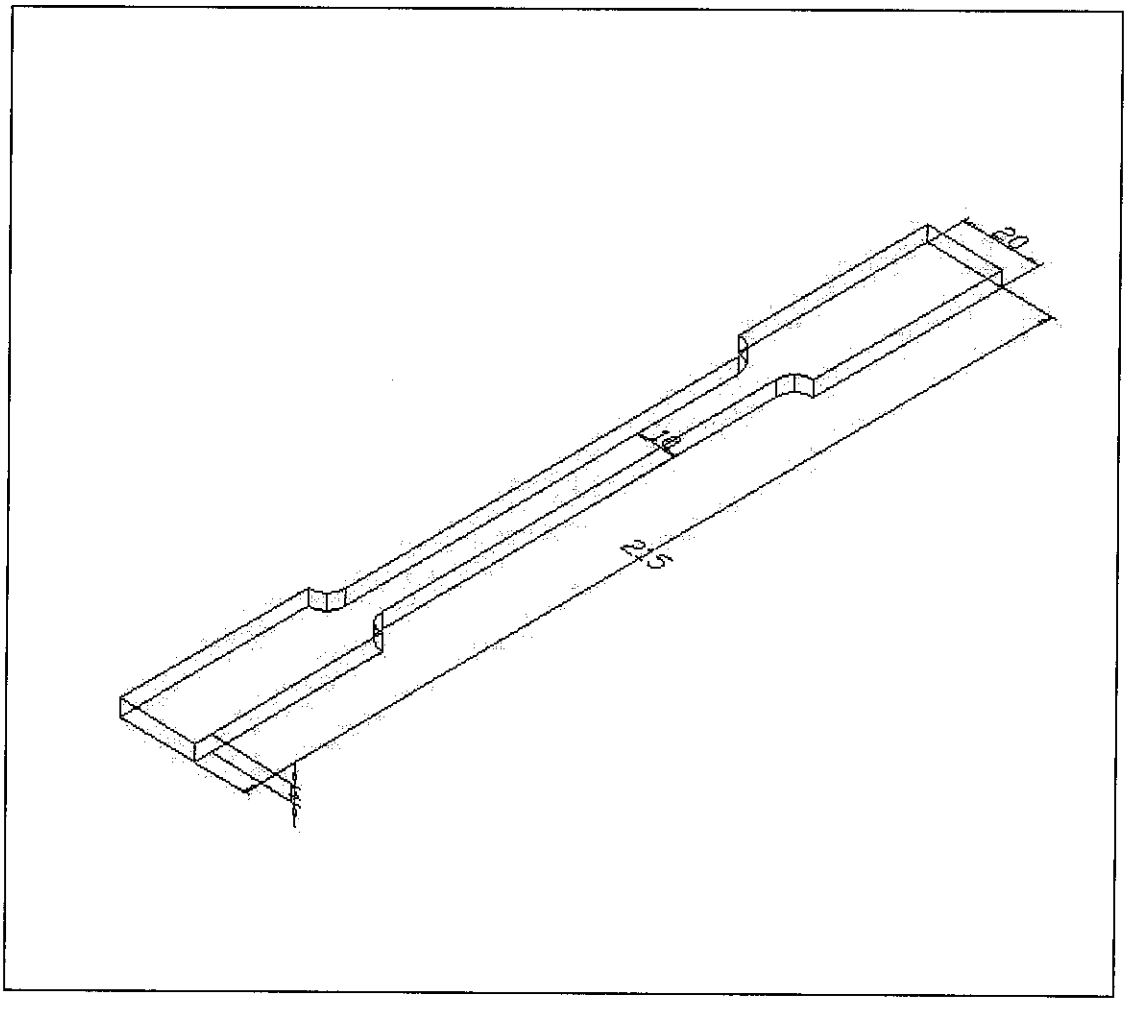

Figure 3.1.3(a): The specimen dimension in millimeter unit.

3.2 Process

3.2.1 Injection Molding

3.2.1.1 Procedure

Injection molding is a productive and widely used technique for shaping plastics. During the laboratory session, PP is used as the material to be injected. In the process, PP is injected into the steel mould cavity which is under high pressure. The process is also assisted by hydraulic system.

Firstly, granules of PP are fed into the screw through the hopper. The screw is of rotating and reciprocating type. Then, PP is heated and subsequently melted when it passes through the heated barrel. The barrel is heated by electricity source. In addition, shear between the barrels and the screw ends is also another source of heat that melts the material. Throughout the process, the molten PP will flow through 3 zones with increment of temperature. During the process, the molten PP is pushed towards the cavity as a result of the rotation of the screw.

After sufficient time, PP is molten and ready to be injected into the mould. The injection unit of the machine move towards the sprue and mould is closed. The rotated screw pushes the molten PP into the sprue through a nozzle and towards the cavity. Before filling the cavity, the molten material passes through sprue, runner, and gate. The molten PP will fill the whole part of the cavity according to the shape of the mould. The molten material will be pressurized and hardened. Lastly, after hardening, the product is ejected.

Feed rate of the PP, temperature of the barrel and injection rate have to be controlled to produce high quality products. The air trapped in the material should be removed to avoid bubbles in the final products.

After the PP is injected for several cycles, the mixture of fiber and PP will be drawn in the hopper. This procedure is taken in order to flush out any undesirable material before reinforcing fiber using the injection molding (see figure 3.2.1.1(a)).

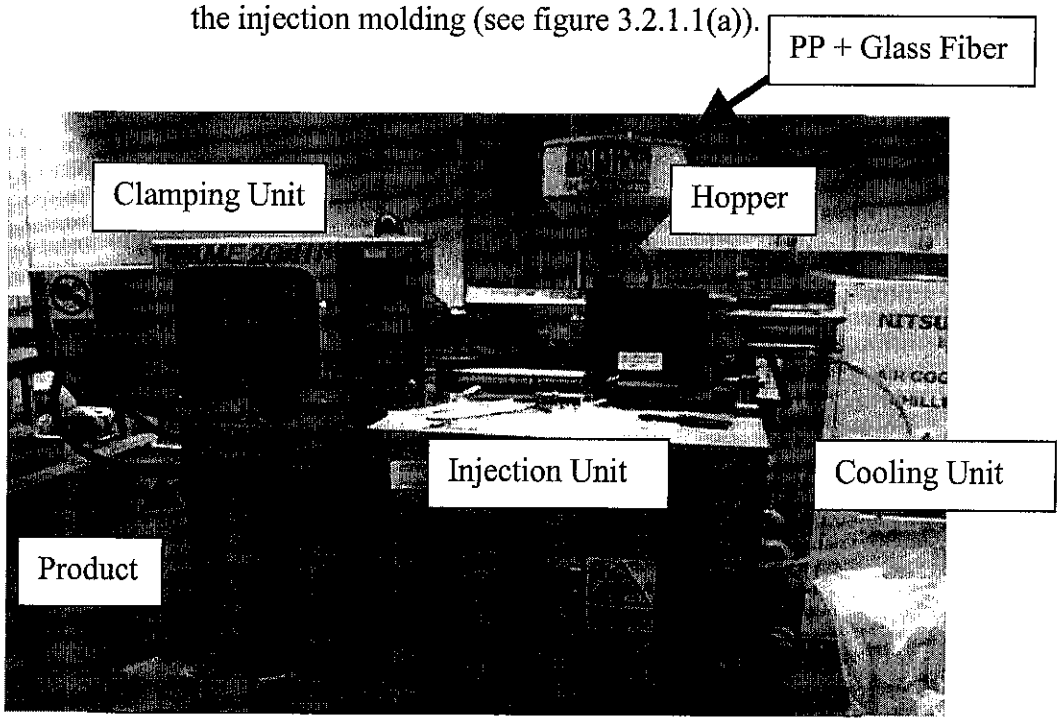

Figure 3.2.1.1(a): Injection molding available in UTP laboratory

3.2.2 Test Specimen Preparation

A test specimen preparation for determination of mechanical properties of samples was prepared by an injection molding machine. Table 3.2.2(a) and Table 3.2.2(b) show the parameter used for reinforcing fiber with polyethylene and volume fraction of specimens respectively.

Table 3.2.2(a): Main parameter of injection molding

Cycle time	Mold Temperature	Shot size	Injection pressure
4 s	30 °C	20 g	130 kg/cm^2

Table 3.2.2(b): Volume fraction of specimens

No.	Polypropylene volume of fraction (%)	Fiber glass volume of fraction (%)	Specimen testing
1	95	5	1. Tensile test 2. Impact test 3. X-ray radiography test 4. Microscopy test
2	90	10	
3	85	15	
4	80	20	
5	85	25	

3.3 Mechanical Testing

3.3.1 Tensile Test

Tensile properties were determined according to ASTM D-638 using the dumbbell-shaped injection molding specimen using Universal Testing Machine manufactured by LLOYD Instruments, Germany (figure 3.3.1(a)). Applied constant load is 5 kN. The specimen was 10mm in width and 4.3mm in thickness with gauge length 109.4mm. The cross speed was kept 10mm/min.

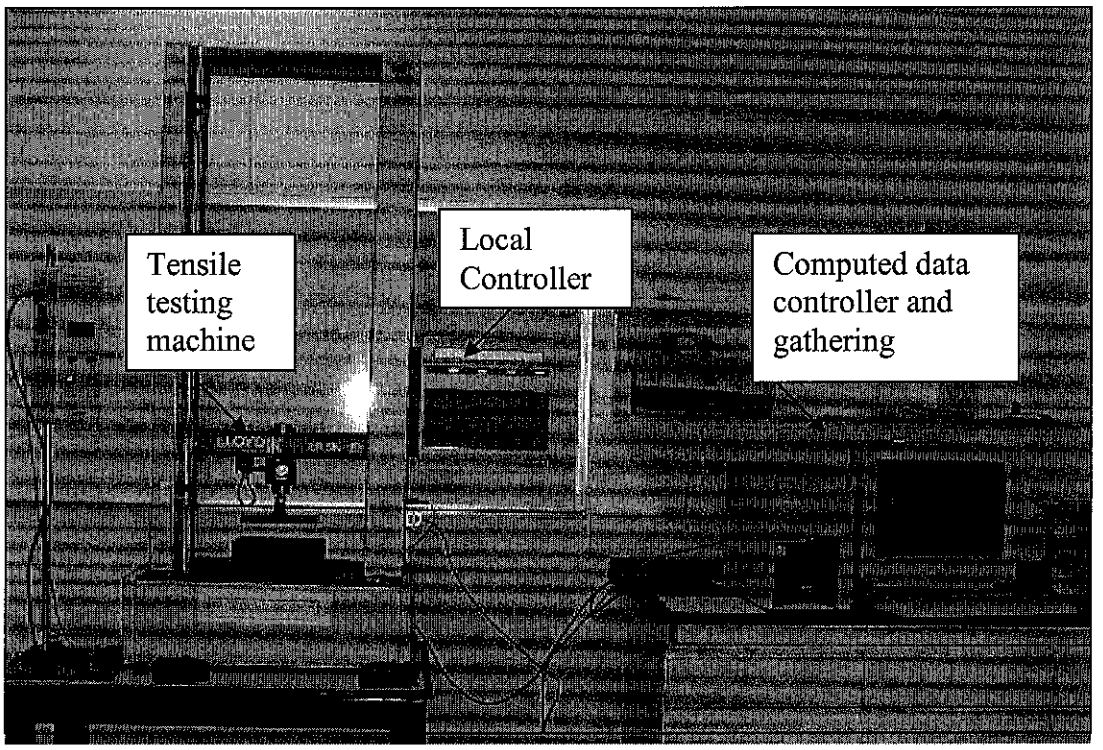

Figure 3.3.1(a): Universal Testing Machine manufactured by LLOYD Instruments, Germany

3.3.2 Impact Test

Test specimens were used for Charpy measurement on 'C' notch type impact strength according to ASTME23-01. The specimens were tested using Impact Testing machine manufactured by Amsler RKP 450, Germany (Figure 3.3.2(a)). The schematic sketch of the impact test is shown in Figure 3.3.2(b). The edges of clamping surfaces angles were kept at 90°. The velocity of the pendulum (impact) was adjusted to 3.4 m/sec.

For notched batch, the test specimens were cut from the original dumb-bell shape of fiber reinforced molding (Figure 3.3.2(c)). The cutting part then will be 'notch' at the side edge (Figure 3.3.2(d)). There will be four specimens for one batch will be used (Figure 3.3.2(e)). This is because the Impact testing machine could not give precise result when only one

specimen was used. In other words, this Impact Testing is not sensitive for small specimens.

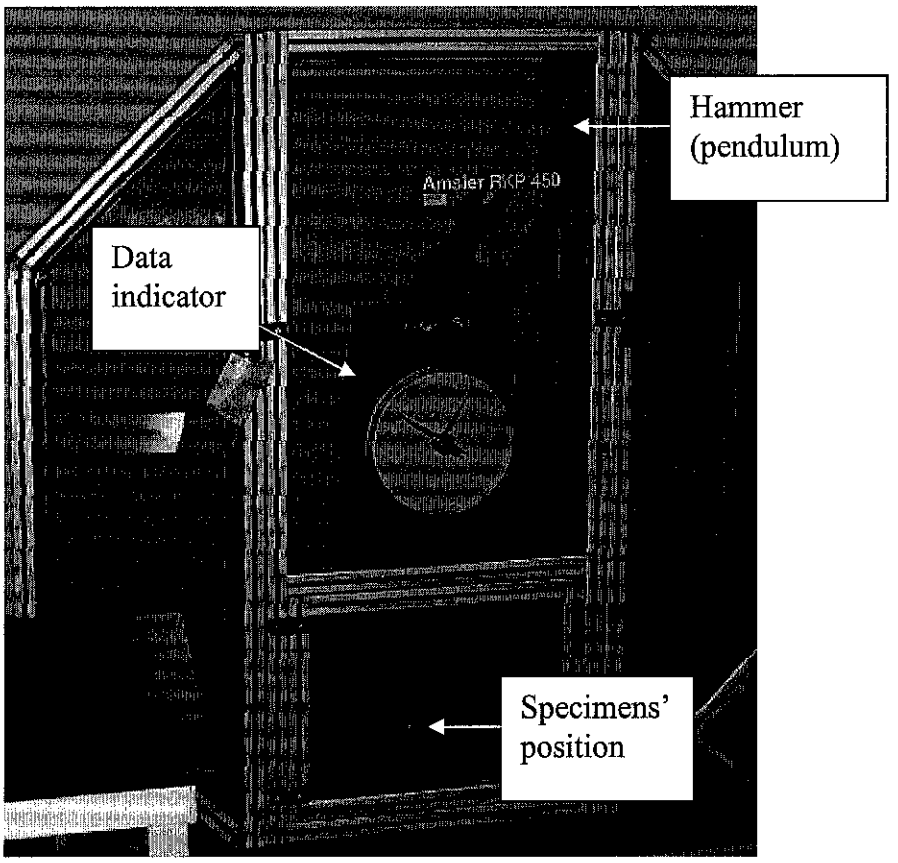

Figure 3.3.2(a): Impact Testing machine manufactured by Amsler RKP 450, Germany

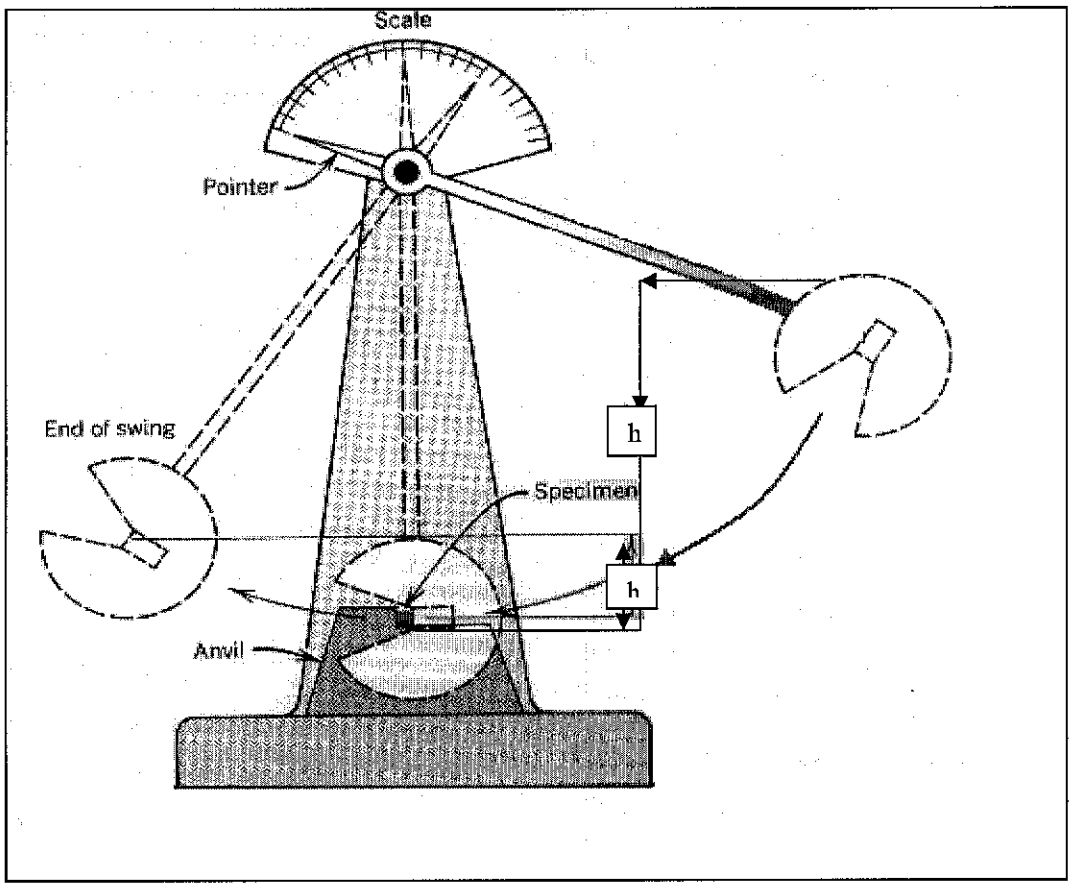

Figure 3.3.2(b): A schematic drawing of an impact testing apparatus. The hammer is released from fixed *h*, and strikes the specimens; energy expended in fracture is reflected in the difference between *h* and the wing *h'*.

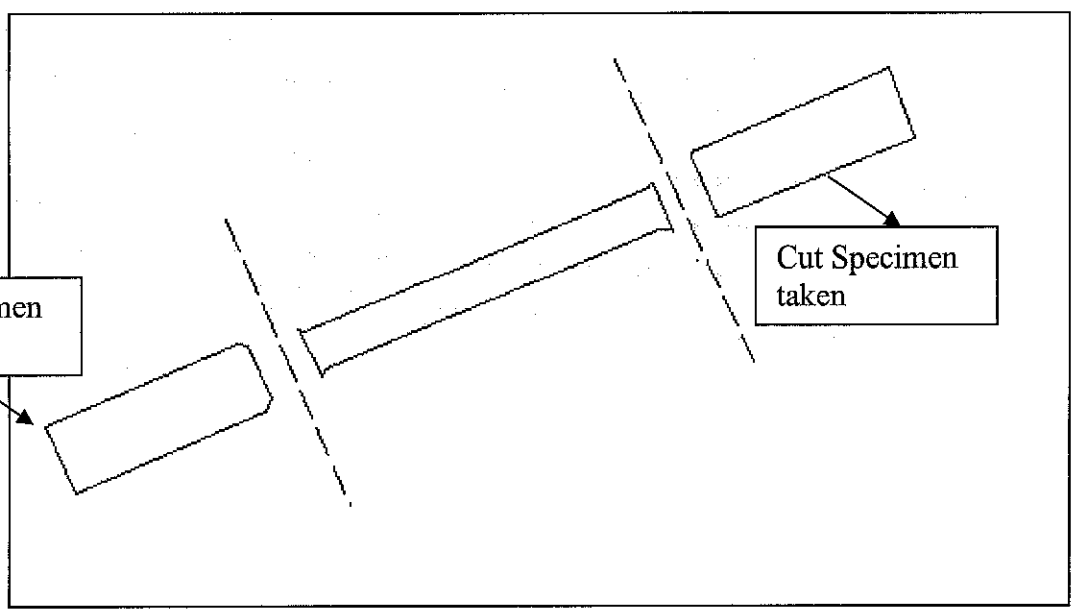

Figure 3.3.2(c): Cut Section of original dumb-bell shape

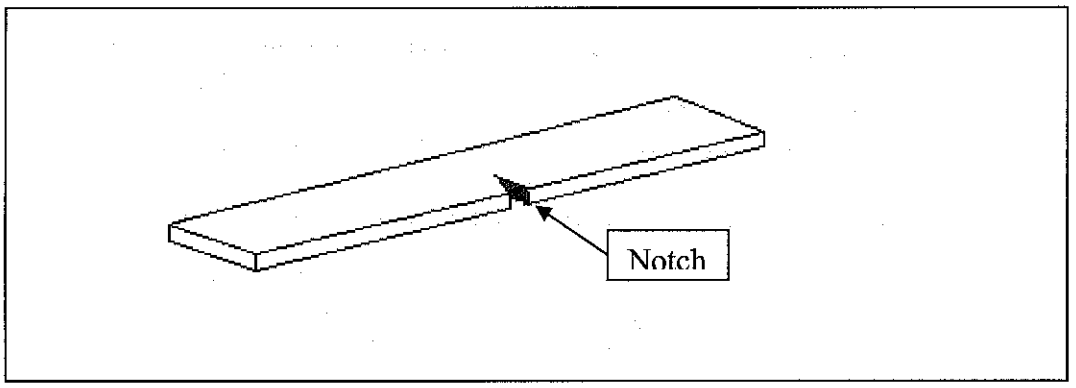

Figure 3.3.2(d): Notch position of cut specimen

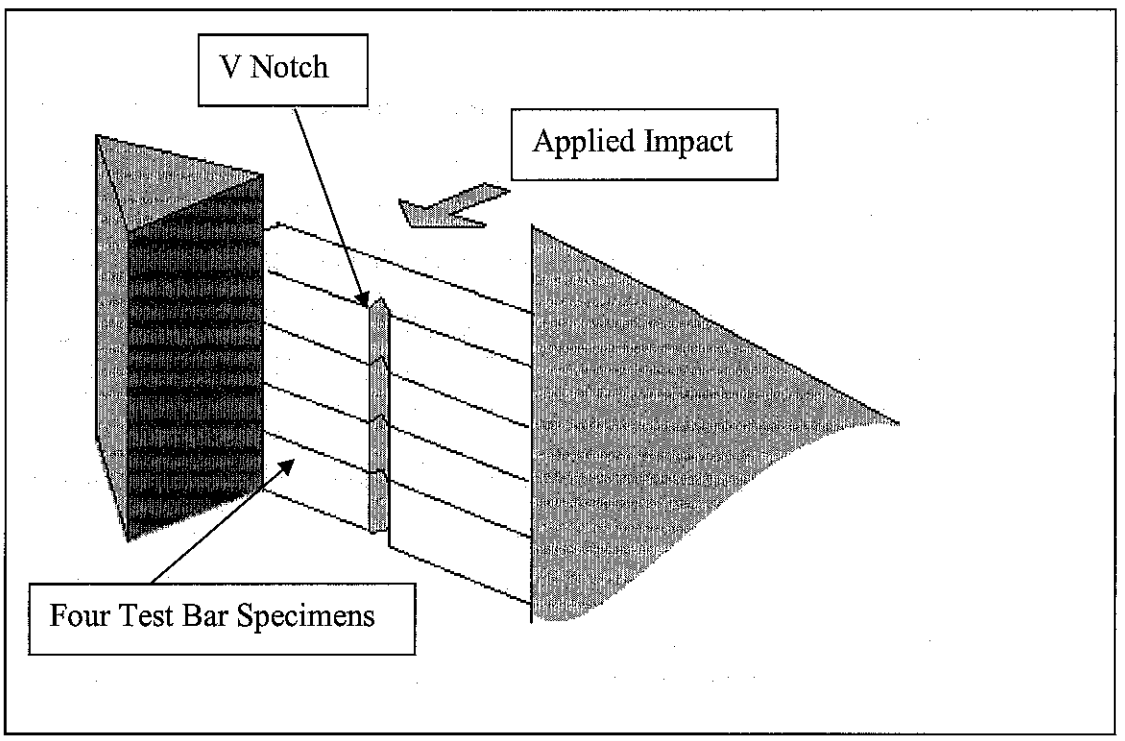

Figure 3.3.2(e): Four specimen were placed in Impact testing machine for one batch

3.4 Examination of microstructure

3.4.1 Microscopy

The test was held using microscopy available in the lab (Figure 3.4.1(a)). The test was only using 100x magnificent as the objective is to determine surface flaws and voids in the sample. Four different volume fibers were examined using the microscopy test.

Figure 3.4.1(a): Microscopy available

3.4.2 X-ray Radiography

X-ray radiography test was held using x-ray machine manufactured by X-Tek System Ltd., England. Test condition; 225 kV and 225 kW defocused. The range of voltage and ampere were kept at 90 – 115 kV and 10 – 20 uA respectively. Distance between specimen and x-ray radiography was kept to 10 – 40 mm.

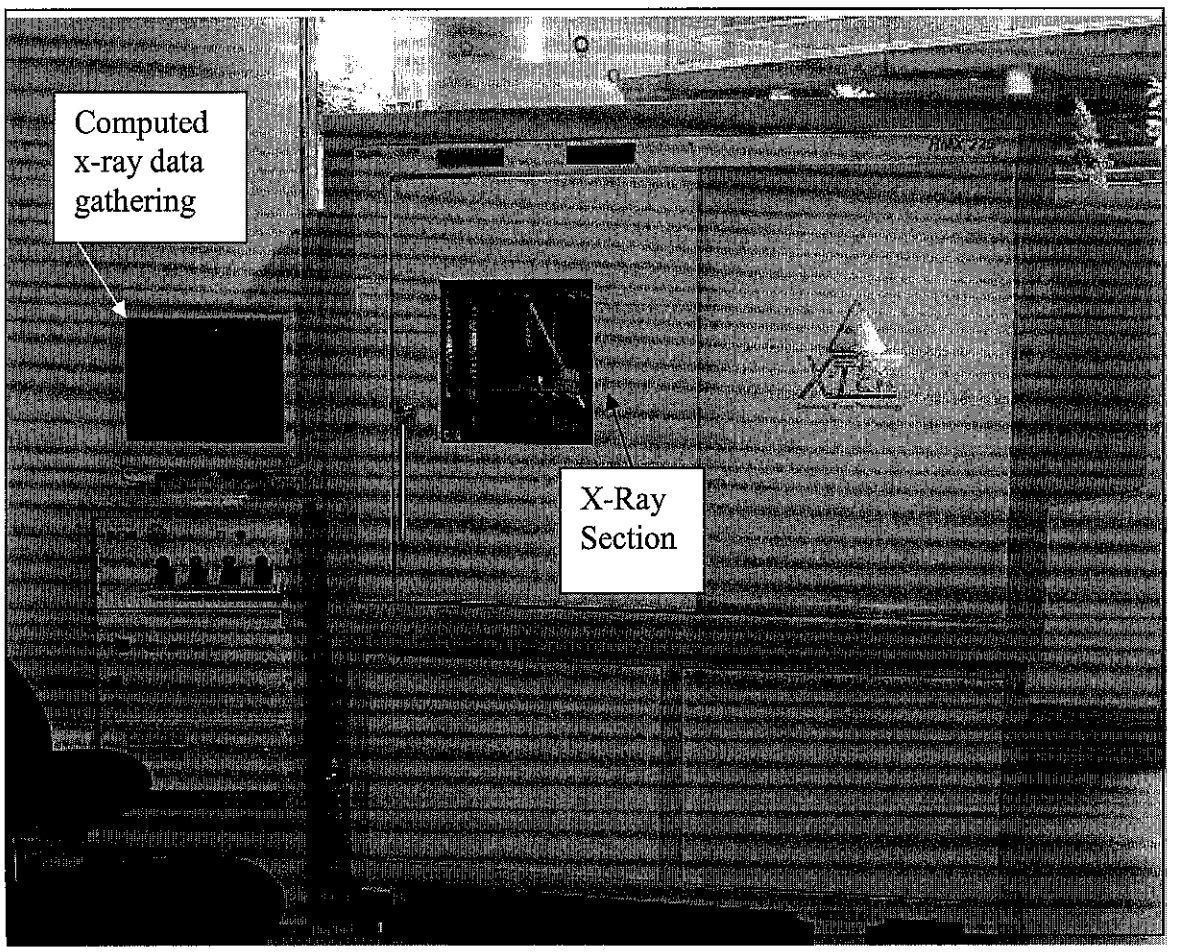

Figure 3.4.2(a): X-ray machine manufactured by X-Tek System Ltd., England

CHAPTER 4

4.0RESULT

4.1 Effects of Injection molding parameter.

Controlling parameter in processing condition will lead to good molding and if not, the result will be vise versa. It is important to be able to use suitable parameter in order to produce perfect product. Below are the bad and good molded samples.

Figure 4.1(a): Molded reinforcement of polypropylene with 5% of volume fiber.

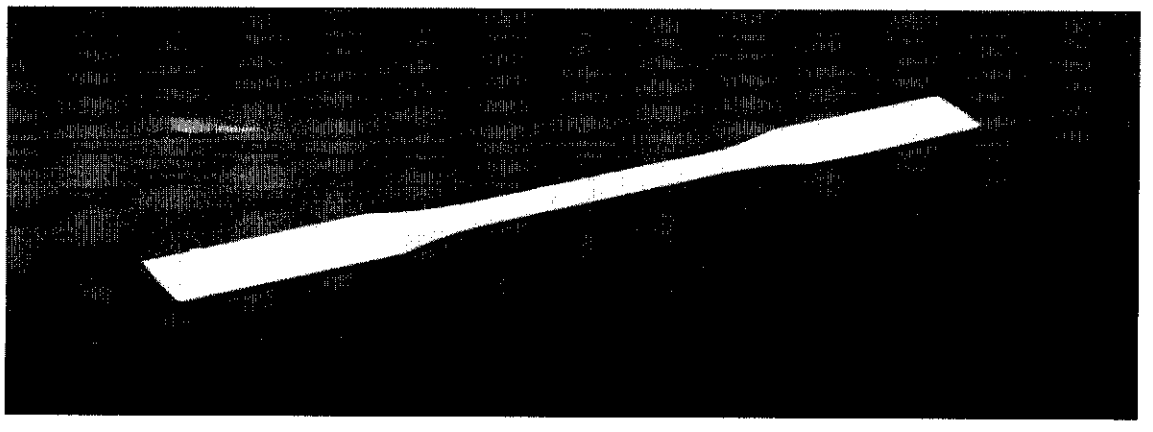

Figure 4.1(b): Good molded sample

4.2 Mechanical Testing

4.2.1 Tensile Test

The test has been done with five different fiber volume fractions. The objectives are to analyze the elongation, modulus and tensile strength within different volume fiber content. Below are the result determined and comparison between theoretical value and experimental value.

Table 4.2.1(a): Result of tensile test

Sample no.	Volume % fiber	Elongation (mm)	Young's Modulus(MPa)	Tensile strength(MPa)
1	0	9.00	1182	30.15
2	5	7.03	1222	32.47
3	10	3.94	1262	45.74
4	15	3.51	1536	64.93
5	20	2.27	1822	70.13

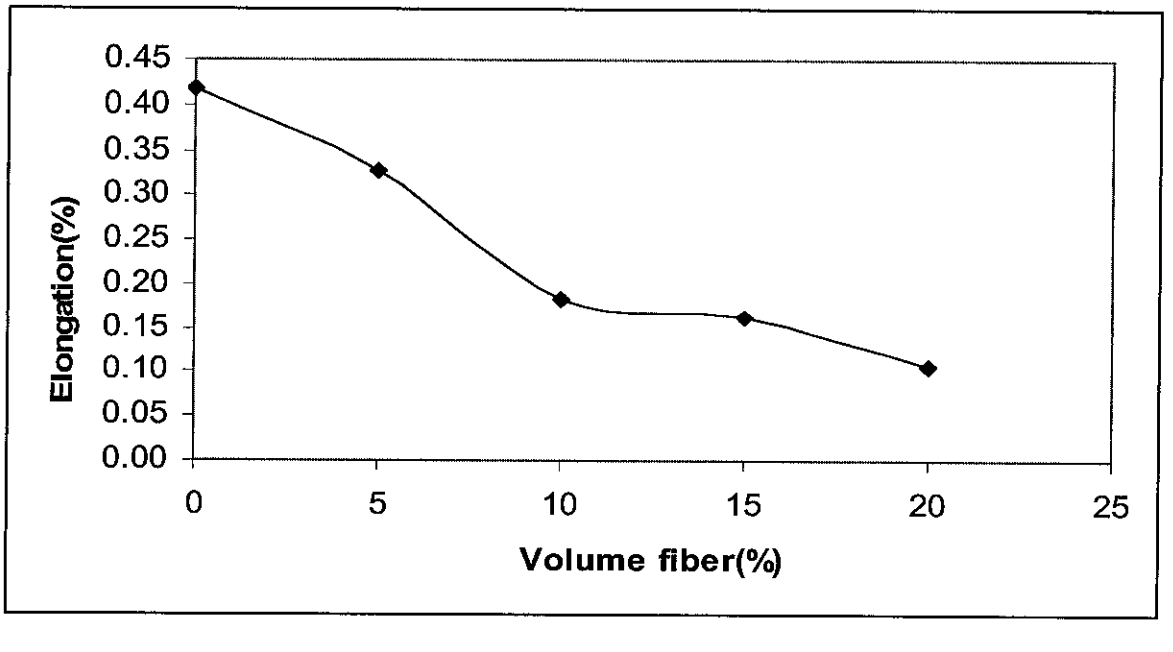

Figure 4.2.1(a): Elongation vs Volume fiber

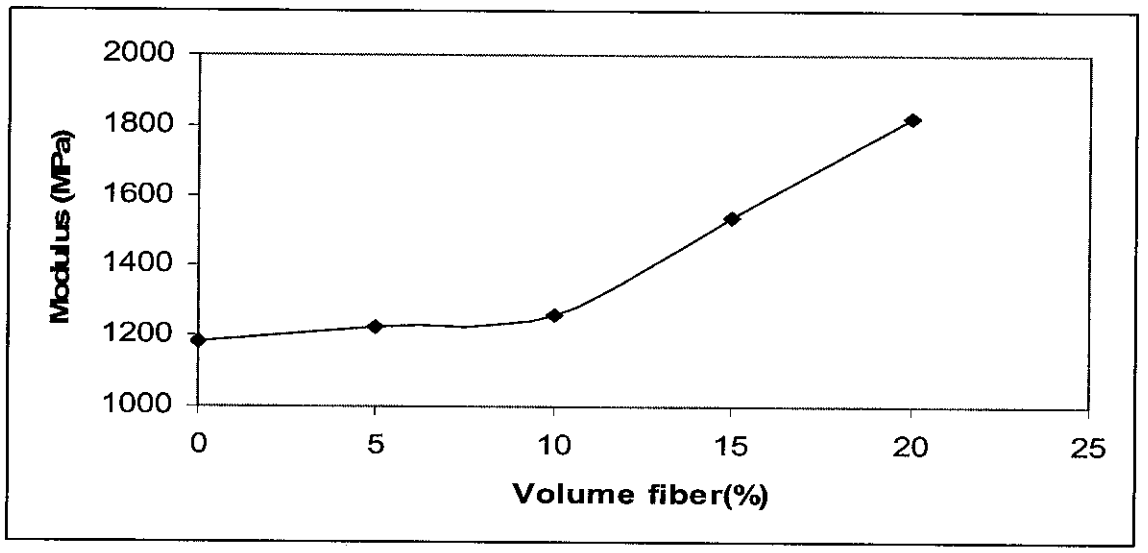

Figure 4.2.1(b): Modulus vs Volume fiber

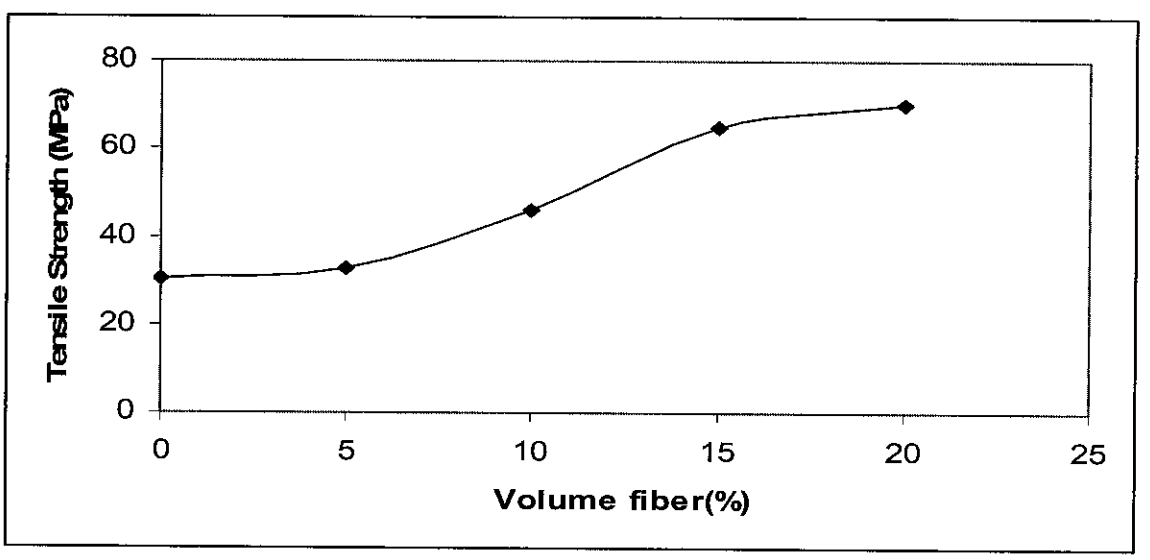

Figure 4.2.1(c): Tensile strength Volume fiber

4.2.1.1 Theoretical value

Using Kelly's equation, a theoretical value of fiber reinforced tensile strength was determined. Before getting the value, shear strength and critical fiber length should be calculated as below;

Shear strength of the interface;

$\tau_U = \sigma_M / 2$

$= 25 \text{ MPa} / 2$

$= 12.5 \text{ MPa}$

Critical fiber length;

$l_C = (\sigma_F \text{ x } d) / (2 \text{ x } \tau_U)$

$= (2200 \text{ MPa x } 20e^{10\text{-}6} \text{ m}) / (2 \text{ x } 12.5 \text{ MPa})$

$= 1.76e10^{-3} \text{ m}$

i. *The following is the theoretical tensile strength value of 5% fiber content*

$\sigma_C = \sigma_F \times V \times [1-(l_C / 2l)] + [(1 - V) \times \sigma_M$

$= 2200 \text{ MPa} \times 0.05 \times [1 - (1.76e10^{-3} \text{ m} / (2 \times 3.0e10^{-3} \text{ m}))]$

$+ [(1-0.05) \times 25 \text{ MPa}]$

$= 101.48 \text{ MPa}$

ii. *The following is the theoretical tensile strength value of 10% fiber content*

$\sigma_C = \sigma_F \times V \times [1-(l_C / 2l)] + [(1 - V) \times \sigma_M$

$= 2200 \text{ MPa} \times 0.10 \times [1 - (1.76e10^{-3} \text{ m} / (2 \times 3.0e10^{-3} \text{ m}))]$

$+ [(1-0.10) \times 25 \text{ MPa}]$

$= 177.97 \text{ MPa}$

iii. *The following is the theoretical tensile strength value of 15% fiber content*

$\sigma_C = \sigma_F \times V \times [1-(l_C / 2l)] + [(1 - V) \times \sigma_M$

$= 2200 \text{ MPa} \times 0.15 \times [1 - (1.76e10^{-3} \text{ m} / (2 \times 3.0e10^{-3} \text{ m}))]$

$+ [(1-0.15) \times 25 \text{ MPa}]$

$= 254.45 \text{ MPa}$

iv. *The following is the theoretical tensile strength value of 20% fiber content*

$$\sigma_C = \sigma_F \times V \times [1-(l_C / 2l)] + [(1 - V) \times \sigma_M$$

$$= 2200 \text{ MPa} \times 0.20 \times [1 - (1.76e10^{-3} \text{ m} / (2 \times 3.0e10^{-3} \text{ m}))]$$

$$+ [(1-0.20) \times 25 \text{ MPa}]$$

$$= 330.93 \text{ MPa}$$

Table 4.1.1(b): Tensile strength comparison between experimental and theoretical value

Sample no.	Volume % fiber	Experimental(MPa)	Increase Strength (%)	Theoretical(MPa)
1	0	30.2	DATUM	25.0
2	5	32.5	7.1	133.8
3	10	45.7	51.3	292.5
4	15	64.9	115.0	351.3
5	20	70.1	132.1	460.0

From table above, it shows that an increase in fiber content from 0 % to 20 % will increase the tensile strength to 132.1%.

4.2.2 Impact Test

Table 4.2.2(a): Result of impact energy for notch condition

Sample no.	Volume fiber (%)	θ_1	θ_2	Impact Energy(J)
1	0	150°	136.0°	23
2	5	150°	132.5°	32
3	10	150°	125.5°	46
4	15	150°	125.0°	47
5	20	150°	122.0°	54

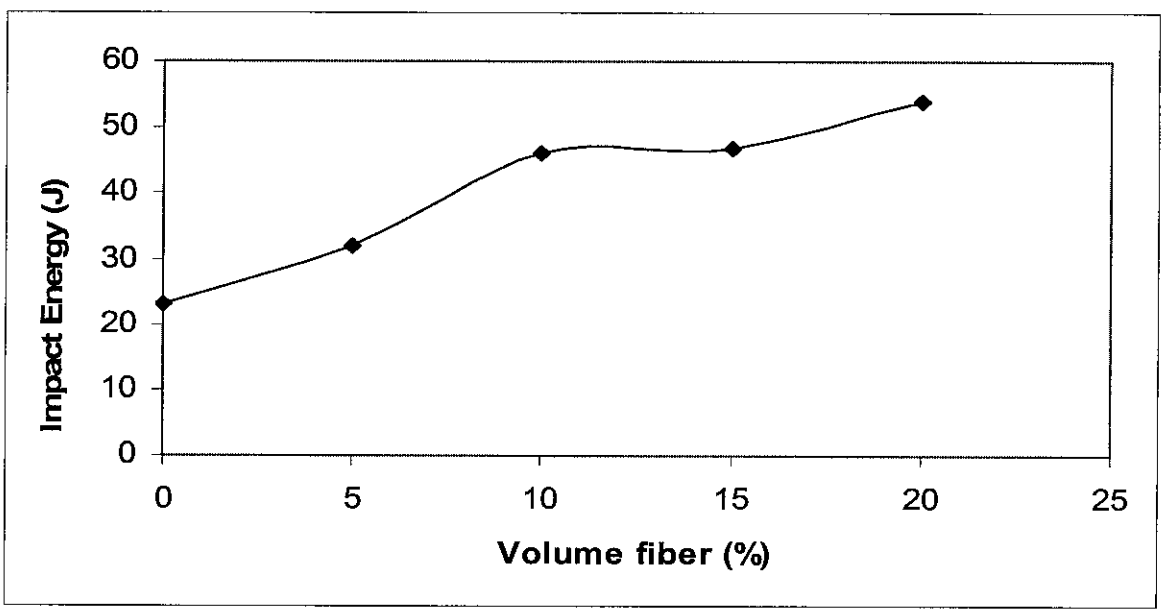

Figure 4.2.2(a): Impact energy vs Volume fiber for notched specimens.

4.1.2.1 Samples Calculation

Below are the sample calculations to determine the impact energy based on data obtained in Table 4.1.2(a)

To determine the impact energy of the composite, calculation below is used.

Impact energy = mgh[sin (θ_1-90°) + cos θ_2] ....**Equation 4.1.2.1(a)**

4.1.2.1.1: For notched specimens:

i. *The following is the impact energy calculation of polypropylene:*

Impact energy = mgh[sin (θ_1-90°) + cos θ_2]

= 21.8 x 9.81 x 0.749 [sin (150°- 90°) + cos 136.0°]

= 23 J

ii. *The following is the impact energy calculation of 5% volume fiber:*

Impact energy = mgh[sin (θ_1-90°) + cos θ_2]

= 21.8 x 9.81 x 0.749 [sin (150°- 90°) + cos 132.5°]

= 32 J

iii. *The following is the impact energy calculation of 10% volume fiber:*

Impact energy = mgh[sin (θ_1-90°) + cos θ_2]

= 21.8 x 9.81 x 0.749 [sin (150°- 90°) + cos 125.5°]

= 46 J

iv. *The following is the impact energy calculation of 15% volume fiber:*

Impact energy = mgh[sin (θ_1-90°) + cos θ_2]

= 21.8 x 9.81 x 0.749 [sin (150°- 90°) + cos 125.0°]

= 47 J

v. *The following is the impact energy calculation of 20% volume fiber:*

Impact energy = mgh[sin (θ_1-90°) + cos θ_2]

= 21.8 x 9.81 x 0.749 [sin (150°- 90°) + cos 122.0°]

= 54 J

4.3 Examination of microstructure

4.3.1 Microscopy

The test was held with four different volume fiber and using 100x magnificent microscopy. The objective is to determine any evidence of defects or voids in the samples.

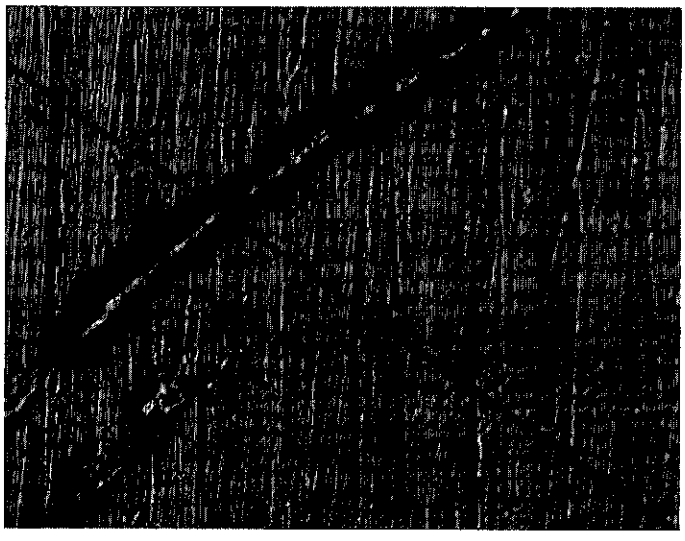

Figure 4.3.1(a): 5% volume fiber with 100x magnificent

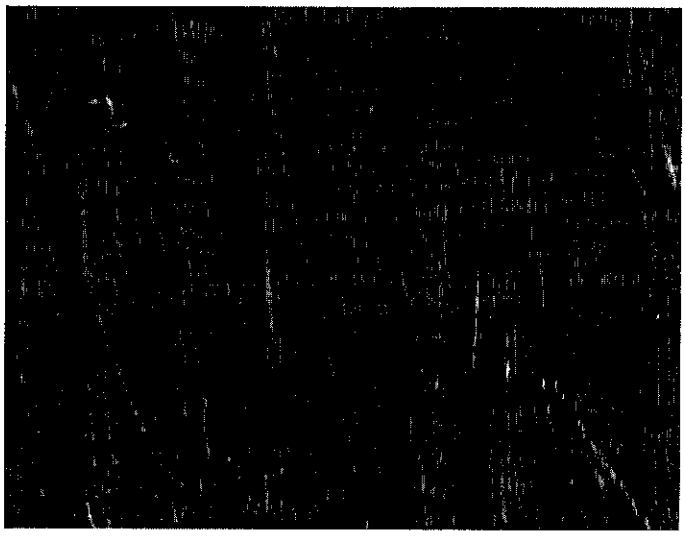

Figure 4.3.1(b): 10% volume fiber with 100x magnificent

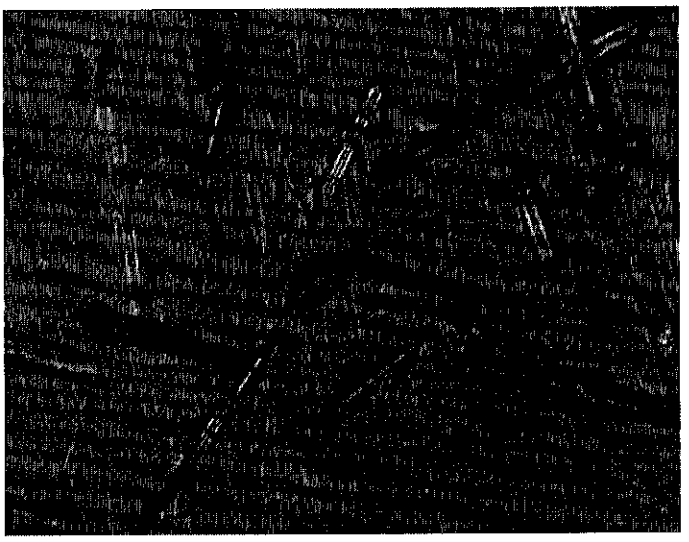

Figure 4.3.1(c: 15% volume fiber with 100x magnificent

Figure 4.3.1(d): 20% volume fiber with 100x magnificent

4.3.2 X-ray Radiography

The test was held with four different volume fiber using x-ray radiography .The objective is to determine any evidence of internal defects or micro-voids in the samples. There was insufficient information that could be extracted using X-ray radiography, thus the result will be put on Appendix III for references.

CHAPTER 5

5.0 DISCUSSION

5.1 Mechanical Testing

5.1.1 Effects of Injection Molding Parameter

Since the properties of a short fiber reinforced thermoplastics are very dependent on fiber length and orientation, and not to forget the existence of volume fiber in the composite. It is important that those parameters can be controlled to produce the final molding, by an appropriate choice of processing conditions.

A suitable parameter in processing condition could lead to a good product (Figure 4.1(b)). However, if the parameter is not suitable for reinforcing this particular fiber, this will lead to a 'flash' condition (Figure 4.1(a)). This condition occurred most likely because of excessive material flow in the clamping unit. Thus, low injection speed should be used in order to achieve a good surface finish and to prevent flash condition of the product. Complete parameters for a good molding are shown in Appendix IV.

5.1.2 Tensile strength

Tensile strength (TS) can be referred as maximum engineering stress, in tension, that may be sustained without fracture. This corresponds to the maximum stress that can be sustained by a structure in tension; if this stress is applied and maintained, fracture will result.

From the result determined, it was observed that an increase of volume fiber in composite will increase the tensile strength of the composite. For 5%, 10%, 15% and 20% of volume fiber in composite, the tensile strength determined are 32.47 MPa, 45.74 MPa, 64.93 MPa and 70.13 MPa respectively. In other words, tensile strength is dependent to volume faction of fiber in composite.

This happened because the composite have an extra tensile strength when fiber is introduced in the composite. The fiber itself has high tensile strength whereas the matrix (polypropylene) has less tensile strength. Yet, by reinforcing those two will result a higher tensile strength, as the fiber will 'take place' for tensile properties position.

From the experimental result determined, it was calculated that an increase of fiber from 0 % to 20 % will increase the tensile strength up to 132.1%. However, from the result determined, it was observed that value for the comparison between experimental and theoretical value have a great differences. There are several parameters that affect the result determined.

The first parameter that affects the performance of the reinforced fiber is existence of dimples, voids, micro-voids and surface flaws. This evidence of defects will reduce the tensile strength of the composite. The defects criteria will be discussed in the following section.

The second parameter that could affect the result obtained is the molding process parameter of reinforced fiber. There is some prevention actions need to be taken before using injection molding. The short glass fiber is actually very sensitive to the environment. Any long exposure of short glass fiber to the environment will affect the strength and stiffness of the fiber itself. Thus, actually the fiber should not be exposed to surrounding

before reinforced it. In other words, the fiber should immediately put together to the hopper as fast as possible.

Another parameter that will affect the mechanical properties of glass fiber is abrasion. Abrasion could happen by only rubbing the glass fiber with other material. In the project, it is obviously that the fiber is rubbing with the polypropylene before putting it in the injection molding hopper. This happened when the mixture is manually blended in order to have homogenous product. Thus, it is recommended that the glass fiber and the polypropylene should be compound first using extrusion machine. This will prevent the short glass fiber and polypropylene to rub with each other in order to prevent any abrasion.

Last but not least, it was believed that the bonding between glass fiber and polypropylene is not enough. A poor bonding will decrease the tensile strength of the composite. It also believed that the bonding strength of the composite is different from one point to another point. Thus, it is recommended that a coupling agent is needed to mix with reinforced fiber for bonding strength purpose. This will be a future work plan related to this project.

5.1.3 Impact Test

Impact energy (notch toughness) is a measure of the energy absorbed during the fracture of specimen of standard dimensions and geometry subjected to very rapid (impact) loading. Charpy and Izod impact tests are used to measure this parameter, which is important in assessing the ductile-to-brittle behavior of material. For this experiment, Charpy impact test was used to determine the impact energy.

From the result determined, it was observed that an increase of fiber will increased the impact energy of the composite. However, this only applies in range of 5%- 20% volume fiber of composite. In other words, reinforced fiber in this experiment has optimal impact energy at 20% of volume fiber. The impact energy of 0%, 5%, 10%, 15% and 20% of volume fiber are 23 J, 32 J, 46 J, 47 J and 54 J respectively

This shows us that an increase of fiber content in the composite will increase the impact energy. Higher fiber volume content surely will absorb more impact energy compared to lower fiber volume. We also can say that when the impact test was done, fiber will absorb the impact energy, whereas the polypropylene will only divert the impact energy to the fiber.

However, it is believed that for unnotched condition, the increase of fiber content will decrease the impact energy. This is because the interpretation of impact energy data as measured using pendulum method is still the centre of continuing debate even for unreinforced polymer. When short fiber reinforced thermoplastic are tested under impact conditions, the variation of impact energy versus fiber content is confused, in that for some polymers it increase with addition of fibers and decrease in others. Please be noticed that impact test for unnotched condition was not held because of uncertainty of composite behavior.

As an example of complexity of the situation, figure 2.3.2(a) and 2.3.2(b) show the notched and unnotched impact strength for a number of short glass reinforced polymers. Nylon shows an increase in impact strength with fiber content, for both notched and unnotched specimens, but the behavior of reinforced polypropylene is very dependent on notching condition. Polypropylene shows increase in impact strength with fiber content for notched condition and shows decrease in impact strength with fiber content for unnotched condition.

5.2 Molding Defects

5.2.1 Visual Inspection

From the naked eye, it was found that there is no evidence of existence of defects or surface flaws. Any of those will decrease the performance of reinforced fiber thermoplastic composites.

5.2.2 Examination of microstructure

5.2.2.1 Microscopy

The microscopy was held using 100x magnificent, from results obtained, it was found that the samples experience dimples and voids for particular samples. It was also found an evidence of surface flaws occurred at the samples.

The dimples and voids occurred mainly because of processing condition. Any breakage of fiber will produce a voids or dimples in the samples.

Thus, it was recommended that high injection speed should be used in order to achieve a good surface finish .The screw speed and back pressure must also be kept to a minimum, since although a homogenous melt is required, fiber breakage may become excessive.

5.2.2.2 X-ray radiography

The x-ray radiography test done is base on micro- graph test. From the result determined, it was observed that there are no defects at the surface of the molded specimens. However, it is believed that the result is not accurate enough as the picture taken from x-ray radiography show less information. This is because of the x-ray machine parameter and limits. There are two reasons that relate to this matter.

The first thing is lack of information in order to perform the test. The machine is actually very new in the laboratory, thus technician and students have lack of information and skills to perform the x-ray radiography test.

Secondly, it was believe that the machine is very sensitive as the machine has turn down several times before. It makes the operator of the machine to manipulate and re-setting the parameter of the machine. Consequently, this has leaded the result of x-ray radiography not perfect.

For the future plan, the author has plan re-do the test after mastering the parameter that is suitable for x-raying the reinforced fiber. By having this, an accurate and perfect result will be determined. Defects at the surface of the composite may be will be determined. Basically, the molding defects were divided into two categories. There are internal defects and surface defects. Furthermore, the author will do SEM test for the future plan.

CHAPTER 6

6.0 CONCLUSION

It was conclude that by introducing glass fiber in thermoplastic, there was significant increase of tensile strength in the composite. Thus, tensile strength is dependent to volume fraction of fiber in composite. An increase of fiber content from 0% to 20% resulted an increase of tensile strength up to 132.1%.

For impact testing, it was concluded impact energy is most likely dependent on the volume fiber and notching condition. For notched condition, an increase of volume fiber will increase the impact energy of the samples.

There are mold defects investigation tests that have been done. This examination of microstructure is divided into two tests; x-ray radiography and microscopy test. It was believed that x-ray radiography is the best test for examining composite microstructure. However, in this experiment, a microscopy test is better than the x-ray radiography as shown in result section.

Thus, it was concluded that by introducing fiber in thermoplastic, it should have a significant increase in tensile strength and higher impact energy absorption. However, a suitable processing condition and parameter should be taken in order to have high performance of reinforced fiber.

APPENDICES

Appendix I: Economic production quantities for various molding method.

ECONOMIC PRODUCTION QUANTITIES FOR VARIOUS MOLDING METHODS				
MOLDING METHOD	RELATIVE INVESTMENT REQUIRED		RELATIVE PRODUCTION RATE	ECONOMIC PRODUCTION QUALITY
	EQUIPMENT	TOOLING		
Hand lay-up	VL	L	L	VL
Spray-up	L	L	L	L
Casting	M	L	L	L
Vacuum-bag molding	M	L	VL	VL
Compression-molded BMC	H	VH	H	H
SMC and preform	H	VH	H	H
Pressure bag molding	H	H	L	L
Centrifugal casting	H	H	M	M
Filament winding	H	H	L	L
Pultrusion	H	H	H	H
Rotational molding	H	H	L	M
Injection molding	VH	VH	VH	VH

VL = Very Low
L = Low
M = Median
H = High
VH = Very High

Appendix II: Gantt chart

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Work Continue														
	-Practical/Laboratory Work														
2	Submission of Progress Report 1			●											
3	Project Work Continue														
	-Practical/Laboratory Work														
4	Submission of Progress Report 2								●						
5	Project work continue														
	-Practical/Laboratory Work														
6	Submission of Dissertation Final Draft												●		
7	Oral Presentation													●	
8	Submission of Project Dissertation														●

● Suggested milestone

Appendix III: X-ray Radiography for Reinforced thermoplastics

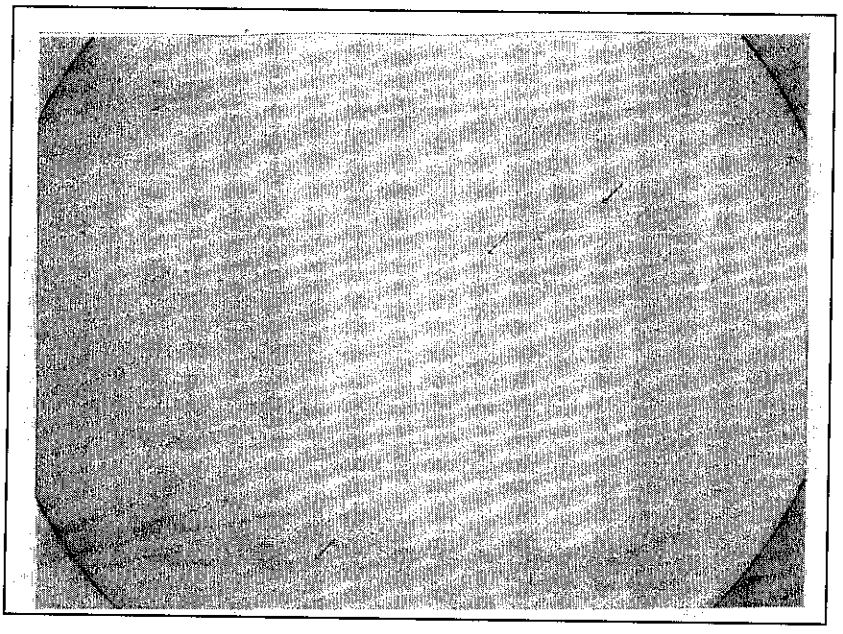

Figure III(a): X-ray radio graphed for 5% of volume fiber content

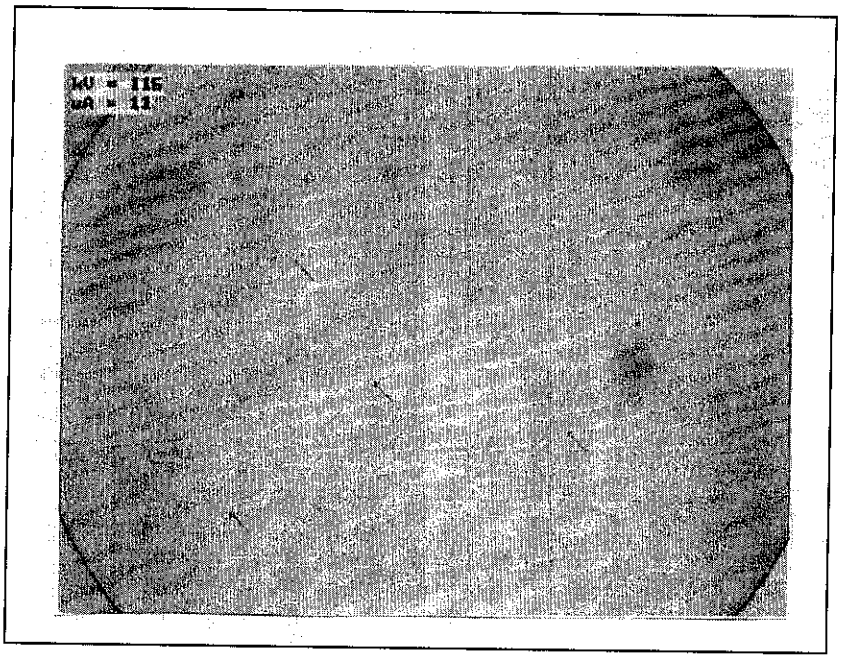

Figure III(b): X-ray radio graphed for 10% of volume fiber content

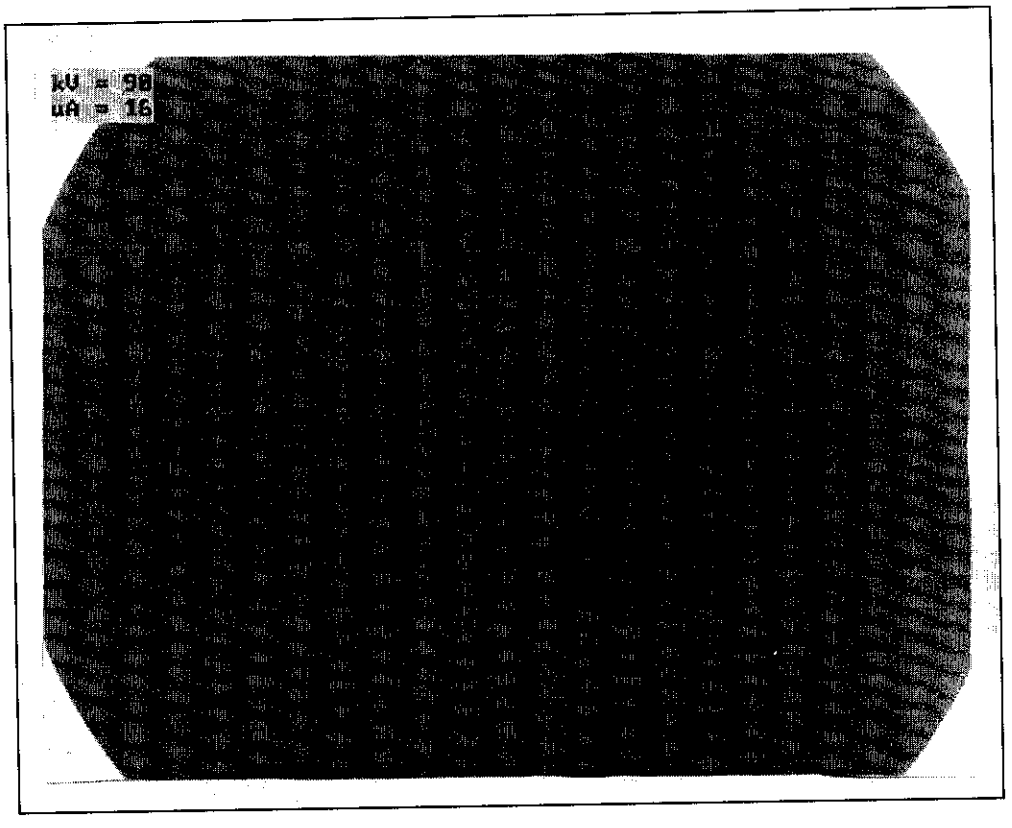

Figure III(c): X-ray radio graphed for 15% of volume fiber content

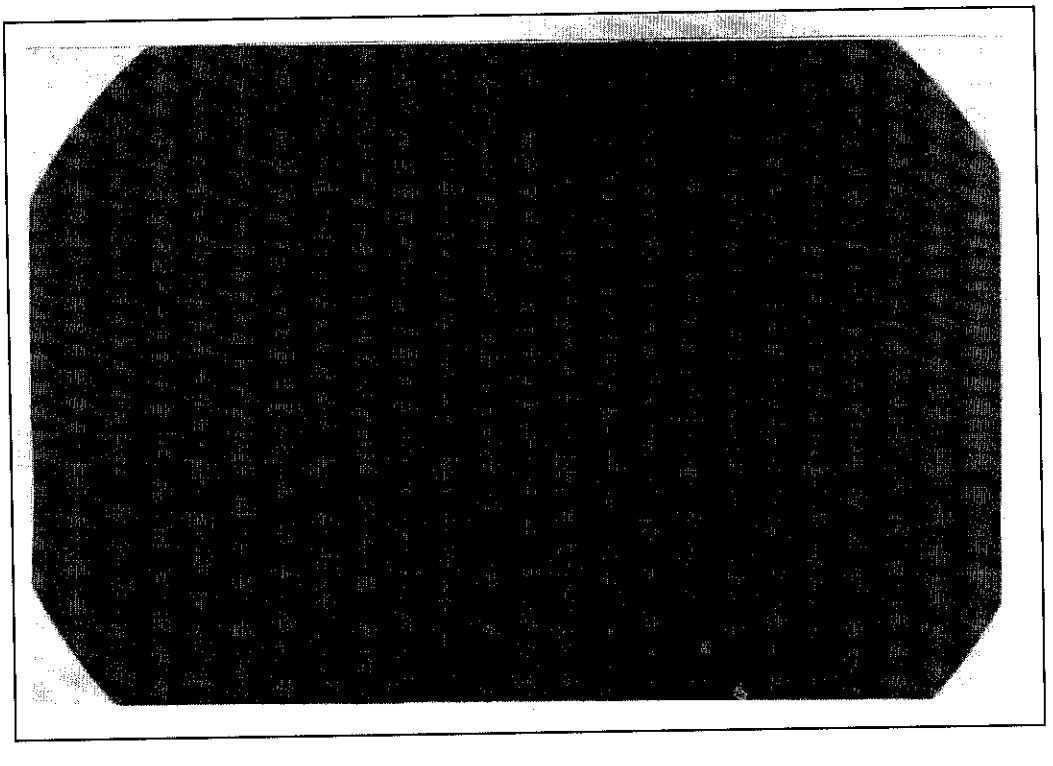

Figure III(d): X-ray radio graphed for 20% of volume fiber content

Appendix IV: Suitable injection molding parameter for reinforcing fiber in polypropylene

<TEMP>

TEMP	1	2	3	4	5	6	7
ACTL	25	25	25				
SET	140	185	160	-----	-----	-----	-----
UP LIMIT	+20	+20	+20	+	+	+	+
LOW LIMIT	-20	-20	-20	-	-	-	-
IDLE	100	100	100				

OIL TEMP	HEAT	COOL	OVER	STATE
25	20	40	45	NORMAL

HEAT TYPE: NORMAL
NOZZLE HEAT: 100%
IDLE FUN.: ON

<MOLD>

	POSITION	PRESSURE	TIME
CLOSE 1		120	
CLOSE 2	25.0	20	
PROTECT	9.0	10	2.0
LOCK-UP	1.0	140	0.5
OPEN 1		60	
OPEN 2	1.0	140	
OPEN 3	120.0	0	
OPEN 4	130.0	0	
OPENEND	140.0		

FST CL: OFF MOLD POS.: 149.6 mm

<INJ>

	POSITION	PRESSURE
INJECT 1		75
INJECT 2	0	
INJECT 3	0	
INJECT 4	0	

HD POS.: 5.0 mm INJ. TIME: 80.0 s

	PRESSURE	TIME
HD. PRS. 1	20	0.1
HD. PRS. 2	10	0.0
HD. PRS. 3	20	0.0
HD. PRS. 4	20	0.0

SCRW. POS.: 0.0 mm

<CHARGE>

	POSITION	PRESSURE
SUCK BK 1	0.0	0
CHARGE 1		80
CHARGE 2	0.0	60
CHARGE 3	0.0	0
CHARGE END	40.0	
SUCK BK 2	0.0	0

RPM: rpm SCRW. POS.: 0.0 mm

<EJECT>

EJECT	PRESSURE	TIME
EJECT FWD.	30	1.0
EJECT RTN.	30	

EJECT TYPE: CONT. EJECT CT: 2 times

BLOW	FUNCTION	DELAY	TIME
MOVE SIDE	OFF	0.0	0.0
FIX SIDE	OFF	0.0	0.0

MOLD POS.: 146.9 mm

<CORE>

CORE 1: COUNT
CORE 1 IN: BF CLP. CORE 1 OUT: POS.

CORE 1	PRESSURE	CNT.	POS.
IN	0	20	
OUT	0	20	0.0

CORE 2: COUNT
CORE 2 IN: POS. CORE 2 OUT: POS.

CORE 2	PRESSURE	CNT.	POS.
IN	0	20	0.0
OUT	0	20	0.0

<Q.C. 1>

COOL TIME : 10.0 s
CYCLE DELAY : 0.0
CYCLE ALM : 100.0 s
CLOSE ALM : 20.0 s
OPEN ALM : 20.0 s
INJ. ALM : 80.0 s
CHR. ALM : 20.0
PHO. ALM : 0.0

S.B MODE : OFF
INJ. MODE : POS.
INJ. UP : 9.0 mm
INJ. LOW : 1.0 mm
AUTO_NZB : OFF
PHO. USE : OFF
USE ROBOT : OFF