

**Characterization of Thermal and Mechanical Properties of
Polypropylene/Polycarbonate/PP-g-MA Blends**

by

ZULHASRIL BIN ZULKIFLY

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

MAY 2011

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

**Characterization of Thermal and Mechanical Properties of
Polypropylene/Polycarbonate/PP-g-MA Blends**

by

Zulhasril Bin Zulkifly

A project dissertation submitted to the

Mechanical Engineering Programme

Universiti Teknologi PETRONAS

In partial fulfillment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(MECHANICAL ENGINEERING)

Approved by,



(AP. Dr Faiz Ahmad)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2011

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.



ZULHASRIL BIN ZULKIFLY

ABSTRACT

Polymer blending is a process of combining two or more types of polymer in order to achieve the desired properties rather than developing new polymer. This study is conducted to characterize the thermal conductivity properties and tensile strength properties of polymer blend consisting of polypropylene and polycarbonate. Polypropylene-grafted-maleic anhydride was chosen as compatibilizer to improve the miscibility of the blend. Eight different weight composition ratios of the blend are designed which are 90/5/5, 85/10/5, 75/20/5, 65/30/5, 90/10/0, 80/20/0, 70/30/0 and 60/40/0 (in PP/PC/PP-g-MA respectively). The glass transitional and melting temperatures of PP, PC, and PP-g-MA were obtained by differential scanning calorimetry (DSC) and the values were consistent with literature. Then, the polymers will be compounded in twin screw extruder. Samples for thermal conductivity test are fabricated by compression moulding. Lab testing will be done on the samples to determine the value of thermal conductivity of each formulation by using ASTM E1225 -04 Standard Test Method for Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique. Samples for tensile strength test are prepared by injection molding machine and the testing is done according to ASTM D638-10 Standard Test Method for Tensile Properties of Plastics.

ACKNOWLEDGEMENT

First of all, my deepest gratitude to Allah S.W.T the Most Gracious because providing me the strength and wisdom to complete my final year project. In addition, special thank goes to my lovely family for encouraging and give moral support to me to work hard and complete the project.

I would like to give my highest appreciation to my project and FYP II supervisor, AP Dr Faiz Ahmad, and my FYP I supervisor, Dr Puteri Seri Melor Megat Yusoff for their knowledge, support and guidance for the 15 weeks during this report and project been conducted. Their knowledge sharing and support makes the completion of this project possible. I am very thankful and proud to be under the supervision of these two dedicated lecturers.

A highest gratitude also goes to entire lecturer in Mechanical Department and Mechanical Department Lab Technician for the precious support, guidance, help and encouragement that were given throughout the period of my project. Apart from that, I would like to give credits to my fellow colleagues which also related directly or indirectly to the project, who give excellent cooperation in completing this Final Year Project. Lastly, thank you to all parties who participate directly or indirectly in completing this project. Your contributions are highly appreciated.

LIST OF FIGURE

Figure 1: Fracture toughness of the material system processed by CIM	5
Figure 2: Fracture energy of composite for low and high temperature settings of N-CIM	6
Figure 3: Molecular structure of polypropylene	8
Figure 4: Molecular structure of polycarbonate	10
Figure 5: Tensile strength of PP/PA6 70/30 blends with various amount of PP-g-MA	12
Figure 6: Schematic diagram for compression molding	13
Figure 7: Schematic of typical test stack of thermal conductivity measurement	16
Figure 8: PP and PC blend formulations	17
Figure 9: Weight vs. Temperature (PP/PC)	18
Figure 10: Weight vs. Time (PP/PC)	19
Figure 11: Weight vs. Temperature (PP/PC/PP-g-MA)	19
Figure 12: Weight vs. Time (PP/PC/PP-g-MA)	20
Figure 13: Heat Flow vs. Temperature of PP/PC	21
Figure 14: Heat Flow vs. Temperature of PP/PC/PP-g-MA	21
Figure 15: Heat Flow vs. Time of PP/PC	22
Figure 16: Heat Flow vs. Time of PP/PC/PP-g-MA	22
Figure 17: Thermal conductivity value of selected blends	24
Figure 18: Stress Strain graph (PP/PC)	25
Figure 19: Stress strain graph (PP/PC/PP-g-MA)	26
Figure 20: Tensile strength vs. PP wt% in blend	26

LIST OF TABLE

Table 1: Properties of Polypropylene	7
Table 2: Properties of Polycarbonate	9
Table 3: Selected blend formulation for thermal conductivity test	23

CHAPTER 1

INTRODUCTION

1.1 Background of study

The concept of blending polymers to improve their properties is not new as it has been practiced in the rubber industry for decades. Blending polymers is a better economically in achieving the desired properties rather than developing new polymer. For many years, blending of polymer was unsuccessful due to the fact that many polymers were incompatible with each other. Lately new polymer blend has been successfully made by the use of compatibilizers and since then a lot of studies have been conducted on various types of polymer blend to further characterize their properties.

The blend of PP with PC is intended to achieve higher impact and compression strength, in addition to wider working temperature. It will also provide a mean to get PP- based material that has good impact strength with sufficient stiffness. The blend will also retain PP special properties such as high chemical and temperature resistance, low thermal conductivity and low water absorption. The research of PP/PC blends has moved beyond impact strength and stiffness, as other properties are also being studied.

Thermal conductivity is a property of a material which relates to its ability to conduct heat and it is regarded as one of the most important properties for polymers. This project aims to characterize thermal conductivity behavior of PP/PC blends compatibilized with polypropylene – graft – maleic anhydride (PP-g-MA).

1.2 Problem statement

Polypropylene is a type of polymer with drastic increase in usage due to its ease to manufacture and good overall properties. Polypropylene has wide range of application in engineering such as under-the-hood automotive applications, insulation for cable application and polypropylene insulation coating system designed for offshore flow assurance. Majority of these applications are being used in area associated with high temperature exposure due to the fact that polypropylene is regarded as heat insulator since they have low thermal conductivity. Previous study showed that blending with polycarbonate will provide improvement to polypropylene properties such as increase in fracture toughness [1] and flexural modulus [2]. However, it is found that there is lack of research in the area of thermal properties of PP/PC blend. This project will focus on thermal conductivity behavior of PP/PC blend that can further widen the application for the PP/PC/PP-g-MA blend.

1.3 Objectives and Scope of study

The objectives of this research are to study the effect of changing the composition of PP/PC blends and study the effect of adding compatibilizer (PP-g-MA) on coefficient of thermal conductivity of the blends.

For PP/PC blend without compatibilizer, four weight composition ratios are designed by changing the composition of PP and PC. The formulations that have being chosen are 90/10, 80/20, 70/30 and 60/40 (in PP/PC respectively).

PP/PC/PP-g-MA blends are designed by changing the composition of PP and PC while PP-g-Ma is being set at 5 wt%. The formulations that have being chosen are 90/10/5, 80/20/5, 70/30/5, and 60/40/5 (in PP/PC/PP-g-MA respectively). The research also aims to study the effect of adding compatibilizer on the miscibility of the PP and PC blends by scanning electron microscopy (SEM).

CHAPTER 2

LITERATURE REVIEW

2.1 Thermal conductivity

Plastics are categorized as heat insulators because of their very low thermal conductivities [3]. Thermal conductivity (λ) is the intrinsic property of a material which relates to its ability to conduct heat. Thermal conductivity has major influence in cooling rate of molding during processing which is important to determine the processing cycle time.

There are several studies that have been successfully done in the area of thermal conductivity of polypropylene and polycarbonate. A study has been conducted on characterizing the coefficient of thermal conductivity of polypropylene by adding filler particle such as glass fiber, barite, magnetite, strontium ferrite, aluminum oxide, talc and copper [4]. All specimens have experienced increase in their thermal conductivity where talc filled polypropylene specimen gave the highest value of thermal conductivity (2.5 W/m.K for 30 vol% of talc). This behavior is a consequence of microstructure of talc filled PP showing high molecular interconnectivity.

A research focusing on thermal diffusivity and conductivity of polymethyl methacrylate (PMMA)/polycarbonate (PC) blend also has been conducted [5]. This melt blend of PMMA and PC is partially miscible and doesn't need the usage of compatibilizer. Thermal diffusivity is a material property which describes the rate at which heat flows through a material and is dependent on the value of thermal conductivity, density and heat capacity of the material. The result showed that the diffusivity in the liquid state and conductivity in the solid state changed linearly with the PC content. Thermal conductivity will increase as with increasing PC content.

Thermal conductivity of the polymer not only can be changed by introducing other particles into the polymer matrix, but also can be altered by changing the process parameters. The effect of pressure on the thermal conductivity of polymer melts also has been studied by several researchers [6]. In their study, they measured thermal conductivity at pressure of 20, 80, and E 120 MPa over a temperature range of 50-250°C. In general, the findings showed that the thermal conductivity will increase with increasing pressure and temperature.

Previous studies have found out that thermal conductivity is the least accurately measured property of polymer [7] and yet it is one of the most important properties in polymer processing. Thermal conductivity can be measured by using ASTM Standards: E 1225-04 and commercial techniques generally calculate thermal diffusivity and calculate thermal conductivity using heat capacity value, which are measured separately. However, several studies also have been done on finding other method of measuring the thermal conductivity of polymer.

Thermal conductivity measurement of small polymer is being conducted with the usage of differential scanning calorimetry [8]. Using DSC as method for measuring thermal conductivity does not require any modification to the existing DSC instrument. The measurements are very rapid with each measurement only take a few minutes. It is suitable for thermal conductivity of small sample, which is a cylinder of 6 mm in diameter and 2-8 mm in length. Several polymers such as PTFE, PMMA and HDPE have been analyzed by this method and the resultant values are in good agreement with literature value. The method developed can also minimize the effect of thermal contact resistance on the measurement of thermal conductivity.

2.2 PP and PC blend

A research has been conducted on the reinforcement of PC as dispersed phase inside PP matrix and improvement of the properties of these composites by addition of nanoclay, montmorillonite (MMT) [1]. PP/PC blend in this research was mixed at the ratio 70/30 wt% of PP/PC while nanoparticles were blended in the ratio 67/30/3 wt% (PP/PC/MMT). The result in Figure 1 shows that pure PP/PC blend experience high fracture behavior at both melt temperatures compared to other composites (a maximum value of 0.032 J/mm^2).

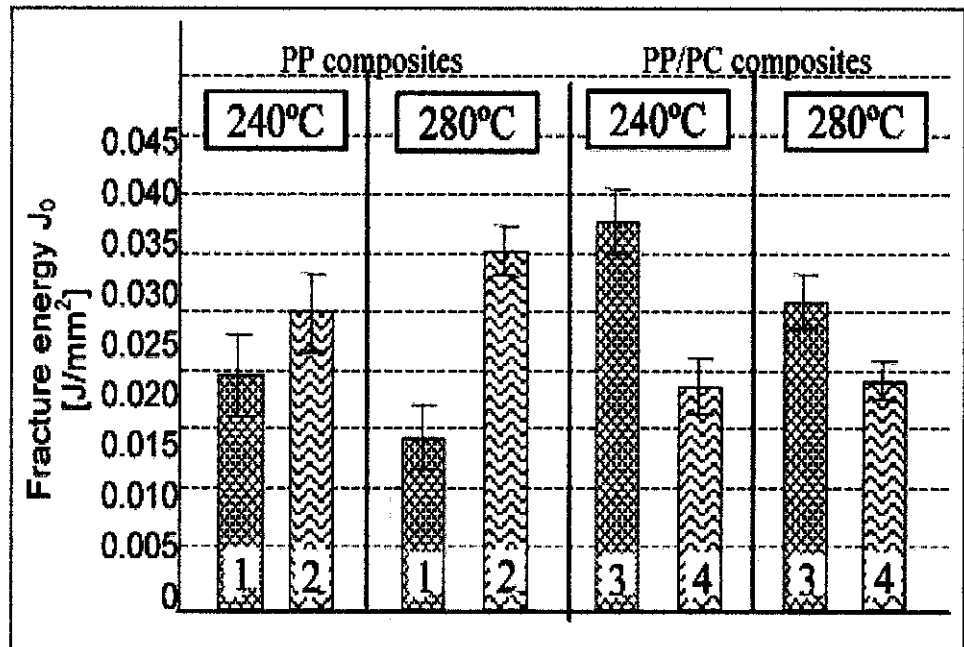


Figure 1: Fracture toughness of the material system processed by conventional injection molding (CIM), where 1- PP, 2- PP/MMT, 3- PP/PC, 4 – PP/PC/MMT

Figure 2 shows the variations of the fracture toughness of pure PP and PP/PC blend with the processing conditions for non-conventional injection molding (N-CIM). Results presented on graph are divided in two sections accordingly to low and high T_m . The x-axis illustrates the respective of the number and time of piston movements (strokes). The maximum fracture energy obtained in this test is by PP/PC blend with J_0 value of 0.028 J/mm^2 . Overall result shows that PP/PC blend presents higher values of J_0 for almost all conditions compared with the neat PP. Based on their findings, it can be concluded that the presence of PC content inside a PP matrix will cause a significant increase of mechanical properties of PP/PC blend. PC will act as a dispersed phase and provide reinforcement to PP matrix.

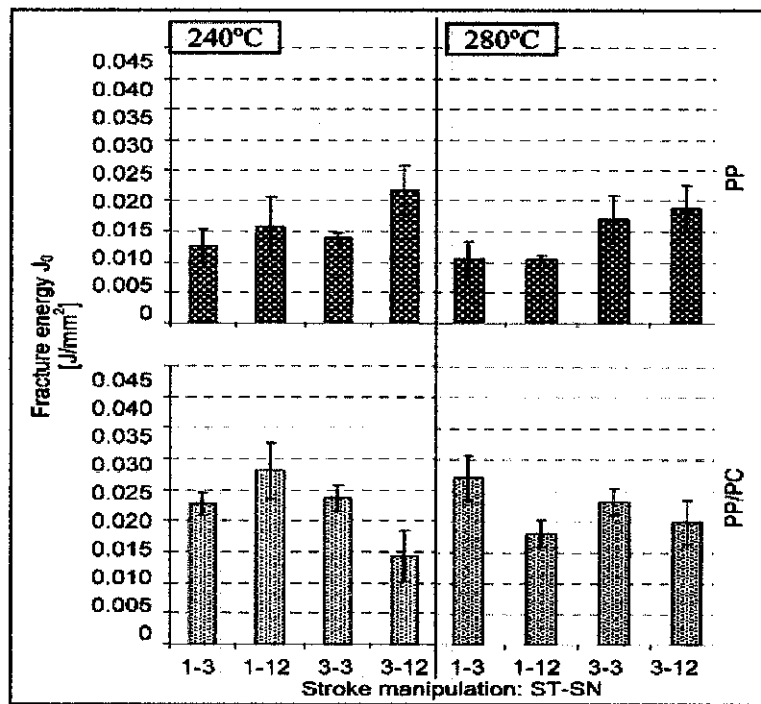


Figure 2: Fracture energy of composite for low and high temperature settings of non-conventional injection molding (N-CIM)

2.3 Polypropylene

Polypropylene is one of the most used polyolefins in industries because of its versatility and good properties such as excellent chemical resistance, good mechanical and thermal properties and relatively inexpensive [9] as summarized in Table 1. Polypropylene also has good workability and can be processed by a variety of method including extrusion, blow molding, injection molding and thermoforming [10].

Table 1: Properties of Polypropylene

Mechanical properties	
Abrasive resistance – ASTM D1044 (mg/1000 cycles)	13-16
Coefficient of friction	0.1-0.3
Elongation at break (%)	100 - 600
Hardness – Rockwell	80-100
Izod impact strength (J m ⁻¹)	20-100
Tensile modulus (Gpa)	1.14 – 1.55
Tensile strength (Mpa)	31 – 41.4
Physical Properties	
Density (g cm ⁻³)	0.9
Limiting oxygen index (%)	18
Water absorption – equilibrium (%)	0.03
Thermal Properties	
Thermal conductivity (W/m.K)	0.117
Melting/Glass transition temperature (°C)	170/-20

According to ASTM D883 80c, plastics are divided into two groups with regard to their chemical and technological behavior: (a) thermosetting plastics and (b) thermoplastics. Polypropylene is one of eleven major classes of thermoplastic. In industries, polypropylene is regarded as the commodity plastics. Commodity plastics are thermoplastic material that commonly used in great quantities. Generally, thermoplastics become soft when they are exposed to heat and harden when they are cooled regardless of how often the process is repeated. By alternating heating and cooling they can be reshaped many times. In the melted state they are rubber-like liquids, and in the hard state they are glassy or partially crystalline [11].

In thermoplastics, the atoms and molecules are joined end-to-end into a series of long chains, each chain being independent of the others. When subjected to heat, the individual chains slip, causing plastic flow. There are practical limitations to the number of heating cooling cycles to which thermoplastics can be subjected: an excessive number of such cycles may result in a loss of colour or plasticizer, thereby affecting the appearance and properties. The molecular structure of PP is shown in Figure 3.

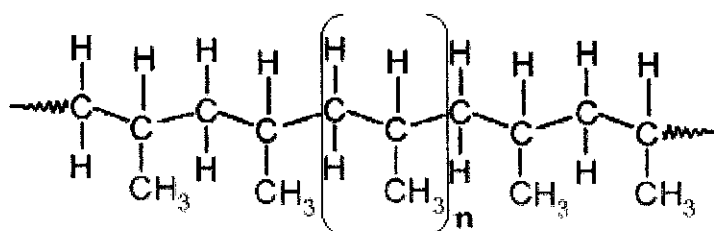


Figure 3: Molecular structure of polypropylene

2.4 Polycarbonate

Polycarbonate also been categorized as thermoplastic. Polycarbonate has good impact strength, heat-distortion temperature, good electrical insulation, flame resistance and high toughness and these combined properties led to extensive use of polycarbonate in the electric and electronic field [10]. Properties of typical PC are summarized in Table 2 and the molecular structure of PC is shown in Figure 4.

Table 2: Properties of Polycarbonate

Mechanical properties	
Abrasive resistance – ASTM D1044 (mg/1000 cycles)	10 -15
Elongation at break (%)	110 - 150
Hardness – Rockwell	70 - 121
Izod impact strength (J m ⁻¹)	600 - 850
Yield strength (MPa)	62.1
Tensile modulus (GPa)	2.38
Tensile strength (MPa)	62.8 – 72.4
Physical Properties	
Density (g cm ⁻³)	1.17 to 1.22
Melt Mass Flow Rate (g/10 min)	3.8 - 26
Water absorption – equilibrium (%)	0.16 – 0.35
Thermal Properties	
Thermal conductivity (W/m.K)	0.19
Melting/Glass transition temperature (°C)	267/150

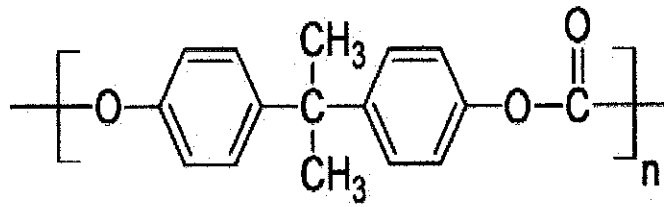


Figure 4: Molecular structure of PC

In industries, polycarbonate is regarded as an engineering plastic. Engineering plastics are those high-performance plastics that provide that exhibit superior mechanical and thermal properties in a wide range of conditions over and above more commonly used commodity plastics. However, they are sold in much lower quantities and are thus more expensive per unit weight. Market of polycarbonate are continuously growing as many research has been done to overcome the disadvantages of polycarbonate such as limited scratch and weathering resistance.

2.5 Compatibilizer

In the earlier stage, blending is only limited to miscible polymers. The major problem with immiscible blends is high interfacial tension and poor adhesion between two phases resulting in poor mechanical properties. A few solutions have been incorporated to address the problem and one of the ways is using compatibilizing agents to improve adhesion between phases of polymer blends. A compatibilizer is a type of coupling agent that can improve interfacial adhesion of separated phases in polymer blend and reduces interfacial tension in phase boundaries, making the particulate smaller in size to increase surface area in contact. As a result, any force or energy exerted on the blend will be transferred from one phase to another, thus improving mechanical properties of the blend.

One of the compatibilizers for PP/PC blend is polypropylene-grafted-maleic anhydride (PP-g-MA). It was reported that graft copolymer can be used effectively as compatibilizer for polymer blend [12]. A study by Renaut et al [13] concluded that PP-g-MA was more efficient than the terpolymer ethylene/acrylic ester/maleic anhydride (EBuAMA) and provide better thermomechanical properties of PP/PC blends. PP/PC blend with PP-g-GMA showed overall good result of compatibilization as Young's modulus, tensile strength and Izod impact strength had experienced significant increase [13]. The tensile strength of and Izod impact strength of PP/PC/PP-g-GMA are 90% and 67% higher than values for PP/PC blend (70/30). The compatibilizer reduces interfacial tension, increase interfacial adhesion and homogenizes the domain size and thus resulting in better properties [14].

A group of researchers from Chulalongkorn University have done a research of using PP-g-MA as compatibilizer in polypropylene/polyamide 6 blends [15]. They designed and tested 3 compositions of PP/PA6 blend which are 70/30, 70/30/5, and 70/30/10 (in PP/PA6/PP-g-MA respectively). Their research results indicated that the blend of PP/PA6 70/30 incorporated with 5 and 10 phr of PP-g-MA exhibited much higher tensile strength than uncompatibilized samples and tensile strength of the blends slightly increased as the amount of PP-g-MA increased from 5 to 10 phr. The results are as shown in Figure 5.

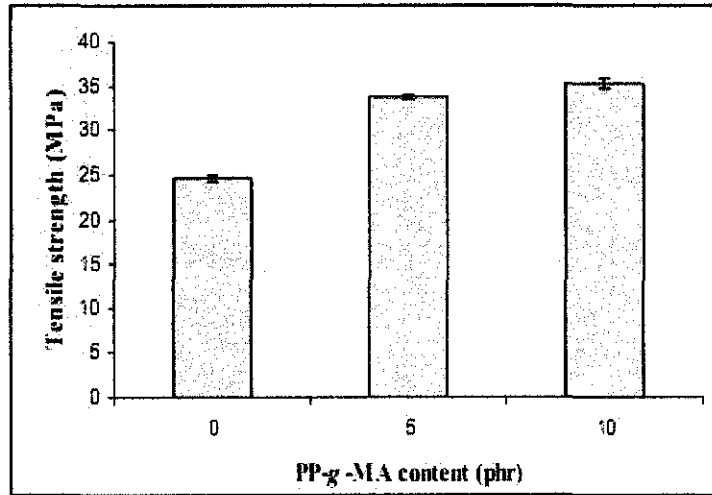


Figure 5: Tensile strength of PP/PA6 70/30 blends with various amount of PP-g-MA.

2.6 Twin Screw Extruder and Compression Molding

Among various types of mixing equipment, twin-screw extruders have most widely been used to prepare polymer blends in industry. Basically, extrusion process is the molding process of a viscous thermoplastic under pressure through an open ended die. A mechanical screw or auger propels through a chamber the pelletized material which is successively compacted, melted, and formed into a continuous charge of viscous fluid [16].

Molding is the most common method for forming plastic polymers. One of the molding techniques are compression. For compression molding, the appropriate amounts of mixed polymer are placed between male and female mold members. Both mold pieces are heated. However, only one is movable. When the mold is closed, heat and pressure are applied. Before molding, raw materials will be mixed and cold pressed into a disc which is called a preform. Preheating of the preform reduces molding time and pressure, extends the die lifetime and produces a more uniform finished piece [16]. The schematic diagram of compression moulding is shown in Figure 6.

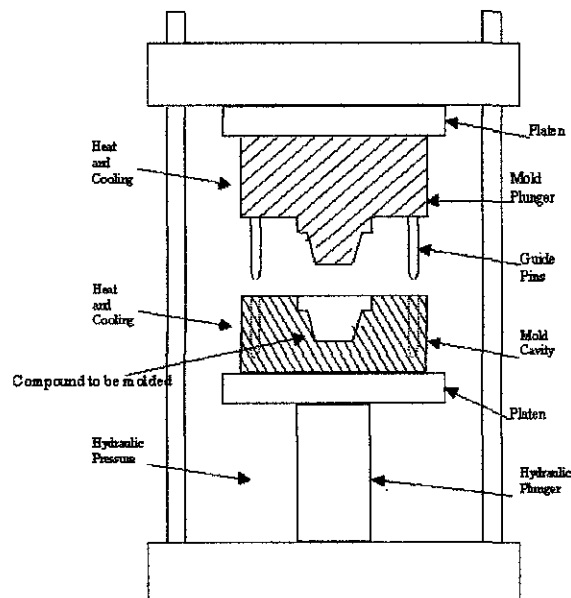


Figure 6: Schematic diagram for compression molding

CHAPTER 3

METHODOLOGY

3.1 Materials

There are three polymers that are being used in this experiment. PP is from the brand Polypropylene Malaysia (PETRONAS) while PC is from the trade name Panlite grade L-1225Y manufactured by Teijin Kasei America Inc.(Teijin Chemicals). The PC has melt volume-flow rate (MVR) 11.0 cm³ /10 min (300°C/1.2kg). The compatibilizer selected is PP-g-MA from the brand Sigma-Aldrich, product number 427845, with molecular weight of 9100 by GPC and maleic anhydride content of 8-10%.

3.2 Characterization

3.2.1 Differential scanning calorimeter (DSC)

Values of melting temperature, T_m and glass transition temperature, T_g of PP, PC, and PP-g-MA will be obtained by using DSC, brand Perkin Elmer Co model Pyris 1. Raw materials were prepared to weigh around 0.5g, placed into a metal case, placed accordingly in DSC and heated at 10°C/minute rate alongside a standard reference sample with sample chamber was continuously purged with dry nitrogen. Graph of heat flow versus temperature then plotted and T_m together with T_g value were obtained.

3.2.2 Thermogravimetric analysis (TGA)

Degradation temperatures will be determined by thermogravimetric analysis (TGA). For TGA specimens need to be prepared having weight around 8-10 mg and put into platinum pan. Next, the heating rate and temperature range are set to be 10 °C/minute and 25°C - 800°C respectively. Then, the filled platinum pan is to be heated electrically in pure nitrogen gas atmosphere to prevent oxidation and other reaction. While the specimen in the pan is heated gradually, weight changes of the filled pan will be determined by the machine. Finally graph of weight changes against temperature can be plotted and the relationship between them and degradation temperature can be obtained.

3.3 Sample Fabrication

The blend formulations, PP/PC/PP-g-MA have eight weight composition ratios which are 90/5/5, 85/10/5, 75/20/5, 65/30/5, 90/10/0, 80/20/0, 70/30/0 and 60/40/0 (in PP/PC/PP-g-MA respectively). Blending of the polymers will be done by co-rotating, twin screw extruder. Temperature is to be set at 220°C-270°C with screw extruder rotating at 90 rpm. Upon blending, the blends will be molded according to cylinder shape with 25 mm in diameter and 15 mm in length. Suitable parameter control such as mold temperature, compression time, as well as pressure exerted is crucial to produce good and acceptable samples as specified by test codes.

3.4 Testing

Thermal conductivity will be measured according to ASTM E1225 -04 Standard Test Method for Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique [17]. The schematic of the experiment is shown in Figure 6. Polymer blend specimen is going to be placed in a test stack between two reference materials of known thermal conductivity. Poly(methyl methacrylate) (PMMA) with thermal conductivity value of 0.167-0.25 W/m.K is selected as the reference material because it has thermal conductivity value close to the one that is expected from polymer blend specimens, and because of ease of thermocouples connection. At the test stack, a dead weight will be placed on top to ensure full surface contact while perlite will be used as insulator surrounding the test stack to minimize radial heat loss. The specimen and the reference material are in cylindrical form, with the size of 25 mm in diameter and 15 mm in length. They will be attached with two type K thermocouples each, while guard heater with three. All the thermocouples will be connected to data logger to get temperature reading. Finally the thermal conductivity is to be calculated from the measured temperature gradient in the respective specimens and the thermal conductivity of the reference material. As for the sampling requirement, only one specimen is needed for one sample.

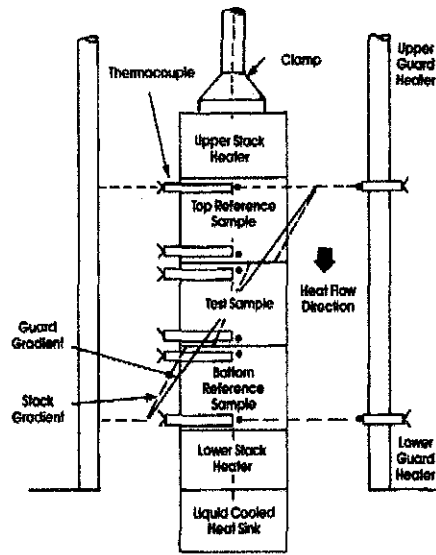


Figure 7: Schematic of typical test stack of thermal conductivity measurement

CHAPTER 4

RESULT & DISCUSSION

4.1 Specimen fabrication

Four weight composition which are 90/10, 80/20, 70/30 and 60/40 for PP/PC respectively were measured by using mass balance machine as shown in Figure 7. Besides, the process to prepare the specimens is already started by using twin screw extruder and compression molding.



Figure 8: PP and PC blend formulations.

4.2 Data Gathering & Analysis

Based on the Figure 8, there are comparison between specimens with difference parameter and technique of compression molding. It is crucial to produce good and acceptable specimen as specified by test codes. After analysis being conducted, there are three factors that affect specimen condition. The factors are mould temperature, compression time, as well as pressure exerted. About 6.0 g of material blend need to place inside the mould to produce an acceptable specimen. At the end of the compression process, the specimen will become 3.0 g as the other 3.0 g will become waste.

PP and PC have been characterized by DSC to determine their T_g and T_m . For PP, T_g is 87.28°C and T_m is 164.11°C . For PC T_g is found to be 159.09°C while for T_m it is not possible to know since a peak indicating its melting temperature does not appear. The graphs of heat flow versus temperature for PP plotted by DSC are shown in Figure 9. This could be due to improper sample preparation or wrong DSC configuration. These T_g and T_m values are important because when fabrication of specimen takes place, the melt processing temperature must be high enough for the polymer to melt and flow.

4.3 TGA analysis

TGA has been used to characterize PP/PC blends and PP/PC/PP-g-MA blends degradation temperature. Degradation temperature play an important role in specimen fabrication as it can help us to determine the accurate melt processing temperature. The temperature must be high enough for the polymers to melt and flow but it must not exceed the degradation temperature to avoid deterioration in its properties. For PP/PC degradation temperature is 280°C and PP/PC/PP-g-MA is 350°C . From the result, it shows that by melting temperature of the blends increase by addition of compatibilizer (PP-g-MA). The graphs plotted by TGA are shown in Figure 9, 10, 11 and 12.

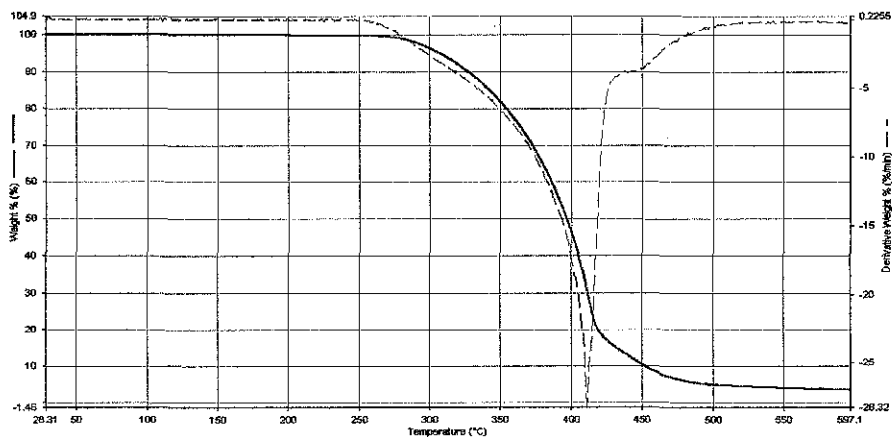


Figure 9: Weight vs. Temperature (PP/PC)

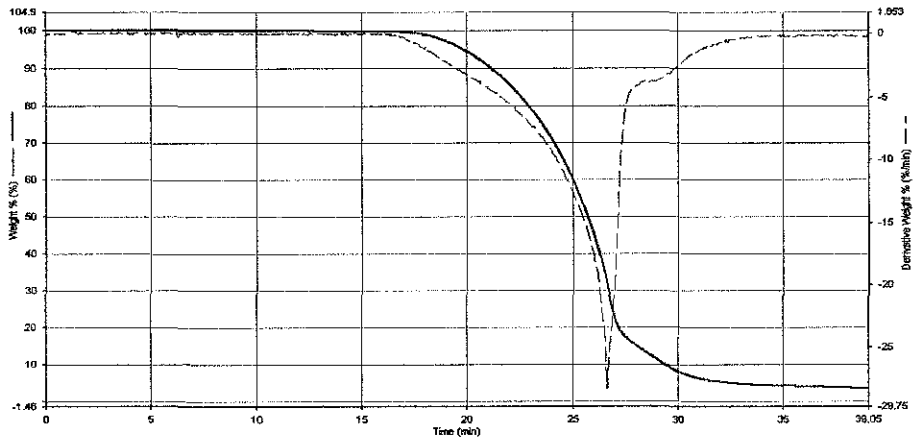


Figure 10: Weight vs. Time (PP/PC)

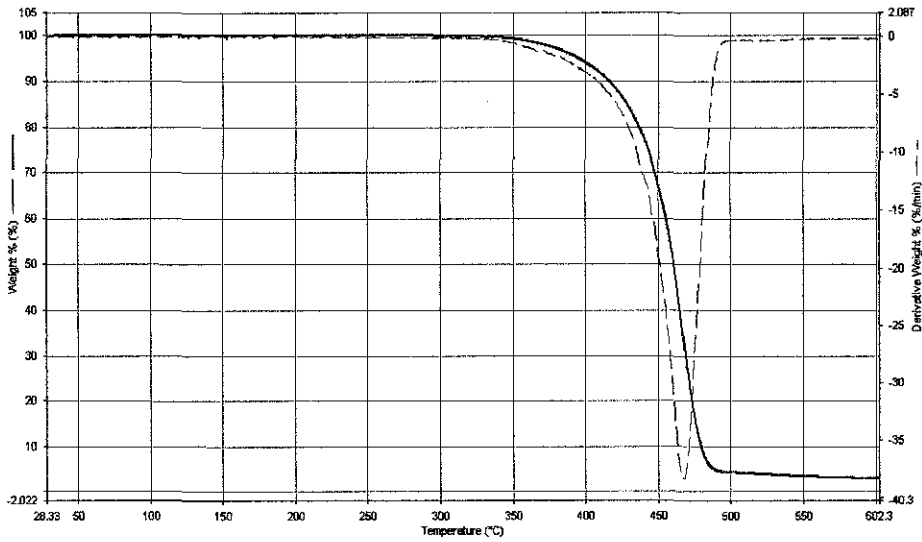


Figure 11: Weight vs. Temperature (PP/PC/PP-g-MA)

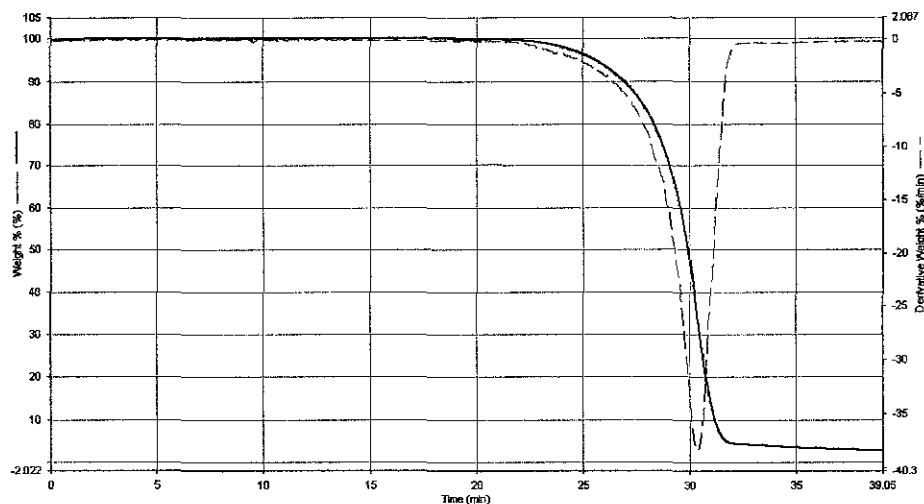


Figure 12: Weight vs. Time (PP/PC/PP-g-MA)

4.4 DSC Analysis

DSC is used to determine the glass transition temperature, T_g , and melting temperature, T_m for PP/PC and PP/PC/PP-g-MA blends. For PP/PC, T_g is 87.28°C and T_m is 164.11°C . For PP/PC/PP-g-MA T_g is found to be 159.09°C while for T_m it is not possible to know since a peak indicating its melting temperature does not appear. The graphs of heat flow versus temperature for PP/PC and PP/PC/PP-g-MA plotted by DSC are shown in Figure 13, 14, 15 and 16. T_g and T_m values also important to determine the fabrication of specimens.

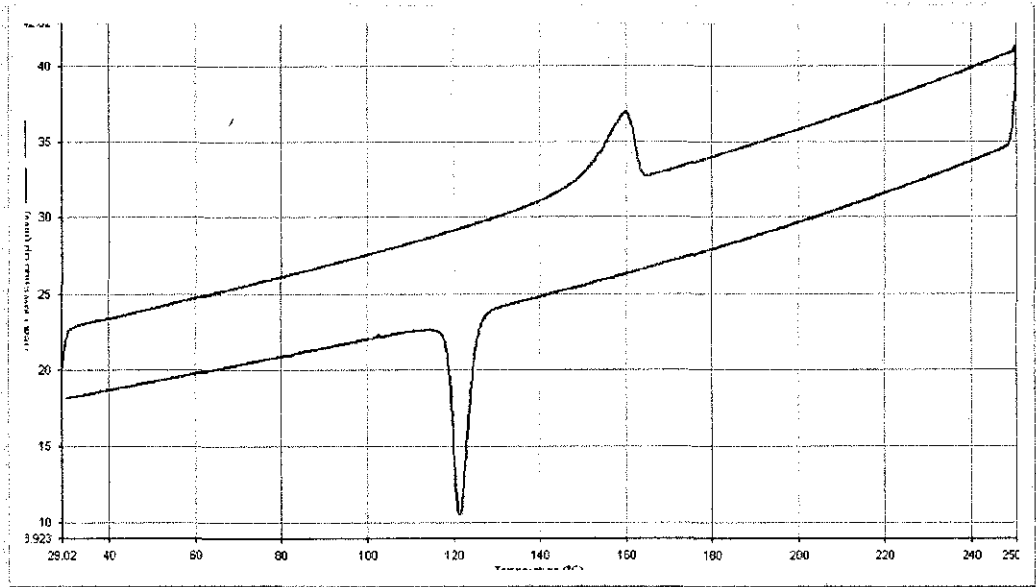


Figure 13: Heat Flow vs. Temperature of PP/PC

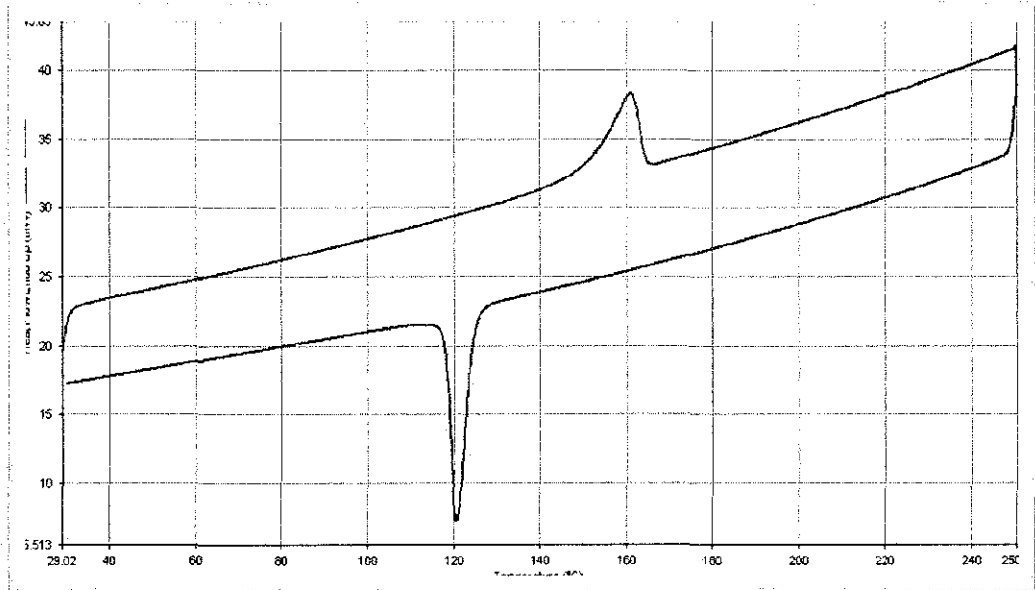


Figure 14: Heat Flow vs. Temperature of PP/PC/PP-g-MA

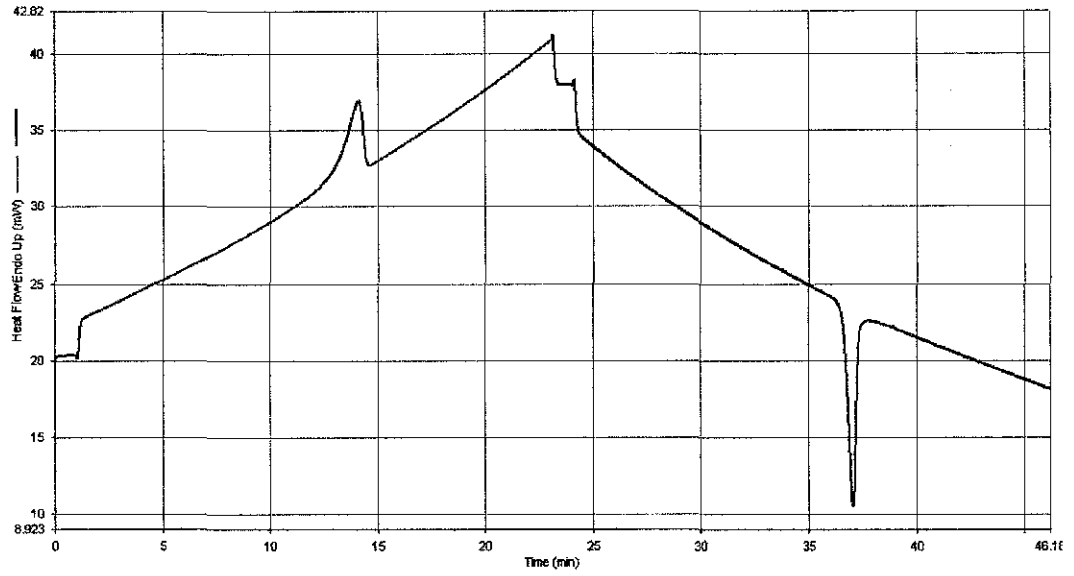


Figure 15: Heat Flow vs. Time of PP/PC

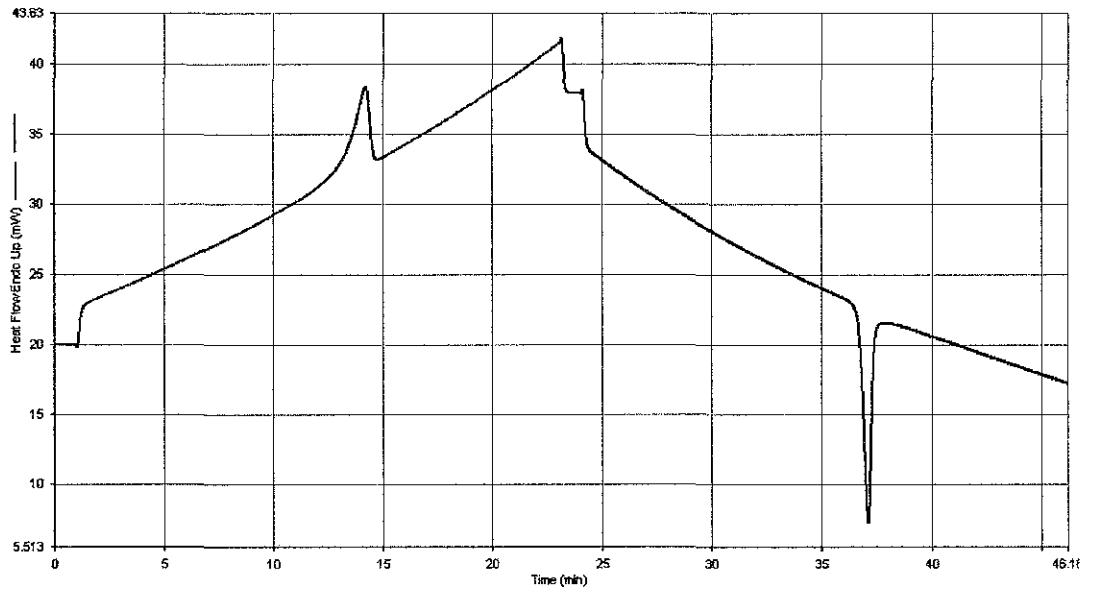


Figure 16: Heat Flow vs. Time of PP/PC/PP-g-MA

4.5 Thermal conductivity test

Thermal conductivity test is done on pure PP, pure PC and selected blend formulations such as 90/5/5, 80/15/5, 90/10, and 80/20. The blends are as listed below:

Table 3: Selected blend formulation for thermal conductivity test

Blends	Thermal conductivity (W/m.K)
PP	0.31
PC	0.21
90/5/5	0.22
80/15/5	0.23
90/10	0.23
80/20	0.25

The results of the thermal conductivity test on the selected blends are shown in Figure 17. The test is conducted on pure PP and PC to verify the exact value with given from the literature and manufacturer's data. Thermal conductivity of PP is found out to be 0.31 while PC is 0.21 which are in agreement with data provided.

From table 3 and figure 17, it shows that adding PC to PP matrix will decrease the value of thermal conductivity of the PP. Blend 90/10 give value of 0.23 and blend 80/20 give value of 0.25 compared to thermal conductivity value of pure PP which is 0.31.

Results of blend of 90/10 are compared with result from blend 90/5/5 and results from blend 80/20 are compared with result from blend 80/15/5. Adding 5wt% of compatibilizer (PP-g-MA) will reduce the value of thermal conductivity coefficient of the blends.

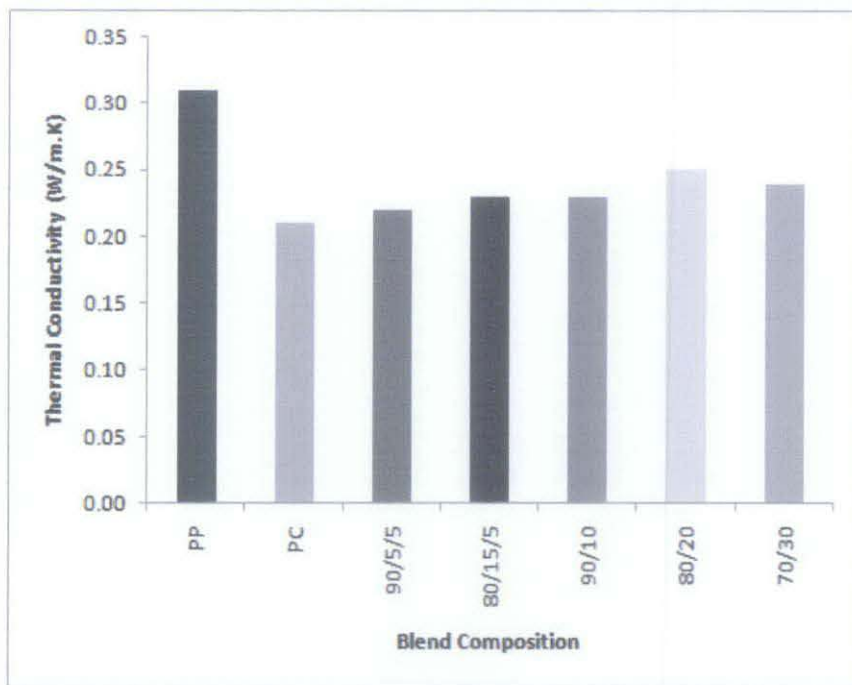


Figure 17: Thermal conductivity value of selected blends

4.6 Tensile strength analysis

Tensile strength is the stress at the maximum on the engineering stress-strain curve. Tensile strength of a material is its ability to withstand external forces without breaking. In brittle materials, the tensile strength will at the end of the linear-elastic portion of the stress-strain curve. In ductile materials, the tensile strength will be situated in the plastic portion of the stress-strain curve.

The results of the tensile test on the specimens are shown in Figure 18 and Figure 19. The values for tensile strength for blends with and without the compatibilizer are compared in Figure 20.

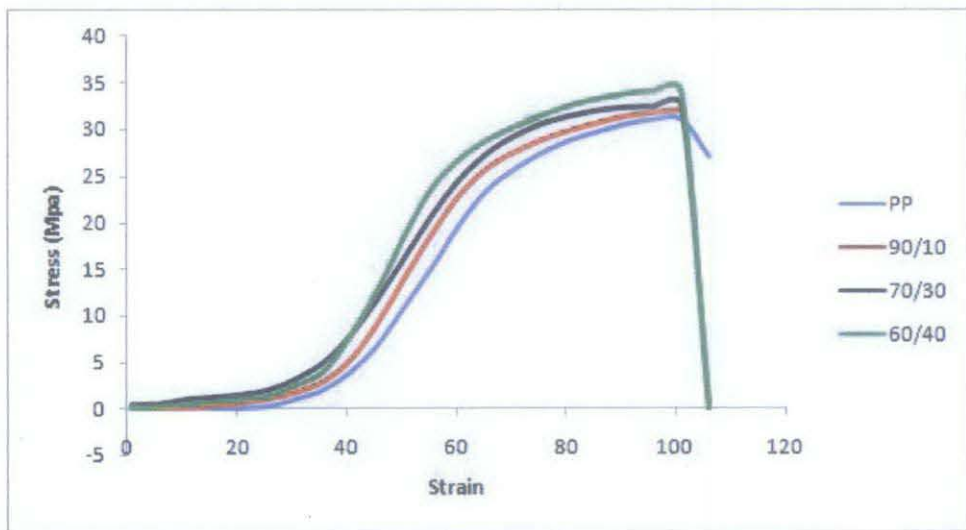


Figure 18: Stress Strain graph (PP/PC)

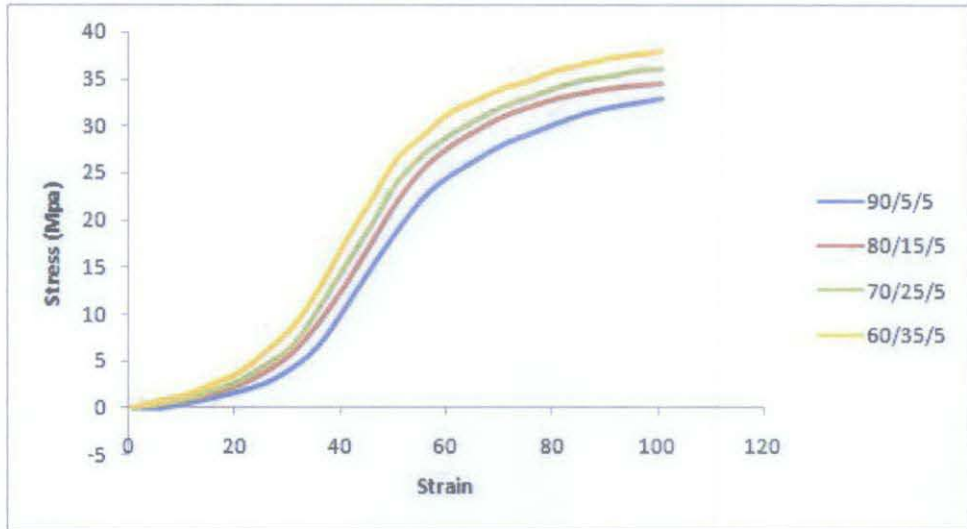


Figure 19: Stress strain graph (PP/PC/PP-g-MA)

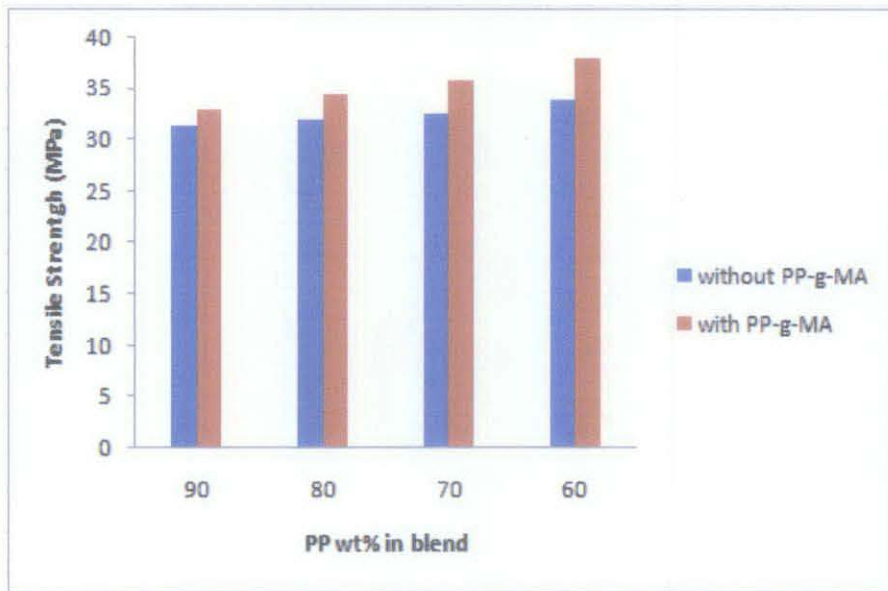


Figure 20: Tensile strength vs. PP wt% in blend

Both of the results are compared in bar graph. From the graph, it can be concluded that tensile strength of the blend is increased with the addition of 5 wt% of PP-g-MA. Tensile strength also increases with increasing of percentage of PC in the formulation. Thus, adding the PC to PP matrix will increase PP tensile strength.

CHAPTER 5

CONCLUSIONS

The study on thermal conductivity properties of PP/PC and PP/PC/PP-g-MA blends is important to determine the process parameter and capability of the blend in industry application. The parameters are crucial to produce high quality product and avoid degradation that cause various changes in the mechanical strength and will further affect the condition of material, and production process. The objective of this project is to study the effects of varying composition of PP/PC and PP/PC/PP-g-MA blends on thermal conductivity properties and mechanical properties in term of tensile strength behavior.

TGA and DSC analysis help us determine the properties of pure PP and PC and aid us in producing samples for the project. Tensile test is conducted to study the effect of varying composition of the blends with its mechanical properties. It can be concluded that tensile strength increase with higher polycarbonate (PC) contents in and addition of compatibilizer (PP-g-MA) in PP/PC/PP-g-MA blends.

Thermal conductivity test has been conducted on several selected blend composition which are pure PP, pure PC, 90/10 blend, 80/20 blend, 90/5/5 blend and 80/15/5 blend respectively. Adding PC to pure PP matrix will reduce the value of the PP thermal conductivity coefficient. It also can be concluded that adding compatibilizers to PP/PC blend will decrease the thermal conductivity coefficient.

There are still some rooms left for improvement for this study. In this study, the value of compatibilizers added is set at 5 wt% for each blend. For further study, we can take the approach to vary the amount of compatibilizer between 4 wt% to 8 wt%.

REFERENCES

- [1] M. Bilewicz, J. C. Viana, and L.A Dobrzanski, 2007, Self Reinforced Polymer-Polymer, *Journal of Achievement in Materials and Manufacturing Engineering*, Vol 24, Issue 2, 43-46

- [2] L.A. Dobrzanski, M. Bilewicz, J. C. Viana, and M. Krol, 2008, Microstructure and Mechanical Properties of Polypropylene/Polycarbonate Blends, *Journal of Achievement in Materials and Manufacturing Engineering*, Vol 27, Issue 1, 19-22

- [3] M. Gehrig et al., Determining the co-efficient of thermal conductivity according to a quasi-stationary method, *Journal German Plastics (Kunststoffe)*, 81 (1991) 30-32

- [4] B. Weidenfeller, M. Hofer, F. R. Schilling, 2004, Thermal conductivity, thermal diffusivity, and specific heat capacity of particle filled polypropylene, *Composites: Part A*, 35:423–429

- [5] Y. Agari, A. Ueda, Y. Omura, and S. Nagai, 1997, Thermal Diffusivity and Conductivity of PMMA/PC blends, *Polymer*, Vol. 38, No. 4, pp. 801-807

- [6] A. Dawson, M. Rides, J. Nottay, 2005, The effect of pressure on the thermal conductivity of polymer melts, National Physical Laboratory, Department of Engineering and Process Control, Teddington, Middlesex, TW11 0LW, UK

- [7] S. Chakravorty, C. Brown, Significance of Thermal Material Parameters in Polymer Processing, National Physical Laboratory, Teddington, Middlesex, TW11 0LW, NPL Report, DMM(A) 167, 1995

- [8] M. Hu, D. Yu, and J. Wei, 2007, Thermal Conductivity of Small Polymer Samples by Differential Scanning Calorimetry, *Polymer Testing* 26, pp 333-337
- [9] W. D. Callister, Material Science and Engineering: An Introduction, 7th edition, John Wiley & Sons (Asia) Pte Ltd, New York, 2007.
- [10] M. Chanda, and S. K. Roy, 2009, *Industrial Polymers, Specialty Polymers, and Their Application*, CRC Press, Taylor & Francis Group
- [11] M. Alauddin, I.A. Choudhury, M.A. El Baradie and M.S.J. Hashmi, 1995, Plastic and Their Machining: A Review, *Journal of Material Processing Technology*, Vol 56, 40-46
- [12] R. Asaletha, M. Kumaran, and S. Thomas, 1995, Effect of Casting Solvents and Compatibilizer Loading on the Morphology Properties of Natural Rubber/Polystyrene Blends, *Polymer Plastic Technology Engineering*, 34 : 633
- [13] N. Renaut, S. Duquesne, S. Zanardi, P. Bardollet, C. Steil, and R. Delobel, 2005, Fire Retardancy, Thermomechanical and Thermal Properties of PP/PC Blends, *Journal of Macromolecular Science, Part A: Pure and Applied Chemistry* 42: 977-991.
- [14] Y. Zhihui, Z. Xiaomin, Z. Yajie, and Y. Jinghua, 1997, Morphological, Thermal and Mechanical Properties of Polypropylene/Polycarbonate Blend, *Journal of Applied Polymer Science* 63:1857-1863
- [15] S. Chongprakobkit, M. Opaprakasit, and S. Chuayjulkit, 2007, Use of PP-g-MA Prepared by Solution Process as Compatibilizer in Polypropylene/Polyamide 6 Blends, *Journal of Metals, Materials and Minerals*, Vol.17, No. 1, pp. 9-16

- [16] C.Li, G.Tian, and Y.Zhang, 2002, Crystallization Behavior of Polypropylene/Polycarbonate blends, *Journal of Polymer Testing*, Vol. 21: 919-926.
- [17] ASTM Standards: E 1225-04, Standard Test Method for Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique.

NO	DETAIL	WEEK														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	Primary Research Work		■	■	■											
2	Submission of Preliminary Report				▲											
3	Project work (prepare specimens with screw extruder. Composition of PP/PC/PP-g-MA 90/5/5, 85/10/5, 75/20/5, and 65/30/5)									■	■					
4	Project work (thermal conductivity test)											■	■	■	■	■
5	Obtained melting & glass transition temperature.									■	■	■	■	■	■	■
6	Polymers will be mixed in extruder and fabricated by compression moulding									■	■	■				
7	Morphology of polymer being tested using SEM											■	■	■	■	■
8	Submission of Progress Report									▲						
9	Seminar (compulsory)									▲						
10	Submission of Interim Report Final Draft															▲
11	Oral Presentation(study week)															

MID-SEMESTER BREAK

NO	DETAIL	WEEK																
		1	2	3	4	5	6	7	MID-SEMESTER BREAK	8	9	10	11	12	13	14	15	
1	Literature Review																	
2	Project work (prepare specimens with screw extruder. Composition of PP/PC/PP-g-MA 90/5/5, 85/10/5, 75/20/5, and 65/30/5)																	
3	Project work (thermal conductivity test)																	
4	Project work (tensile test)																	
5	Project work (SEM analysis)																	
6	Submission of Progress Report																	
7	Pre-EDX																	
8	Submission of Draft Report																	
9	Submission of Dissertation (soft bound) and Technical Paper																	
10	Oral Presentation																	
11	Submission of Dissertation (hard bound)																	