UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PHYSICAL AND MECHANICAL PROPERTIES OF POLYPROPYLENE/RECLAIMED RUBBER COMPOUND

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Manufacturing Engineering Technology (Process and Technology) (Hons.)

by

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DECLARATION

I hereby, declared this report entitled "physical and mechanical properties of polypropylene/reclaimed rubber compound" is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Process) (Hons.). The member of the supervisory is as follow:

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En. Hairul Effendy Bin Ab Maulod

ABSTRAK

Perkembangan pesat industri getah menghasilkan lebih banyak sisa getah. Oleh kerana ciri-ciri bukan getah mesra alam, ia menyebabkan pencemaran alam sekitar yang serius. Oleh itu kitar semula getah sisa telah menjadi masalah yang semakin meningkat daripada strategi global. China adalah pengeluar produk getah terbesar di dunia dengan penggunaan tahunan 3,700,000 tan getah. Termoplastik menunjukkan kepentingannya dalam produk kejuruteraan. Daripada kedua-dua bahan permukaan patah bahan gagal untuk menentukan kaedah pembentukan retak dan lanjutan. Termoplastik (TPE) muncul kepentingannya dalam dalam produk kejuruteraan. Ia adalah gabungan bahan getah dan plasti. Daripada kedua-dua bahan, permukaan patah bahan gagal untuk menentukan kaedah pembentukan retak dan lanjutan. Polypropylene (PP) telah dipilih kerana mempunyai ciri-ciri yang istimewa. Untuk kajian ini, PP / RR kompaun akan menjalani beberapa ujian iaitu ujian mekanikal dan fizikal akan dilakukan oleh PP / RR kompaun. Hasilnya akan dibandingkan berdasarkan peratusan yang berbeza daripada PP dan kompaun RR dalam komposisinya. Terdapat untuk komposisi termasuk sampel kawalan. Terdapat 100PP / 0RR, 90PP / 10RR, 70PP / 30RR dan 50PP / 50 RR. Hasil kajian ini menunjukkan bahawa peningkatan kandungan getah, nilai sifat-sifat mekanik akan menjadi penurunan dan keanjalan kompaun akan meningkat.

ABSTRACT

The rapid development of rubber industry produces more and more waste rubber. Due to rubber's non-biodegradable characteristics, it causes serious environmental pollution. Thus waste rubber recycling has been an increasing problem of global strategy. China is the biggest rubber products consuming country in the world, the annual consumption of 3700000 tons of rubber. Reclaimed rubber will help to develop rubber product. Thermoplastic (TPEs) has emerged its importance in in engineering product. It is the combination of the rubber and plastic materials. From these two material, the fracture surface of failed material to determine the method of crack formation and extension. Polypropylene (PP) has been choosing due to its special characteristic. For this study, PP/RR compound will undergo several testing which are mechanical and physical testing will be done by PP/RR compound. The result will be compared based on the different percentage of the PP and RR compound in its composition. There are for composition including the control sample. There are 100PP/0RR, 90PP/10RR, 70PP/30RR and 50PP/50 RR. The result of this study shows that the increasing of the rubber content, the value of the mechanical properties will be decrease and the elasticity of the compound will be increase.

DEDICATIONS

This report is dedicated to Mr Hairul Effendy Bin Ab. Maulod for his supervision, advices, and guidance during my period of study. To my beloved family, friends and lecturers which have been the source of my inspiration to undergo this project to a success. Thank you for all the support and encouragement from the start until end.

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0	Degree
C	Celsius
MM	Millimetre
RR	Reclaimed Rubber
PP	Polypropylene

CHAPTER 1

INTRODUCTION

1.1 Introduction

In manufacturing industrial product, plastic is a general terms for a wide range of synthetic or semisynthetic organic amorphous solid materials. It is because of the it's malleability and plasticity during manufacturing process. The properties of the plastic also allow them to be cast, pressed, or extruded into an enormous variety of shapes. Most of the plastic contain polymer. The wide majority of these polymers are based on chains of carbon atom alone or with another element like oxygen, sulphur or nitrogen as well. The properties of the polymer are affected by its structural. It can be said because of the fine tuning repeating unit in the polymer itself. Most of the plastic that usually used in our daily life is not 100% plastic because it will have other organic or inorganic compound when blend in together. As the example is wrap food. For this product, the amount of the additive ranges is from zero percentage but for certain electronic the percent of its additive is more than 50%. However, the average content of the additive is 20% by weight of the polymer.

Besides that, plastic also famous with a low cost material and versatility material. The use of the plastic is rapidly increased and it is an enormous and expanding range of product like a paper clip to spaceship. Due to its properties, it can displace many traditional materials such as wood, stone, bone, glass and ceramic. The use of plastic is constrained primarily by their organic chemistry, which seriously limit their hardness, density and their ability to resist heat. In particular, most plastic will melt or decompose when heated to a few hundred degrees celsius. While plastics can be made electrical conductive to some extent, they still have not match for metal like cooper or aluminium.

A thermo softening plastic or a thermoplastic is a polymer that when heated turn into liquid or will turn into glass like when it is frozen. In general, thermoplastic usually have high molecular weight. Unlike Bakelite, this material is thermoset and once it hardened, it will stay that way. These polymers can be melted and remoulded, making them a great product for recycling.

In this study, polypropylene (PP) and reclaimed rubber (RR) will be blend in together in Haake internal mixer. By mixing these two material, it will form thermoplastic elastomer material (TPEs). The mechanical properties will be finding out in this research.

1.2 Problem Statement

The thermoplastic rubber is more commonly called as thermoplastic elastomer (TPEs). This class of material has properties for both of rubber and thermoplastic. The used of TPEs is increasingly due to the significant cost saving possible because their ability to be processed on plastic machinery. Conventional rubber, whether natural or synthetic, is a thermosetting material that must undergo a chemical cross-linking reaction during moulding extrusion, typically called curing or vulcanization. Due to this reaction, it is not general processable in standard thermoplastic equipment. The thermoplastic moulding and extrusion processes used for TPEs, on the other hand, avoid the cross-linking step and can achieve very fast cycle time, which can be as little as 20 second. In various rubber article formulation reclaimed is a product of discard rubber article it has gain much importance as additive. It is true that mechanical properties like tensile strength, modulus resilience and tear resistance are all reduce with the increasing amount or reclaim rubber in a fresh rubber formulation. But at the same time, the reclaim rubber provides many advantages if incorporated in fresh rubber. The increase in the awareness of waste management and environment related issues has led to substantial progress in the utilization of rubber waste. Recycling material back into its initial used often are more sustainable rather than finding new application.

1.3 Objective

The objective of this project:

1) To study the formulation of polypropylene/reclaimed rubber compound.
2) To prepare propylene/reclaimed rubber compound through melt compounding.
3) To determine polypropylene/reclaimed rubber compound physical and mechanical properties.

1.4 Scope

In this project, the material which is polypropylene and reclaimed rubber will be formed by blend with other material in mixing machine and go through with another process. The polypropylene and reclaimed rubber will be tested with the ability of the material to face the stress during its life.

1.5 Outline

This study has been organized into 5 chapters. Chapter 1 introduces the rationale of current study on alternative fuels. It discusses the challenges of current research have to undertake. The scope and objectives are also presented

Chapter 2 begins with the literature background of this study. It discusses on engineering rubber components in due to its widely use in manufacturing. Also discuss about olypropylene and reclaimed rubber.

Chapter 3 then present the methodology of the study conducted. Chapter 4 then continues with result and discussion of the study. Chapter 5 finally conclude and also future recommendation of this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explains about all findings obtained from many literature reviews, which may come from the internet, journals, article and books about the topic related to this study.

2.2 Polymer

Based on the new understanding polymer synthesis and the development of commercialization of economical manufacturing method for a range of monomers, most of the major commodity and engineering plastic in current use were being manufacturer in 1950's. Figure 2.1 illustrate difference of monomer and polymer. During the same period, polymer blending began to embellishment. It was gradually accepted that new economical monomer were less likely but a range of new material could be developed by combining different existing polymer. While most monomer are available cannot be co-polymerize to a product of intermediate properties, their polymer could be melting blended economically.

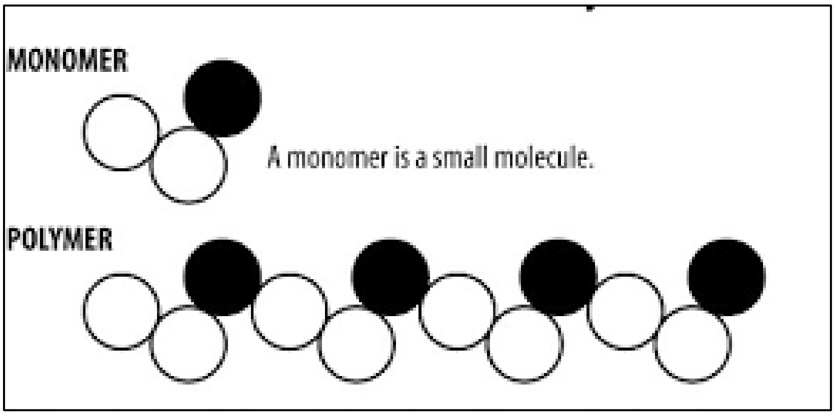

Figure 2.1: Structure of monomer and polymer

The physical properties of blends can be changed to satisfy a wide range of ratios. A desirable performance can be achieved by suitable selection of blend ingredient, followed by control of morphological by appropriate method of compatibility, compounding and processing. Blending process is known to improve the impact strength, mechanical properties, chemical and solvent resistance to enhance the process, abrasion resistance and flame retard. The improvement of the process is the most important criteria as the emphasis is shifting to high performance.

PP is the largest group of commodity by thermoplastic because of the ease of the process and the important thing is low cost. The main of the reason for its popularity is the development of blending technology for property modification. PP also known as a versatile polymer that continues to develop rapidly because of its superb performance and improvement in production economies. The blend this material has attracted much commercial interest. Other than that, the use of PP blend application can be found in automobile, appliance, house ware, furniture, sporting good and industrial component. The most of these manufacturing components process use injection moulded (Heikens 1973).

In polymer blends, properties like ductility and impact strength should be improved by compatibility. It is done by addition of block or graft copolymer with segment capable of interacting with blends constituents. These copolymers lower the interfacial tension and improve adhesion the matrix and dispersed phase (Dagli 1991; N.G.M. 1977). In contrast, there will there a lot of blend which are totally immiscible and incompatible when blended together. It is due to the difference in material characteristic in terms of molecular weight crystalline, and polarity. As a result, these incompatible blends will exhibit poor properties in physical and mechanical. These problems can be solved by the addition of compatibiliser or filler which is consist of modification of the interfacial properties of the blend phase by using a suitable which located at the interfacial between the phases of an immiscible blend and act as an emulsifying agent.

Based on the previous study, the use of PP has been set its limitation in terms of impact resistance at low temperature and poor environmental stress cracking resistance. These properties of the PP can be improved by incorporation with another material.

2.3 Thermoplastic Elastomer (TPEs)

A method to a high level of quality is offered by blending rubber powder with thermoplastic to form material similar to thermoplastic elastomer. TPEs having characteristic of elastomer while retaining process and recycling ability of thermoplastic have been a serious interest to scientists and manufacturer for many years (Karger-Kocsis J. 1999). Thermoplastic vulcanized (TPVs), blends obtained by dynamic vulcanization of rubber in the thermoplastic matrix are of particular interest (Dubinin S. 2008). Similar material can be prepared by replacing a part or total amount of the virgin rubber by ground waste rubber.

TPEs are defined as a group that exhibit instantaneous reversible deformation. Most of the TPEs consist of continuous phase that exhibits elastic behaviour and dispersed phase that represent the physical cross-link. If the dispersed phase is elastic then the polymer is a toughened thermoplastic, not an elastomer. Elastomer reversibility must have physical crosslink. Therefore, these crosslink must be reversible. Physical crosslink do not exist permanently and may disappear with the increase of the temperature. This blend property can be acquired through the presence of soft elastic segment that have extensibility and low glass transition temperature, Tg and therefore are subject to crosslinking. The low glass transition temperature will be maintained because of the rubber phase, while high glass transition temperature of thermoplastic could help in medical integrity. Knowledge of microscope morphology of the blends is important for predicting the macroscopic properties. Enthalpy of mixing, glass transition temperature, dynamic mechanical properties, scanning electron microscopy, transmission electron microscopy and atomic force microscopy that have been utilized extensively for understanding the morphology of these blends (S.S. Banerjee 2005; M. Maiti, A. Bandyopadhyay 2016).

One of the top advantage of TPE is they allow the rubber to be produced by a quick processing technique as thermoplastic industries. The physical properties of rubber that can get from the TPE are as softness, flexibility and resilience (Nakason, C., Worlee, A., and Salaeh 2008; Bhowmick, A., and Stephens 1998).

A thermoplastic elastomer has all the same feature as described for an elastomer except that chemical crosslinking is replaced by a network of physical crosslinks. The ability to form physical crosslink is opposite to the chemical and structural requirement of an elastomer. The thermoplastic elastomer must be two phase materials and each molecule must consist of two opposite type of structural, one of the elastomeric part and the second the restraining and physical crosslinking part. Thermoplastic elastomer are typically blocked copolymers. The elastic block should have high molar mass and possess the other entire characteristic required of an elastomer. The restraining block should resist viscous flow and creep.

Thermoplastic elastomer are technologically very attractive because they can be processed as thermoplastic, this is their main advantage compared with crosslink elastomer. They can be remelted or devitrified and shape again. Hence, they are generally processed by extrusion and injection moulding, which the common are processing method used by thermoplastic. The advantage is the TPE has an operating temperature below that at which the hard phase become dimensionally unstable. Several factor need to be taken into account during the processing of TPEs, including viscosity or rheology of the two phase polymer, temperature and thermal stability since the complex structure will have potential to have a several weak chemical links (Kong 2008).

2.4 Thermoplastic

Thermoplastic are also known as thermo softening plastic because they become malleable when heated. Although they flexible above a certain heat threshold, they return to a solid once they have been sufficiently cooled. This is a contrast to most other type of plastic, which are unable to return to a solid state after they have heated beyond a certain point. For this reason, thermoplastic are put to unique uses in a rubber of manufacturing and engineering industries. Apart from their primary characteristic, thermoplastic vary slightly in usage and properties. For example, PP is a hard, water resistance thermoplastic. This is make an excellent choice for creating toy models and for packaging that will not be exposed to extreme heat source in transit.

The polymer polyethylene, polypropylene, polybutylene, polystyrene and polymethylpentene are made up of only carbon and hydrogen items. Polyvinyl chloride has carbon and chlorine as its backbone. Linear polymer that lack specific order or are amorphous are arranged in a similar fashion to the way that spaghetti noodles look on a plate. These polymers have an amorphous arrangement of molecules, which means that there is no long range order to form that the polymer chain arrange themselves in. amorphous polymer also typically transparent. Common amorphous polymers are suitable to make food wrap, plastic window, contact lens and headlight lenses.

Scientists and engineer often manipulate the molecules structure of the polymer in order to produced more useful materials. By manipulating the molecular structure, scientist and engineer can create different product possibilities. Common molecular structure manipulation includes introducing filler, reinforcement and additive. Most of the polymer that is manufactured is thermoplastic, which means that once the polymer has formed it can be reformed repeatedly through reheating technique. These are the advantages and disadvantages of the thermoplastic.

Advantages of the thermoplastic:

1) The softening or melting by heating allows welding the thermoforming.
2) The process cycles are very short because of the absence of the chemical reaction of crosslinking.
3) The processing is easier to monitor because there is only a physical transformation
4) TPEs do not release gasses or water vapour if they are correctly dried before processing.

Disadvantages of the thermoplastic:

1) When the temperature rise, the modulus retention decrease due to the absence of chemical link between molecules.

2) The creep and relaxation behaviour are not so good as for the thermosets.

3) During a fire, fusibility favours dripping and annihilate final residual physical cohesion.

2.5 Polypropylene

PP also known as polypropene is a semi-crystalline polymer that is widely used due to its unique combination of properties, cost and ease of fabrication. All grades consist of polymer, a neutralizer and antioxidant. There are other additive like clarifiers nucleates, additive, silica, talc and calcium carbonate area added to impact specific functionality. The polymer may be a pure homo-polymer made by polymerizing propylene and another monomer or an impact copolymer made by dispersing rubber in polypropylene matrix (Plastics 2006).

It is the plastic with the lowest specific weight (0.9 g/cm^3), which means that a smaller amount is needed to obtain a finished product. There are four main group of plastic that can be categorized which are thermoplastics, thermosets, elastomers and polymer compounds. Macromolecular structures distinguish the class of any plastic material as well as its physical properties. Elastomer and thermoset have similar properties which are having soft and hard elasticity respectively and their product cannot be recycled. Once these materials are melting by heating process, it cannot be reheated. It is because the polymer chain cross-link together during the curing process to form an irreversible chemical bond. The cross-linking process eliminates the risk of the product remelt when heat is applied, making thermosets ideal for high-heat applications such as electronics and appliances. However, thermoplastic are either amorphous or semi crystalline. Amorphous resin are disorder statistical oriented macromolecules whereas semi-crystalline resin macromolecules are nearly ordered since they are embedded with crystalline phase. Typical amorphous are polycarbonate (PC), polystyrene (PS) and polyvinylchloride (PVC) where typical semi crystalline resin includes polyamide (PA) and PP. since PP is under the semi-crystalline class, the focus will be on the group (Klein 2011).

The PP gained a strong popularity very quickly due to the fact that PP has the lowest density among commodity plastic since 1954. PP has an excellent chemical resistance and can be processes through many converting method such as injection moulding and extrusion. PP is a polymer prepared catalytically from propylene. It is major advantages related to the high temperature resistance which make PP particularly suitable for items such a trays, funnels, pails, bottles, carboy and instrument jar that have to be sterilized or clean frequently for use in a clinical environment. PP is a free colour material with excellent mechanical properties and it is better than polyethylene for the previous reason (Dynalon 2011). Figure 2.3 shows the connection with type of the thermoplastic that widely use. It is rough and resistance to other chemical. PP is also tough but flexible. This make the material to be used easily for chemical and plastic engineering experiments because the tough and flexibility properties.

It is also economical because it can be reused. The fabric that is made is tough and durable so that it can be reuse in different form after being manufacturer. PP fabric can be translucent, but because of it does not fade easily, most people use PP as coloured fabric. So, the fabric can be dyed and will not fade easily (Penny Fleaming 2010).

Besides, PP is a downstream petrochemical product that is derived from the olefin monomer propylene. The polymer is produced through a process of monomer connection called addition polymerization. In this process, heat, high energy radiation and an initiator or a catalyst are added to combine monomers together. Thus, PP molecules are polymerized into very long polymer molecules or chain.

There are four different routes to enhance the polymerization of any polymer.

1) Solution polymerization
2) Suspension polymerization
3) Bulk polymerization
4) Gas-phase polymerization

However, PP properties are vary according to process conditions, copolymer component, molecular weight and molecular weight distribution. PP is a vinyl polymer in which every carbon atom is attached to a methyl group.

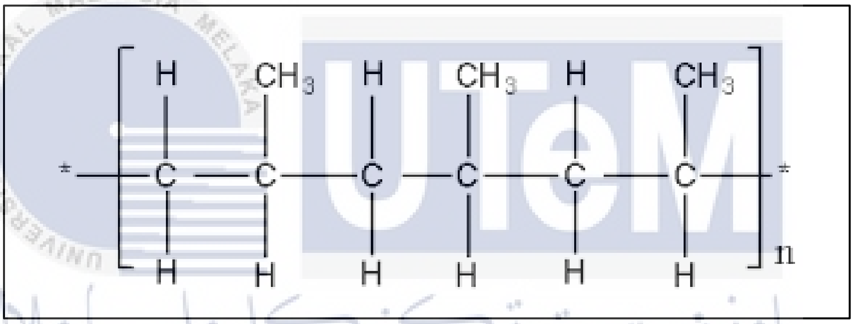

Figure 2.2: Polypropylene structural

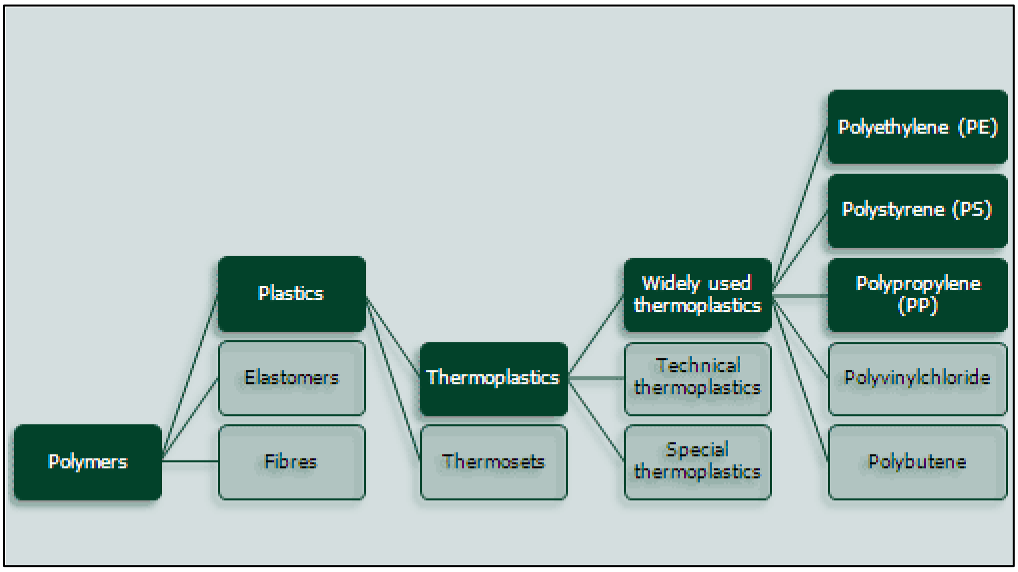

Figure 2.3: Connection of PP with type of thermoplastic that widely used

2.6 Properties and Characteristic of Polypropylene

Characteristic of PP makes it ideal for tough, robust product ranging from protective car bumpers for life saving medical tools to cold weather gear for our soldier. Plus it also can be engineered into a wide range of packaging that helps protect product we rely on every day, from medicine to yogurt for baby food. This is due to it has high melting point, so it can used for many microwave containers. This material also not reacts with water, detergent, acid or base. So it would not break easily. The last is it has quite durable properties to withstand daily wear and tear.

Speaking of recycling, like many other thermoplastics, polypropylene can be melted and reformed into plastic pellets that then are used to make new products. In fact, polypropylene bottles and containers are collected for recycling in most curbside programs across the country. Recycling polypropylene helps keep this superhero out of landfills to live another life as colanders, food storage containers, cutting boards, outdoor rugs, car parts and more.

So, polypropylene is used in nearly every plastics market, from protective packaging to medical equipment. It's tough. It's durable. It's being recycled from cars and households around the country.

2.7 Reclaimed Rubber

Reclaimed Rubber is vulcanized rubber that has been cured chemically and physically in order to re-enable it to have the same plasticity and adhesive ability as natural rubber. At present, because of its better aging and wear and tear resistance and its superior workability efficiency, reclaimed rubber is considered an excellent rubber ingredient with a very favorable evaluation that has led to its widespread use (Daiei Rubber Co. 2013).

Figure 2.4: Reclaimed rubber

On the other words, reclaimed rubber as shown in figure 2.7 is one of the recycle rubbers. Thermo- Chemical process is the process which is this rubber has been through the process for softening and swells. With shortening the polymer chain by mechanical shear and chemical action, the viscosity of the reclaimed rubber is reduced. The first process to form reclaimed rubber is “Pan Process”. This process has been introduced since 1858. Nowadays, there are many different methods to form the reclaimed rubber.

2.7.1 Reclaimed Rubber Issue

In industrial, the big issue that the company needs to be face is about waste management. However it is widely taken up with constant demand for recycling. Based on these demands, the recycle home appliance as show in figure 2.8, recycle home is seem can be a main function due to the recycling plastic and rubber product. It looks more interesting cause of its little attention paid to the recycling rubber. Among the existing technology, there is several ways to recycle the rubber. Most of the famous treatment need to reuse and recycling route of waste tires must be feasible, environmental and sustainable approach (Zhuang et al. 2016). However, in a reality live, recycle rubber is the desired when it comes to recycle product.

Lately, the environmental issues or problems that related to the waste disposal management have been in the interest. In such a situation that in order to reduce the amount of unwanted material, many products can be recycle. The products that can be recycle such as aluminium can, plastic bottle and paper. All of these products are famous in terms of recycling. With the same technique, the rubber also can be recycle rather than make the same with original product or something different. For tires and the other crude rubber have been recycle for many years now and even synthetic rubber will be recycle in the future. Basically, synthetic rubber is an oil product and its disposal has adverse effects on the environment. Also, as it is a limited underground resource, it is essential to recycle it in order to prevent it being exhausted and also to protect the environment.

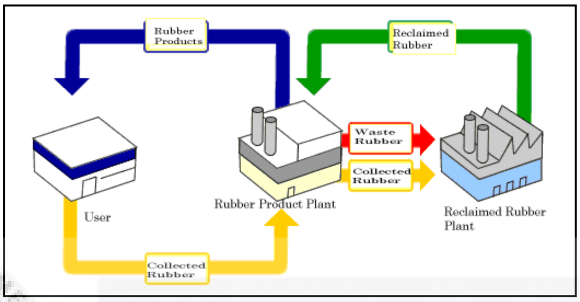

Figure 2.5: Recycle home of rubber product

2.7.2 Type of Reclaimed Rubber

Reclaimed rubber produced from the vulcanization process of rubber scrap and waste rubber. Reclaiming of rubber is a general process which involves conversion of a crosslinked, thermoset polymer to be a partially thermoplastic, ease of process and vulcanized product that possessing many of the properties of virgin rubber (Debapriya 2000). It also can be declare as the product resulting from the treatment of the ground vulcanized scrap tires, tube and miscellaneous waste rubber. The regenerated rubber has almost the original plasticity, permitting the same to be compounded, processed and re-vulcanized.

Even the molecular weight of the elastomeric component is substantially reduce during the reclamation, the chemical unsaturation of finished reclaim is essentially unchanged from that of the original vulcanized scrap. Table 2.1 shows the type of reclaimed rubber and its standard.

Table 2.1**:** Type of reclaimed rubber and its standard

Properties	Superfine-HR Reclaim Rubber	Fine-111 Reclaim Rubber	Medium-202 Reclaim Rubber	Coarse-303 Reclaim Rubber
Ash (%)	7±2	7±2	7±2	7±2
Carbon Black (%)	27±3	27±3	27±3	27±3
Specific Gravity (%)	1140±20	1140±20	1140±20	1140±20
Tensile Strength (Mpa)	40	40	35	25
Elongation Break (%)	240	220	200	180
Hardness (Shore A)	59±3	59±3	59±3	59±3
Mooney Viscosity at 100 o C	25-45	25-45	25-45	25-55

2.7.3 Properties and Characteristic

Cure characteristics and mechanical properties of natural rubber/reclaimed rubber blends were studied. The minimum torque values of the blends were lower than that of the gum compound. The (maximum–minimum torque) and scorch time decreased with increasing reclaim content. The cure rate of the blends was lower than that of the virgin compounds. The tear strength was improved by the addition of reclaimed rubber. The use of ground tire rubber in the preparation of thermoplastic/elastomer blends can provide new product at a lower cost (Hassan 2015). Tensile strength, elongation at break, and resilience decreased with increasing reclaim loading. The heat build-up was higher for the blends (Sreeja & Kutty 2010). Figure 2.4 show the difference of the reclaimed rubber and natural rubber in terms of stress-strain curve.

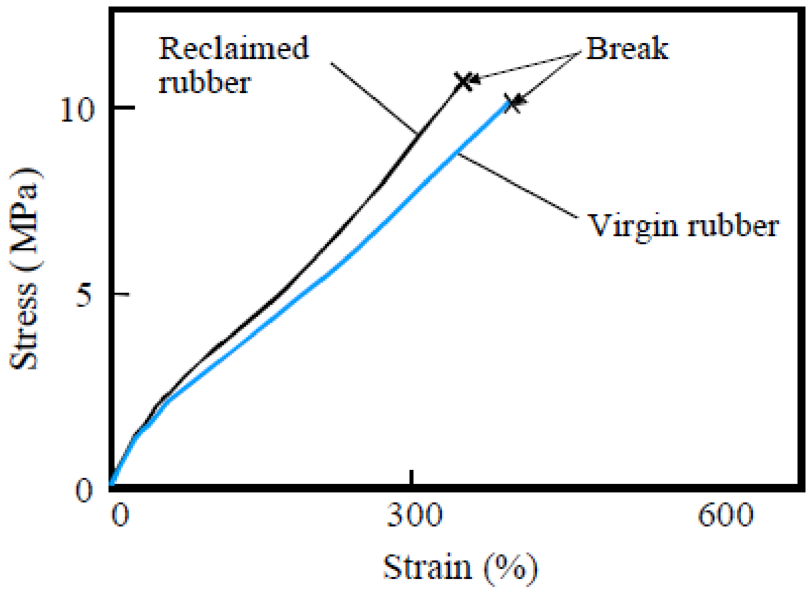

Figure 2.6: Stress-strain curves of crosslinked rubbers (Kenzo, F., and Matsushita, M. 1958)

The reclaimed rubber has low power consumption during breakdown and mixing. During manufacture, reclaimed rubber has already been thoroughly plasticized so that it breaks down and mixes more quickly than the virgin rubber. It also has Low mixing, calendaring and extrusion temperature with non-critical calendaring temperature range. The reclaim is less nervy than virgin rubber and hence builds up less internal heat in the calendar bank, imparting more process safety. However, these reclaimed rubbers can improve the tackiness and can hold the same over a broader range of temperature. By adding reclaimed rubber in the composition, it can increase the tensile strength (Sreeja & Kutty 2010).

2.7.4 Application of Reclaimed Rubber

Generally, there are 3 main reasons to use a reclaimed rubber. First is the source of rubber hydrocarbon. Second, the source of carbon black and lastly is processing aid. The example products that use reclaimed rubber in their product are tire, butyl, natural tube, drab and shoe soling. Other than that, reclaimed rubber also used as cushioning in parks and schools especially, so that if children fall, they are not hurt much. The other application is in sport shoes, working shoes and raincoats in clothing industries as shown in figure 2.9. Rubber along with other strengthening material is used in making sidewalk panels which are more resistant to be damaged by roots and also serve as a more comfortable pavement.it is generally use in landfills as a protective covering.

Figure 2.7: Application of reclaimed rubber

2.7.5 Advantages of Reclaimed Rubber

Reclaimed rubber is a highly intense product that is made with the use of waste rubber products of different kinds. All waste rubber items are collected and then processed under high temperature conditions and with the use of powerful chemical products they are able to provide people with high quality material, known as reclaimed rubber. This form of rubber is as efficient as original rubber material as it holds all great properties that are possessed by normal rubber. Even the cost of this material is very low and for this reason, it is exceedingly used as a raw material by manufacturers for producing different sorts of materials. This rubber offers great advantages to manufacturers and for this reason; it is extensively used in making all other products (Shijiazhuang 2012). There are other advantages of recycle rubber:

1) Recovered rubber can cost half that of natural or synthetic rubber.
2) Recovered rubber has some properties that are better than those of virgin rubber.
3) Producing rubber from reclaim requires less energy in the total production process than does virgin material.
4) It is an excellent way to dispose of unwanted rubber products, which is often difficult.
5) It conserves non-renewable petroleum products, which are used to produce synthetic rubbers.
6) Recycling activities can generate work in developing countries.

Advantages in terms of the manufacturing process:

1) It has low power consumption rate.
2) Its non-critical temperature range of the calendaring.
3) Enhance the thickness.
4) It holds the excellent cross linkages capabilities.

2.7.6 The Important of Reclaimed Rubber

Recycling rubber is an excellent way to dispose of scrap tires and other unwanted rubber products. It conserves non-renewable petroleum resources and can be manufactured into many other useful products. By increasing the recycled rubber use, harmful environmental pollution can be reduced. The several important of reclaimed rubber are:

I. **The number of unused tires in this atmosphere is increase**

All of us know that tires are made of rubber and these pose a big threat to nature if it is not disposed of properly. Even, just dumping these tires in any dumpsites or free space could contaminate nearby water sources. Those, who decide to burn these rubbers, are making the worst decision. Chemical substances, like carbon and lead, which are really dangerous for humans heat will generate with normal heat heating rubber. Dealing with rubber properly is not only advantageous to nature, but also to humans (Gera 2013).

II. Heating rubber in extreme pressure

It is really a good thing that some companies have discovered that. First, the steel and polyester strings of the tires are removed. The reclaimed rubber that can be used for manufacturing different products or materials after the heating process is over. There are a lot of industrial uses of this recycled rubber and some of these are for carpets, roadways, mulch and flooring. It can also be good for products that are usually seen at home, like decorative items, baskets, and doormats. This just proves that there are still a lot of uses of the recycled rubber (Gera 2013).

III. Cheap

When it comes to industrial uses, this reclaimed rubber is a lot cheaper than the virgin rubber. Also, it has good properties that are not present in the virgin rubber, thus, making it really good for products, like flooring. This is the reason why rubber floorings are really durable and are usually used by a lot of establishments today, like day care centres, gym and health centres. Also all of us know, it consumes a lot of power to produce virgin rubber, which is not good for our power sources (Gera 2013).

IV. Clean the environment

Since there are some important of recycling rubber, it would be the right time do something to support the industry of reclaimed rubber.

The first thing that can be done is simply bring any unused tires from home to companies or factories that recycle rubber. By this way, not only the environment that gets the benefits, the participant also can earn some extra bucks. As much as possible, people need to make sure that there is something that has been done to help to save the environment. This is not a concern of only a few, but a concern of everyone (Gera 2013).

V. Durable and high quality

The community should support the reclaimed rubber industry by purchasing the products made from recycled rubber. Aside from being useful, these are also very much durable and of high quality, as compared to other same products available in the market. So, before buy anything from the market, check first if the products are looking for is available in reclaim rubber material. These small efforts that everyone would do could surely make a significant effect on our pursuit address some problems of our environment (Gera 2013).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The aim of this practical work is to study the physical and mechanical properties of the thermoplastic elastomer components. This chapter will introduce the methodology of this study. The process flow for this study will be following the process flow and the Gantt chart. In order to achieve the objectives that have been determined, the project should follow the guidelines to ensure that the efforts poured into completing this project does not stray from the objectives.

3.2 Preparation

3.2.1 Polypropylene

Polypropylene (PP) is used as a main matrix phase in the blend formulation. The PP used in the composites was in the granule form as shown in the following figure 3.1.

Figure 3.1: Polypropylene

3.2.2 Reclaimed Rubber

Reclaim rubber is vulcanized rubber products already or a rubber manufactured from waste or scrap of tires, shoes, tubes and rubber gloves and then reuse through the reclaim process by the molecules of rubber are linked. It decomposed into small molecules that can be mixed with reclaim rubber chemicals will be vulcanized rubber again.

Figure 3.2: Reclaimed Rubber

3.3 Raw Material Preparation

3.3.1 Internal Mixer

The compounding process was performed using a Haake internal mixer figure 3.3 working at 180ºC and a rotor speed of 60 rpm. Firstly, the components were weighted to desire compound composition ratio of polypropylene, reclaimed rubber, zinc oxide, stearic acid and sulphur for a specific formulation. Figure 3.4 and table 3.1 shows the preparations of raw materials of the compound.

Figure 3.3: Internal Mixer

Table 3.1: Polypropylene and Reclaimed Rubber Formulation (phr)

Ingredients	Composition (phr)			
	Control-sample	**Sample-1**	**Sample-2**	**Sample-3**
Polypropylene	100	90	70	30
Reclaimed rubber	0	10	30	70
Zinc Oxide	5.0	5.0	5.0	5.0
Stearic acid	2.5	2.5	2.5	2.5

Sulphur	2.0	2.0	2.0	2.0

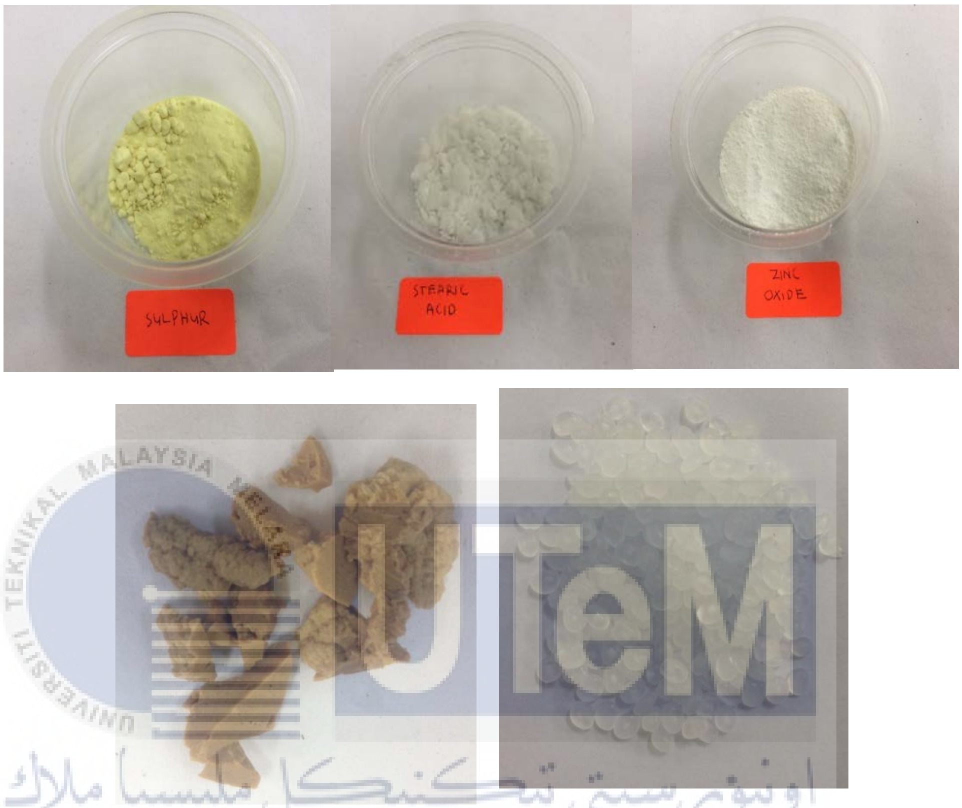

Figure3.4: Material Preparation

3.3.2 Hot Press Moulding

The hydraulic hot moulding machine is switch on and the temperature was set to 180ºc. Then, the material was moulded using hot press for 4 minutes at the temperature of 180ºc for the pre heat. For this process, the mould sizes 200mm x 200mm x 3mm are used.

Then the mould was inserting into the first slot to compress the sample for 10, 11 and 12 minute for each of increasing recycle rubber at the pressure meter of 110psi. Then the cooling time for after hot press is 3 minutes.

Figure 3.5: Hot press machine

3.4 Mechanical Testing

To test for this characteristic the materials are tested in tension, compression, adhesion and impact to determine the elastic modulus, the tensile and compressive strength, the elongation or reduction of area at break, how it will respond to shock forces and the adhesion force between the elastomer and reinforcing material. These characteristics define the expected limits of the material samples tested, which gives a depiction of how the rubber or elastomer will behave under stress.

3.4.1 Tensile Testing

Tensile test is important in order to determine the Modulus of Elasticity which is used to figure out the load carrying ability and the amount of sample deformation before it fracture. Tensile properties elastomer was determined according to ASTM. The standard specification of sample dimension for this test is depicted in the following figure 3.6. For the purpose of statistical reliability, average result of 5 is tested samples will be evaluated.

Figure 3.6: Tensile machine (Instron 5669)

3.4.2 Hardness Test

The shore hardness measures the hardness of the semi-rigid plastics and soft and flexible material can also be measured on the high end of the shore durometer. The hardness value is determined by the penetration of the durometer indenter foot into the sample. Because of the resilience of rubbers and plastics, the indentation reading may change over time. The shore measures hardness in terms of the elasticity of the compounding of PP and RR. Type D shore durometer will be used in this study, show in figure 3.7.

For the hardness test, the thickness of the specimen is 3 mm. For each specimen, there were five minimum different test points on that specimen. The distance between the test points was 6mm and from each edge, the distance must more than 12mm. After 15 second the indicator touch the specimen, the reading of the hardness test was taken.

Figure 3.7: Pointer Shore Durometer

3.4.3 Impact Test

Impact test is to determine the izod pendulum impact resistance of plastic. According to ASTM D256, the size of the specimen is 64.0 mm x 13 mm. Impact Strength (J/m²) value was determined by using Izod impact test. The notched specimens were mounted vertically on a sample holder and break by the pendulum swing as in figure 3.8. The value of impact strength was taking by the average of the five specimens.

Impact tests are designed to measure the resistance to failure of a material to a suddenly applied force such as collision, falling object or instantaneous blow. The test measures the impact energy or the energy absorbed prior to fracture. When the striker impacts the specimen, the specimen will absorb energy until it yields. At this point, the specimen will begin to undergo plastic deformation at the notch. The test specimen continues to absorb energy and work harden at the plastic zone at the notch. When the specimen can absorb no more energy, fracture occurs.

Figure 3.8: Impact Test

3.5 Physical Testing

3.5.1 Density Measurement

The density measurement of PP/RR was performed by using the electronic densimeter model MD-300S as shown in the Figure 3.9. The process was repeatedly done for five times on the different sample of PP/RR. The reading was taken and the total of the average density value of the material was recorded.

Figure 3.9: Densimeter (MD-300S)

3.5.2 Swelling Test

Swelling was an important testing for the compositions containing major proportions of rubber. The swelling of thermoplastic vulcanizes in immersion fluids is constrained. The amount of swelling is less than the average swelling of the rubber and plastic. The constraint in swelling increases with the difference between the swelling of vulcanized rubber and that of the plastic. Swelling and water absorption has the same process that needs to immerse in a solution for the specific period. It can verify by the percentage of the thickness for RR content in this study this.

According to ISO 1817, the dimension of the specimen for swelling test is 20 mm x 20mm x 2mm. The specimen was immersion in a toluene (figure 3.10) for 72 hours at room temperature. The weight of the specimen was taken before and after immersion in the toluene by using electrical balance. The specimen will immerse in toluene at room temperature. The swelling percentage (%) was calculating using equation 3.1.

$$\frac{t2-t1}{t2} \text{ X } 100 \text{ ………………………………….eq.3.1}$$

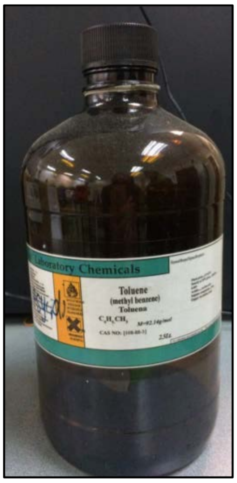

Figure 3.10: Toluene solution

3.6 Analysis

3.6.1 Optical Microscope

Optical microscope (figure 3.12) is an optical instrument that uses the lens and combination of lens to produce the magnified images that are too small to seen by unaided eye. Optical microscope can be used for imaging surface features at 5 to 1000x magnification features. The sample with dimension of 20mm x 20mm x 10mm was placed under microscope slide to see the size of foam of the sample. The light sources was switched on, the brightness of the light are adjusted by using the rheostat. The diaphragm will adjusted to get the best lighting. Optical microscope is used to see the size and morphological of the PP and RR compound (Hakimi 2014).

Figure 3.12: Optical Microscope

3.7 Flow Chart

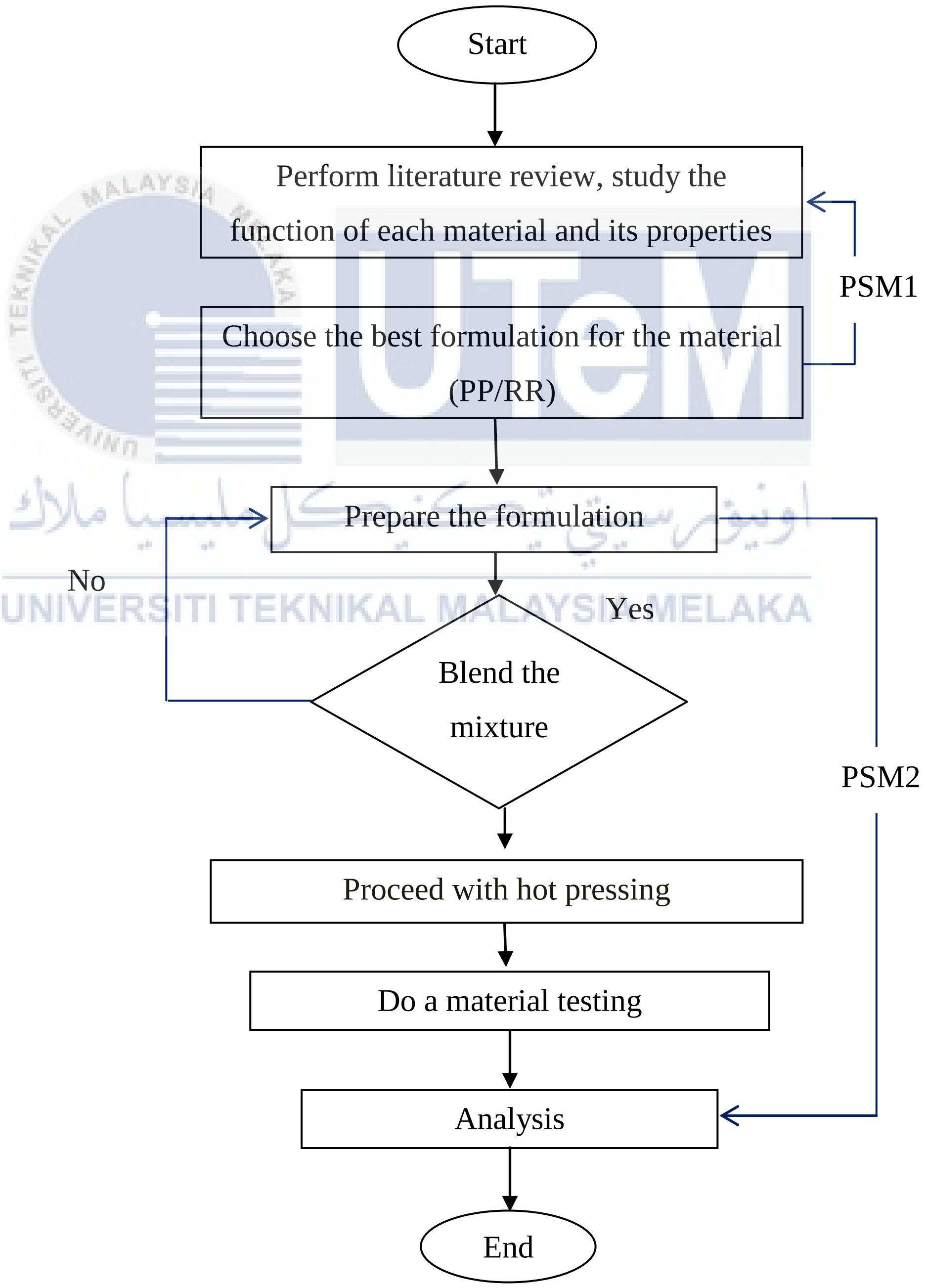

Figure 3.13: Flow chart of the process

3.8 Gantt Chart

Table 3.2: Gantt chart of the Project

Project Activity	2016														
	WEEK (semester 6)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Problem statement, objective and scope identification	BP Briefing							Mid Term Break							
Data collections(book, journals)															
Report writing- PSM 1															
Report review 1															
PSM 1 report submission															
Presentation- PSM 1															
Study Week															
Final Semester Examination															
Semester Break															

Project Activity	2016					2017									
	WEEK (semester 7)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Report review 2								Mid Term Break							
Findings															
Data analysis															
Report writing- PSM 2															
PSM 2 report submission															
Slide preparation															

Presentation- PSM 2															
Study Week															
Final Semester Examination															

Actual Planning

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

All of the experimental result that has been carried out within a period of study will be discuss in this chapter. Each of the results were obtain and discussions in the sequence of methodology.

4.2 Processibility of Material

In order to mix the PP and RR, the internal mixer has been used. The mixing process was done as to obtain the homogenous blending of PP and RR for 8 minutes. In the first two minutes of compounding, only the PP is blended into the internal mixer. This process to allow the PP melts first before combining with the other materials.

After that, RR was added into the internal mixer. Then, follow by zinc oxide and stearic acid. One minute before the compounding process finish, sulphur was added. The temperature was set to 180°C and the rotor speed at 80 rpm.

4.3 Mechanical Testing

A mechanical test shows whether a material or part is suitable for its intended application by measuring properties. This study was focus on tensile, hardness, impact and swelling. Further explanation and discussion on the obtained experimental results were discussed comprehensively in the following sections.

4.3.1 Tensile Test

A simple tension test provides valuable information about stiffness, strength, toughness and ductility of a material (Fatemi 2016). Table 4.1 shows the average value that comes out from the tensile testing. The tensile modulus is the ratio of stress to elastic strain in tension. A high tensile modulus means that the material is rigid - more stress is required to produce a given amount of strain. Based on the previous study, the value of the Young's modulus was in range 1300 to 1800 MPa. It means that when the sample has a high tensile modulus, the elongation of the sample also high. Tensile strength measures the ability of the material to sustain maximum stress before the material undergoes plastic deformation (Karger-Kocsis J. 1999). According to this result, the value of the virgin PP was 1422.485 MPa. That's mean this virgin PP has gone through the complete melting and good processing which successfully meet the standard mechanical properties of PP as in common literature. In comparison, at low rubber content than the elastomer phases remained as dispersed bodies in polypropylene matrices. As rubber phase increases, it increased the particle-particle interaction of the rubber phases, hence results in occlusion and accounts for the decrease in tensile strength. The effect of the recycle rubber in this study can make the tensile strength decrease. When the specimen can absorb high load, it shows that the specimen will have high young's modulus. It can be proved by comparing all of these four different compositions. Figure 4.1 show the dog bone shape for this test. In this test, not all of the specimen break at the middle of the dog bone. However, the result still accepted because the break area still in range.

Based on the graph 4.1, it shows the time taken for the tensile test to break. The time taken for the tensile specimen break was increase due to the increase of the rubber content. The time taken for the 50% RR was 79.9s, while the time taken for the virgin rubber was 40.73s. The elasticity of the samples was increase because of the rubber content. It means the rubber content that has in the specimen gave effect to the properties of the PP.

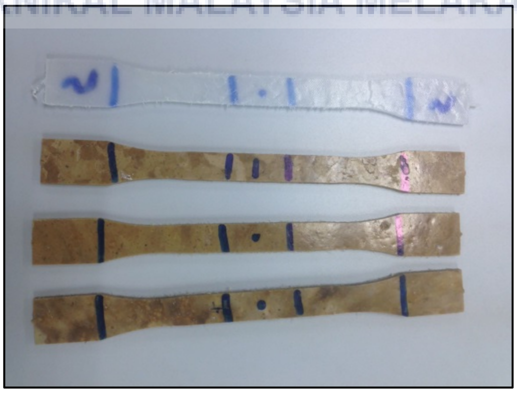

Figure 4.1: Dog bone specimen for tensile test

Table 4.1: Average value for the tensile test

Composition PP/RR	Max Load [N]	Modulus (Automatic Young's) [MPa]	Ultimate Tensile Strength [MPa]
100/0	560.56	1422.485	14.373
90/10	427.97	1181.097	10.974
70/30	329.49	785.546	8.448
50/50	172.47	368.723	4.421

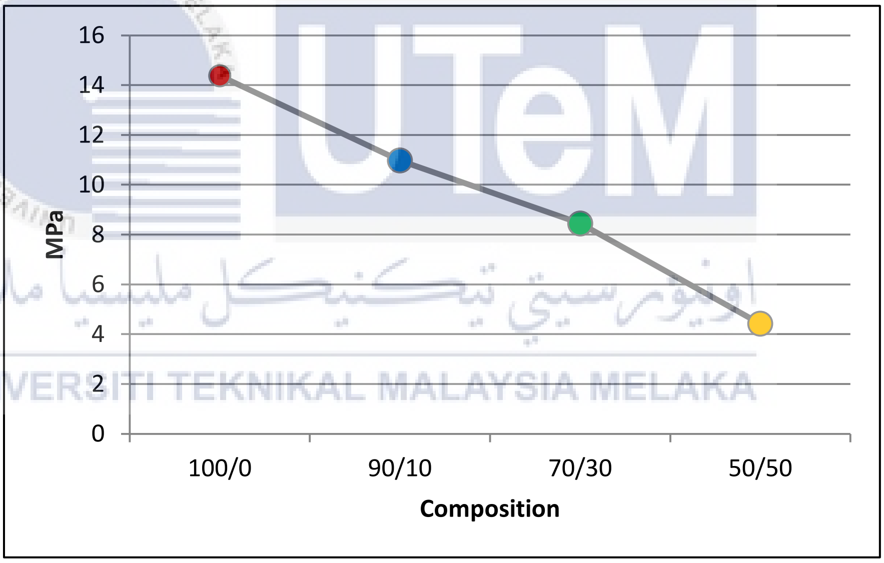

Figure 4.2: Ultimate tensile strength versus RR content in PP/RR blend

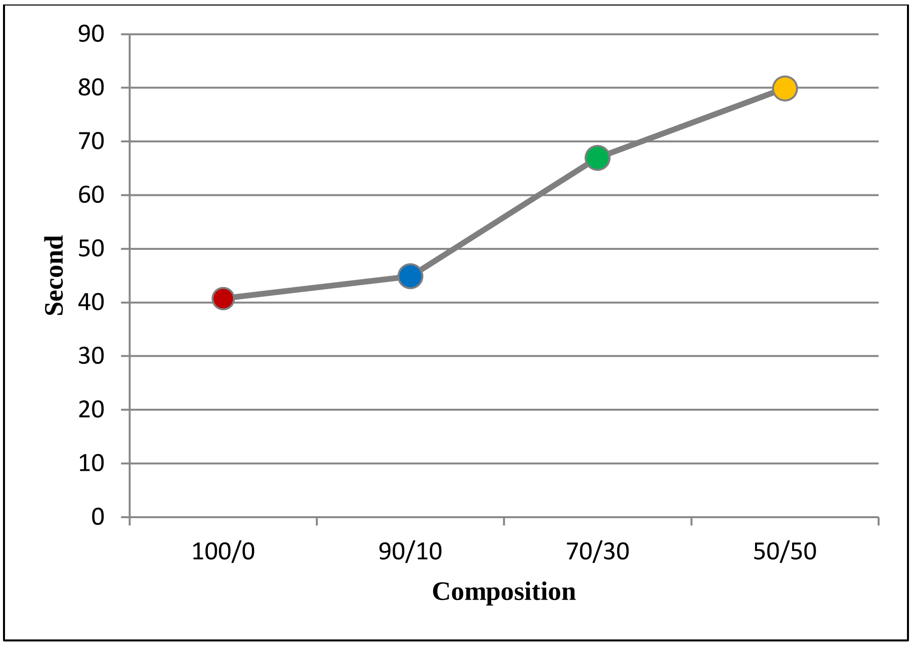

Figure 4.3: Time taken for the tensile break versus RR content in PP/RR blend

4.3.2 Hardness Test

Based on the table 4.2 the result shows the value of the hardness using shore durometer Type D. It was a pin shore durometer. However, the hardness of PP with 10% RR increase compare to the virgin PP. the increasing of the hardness value from 63.13 to 66.80 is 5.76%. When the percentage of the RR increased, the hardness of the material will decrease. Addition 50% RR in the composition shows the lowest value of the hardness.

In short, by make observation on the graph 4.2 that has been illustrated, to get the high hardness material for this composition, only the small portion of the RR needs to add into the PP. The sample with 50% of RR content gave the low hardness and it means the sample was softer. As general, rubber was soft as plastic. One of the plastic properties was hard but easy to break. It was prove by done the hardness testing using pointer shore durometer Type D.

Table 4.2: Average for the hardness test

Composition PP/RR	Hardness values
100/0	63.16
90/10	66.8
70/30	58.34
50/50	53.00

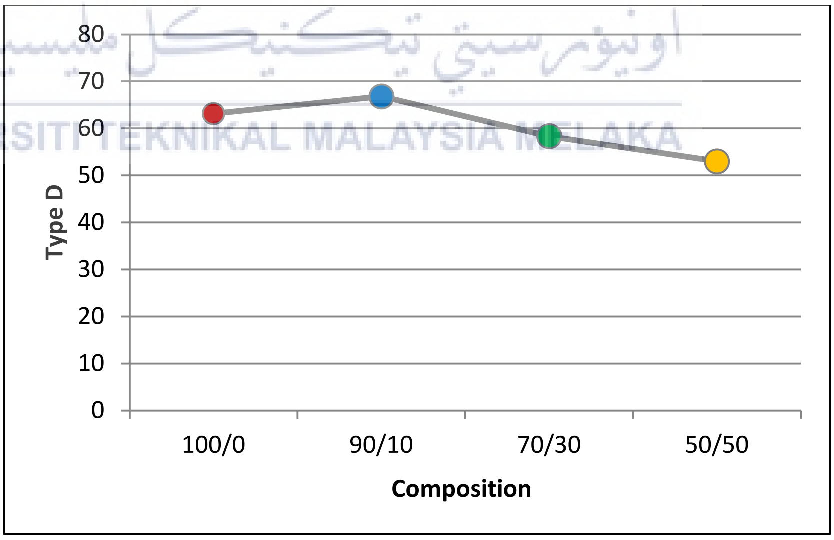

Figure 4.4: Hardness test versus RR content in PP/RR blend

4.3.3 Impact Test

The brittle materials generally have lower impact strengths, while those registering higher impact strengths tend to be tougher. For this study, seven specimens from each formulation were tested in accordance with the ASTM D256 standard. All the specimens were break off because of the hard nature of fabricated composites. Table 4.3shows the average value of the impact test. Based on it, the result shows when the present of 10% RR, the value of the impact test decrease.

Table 4.3: Average value of impact test

Composition **PP/RR**	**Joule**
100/0	1.58
90/10	1.17
70/30	1.50
50/50	1.58

By comparing all the specimens used, it can be concluded that the best composition that gives highest impact energy is 100PP/0RR and 50PP/50RR. Toughness is a property, which is the capacity of a material to resist fracture when subjected to impact. Based on the value of impact test that has been illustrated in graph 4.3, when a small portion of the RR (10%) was added into the PP, the value of the impact test will decreased. Based on the experimental result, it shows that composition has the lowest value of the impact test compare to another sample or composition. Tougher materials such as PP without RR and 50PP/50RR need higher energy or impact to break or fracture. So, this means that the sample can absorb more energy applied to it. So, the hypothesis that can be made from this experiment is the more energy absorbed by the specimen, the more toughness the materials will be. To get the high result high toughness and energy absorbed, 50% of RR was recommended.

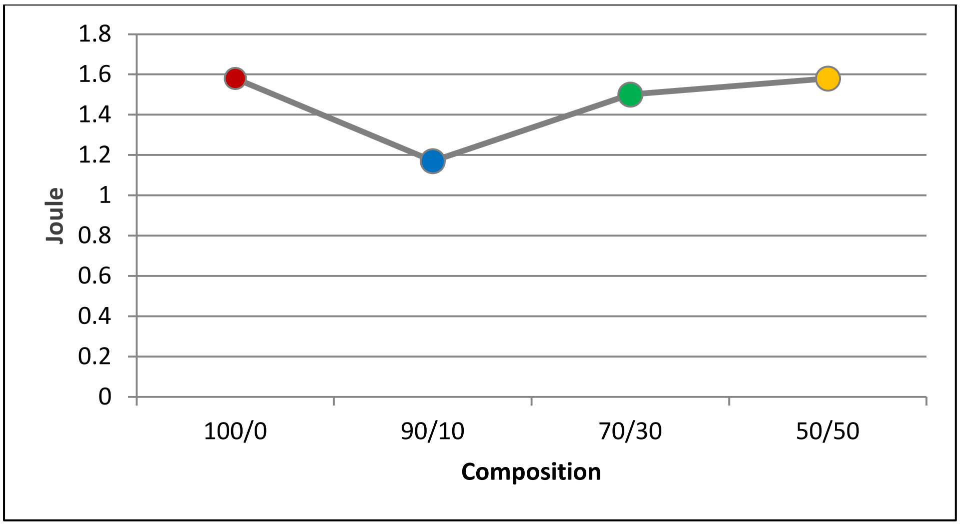

Figure 4.5: Impact test versus RR content in PP/RR blend

4.4 Physical Testing

4.4.1 Density Measurement of PP/RR

To determine the density of each sample, seven small samples from each sample were placed in the water bath at the central part of the measuring tray. The value of the density appeared at the electronic densimeter. The result presented as in the following table 4.4. Sample with 70PP/30RR shows the highest density, 1.04 g/m^3. Based on the graph 4.4, when the rubber content was 50%, the density is lower than 30% of rubber content. As the logical, when the rubber content increases, the specific gravitational also increase. However, for this experiment result in it cause of the unneeded particle.

Table 4.4: Average value of specific gravity

Composition (PP/RR)	**Density Measurement (g/cm^3)**
100/0	0.90
90/10	1.00
70/30	1.04
50/50	1.02

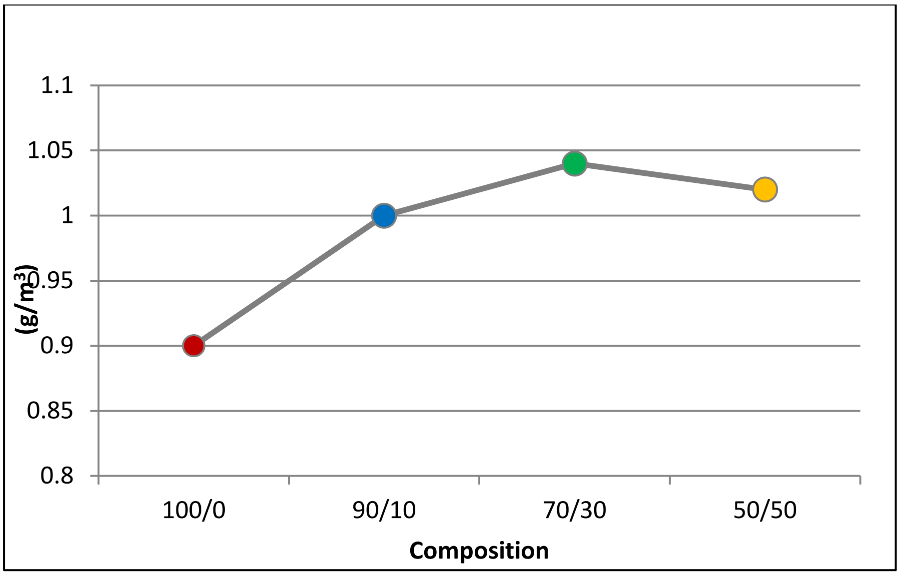

Figure 4.6: Specific Gravity RR content in PP/RR blend

4.4.2 Swelling Test

The swelling test is a test to determine the physical properties of the specimen that have been immersed in the chemical solution, toluene solution. Table 4.4 show the thickness of the specimen for each sample. The thicknesses of the specimen were taken before and after the specimens were immersed. Based on the observation during the swelling proses at 72hours, the colour of the toluene solution change into yellow cause of the corrosion of the material.

Table 4.4 shows the thickness percentage of swelling test. The thickness swellings of the specimens were increased by increasing the rubber content. The presence of 50% of RR and 50% of PP shows the highest percentage value for the thickness of the swelling. It swells 24.7% from the initial thickness. The minimal swelling thickness was virgin PP. There was no absorption for this sample because the percentage that has been come out was 0%. PP was a common hydrophobic material that can be a very good resistance to the moisture and water. In short, the percentage of the rubber content gave the huge effect in order to determine the value of the swelling process. When the rubber content increases, the thickness of the sample will increase.

Table 4.5: Thickness percentage of the swelling test

Composition (PP/RR)	**100/0**	**90/10**	**70/30**	**50/50**
Thickness Before	3.00	3.00	3.00	3.00
Thickness After	3.00	3.04	3.47	3.74
Percentage %	0	1.3	15.7	24.7

4.5 Analysis

4.5.1 Optical Microscope

For the observation under optical microscope, the 50x and 500x Magnifier have been choose. This analysis was to determine the phase of the blend in of these two materials. On the 50x Magnifier for 50% of rubber compound, it can saw that the rubber was not mix well in with the PP. The hole and void also can be defined under this optical microscope. For the 70% of rubber compound, it can say that the materials were mix well. It is because the holes that have been found not too much compared to the 50% of rubber compound. In short, the parameter of the internal mixing was important to determine the mechanical properties in this material.

Figure 4.7: 50% RR content in PP/RR compound under optical microscope for 50x Magnifier

Figure 4.8: 50% RR content in PP/RR compound under optical microscope
500x Magnifier

Figure 4.9: 70% RR content in PP/RR compound under optical microscope
50x Magnifier

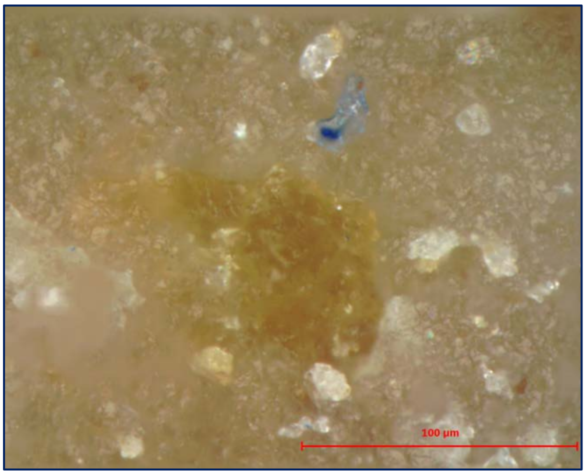

Figure 4.10: 70% RR content in PP/RR compound under optical microscope 500x Magnifier

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on this study, the systematic investigation on the development and characterization of PP/RR blend have been done with emphasis on the effect of processing parameter, compatibilizer and RR loading in properties in this blend. At the early stage, design of experiment was used to analysed and determined the optimization formulation of the PP/RR blend. Then, the blends of the material go through physical and mechanical study to determine its characteristic. It was also support with analysis technique.

For this study, it can be said that on the first phase the formulation of the PP/RR was a great formulation because they give effect to their characterization. These both material mix well in internal mixer with temperature 180º c, 80 rpm in 8 minutes. The result based on the mechanical testing shows when the percentage of rubber content increase, the result will be decrease such as for tensile testing and the hardness test. However, the result for the impact test was increase. It is because the increasing of the rubber content makes this compound more elasticity. It was one of the improvements in this study. For the physical testing, it can say that this compound has ability to absorb the solution. It can be said because of the material swollen when it was immersed in chemical solution. It also can be determine by increasing of its thickness. In chapter four, percentage of the swelling result had been discuss. For analysis of this study, the optical microscope has been used to determine the compound mix well or not. The compounding process will affected the testing result due to the way its mix.

5.2 Recommendation

From the present study, the following are typical are suggestions for the future study:

1) This study is about compounding that using internal mixer and hot press. Since the material is thermoplastic, the future study can use injection moulding and study the parameter for the injection moulding.
2) It would be interesting if study about degradation by using this material and its composition.

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