PREPARATION AND CHARACTERIZATION OF PP/rPP BLENDS AT DIFFERENT FORMULATION RATIO BY INJECTION MOULDING PROCESS

Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons)

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Date : 9 January 2019

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Bachelor Degree of Manufacturing Engineering (Hons). The member of the supervisory committee are as follow:

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(Dr. Jeefferie Bin Abd Razak)

ABSTRAK

Kepelbagaian dalam nisbah campuran polimer untuk dua fasa polimer yang berbeza boleh menghasilkan penemuan baru dalam sifat dan keserasian bahan adunan. Gabungan menghasilkan ciri yang lebih baik akan membantu dalam pelbagai aplikasi kejuruteraan. Dalam kajian ini, sisa bahan yang dihasilkan daripada operasi pengacuan suntikan dikitar semula untuk pembangunan campuran polimer adunan. Proses kitar semula akan menjadi kaedah yang menyokong dalam memelihara alam sekitar dan sumber semula jadi dengan mengurangkan penggunaan hidrokarbon. Kajian ini telah dilakukan untuk mencirikan dan mengoptimumkan adunan PP/rPP dari sisa proses pengacuan suntikan. Matlamatnya adalah untuk menggantikan dan mengurangkan penggunaan PP asli terhadap sesetengah aplikasi yang sudah tentu meningkatkan kos operasi. Campuran PP/ rPP disediakan pada nisbah formulasi tersendiri dengan menghancurkan PP dan rPP untuk dicampur dalam mesin pengacuan suntikan semasa proses penyediaan sampel dijalankan. Nisbah PP/rPP yang berbezadigunakan untuk menyiasat kesan bahan adunan PP / rPP terhadap sifat mekanikal, haba dan fizikal. Sifat mekanikal dan sifat fizikal akan diuji untuk semua sampel. Terdapat juga ujian haba yang akan dilakukan iaitu Kalorimeter Imbasan Kebezaan (DSC)) untuk menentukan sifat maksimum haba spesimen dan kestabilan haba. Kemudian, morfologi permukaan patah sampel PP/rPP terpilih akan dianalisiskan melalui pemerhatian menggunakan Mikroskopi Imbasan Elektron (SEM). Pada akhir kajian ini, didapati bahawa campuran dengan nisbah 50:50 PP / rPP mempunyai ciri-ciri mekanikal dan fizikal yang luar biasa dari segi tegangan, pemanjangan pada rehat dan kekuatan kesan serta peningkatan sifat terma. Sebagai kesimpulan, semua objektif dicapai dan hasil yang dihasilkan dapat digunakan untuk penambahbaikan dan penyelidikan yang dapat menyelesaikan masalah penggunaan sisa yang berlebihan.

ABSTRACT

Variation in the formulation ratio of polymer blend for two difference polymeric phases may produce a new resulted properties and compatibility condition of the blend. A good blend that generated better characteristic would assist in various engineering applications. In this research, the scrap material produced from injection moulding operation is recycled for development of polymer blend. The recycling process will be a supportive method in conserving the environment and natural resources by reducing the usage of hydrocarbon. Yet, there are not enough research been made on the recycling of polypropylene (PP) waste to be blended with virgin PP. Thus, this study has been done to characterize and optimize the PP/rPP blends from the injection moulding scrap. The aim is to replace and reduce the utilization of virgin PP for some applications that consume high operation cost. The PP/rPP blends are prepared by crushing both PP and rPP materials and mixed in the injection moulding machine during the sample preparation process at their respective formulation ratio. Different ratio of PP/rPP (100/0 wt. %, 75/25 wt. %, 50/50 wt. %, 25/75 wt. %, 0/100 wt. %) are used to investigate the effects of materials phases towards the resulted mechanical, thermal and physical properties of PP/rPP blends. Mechanical properties and physical properties was tested for all the samples. There are also thermal testing was performed which are Differential Scanning Calorimetry (DSC) to determine the maximum thermal properties and the thermal stability of the specimen. Scanning Electron Microscope observation also was done to observe the fracture surface morphology of the sample. At the end of this study, it was found that the blend with ratio 50:50 of PP/rPP was significantly possessed outstanding mechanical and physical characteristic in terms of tensile, elongation at break and impact strength as well as improvement in their thermal properties as proven by DSC analysis. As a conclusion, all the objectives are achieved and the result produced can be used for further improvement and research that may solve the excessive usage of waste problem.

DEDICATION

Only

my beloved father,my appreciated mother

my adored brother and my beloved friends

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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CHAPTER 1
INTRODUCTION

1.1 Research Background

The sum of plastic wastes disposal are becoming worse because of the increase in the industrial activities, growth in population, socio-economic and advanced lifestyle. Lack of awareness in our society regarding to the issue that contributes to the plastic waste disposal problem is getting troublesome and alarming. According to the statistic, there are about 10000 tonnage plastic waste per day are being produced or easily disposed mostly from the advance country. In India, the total post-consumer plastic produced, which include the two main category of polymers which are thermoplastic had contributed into 80% of total wastes while the other balance is generated by the thermoset based wastes. The thermoplastics materials are the plastic that are recyclable which including the polyethylene terephthalate (PET), low density polyethylene (LDPE), polyvinyl chloride (PVC), high density polyethylene (HDPE), polystyrene (PS), polypropylene (PP) and some others. The plastic wastes might be generated from both manufacturing process by-product and post-consumed by the consumer. Figure 1.1 shows the examples of plastic scrap from injection moulding process.

Figure 1.1: Plastic injection moulding scrap from injection moulding process

Management of waste material is becoming one of the important issue in developed and industrialize country. The management of waste without the right method that will be giving impact not only for the environment but to the society and economy of the country. In the context of this research, the recycling of recyclable plastic waste materials which produced from an injection moulding process has becoming the main objective of this research. Waste by injection moulding was generated from trial-run procedure, purging operation, machineries cleaning, product defects and many others. The wastes produced creating major loss in the manufacturing process and this issue should be overcome strategically and creatively by transforming waste into wealth through recycling method.

Recycling the polymer can be one of a good method to reduce the pollution issues that causes by the polymeric waste production from daily usage of polymer materials such as construction, house hold, food packaging and parts. The natural resources of hydrocarbons which is a main back-bone materials could be significantly conserved with the help of polymer waste recycling.

The increase in the consumption of plastic may lead to the mass volume of disposed plastic. A statistics from the Association of Plastics Manufactures in Europe state, in 20l0, has stated that polypropylene (PP) has represented about 19% of thermoplastic consumption in Europe. In terms of market share, this is the highest of the other plastic types in Europe and international production approach around 30 million tons per year and a 7% annual growth to be expected. But, recycling produce some downturn in which there is some properties reduction of the recycled based product or materials. These plastic materials are non-biodegradable and the process of decomposition requires longer period of time.

The recycling was a recommended choice because the other possible method to handle waste such as incineration and pyrolysis will commit more cost and set up. Even more, both incineration and pyrolysis will release a lot amount of greenhouse gases to the environment during the process. So, it will lead to more negative effects towards environment. Recycling the thermoplastic can be categorized as a promising future aspect. Recycling or making products from mixed plastics waste is a process that is more economical on raw material cost. This is because of a large amount of mixed plastics waste generated on daily consumptions of product as they are being used widely.

Compared to virgin materials, the deterioration of recycled plastic in quality and durability, physical and mechanical properties, surface appearance, and thermal properties have limited its use in the market. Recycled plastics are generally compounded with small amounts of chemical substances which is called the additives to change some properties and reduce their usage limitations. There are some research had been made about blending the recycled material with a virgin material to study its properties. But, the results gained are still cannot prove the possibility of recycled material to replace virgin material in certain applications. Therefore, more research and investigation should be performed in order to cope with the situation, as well as to establish the understanding about recycled/virgin blends form PP generated from an injection moulding process. In addition, this research will give insight about the feasibility of producing blends between recycled PP (rPP) and virgin PP (PP) at various proportion ration between them. Up to this stage, related characterization for rPP/PP blends in-terms of their mechanical, physical and thermal performances were investigated, in comparison with 100% virgin PP and 100% recycled PP samples. This preliminary stage will provide a reference of rPP/PP blends materials properties for the next step of product design which however not in the scope of this study.

1.2 Problem Statement

The main problem of the study is the generation of waste plastic from injection moulding in industries. According to the standard operating procedure of injection moulding, the machine must have a try-run or dry run to test the material and machine setting. From the test, some waste are produced whether it fail or not. With the material waste increase, there are many consequences followed that affected various aspect. So, it is a priority to control the management of waste material generated from the operation setting of injection moulding machineries.

From the dry run by injection moulding, the material that had been used are considered as waste and no longer needed. The quantity of the waste also cannot be controlled as they could be over than expectation. If the amount of wastage are exceed the budget, there will be lacking in the main supply and there will be an additional order of new stock of raw material. This condition will increase the production cost and time consuming as they need to wait for the new material to be used. Hence, the polymer recycling effort

should change the problem if they can reuse the same material from the waste for blend development combining with the virgin raw materials for a suitable application.

Without proper setting and optimization method, to manufacture injection moulding based products, there are lots of material waste could be generated. The problems had been noticed when there tons of and rejected products have been wasted due to high volume of injection moulding process utilization. Normally, the wastes are being scrapped and then disposed without any recycling purpose. This situation could affect the environment in a harm way. As we know, thermoplastic based materials such as PP wastes are not easy to degrade as it may takes more than 1000 years. Thus, this study aims to recycle the wastes generated from the injection moulding process so that the material can be used either stand alone or in the blend form without requiring the utilization of 100% of virgin PP raw materials. The following Figure 1.2 shows the examples of products that can be recycled instead of disposed.

Figure 1.2: Plastic product that could be recycled

Up until today, there are some research had been done about the polymer recycling and polymer blending. However, there are limited number of researches that have been developed by using PP and rPP from the injection moulding scrapped materials. Yet, the combination of various ratio between two difference polymer phases could change the resulted properties of new rPP/PP polymeric blends. Some study found that recycled polypropylene (rPP) is still not ready to be used for blending due to impurity and the need for additive material. Therefore, this study will try to find the best formulation ratio to improve the blend of PP and rPP in terms of mechanical, physical and thermal properties with a good observation on the miscibility between rPP and PP in the rPP/PP blends.

1.3 Objectives

The main objective of this study is to find the best formulation ratio between recycled PP (rPP) generated from the injection moulding process with the virgin PP (PP). Various characterization and testing were conducted to evaluate the performance of rPP/PP blends in terms of their physical, mechanical, thermal and fracture morphological behaviour, in comparison to 100% virgin PP and 100% rPP based samples. To achieve all the objectives, these studies are sets out the specific objectives as follows:

- To prepare PP/rPP blends samples at different formulation ratio by using an injection moulding process
- To characterize the PP/rPP blends samples in terms of mechanical, thermal and physical properties by using various related characterization tools.
- To evaluate the fracture surface morphology of PP/rPP blends samples by using the Scanning Electron Microscope (SEM) observation.

1.4 Scopes of the Research

The scope of this research is to formulate the best PP/rPP blend ratio from the injection moulding process waste. There are five different formulations of PP/rPP blends to be experimented with the target to evaluate the best performances of PP/rPP blended recycled materials through physical, mechanical, thermal and morphological properties testing. The performance and miscibility of produced PP/rPP blends were investigated further by manipulating and analysing all the experimental results.

To actualize these research objectives so that it will be successful, the following scope of studies has been considered and decided further.

a) Materials: One of the most used plastic which is commercial polypropylene (PP) is selected as well as the waste of PP generated from injection moulding to be utilized for PP/rPP blends development. Both of these materials will be formulated and

further tested to be decided for the best PP/rPP blend formulation materials for injection moulding.

b) Preparation of specimens: The PP waste materials from injection moulding process were cut in small pieces with a standard size by using grinder. Subsequently, it were be divided into five (5) different PP/rPP blend formulations. The following are the control samples and blends formulation ratio that has been utilized in this research study:

i) 100% PP;
ii) 75% PP and 25% rPP;
iii) 50% PP and 50% rPP;
iv) 25% PP and 75% rPP; and
v) 100% rPP

Specimens for mechanical testing were cut out into their specific dimension, in accordance to their respective ASTM standard methods.

c) Testing techniques;

i) One of the mechanical testing that to be used is tensile testing (ASTM D638). The test is done to measure the force required to break a PP sample specimen and the maximum to which the specimen stretches or elongates to that breaking point. Tensile tests for plastics provide the information on ultimate tensile strength, Young modulus, flexural strength and elongation at break. There are also flexural test (ASTM D790) and impact test (ASTM D256) to study further the mechanical properties of PP/rPP blends.

ii) For physical testing, the water absorption testing is used to test the ability and resistance towards water. The test is conducted by referring to the ASTM and ISO standards. Besides that, a density analysis also been done to determine the performance of PP/rPP blend in terms of their physical attributes.

iii) Thermal testing also been conducted by using Differential Scanning Calorimetry (DSC). DSC is a thermal analysis technique that is done to measure changes in heat flow as well as material phase transitions. The DSC technique can help to determine the miscibility of the samples. The thermal characterization has been performed in accordance to the standard operation procedure of characterization tools.

iv) Last but not least, the fractured surface morphological observations has been conducted by using the Scanning Electron Microscope (SEM) to evaluate fracture characteristic, miscibility and compatibility between of both phases of rPP and PP, as well as to correlate the fracture behaviour with the resulted mechanical and physical performances of resulted PP/rPP blends.

1.5 Thesis Organization

This thesis comprises of five (5) main section which are the introduction, literature review, methodology, result and discussion, and conclusion. Chapter ONE covers the background study, problem statement, objectives and research scope as well as thesis organization. Followed by Chapter TWO, this section is generally reviewed the past study about polypropylene, polymer recycling, polymer blending and blending specific to PP/rPP. Besides, the information about the injection moulding was also explained in this section. In Chapter THREE, the methodology of the experimental works are illustrated by using the flow chart and related simple diagram. The methodology involves the overall research frame and all related testing procedure and steps. All the data collected from all related experiments w included in the Chapter FOUR for further analysis and discussion. Lastly, overall findings from this research were concluded in Chapter FIVE. In this chapter, the recommendation for future works was suggested.

CHAPTER 2
LITERATURE REVIEW

This chapter provides an overview of the preparation and characterization of PP/rPP blends using injection moulding process. Therefore, the basic overview of PP/rPP blends material are explained and comprehensively reviewed in this chapter. Furthermore, the manufacturing process related with injection moulding is also explained and discussed as well as some past study related to injection moulding and mould flow analysis. At a final part, the related characterization testing and performance studies focusing physical, thermal and mechanical by injection moulding and plastic blend from recycled sources are reviewed.

2.1 Polymer Recycling

2.1.1 Polypropylene (PP)

Polypropylene (PP) is standard thermoplastic polymer that are widely utilize in the industrial usage due to its properties which made them flexible. The elements of PP are crystalline, semi-rigid, and resistant to wear and heat (Farotti & Natalini, 2018). PP is derived from the basic repeat unit of propylene, meaning that its polymer chains has a methyl (CH_3) group attached to half of the carbon atoms along the chain (Mastellone, Cremiato, Zaccariello, & Lotito, 2017). Figure 2.1 shows the macromolecule repeat unit of PP.

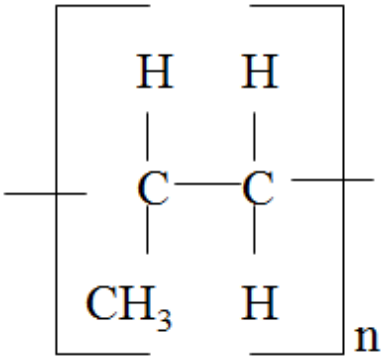

Figure 2.1: Polypropylene (PP) Macromolecule Repeat Unit (Baker et al. 2001).

Maddah (2016) stated that Polypropylene (PP) which was found in 1954 have attracted big attention as it has the lowest density compared to other polymers. PP also have a good properties in chemical resistance as it can be used in various process like extrusion and injection moulding. Figure 2.2 shows the chemical structure of PP.

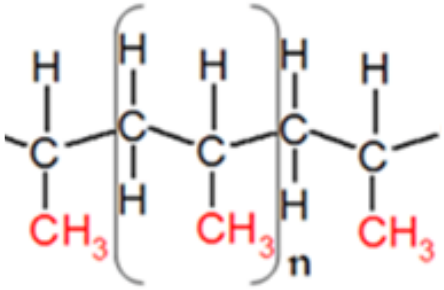

Figure 2.2: Structure of Polypropylene (Maddah, 2016)

PP is a standout amongst the most generally utilized polymers, and has great mechanical properties, warm protection, ease, simplicity of handling, and full recyclability. Its greatest disadvantage is low effect quality, which can be enhanced by a toughening modification (Lin et al., 2015). Table 2.1 shows the comparison of properties between homopolymer and copolymer of PP materials.

Table 2.1: Comparison of properties between Homopolymer and Copolymer (Maddah, 2016)

Properties	Homopolymer			Copolymer	
Melt flow index	3	0.7	0.2	3	0.2
Tensile strength (MPa)	34	30	29	29	25
Elongation at break (%)	350	115	175	40	240
Flexural modulus (MPa)	1310	1170	1100	1290	1030
Brittleness temp. (C)	+15	0	0	-15	-20
Vicat softening point	154-150	148	148	148	147
Impact strength	10	25	34	34	42.5

Based on Table 2.1, it was found that the homopolymer PP have greater properties than copolymer PP in terms of melt flow index, elongation at break and flexural modulus. The tensile strength result shows that homopolymer PP is slightly greater than copolymer PP as well as the brittleness temperature. There are not much difference in Vicat softening point for both copolymer and homopolymer of PP. Meanwhile, the impact strength of homopolymer PP is lower than copolymer PP. The drawback of PP properties of both homopolymer and copolymer opens wide opportunity for further research to improvise their existing performance.

2.1.2 Recycled Polypropylene

Usage of recycled plastics in manufacturing are more economically and environmental friendly (Gu, 2016). Hamad et al. (2013) has stated that recycling of polymer is one of the method to reduce the problems related to environment which caused by massive polymeric waste produced from daily applications of polymer materials in industries. The polymer waste recycling aid to save natural resource. The following Table 2.2 shows the properties of recycled polypropylene after being process compared to virgin PP.