Mechanical Properties of PP/RPET Blends and PP-g-MAH as Compatibilizer

Aina Aref[a], Salihin Saidi[a], Fadhilah Zainy[a], Haikal Mustafa[a], Suhee Tan[b], Mat Uzir Wahit[b]

[a,b,c,d] *Faculty of Chemical Engineering, UiTM Pasir Gudang,* [e] *Faculty of Chemical and Energy, Universiti Teknologi Malaysia*

Abstract

There are many problems regarding recycling of plastic materials products such as recycle polyethylene terephthalate (RPET) which has been a major problems of regading recycle method. This study was carried out to observe on the ratio that give high strength of polypropylene (PP) reinforced with recycle polyethylene terephthalate (RPET) blend with maleic anhydride grafted propylene (PP-g-MAH). The addition of PP-g-MAH intended to improve the compatibility between PP and RPET. These composites were mix and compounded using a single screw extruder before been injected using injection molding machine. The product of the molded compound was cut according to the ASTM D618 standard and has been tested on tensile and flexural test using tensile strength machine. The formulation of PP and 10%RPET shown to improve the flexural and tensile properties.

Keywords: Polypropylene; Recycled Polyethylene Terephthalate; Maleic Anhydride Grafted Propylene, (PP-g-MAH).

1. Introduction

The current trend of plastic usage such as plastic bottles and packages has become an issue regarding the waste of those composites, therefore recycling has become an important method to overcome the issue. Recycled polyethylene terephthalate more commonly known as RPET, which includes in the polyesters type, is a thermoplastic polymer which their wastes can be usable and bring economic benefits by using appropriate recycling methods (Mamoor, Shahid, Mushtaq, Amjad, & Mehmood, 2013). These plastics stated such as RPET could be recycle in the form of blends. Hence, PP with RPET blend has better mechanical properties which is easy to recycle back. Some of the blends of incompatible polymers are mostly very brittle and could not be consider for many applications. By using additive blend together with the mixed plastics for recycle could modify the blends by giving it ductility and increases the elongation at break (Achilias et al., 2012). This is because the entry of used RPET bottles has been widely used due to its high resistance of these bottles compared to other packaging materials such as metal and glass. About 300 years estimated took by the plastics to be break down in nature. Thus, in recent years, this problem is going to be in a great deal of attention on recycling these plastics bottles (Khoonkari, Haghighi, Sefidbakht, Shekoohi, & Ghaderian, 2015).

Polypropylene (PP) was discovered in 1954. PP is a semi-crystalline in structure that give the stiffness level and melting point increases (Maddah, 2016). PP is also known as vinyl polymer which in its molecular structure shown that every carbon atoms is connected to methyl group (Maddah, 2016) that it will give the hardness to the PP. The production of PP can be obtained by undergoing the catalytic process of propylene. PP is well-known thermoplastic and widely used compared to the other commodity plastics because it is cheap, have high chemical resistance and low density as well as flexible for molding processes (Maddah, 2016). Compared to polyethylene, PP has a great mechanical properties with their free-color material. Injection molding and extrusion compounding are some of converting methods that can be used in polypropylene processing which they are frequently utilized to form polymer composites (Santos & Henrique, 2003). PP has been experimented having a great physical, thermal and mechanical properties when employ in room temperature as PP is fatigue resistance because it can withstand when given the highest stress and keep its shape after lot of flexing or bending. It has been proved that the polymer that contain more fiber will improve the strength and modulus (Santos & Henrique, 2003).

Recycled polyethylene terephthalate or (RPET) is one of the most essential polymer for plastic manufacturing production. Due to its high performance, low cost, and recyclability, it is one of the most attractive candidates for high strength fibres (Hobbs & Lesser, 2000). The production of RPET is destined to such as molding of automobile parts, plates for vacuum thermoforming, carpets, textiles, pillows and detergent bottles. Recycling, besides eliminating plastic waste, uses up to only 30% of the energy necessary to the production of the virgin resin. The RPET can be put back into PET uses by blending small amounts of it with virgin PET, or it can go into methanolysis. It also can be put into incinerators in order to recover fuel value, which is similar to that of fuel oil. Although this is a good alternative to eliminate the problem of accumulation of recycled products, it is not politically correct (Santos & Henrique, 2003).

Studies of blends and composites using RPET have been carried out with several polymeric materials, like polyethylene and polystyrene (E.B. Pacheco, C.A. Hemais, 1999). Blends of RPET and PP with PP-g-MAH are also reported (C.T Maa, F.C Cheng, 1993).

Filler-matrix combination is important in order to get better properties in plastic that will be produced. Hence, the blended filler-matrix with low surface tension, low viscosity and higher crystallinity is needed to achieve the better blending (Maddah, 2016). Based on the research, RPET is semi-crystalline in physical properties and has low melt viscosity which easily to be injection molded. Thus, RPET can withstand higher load as well as get better reinforcing due to have high tensile strength and Young's modulus (Shi et al., 2013). For the process of RPET as a filler blend with PP, PP-g-MAH is added in this process as an additives or compatibilizing agent. It is because adhesion between PP and RPET is poor due to low impact strength and PET's properties which is more brittle which is hard and fragile. Hence, PP-g-MAH is needed as the coupling agent to be blended together with PP and recycle PET to get better adhesion between this blend and can overcome the brittleness (Chiu & Hsiao, 2006). PP-g-MAH contains different value of molecular weight of PP and MAH content (Tokumitsu, Nakajima, & Aoki, 2016). The factor that PP-g-MAH is added to this process is to improve the mechanical performance and stabilize the blend. Hence, it is highly reactive compound and can develop covalent bond on polar polymer chain (A., H., & S., 2014).

For the current work, polypropylene (PP) composites reinforced with recycled-PET fibres were prepared by using extrusion compounding and injection molding techniques. The mechanical properties of these composites were investigated by tensile and mechanical strength. The objectives for this work are to study the behaviour on mechanical properties and its effects on different composition between the recycled PET and PP blends.

2. Methodology

2.1 Raw Material

Raw material was produced from plastic bottles which contained polyethylene terephthalate that has been shredded into small pieces from Faculty of Chemical and Energy, Universiti Teknologi Malaysia.

2.2 Preparing Recycled Polyethylene Terephthalate (RPET)

2.2.1 Drying of Recycled Polyethylene Terephthalate (PET)

RPET is hygroscopis means it absorbs water easily from the surrounding. To maintain the RPET without any moisture content upon conducting the next step, RPET was dried in the hopper dryer at a temperature of 71℃ for 24 hours before proceeding into the extruder to make it as a pallet.

2.2.2 Extrusion and Palletizer

After the RPET has been dried, the RPET was inserted in the single screw extruder to be melt and form of

continuous thin cylindrical shape. The thin cylindrical shape was then been inserted into the palletizer to obtain granules form. Then, the pallet of the RPET was kept in the hopper dryer while preparing for the next material.

2.3 Blending of Polypropylene blended with Maleic Anhydride Grafted (PP-g-MAH)

PP was ready in the form of granules as well as the PP-g-MAH. Both has been weighed according to the formulation for three formulations. Both of these materials were mix together.

Table1: Weighing samples for polyethylene terephthalate with maleic anhydride grafted.

Formulations	PET	Polypropylene	Maleic Anhydride Grafted (10phr)
1	400g	1600g	200g
2	300g	1700g	200g
3	200g	1200g	200g

2.4 Polyethylene terephthalate (PET) blend with Polypropylene and Maleic Anhydride Grafted

The pallet form of RPET was taken out from the hopper rryer and mixed with the granules mixture form of polypropylene and maleic anhydride grafted. The mixture of granules form was stirred and it was been inserted in the Single Screw extruder to be melt and form of continuous thin cylindrical shape. The thin cylindrical shape of the mixture of RPET with polypropylene and maleic anhydride grafted has been inserted into the palletizer to obtain granules form. Next, this mixture pallet form was kept in the Hopper Dryer at a temperature 71°C of to avoid exposure to moisture. This method has been repeated for another 2 samples.

2.5 Injection Molding

The mixture of RPET with polypropylene and maleic anhydride grafted was been injected through a nozzle of the injection molding machine where the granules form was melted until it is soft enough to be injected to fill a mould. The shape coming out for each samples are the same according to ASTM D618, ASTM D638 and ASTM D790.

2.6 Mechanical Properties Analysis

2.6.1 Tensile Strength Analysis

The tensile strength is required to apply force to the sample of mould that have been cut into "dumbbell" shape. Tensile testing is then conducted on the specimen with different composition of PP and RPET. Each specimen have six samples to be tested. Then, the specimen is place to the tensile testing machine with two gripes on the machine to hold the specimen (Asgari & Masoomi, 2015). This sample is to determine how the sample elongate towards how much force applied to the sample.

2.6.2 Flexural Strength

The mold of the injection molding for the shape of rectangular has been tested by using flexural test as to determine the ability to resist deformation under load.

3. Result and Discussion

In this study, we intended to observe the ratio for these reinforced composites between polypropylene (PP) and

recycled polyethylene terephtalate (RPET) along with maleic anhydride grafted (PP-g-MAH) as a compatibilizer. These composites were mixed by using injection molding machine and then cut according to ASTM D618, ASTM D638 and ASTM D790 standards. Then five specimens of each formulations were tested to acquire the average readings. The formulation has been tested on its mechanical properties as shown below:

3.1 Tensile Strength Test

Based on the table 1, we know that formulation 3 with composition 90 and 10% of polypropylene (PP) and recycled polyethylene terephtalate (RPET) has higher average tensile strength for its mechanical strength compare to formulation 1 and 2 . This test is done to measure the ability of reinforced composites stretches stand forces that tend to pull it apart and to determine to what extent the material stretches before breaking.

As we can see in Figure 1, tensile strength on formulation 3 is slightly increase compared to polypropyplene (100%) which its tensile strength is about 27.52 MPa (Noor, Rahman, Reza, & Khairof, 2008). Thus the slight increase in value is about 1.5% of composite with addition of RPET in PP at 10%. This is because both PP and RPET can form covalent bond with PP-g-MAH as compatibilizer (A. et al., 2014). On the other hand, the increasing in RPET on formulation 1 and 2, it is observed that slight decrease of tensile strength compared to the polypropylene itself. It is happened due to the increases of RPET fibre dramatically decreases the strength of composites blends and tend to be more brittle (Noor et al., 2008).

Table 1. Tensile strength test for each specimen.

Formulation	Composition PP and RPET Fibre (%)	Average Tensile Strength (MPa)
	80 PP/20 RPET	25.012
2	85 PP/15 RPET	25.434
3	90 PP/10 RPET	27.952

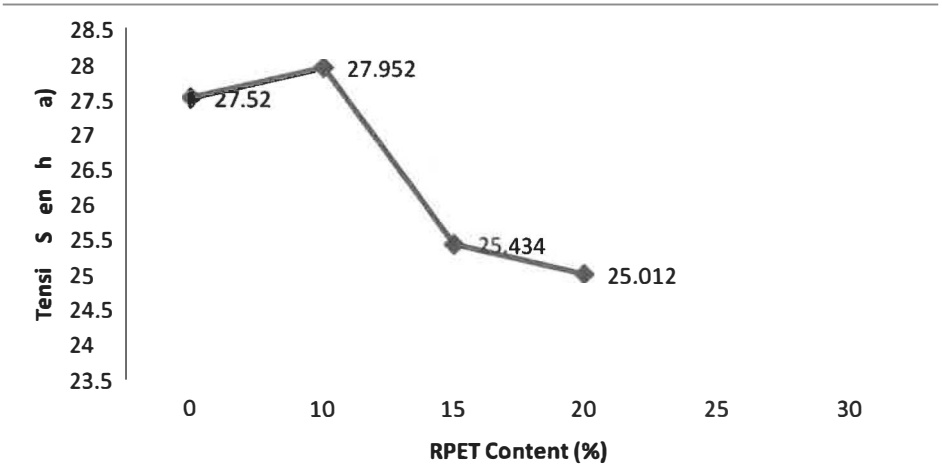

Fig. 1. Effect of RPET Content (%) on Tensile Strength of PP/RPET Blends

3.1 Flexural Test

Figure 2 shows the effect of RPET content (%) to the flexural strength of PP and RPET blends. It is observed that with the addition of 10% of RPET slightly increase the flexural strength of polypropylene itself which is 40 MPa. The graph also shows a drop value with the addition of RPET content in formulation 1 and 2 of the composites blends of PP and RPET. This behaviour results from low interaction and poor interfacial adhesion also the degradation of RPET during their service life and heat processing stage between PP and RPET phase.

Based on the previous studies, reinforcing PP with recycle PET fiber shows the tendency to increase the flexural of composite material. The higher value of flexural shows that the material is more ductile. This shows that recycle PET fibers has influencing the ductility of composite material but at maximum level of 7% recycled PET (Noor et al., 2008). But with the addition of (PP-g-MAH) as compatibilizer has further increase the maximum level to 10% recycled PET.

Table 2. Load displacement for each sample.

Formulation	Composition PP and RPET Fibre (%)	Maximum Load (MPa)	Flexural Strength (MPa)
	80 PP/20 RPET	142.02	36.747
2	85 PP/15 RPET	145.16	39.213
3	90 PP/10 RPET	163.92	42.350

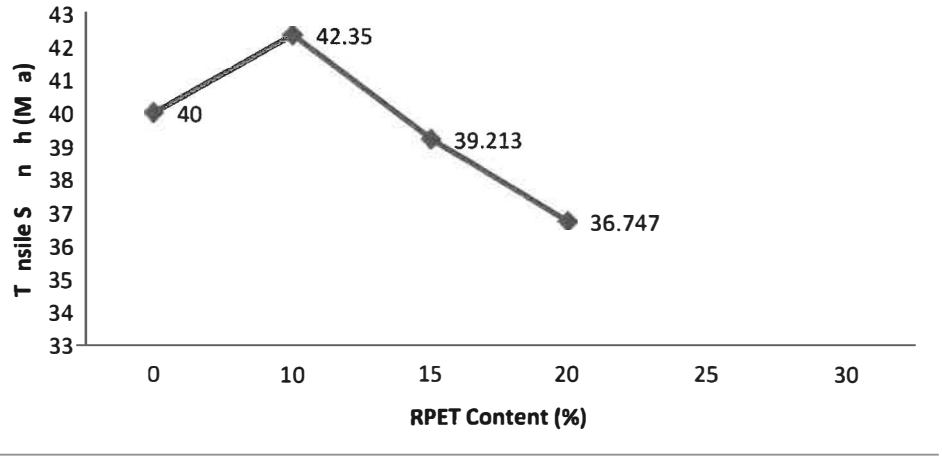

Fig. 2. Effects on Flexural Strength in Different Composition of RPET

4. Conclusion

The formulation of PP and 10%RPET has shown improved result of its flexural and tensile properties. However, as the content of RPET increased more than 10%, the mechanical properties performance decreased. This may due to increase immiscibility of RPET material which reduces the overall mechanical properties of the specimen. Thus, the presence and increasing amount of compatibilizer agents especially (PP-g-MAH) in a PP/recycled PET matrix can be an efficient way to recycle PET, increasing significantly the mechanical properties of the PP.

References