PROPERTIES OF CHICKEN FEATHER FIBER/TYRE DUST HYBRID COMPOSITION FILLED RECYCLED HIGH DENSITY POLYETHYLENE COMPOSITES

by

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In the name of Allah The Most Gracious and The Most Merciful

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LIST OF SYMBOLS

ASTM	American Society for Testing and Materials
CFF	Chicken Feather Fiber
cm	Centimeter
cm^3	Volume
CRH	Chopped rice husk
FRPs	Fiber reinforced polymer
FTIR	Fourier Transform Infrared
g	Gram
HDPE	High Density Polyethylene
ICI	Imperial Chemical Industry
LDPE	Low Density Polyethylene
MAH	Maleic Anhydride
MAPE	Maleic Anhydride Polyethylene
MAPP	Maleic Anhydride Polypropylene
mm	Milimeter
MPa	Mega Pascal
^{o}C	Celsius
PA	Phthalic Anhydride
PE	Polyethylene
PEG	Polyethylene Glycol
PE-g-MAH	Polyethylene Grafted Maleic Anhydride
PET	Polyethylene Terephthalate
phr	Per hundred resin
PLA	Poly Lactic Acid
PP	Polypropylene
R-HDPE	Recycled High Density Polyethylene

SEM	Scanning Electron Microscopy
TD	Tyre Dust
Tg	Glass transition temperature
Tm	Melting temperature
WF	Wood fiber
WPC	Wood polymer composites
WTD	Waste tyre dust
XRD	X-ray Diffraction

Sifat-Sifat Bagi Komposisi Pengisi Serat Bulu Ayam/Habuk Tayar Mengisi Komposit Polietilena Berketumpatan Tinggi yang Dikitar Semula

ABSTRAK

Komposit serat bulu ayam (CFF)/polietilena berketumpatan tinggi yang dikitar semula (R-HDPE), habuk tayar (TD)/polietilena berketumpatan tinggi yang dikitar semula (R-HDPE), dan komposit pengisi hibrid antara serat bulu ayam (CFF)/habuk tayar (TD)/polietilena berketumpatan tinggi yang dikitar semula (R-HDPE) telah dikaji. Kesemua komposit ini disediakan dengan menggunakan Brabender Plasticoder pada suhu 160 °C dengan kelajuan pemutar 50 rpm. Kesan kandungan CFF, TD dan pelbagai jenis pengserasi terhadap sifat tegangan, peratusan pengembangan jisim, sifat morfologi, spektroskopi inframerah dan pencirian XRD bagi komposit R-HDPE/CFF, R-HDPE/TD dan komposit pengisi hibrid R-HDPE/TD/CFF telah disiasat. Pengserasi yang digunakan dalam kajian ini adalah asidik maleic (MAH), acetic phthalic (PA), dan polietilena dicantumkan dengan asidik maleic (PE-g-MAH). Peningkatan jumlah muatan pengisi membawa kepada pengurangan kekuatan tegangan dan pemanjangan pada takat putus bagi komposit R-HDPE/CFF dan R-HDPE/TD manakala modulus keanjalan dan jarak antara zarah (d) telah meningkat. Adalah juga didapati bahawa peningkatan kadar CFF dalam komposisi pengisi hibrid TD/CFF menurunkan kekuatan tegangan, pemanjangan pada takat putus, manakala modulus keanjalan dan jarak antara zarah (d) meningkat. Penambahan MAH, PA, dan PE-g-MAH sebagai pengserasi dalam komposit pengisi hibrid R-HDPE/TD/CFF mempamerkan peningkatan dalam kekuatan tegangan dan modulus keanjalan manakala menurun bagi pemanjangan pada takat putus, peratusan pengembangan jisim dan jarak antara zarah (d). Mikroskop elektron imbasan (SEM) berjaya menunjukkan penyebaran pengisi di dalam matriks. Mikroskop elektron imbasan (SEM) juga menunjukkan bahawa penambahan kesemua pengserasi menambahbaik kadar lekatan antara muka dan kesan patah akibat tegangan antara R-HDPE dan TD/CFF. Analisis FTIR membuktikan kehadiran MAH, PA dan PE-g-MAH di dalam komposit pengisi hibrid R-HDPE/TD/CFF.

Properties of Chicken Feather Fiber/Tyre Dust Hybrid Composition Filled Recycled High Density Polyethylene Composites.

ABSTRACT

The composites of chicken feather fiber (CFF)/recycled high density polyethylene (R-HDPE), tyre dust (TD)/recycled high density polyethylene (R-HDPE), and hybrid fillers composite between chicken feather fiber (CFF)/tyre dust (TD)/recycled high density polyethylene (R-HDPE) were studied. Both composites were prepared by using Brabender Plasticoder at 160 °C with rotor speed of 50 of rpm. The effect of CFF, TD content and various type of compatibilizer on tensile properties, mass swell percentage, morphological properties, spectroscopy infrared and XRD characterization of R-HDPE/CFF, R-HDPE/TD and R-HDPE/TD/CFF composites were investigated. The compatibilizer used in this study was maleic anhydride (MAH), phthalic anhydride (PA), and polyethylene grafted maleic anhydride (PE-g-MAH). The increasing of filler loading leads to decreased the tensile strength and elongation at break of R-HDPE/CFF and R-HDPE/TD composite while the modulus of elasticity and interparticle spacing (d) was increased. It was also found that increasing of CFF content in the composition of TD/CFF of hybrid filler decreased the tensile strength, elongation at break while the modulus of elasticity and interparticle spacing (d) was increased. The incorporation of MAH, PA and PE-g-MAH as compatibilizer in R-HDPE/TD/CFF hybrid filler composites exhibit an improvement in the tensile strength and modulus of elasticity whereas decreased in the elongation at break, mass swell percentage and interparticle spacing (d). Scanning electron microscopy (SEM) successfully illustrates the dispersion of fillers in the matrix. Scanning electron microscopy (SEM) also show that the incorporation of both compatibilizer improved interfacial adhesion and tensile fracture between R-HDPE and TD/CFF. FTIR analysis proved the presence of MAH, PA and PE-g-MAH in the R-HDPE/TD/CFF hybrid composites.

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, emphasis is being focused on fiber-reinforced polymers (FRPs) as high-performance materials in various fields due to their unique properties (Seema and Kutty, 2005, Friedrich et al., 2004). These properties are including mechanical strength, high corrosion resistance, dimensional stability, low assembly costs, and light weight (Ganan and Mondragon, 2004, Nekkaa et al., 2006). Polymer composite materials are being applied in aerospace, automotive, marine, infrastructure, military, leisure boats, aircraft industry, sport equipment, and industrial fields. Originally, polymer have been derived and originally from petroleum. However, the applications of polymeric materials have increased numerous times due to the rapid growth of industry. To cope with the requirements of industry, alternate and newer sources of polymer materials are being investigated.

One of the low cost sources of such type of resins is recycled thermoplastics. Post-consumed polyethylene terephthalate (PET), for occasion, has a cost of 10 cents/kg while polystyrene (PS), high and low density polyethylene (HDPE, LDPE), and polypropylene (PP) have an even lower cost, three to six cents/kg. Their low cost is normally due to the large amount of post-consumed plastic waste generated daily in big cities worldwide. To give an example, a city in an emergent country with a population of three million inhabitants produces each day approximately 400 tones of plastic waste (Burgiel et al., 1994).

Polyethylene is the largest volume of plastic that produced in the world and widely used type of polyolefin. Polyethylene is manufactured in a range of polymeric forms, differing by their molecular weight and "linearity", or presence of irregularities, or unsaturations, or branches. This in turn to determined the rate of density for this polymer, which is used as the principal's classification appearance of polyethylene (Klyosov, 2007). Polyethylene which exhibits a range of tensile strength and flexibilities, is generally tough, can be readily extruded or molded, and is relatively inexpensive. These characteristic guarantees that the variety of families of PE find major use as commodity polymer (Peacock and Calhoun, 2006).

HDPE that also known as linear polyethylene is much stronger than branched polyethylene, but branched polyethylene is less in cost and easier to make. Due to good chemical resistance and mechanical strength, HDPE in general is used in numerous outdoor engineering applications including pipelines, containers, and geomembranes (Ghanbari-Siahkali et al., 2005). HDPE in general undergoes little degradation that occurs during its lifetime and during the recycling operations. However, the scope of thermomechanical degradation and the properties of the recycled material are strongly dependent on the structure of the HDPE and the processing conditions. The recycling of HDPE has already been studied by several authors and in general, provided that suitable reprocessing conditions are adopted, the properties of the recycled material are near to those of virgin or original HDPE (Loultcheva et al., 1997, Kamdem et al., 2004).

Incorporation of fillers or reinforcement into the polymer matrix lead to produce a material called polymer composites. The main function of addition of fillers or reinforcement into composites is to enhance certain properties and to lower the cost of the composites (Lopez-Manchado and Arroyo, 2002). A composite is a division of materials made up fillers embedded in a solidified material. In such composites, the properties of the composites with fillers lower than those either of these materials individually (Wanberg, 2009). Fillers are solid materials either in fine particle size (particulate fillers such as a china clay) or they are in fibrous shape (Whelan, 1994, Jayasree and Predeep, 2008).

Several researches were previously done on filler and fiber filled polymer composite. A study of Xiong et al.(2009) on wood-thermoplastic composites from wood flour and HDPE found that the tensile strength decrease significantly with the increasing of wood fiber (WF) content, and they are lower than those of the original matrix but still obtained and acceptable strength. Overviewed from the microcosmic aspect obtain that wood fiber has a bunchy structure with a high diameter ratio and relatively high strength. For that reason, WF could act as a reinforcing filler to strengthen thermoplastics although the tensile strength of the WF/HDPE composites decreases with the content increase of WF.

Kim et al., (2000) study the mechanical and dynamic mechanical properties of waste rubber powder/HDPE composite. In this research, rubber powder was previously surface-modified with acrylamide (AAm) using ultraviolet. Rubber powder and HDPE are then was extruded using a single-screw extruder and maleic anhydride-grafted polypropylene was incorperated as a compatibilizer to improve the adhesion between rubber powder and HDPE. It was found that the tensile stress and strain of acryl amide grafted rubber powder/compatibilizer/HDPE composites constantly exhibit higher values than those of unmodified rubber powder/HDPE composites. These experimental results showed that acryl amide-grafted rubber powder reacts with maleic anhydride and it results in improved mechanical properties of the HDPE composite.

Another research by Migneault et al., (2008) studies the effect of fiber length on processing and properties of extruded wood-fiber/HDPE composites. For this study, they only investigate role of fiber length, shape, and distribution in the formation process and property development of wood fiber in the HDPE plastic composites (WPC). Fang et al., (2013) also does the study of fiber filled HDPE composite. They investigate the effect of fiber treatment on the water absorption and mechanical properties of hemp fiber/polyethylene composites. They firstly measured the moisture absorption properties of the treated fibers. It was found that the introduction of coupling agent during fiber treating process decreased effectively the moisture uptake or also known as swelling percentage. Then, the water absorption and mechanical properties were investigated on the hemp/PE composites. The loading of coupling agent during fiber treating process decreased the water uptake but increased the tensile strength.

Commonly filler can be classified into organic and inorganic fillers where the organic fillers are usually more flexible whereas the inorganic fillers have rigid properties. A number of possible factors that can affect the fillers or reinforcement activity in polymer composites such as size, shape, aspect ratio, amount of filler content, filler dispersion, wettability, adhesion, and filler-matrix bonding (Ivanov et al., 2001, Rothon, 2003). Typically, fibers with uniform circular cross-section and certain aspect ratio are capable to improve the tensile strength of the composites due to inability of the fibers support the stresses transferred from the polymer matrix (Ismail and Jaffri, 1999, Stark and Rowlands, 2003).

Natural fiber reinforced composites have extensive potential to replace conventional materials. The matrix, frequently a polymeric material, surrounds the reinforcement and keeps it stay in place. The reinforcing fibers are select to improve the properties of the matrix, in example, stiffness and strength (Singha and Thakur, 2008b). As compared to conventional synthetic fibers, natural fibers are able to impart the polymer composite with some properties like low cost, low health hazards, low specific gravity, non-abrasive effect, enhanced mechanical properties, biodegradability, high degree of flexibility, good acoustic and thermal insulation, less machine wear and good availability (Joseph et al., 2006, Gomez et al., 2006, Singha and Thakur, 2008a).

There are many byproducts of chicken production. One of it is feathers. Around 11 billion pounds of feathers a year are produced internationally and turned into low value feedstock or tossed in landfills. Andrew Poole is heading up the team at the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) under the Materials Science and Engineering division. The aim of the project is to find a substitute for the 84 billion pounds of petrochemical-based synthetic fibers that produced annually, and the team is focusing more on protein fibers instead of plant-based cellulosic fibers (Agrahari and Wadhwa, 2010). One of the protein fibers is keratin, which is what chicken feathers are comprised of and is also a main component of wool. Chicken feathers are an ideal choice for the study since they are normally abundant, there have a guaranteed supply and they are of consistent quality. A group of Australian researchers are running on another use for them, turning the feather into fiber that can be making into clothes and textiles. In University of Waikato, New Zealand, researchers are struggle working on taking chicken feathers and turning them into fibers that, when added to plastic, could be strong enough to be applied in the marine industry. Barone (2005b), Barone (2005a) studied polyethylene reinforced with keratin fibers obtained from chicken feathers state that keratin feather fibers have capability to reinforce the LDPE polymer matrix. The feather fiber division of the feather waste is used and yields fibers of small constant diameter. They also found that physical property testing and microscopy exhibit some interaction between the fiber and polymer without the need for coupling agents in the composition. Not only it is imperative to use a fiber with higher modulus, but it is important to have great fiber-polymer interaction to obtain from fibers (Martinez-Hernandez et al., 2007).

Another waste material is tyre dust that made mainly from rubber. Disposal of waste rubber is a serious environmental issue around the world, due to its health hazards and its complexity for land filling. The high cost of disposal and the requirement of large landfill area regularly result in random and illegal dumping of waste rubber (Siddique and Naik, 2004). Hence, there is an urgent need to recognize and find the alternative solutions to reuse the tire rubber for other applications, and concrete has been identified to be one of the feasible options. There are also lot of researchers have been investigated the effect of used tire as a replacement for sand or aggregates in concrete mixtures (Al-Tayeb et al., 2012, Khaloo et al., 2008).

Tyre dust is one of the inorganic filler types that can be used in polymer composite. Awang et al. (2006) reported that the incorporation of waste tyre dust seems effective in improving the overall tensile properties, morphology and swelling resistance of the polypropylene-based blends. Tyre dust is added to the blend simply to increase the performance of the blends. According to Supri and Ismail (2012), the presence of vinyl alcohol-phthalic anhydride as a coupling agent improved the interfacial adhesion between LDPE and tyre dust thus improving compatibility of the composites, as evidenced by the morphological study using SEM.

The hydrophilic natural fibers and hydrophobic polymer matrix are incompatible and this gives restrictions to the properties and performance of the composites. Therefore, methods such as incorporation of interfacial agent (compatibilizer) into the composites must be done in order to improve the compatibility of the hydrophilic fibers or fillers and hydrophobic polymer matrix (Lertwimolnun and Vergnes, 2005). The major purpose of the modification is to reduce the hydrophilicity of natural fibers and promote better adhesion and bonding at the interface of fibers and matix. Some of chemical treatment might eliminate natural impurities such as hemicelluloses, lignin, and waxes from the fiber surfaces to create rougher surface which enhance surface's adhesive characteristic and improve bonding on the fibers and matrix. Application of compatibilizer was highly reported leading to an improvement of properties of natural fibers filled polymer composites (Khalf and Ward, 2010, Kim et al., 2008, Suardana et al., 2011).

A large number of studies have already been reported on the use of compatibilizer to improve compatibility of natural fibers and hydrophobic polymer matrix. Ibrahim et al. (2010) reported that the use of banana fibers and banana microfibrils as lignocellulosic reinforcement in polyethylene. Banana fibers were treated with maleic anhydride to enhance the adhesion and properties of the composites. They found that fibers treated with maleic anhydride at 20% fiber loading resulted better adhesion with polymer matrix compare to other filler loading amount, therefore provided higher tensile strength. However, extra increases fiber content led to poor adhesion and bonding among fibers and matrix.

Yan et al. (2012) previously studied the effect of maleic anhydride polypropylene (MAPP) in hemp fibers reinforced PP composites. The increasing of MAPP content into the composites enhanced the mechanical properties such as tensile strength, impact strength, and flexural strength of the composites. Microscopy results showed that high content of MAPP in the composites caused the improvement of fiber-matrix interface bonding and fiber breakage destruction.

1.2 Problem Statement

There are little researches and works studying and focusing on chicken feather fiber as reinforced fiber in polymer composites. However, the potential of development of chicken feather fiber in polymer matrix become attractive and interesting. It possesses the properties like other natural fibers such as low density, biodegradable, renewable, and low abrasive which provide a good choice as reinforced fiber.