MECHANICAL PROPERTIES OF CALCIUM CARBONATE AND COCONUT SHELL FILLED POLYPROPYLENE COMPOSITES

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Special dedication to my beloved family and friends…

Thanks for the love, support and memories

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ABSTRACT

Natural lignocellulosics and mineral fillers have an outstanding potential as reinforcement in thermoplastics. This study deals with the preparation of coconut shell lignocellulosic and calcium carbonate mineral filler composites by reactive extrusion processing in which good interfacial adhesion is generated by a coupling agent of maleic anhydride. Polypropylene (PP) matrix was modified by reacting with maleic anhydride and subsequently bonded to the surface of the modified lignocellulosic component, in-situ. The PP was extruded with the fillers to form the compatibilized composite. These composite blends were then injection molded for mechanical characterization. Typical mechanical tests like tensile strength, flexural strength and Izod impact energy were performed and the results are reported. Also water absorption test was performed to assess the absorption value of moisture in the composite. Tensile properties of coconut shell and calcium carbonate filled polypropylene composites was increased and also the impact strength and elongation at break were increased too. Water absorption of PP filled coconut shell was increased significantly. These finding are discussed in view of the improved adhesion resulting from reactions and enhanced polar interactions at phase boundaries. The mechanical properties indicate that these fillers are desired as reinforcement for making a good composite.

ABSTRAK

Lignoselulosa semulajadi dan pengisi mineral mempunyai potensi yang cemerlang sebagai tetulang dalam termoplastik. Kajian ini berkaitan dengan penyediaan komposit lignoselulosa tempurung kelapa dan mineral semulajadi kalsium karbonat menggunakan pemprosesan penyedutan reaktif di mana lekatan antara muka terjana dari ejen pengikat malik inhidrida. Matriks PP telah diubahsuai dengan menindakbalaskan malik inhidrida dan seterusnya diikat kepada permukaan komponen lignoselulosa terubahsuai, secara in-situ. Kemudiannya ia disedut bersama pengisi untuk membentuk komposit yang serasi. Adunan komposit ini kemudiannya di suntik dan diacukan untuk pencirian mekanikal. Ujian mekanikal yang tipikal seperti kekuatan tensil, lenturan, daya impak Izod telah dilaksanakan dan keputusannya dilaporkan. Ujian serapan air juga telah dilaksanakan untuk menilai kelembapan serapan dalam komposit. Sifat-sifat tensil pengisi ini telah meningkat dan juga kekuatan impak dan pemanjangan pada takat putus juga telah meningkat. Serapan air PP terisi tempurung kelapa telah meningkat lebih dari PP terisi kalsium karbonat. Keputusan ini telah dibincangkan dari sudut lekatan yang telah diperbaiki hasil dari tindakbalas dan peningkatan interaksi kutub pada sempadan fasa. Sifat-sifat mekanikal menunjukkan pengisi ini adalah sesuai sebagai pengikat untuk membuat komposit yang bagus.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In recent years, there has been considerable increase in research on natural or lignocellulosic fillers to reinforce polymers, due to several positive contributions of fillers to the composites, such as reduction in density and cost. Moreover, they are recyclable, biodegradable, present low abrasiveness, and may be incorporated at high contents, resulting in considerable increase in stiffness (Yam *et al.*, 1990). Several types of natural fibers and fillers have been studied as thermoplastic reinforcement, including jute, sawdust, sisal, coconut fiber and coconut shell (Bettini *et al.*, 2010). Many of the natural fibers and also fillers filled thermoplastic composites have found their applications in furniture, packaging, building, automobile and some other industries which are possible (Wu, 2009). Among the various natural polymers, coconut shell has shown a great potential for use in composite structures (Sindhu *et al.*, 2007). The use of materials from renewable resource is attaining great importance because every organization tends to shift from petroleum based to composite derived from natural materials. Recently, many researchers have conducted study on the use of coconut fiber and also coconut shell as filler as reinforcement agents in polymers which mean that it can replace the synthetic fibers and fillers. Their results on the mechanical properties of the composites are considerably really impressive (Sindhu *et al*., 2007, Haque *et al*., 2009). The advantages of using coconut shell are low cost, low density, have acceptable mechanical properties, renewable resources and biodegradable (Islam *et al.*, 2010). And also coconut shell has high content of lignin which results good mechanical properties such as stiffness, thermal properties and low density when is used in thermoplastic composites (Javadi *et al*., 2010)

One other type of fillers that is a mineral filler with appropriate properties is calcium carbonate. The advantages of using calcium carbonate are low cost and improve mechanical properties such as impact strength and modulus. The main difficulty with using fillers in the thermoplastic matrices is their tendency to entangle and form filler agglomerates during processing due to filler-matrix interaction. This tends to prevent better dispersion of the filler into the matrix, resulting in poor interfacial adhesion between the hydrophobic matrix and the hydrophilic filler (Karmarkar *et al*., 2007). The commonly used thermoplastic matrixes consist of nonpolar polymers whereas the natural fillers and also fibers consist of polar cellulose, hemicellulose, and lignin. These differences result in poor adhesion between the phases, with high surface tension, rendering an incompatible system (Bettini *et al*., 2010). Mechanical properties of composites also depend in good filler dispersion, minimization of voids and appropriate filler-matrix interfacial adhesion. If there is no suitable surface modification of the filler or a compatibilizer or coupling agent that bridges the filler-matrix interface, the weak interfacial adhesion between the components results in poor mechanical properties of the resultant composite. The compatibility between components can be achieved by physical and chemical modification of filler. To improve adhesion for adequate stress transfer, compatibilizers, or treatment with coupling agents are required. Another alternative is to promote chemical attack of the filler surface, rendering it more irregular to facilitate adhesion to the polymer matrix (Bettini *et al*., 2010).

Polypropylene (PP) is the most thermoplastic which is used widely nowadays due to its low cost and good processing property. It is a linear polymer and is classified as a polyolefin. It is available in two basic types as either homopolymer or copolymer material. PP has a low density, good stiffness and toughness and tensile strength especially in the type of tacticity. Therefore, this area of research will widen the uses of coconut waste as a source of raw materials and extender filler such as calcium carbonate to the plastics industry. This expected a new plastic/filler composite materials that will impart a good environmental-friendly ecosystem be produced with properties comparable to synthetic the composite (Fabio *et al*., 2007).

1.2 Problem Statement

For years, fillers have been used extensively to improve the mechanical properties of polymeric material. Fillers combined with thermoplastic matrixes are known as plastic/filler composites. Matuana *et al*. (1998) mentioned that main benefits of incorporating fillers in plastics are the increased stiffness and lowered cost of the resulting composites. Besides, plastic/filler composites also provide higher density as compared to unfilled thermoplastics. However these improvements are usually accompanied by the loss in the impact resistance of the composites. Moreover, the compatibility of fillers and thermoplastics is usually weak, so it is necessary to use compatibilizer or coupling agent to increase interfacial strength of them (Maldas and Kokta, 2004). Thus, in this research calcium carbonate and coconut shell with a coupling agent maleic anhydride will be used as reinforcing agent and impact modifier in polypropylene to enhance impact strength, stiffness and tensile strength. Because calcium carbonate acts as a reinforcing agent in impact properties when used in plastic composites (Kats and Milewski, 1987). The use of calcium carbonate as filler in PP composites by manufacturers has been growing since the 1980's and today calcium carbonate plays a dominant role as the most widely used filler in PP composites. The vast resources of $CaCO_3$ in Malaysia have driven malaysia plastic manufacturers to switch to use $CaCO_3$ as a cheaper alternative to fill PP composites. In fact, $CaCO_3$ is very cheaper than most of other fillers such as talc and etc, and it takes an overwhelming proportion of the filler market in plastics (Leong *et al.*, 2004). Addition of calcium carbonate yields a finished product with an excellent balance of stiffness and impact, and can enhance toughness of unfilled resins. Amongst fillers, it provides superior appearance and color consistency. These materials are commonly used in building and construction products, and industrial applications where durability is necessary. Disadvantages of incorporation of calcium carbonate into polypropylene composite include lowered tensile strength and compressive strength, greatly reduced elongation of polypropylene and calcium carbonate composites (Leong *et al.*, 2001), whereas natural lignocellulosics such as coconut shell powder has outstanding potentials as reinforcement in plastic. Coconut shell is important filler for the development of new composites as a result of its inherent properties such as high tensile strength and high modulus because of the existence of lignin into coconut shell filler that it makes this filler very tough and stiffness (Sapuan and Harimi, 2003). So, incorporation of coconut shell into polypropylene and calcium carbonate composites results increasing in tensile strength and also the elongation at break is higher than calcium carbonate used in polypropylene (Sapuan, 2003). Bettini *et al.* (2010) mentioned that the compatibility of polypropylene and fillers such as calcium carbonate and coconut shell is weak without using coupling agent, So, the role of maleic anhydride as a coupling agent is critical in this study to improve the compatibility and good dispersion of filler into the matrix. Maleic anhydride as a coupling agent can improve interfacial adhesion between the filler surface and polymer matrix, so the dispersion of fillers into the matrix becomes good (Bettini *et al.*, 2010). The problems that need to be addressed in this research are:

i. What is the effect of using different loading of coconut shell on the mechanical properties of polypropylene?

ii. What is the characteristic of the coconut shell/PP plastic composite filled calcium carbonate?

1.3 Objectives of the Study

In this study, PP/calcium carbonate/coconut shell modified are used to develop a new composite with better mechanical properties and investigate these properties. Therefore, the specific objectives of this research are:

i. To investigate the effect of coconut shell (by weight of 10 to 30 %) on the mechanical properties of PP/coconut shell composites.

ii. To study the effect of calcium carbonate (by weight of 10 to 40 %) on the mechanical properties of PP/calcium carbonate/coconut shell composite.

1.4 Scope of Research

1.4.1 Composite Preparation

Polypropylene, coconut shell and calcium carbonate with coupling agent (maleic anhydride) were compounded using twin screw extruder, and the composite were then injection molded for mechanical properties characterization.

i. Coconut shell which is used in powder in the size of 35μm form in different loadings, 10 to 30 % on weight.

ii. Maleic anhydride was used to modification the polypropylene and improve the compatibility of fillers and matrix in 2 % on weight.

iii. Calcium carbonate on weight of 10 to 40 % .

1.4.2 Testings

Three mechanical tests were conducted as tensile test that follows ASTM D638, flexural test (ASTM D790), Izod impct test (ASTM D256) as well as water absorption that follows ASTM D570.

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