Applied Mechanics and Materials Vol. 699 (2015) pp 146-150
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doi:10.4028/www.scientific.net/AMM.699.146

Submitted: 18.07.2014
Accepted: 09.09.2014

Effect of Reprocessing Palm Fiber Composite on the Mechanical Properties

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Keywords: Oil palm fiber; composite; reprocessing; mechanical test; natural fiber.

Abstract. Concern for the environment, both in terms of limiting the use of finite resources and the need to manage waste disposal, has led to increasing pressure to recycle materials at the end of their useful life. This work describes the effects of reprocessing on the mechanical properties of oil palm fiber reinforced polypropylene composites (PFC). Composites, containing 30wt% fiber with 3wt% Maleate Polypropylene as a coupling agent, were reprocessed up to six times. For this composite, tensile strength (TS) and Young modulus (YM) were found to decrease by 9.6% and 4.7% after being reprocessed for six times. Flexural strength was found to decrease by 23.8% with increased number of reprocessing. The hardness numbers of the composite were found to increase by 7.43% from 72.10 to 77.89 after the sixth reprocessing. In general the degradation on the mechanical properties is considered to be small and PFC has potential to be reprocessed.

Introduction

Concern for the environment, both in terms of limiting the use of finite resources and the need to manage waste disposal, has led to increasing pressure to recycle materials at the end of their useful life. In the metals industries, for instance, materials recycling operations are already well established and are driven by economics [1]. In the recent decades, growing environmental awareness has resulted in renewed interest in the use of natural fibers for different applications [2].

Some stringent policies have forced industries to use more biodegradable, less harmful natural fibers as the reinforcement material instead of traditional inorganic reinforcements to manufacture composite material. Several studies have shown that natural fibers have a slight impact on the environment when compared with the inorganic fibers such as glass fiber due to their biodegradability. Most researchers agree healthier ecosystem can be attained with natural fibers while their low cost and high performances are very interesting for industry and the researchers [3]. Pervaiz [4] studies showed 60% per-ton-of product energy savings could be achieved by using natural fibers rather than glass fibers. Another advantage of using natural waste in the composite production is their recyclability. Many studies have been conducted on natural fiber reinforced composites. For example, Iannace [5] used sisal fibers in the composites in their researches while Migneault [6] studied the wood fiber as natural fiber reinforcement or filler element in polymeric matrix to minimize the usage of plastics. Utilization of wastes in this way is expected to be both economical and environmentally beneficial in the near future.

This research is carried out to investigate the effect of reprocessing polypropylene (PP) reinforce with oil palm empty fruit bunch (OPEFB). Malaysia is among the world's largest producer and exporter of the oil palm. The oil palm industry in Malaysia, with its 6 million hectares of plantation, produced over 11.9 million tons of oil and 100 million tons of biomass. This leads to large quantity of waste materials. Exploiting the waste materials will helps preserve natural resources and maintain ecological balance [7]. The OPEFB fibers are clean, biodegradable, and compatible than many other fibers from wood species. OPEFB fiber is extracted from palm oil empty fruit bunch (EFB) and during the manufacturing process of oil palm; EFB is shredded, separated, refined, and dried. Fresh oil palm fruit bunch contains about 21% palm oil, 6-7% palm kernel, 14-15% fiber, 6-7% shell, and 23% empty fruit bunch [8].

In this work, oil palm fiber had been used as the reinforcement element to develop a polymer matrix composite. This research is to investigate the effect of reprocessing palm fiber composite (PFC) on its mechanical properties. Polypropylene (PP) will be used as the matrix and EFB fiber as the reinforcement with Maleate polypropylene (MAPP) as a coupling agent to produce palm fiber composite (PFC).

Materials and Method

Material. Three types of raw materials were used in this research, namely empty fruit bunch (EFB) fiber acting as the reinforcement, commercial Polypropylene (PP) as the matrix and Maleic anhydride grafted Polypropylene (MAPP) as the coupling agent for the composite.

Fiber treatment. The EFB fibers were soaked in a 2% sodium hydroxide (NaOH) solution at room temperature for 30 minutes. Then the EFB fibers were filtered out and washed several times with water until all the sodium hydroxide was eliminated as suggested by Izani [9].

Preparation of composite. After drying, the EFB fibers were chopped randomly ranging from 2-3mm in length. PFC sample is prepared with 30wt% oil palm fiber with 3wt% MAPP and 70wt% PP using Haake Rheomix OS internal mixer. The internal mixer rotates at a speed of 50rpm at 190°C for 12 minutes. The composite materials were later crushed to form pallets. The pellets were placed in a 250mm x 250mm x 2mm mold and heated in a hot press machine. The mixture is molded into sheets by hot pressing at 190°C and 95 kgf/cm^2 for six minutes followed by cold pressing at 95 kgf/cm^2 for six minutes. Mechanical testing samples were prepared from the PFC sheets. The remaining PFC sheets were crushed and hot pressed. Again specimens for mechanical testing were prepared. The process of crushing and hot pressing was repeated for a total of six times.

Mechanical Testing. Tensile test was carried out according to ASTM D 3039/D 3039M-00. The dimensions of the specimens were 160mm x 20mm x 2mm. The tensile test was performed using Universal Testing Machine (Instron 5585) at a cross head speed of 2mm/min at 25± 5°C. The experiments were repeated three times.

Flexural test was conducted according to ASTM D790-86: Test Method 1, Procedure A, which is a three point loading system utilizing center loading, using the Universal Testing Machine (Instron 5585)) at a cross head speed of 2mm/min at 25± 5°C. The support span was 80 mm, the diameters of the loading nose and supports were 20mm and 10mm, respectively. The dimensions of the specimen were 140mm x 12.7mm x 2mm. The experiments were repeated three times.

Hardness test was conducted according to ASTM D2240 type A by using Shore D Durometer. Hardess was taken at five different locations.

Results and Discussions

Tensile Test. Reprocessing of palm fiber composite had influenced the tensile strength (TS) of the composite. Fig. 1 shows TS of the palm fiber composites decreases with increased number of reprocessing. The TS decreases in a linear manner represented by empirical formula $TS = -0.32x + 23.5$. The virgin palm fiber composites showed an average tensile strength of 23.21MPa which reduced after being reprocessed six times to 20.99MPa. A 9.6% reduction of tensile strength due to reprocessing was observed for the PFC after being reprocessed for six times.

Processing of PFC also influenced the Young's modulus. Fig. 2 shows Young's modulus of PFC decreasing in a linear manner and represented by equation $YM = -10.14x + 1533$. The PFC initial average Young's Modulus was 1524MPa which reduced by 4.7% to 1453MPa after the sixth cycle.

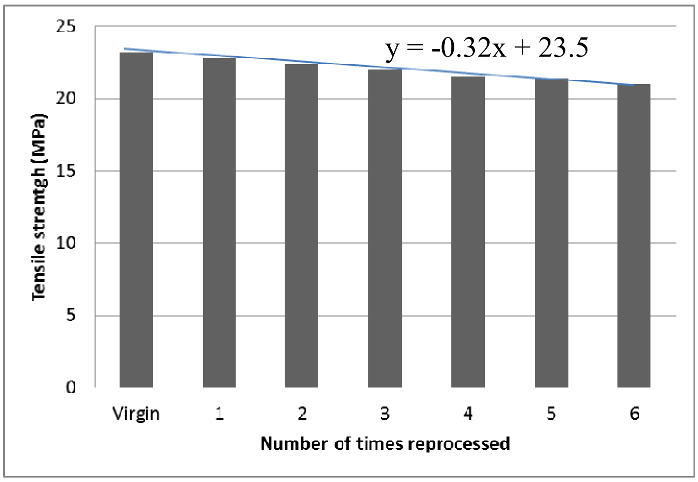

Fig.1. Tensile Strength of Virgin and Reprocessed Composite

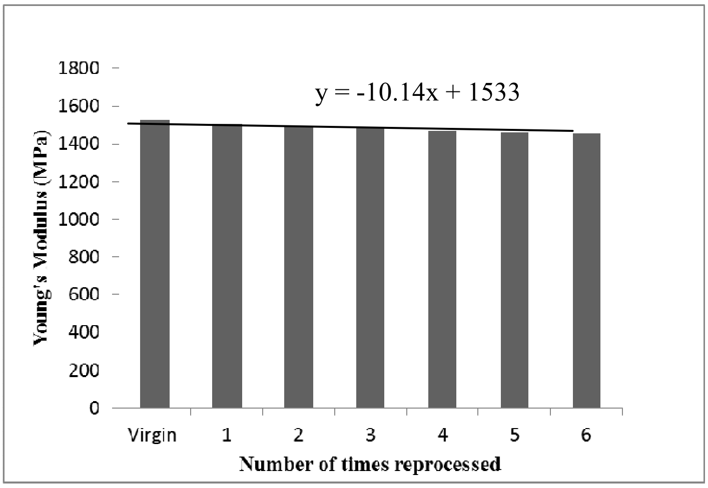

Fig.2. Young's Modulus of Virgin and Reprocessed Composite

The higher reduction of tensile strength compared to Young's modulus after reprocessing can be explained by observing simple load transfer, Young's modulus is a parameter measured at low strain, however, load transfer into fiber is more limited by fiber length at high strain where failure occurred and therefore, tensile strength could be expected to be more affected by fiber length than Young's modulus. Fiber length reduces after each reprocessing during the crushing process to make a new PFC sheet. Fiber damage due to reprocessing is also identified as a reason for the reduction on TS and YM.

Flexural Test. Fig. 3 shows flexural strength decreasing with increased number of reprocessing. The flexural strength of the reprocessed palm fiber composites showed an average flexural strength of 55.77MPa reducing by 23.8% to 42.47MPa after the sixth cycle.

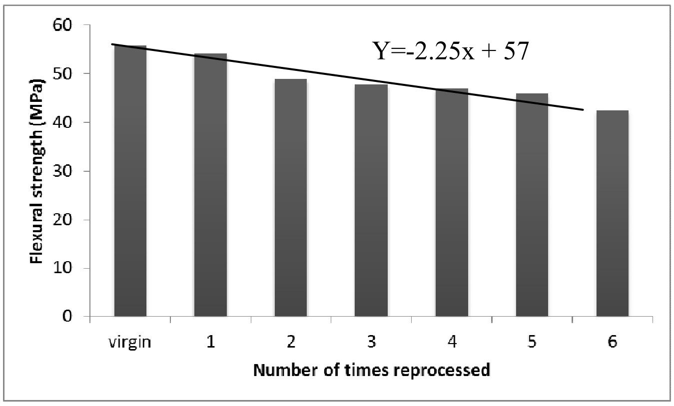

Fig.3. Flexural strength of Virgin and Reprocessed Composite

Though reprocessing will improve the interfacial bonding and was expected to give better mechanical properties in the current work tensile strength, Young's modulus and flexural strength were found to decrease in values. Fiber damage was also identified by Beg [10] as a reason for the reduction on mechanical properties. The second reason identified for the reduction on the mechanical properties is fiber length. Visual observation revealed fiber length reduces with increase in reprocessing mainly due fiber breakage during repeated granulation process. Reduction of fiber length would be expected to reduce reinforcing efficiency; leading to reduction in the mechanical properties.

Hardness Test. Reprocessing increases the PFC hardness as can be observed in Fig. 4. Hardness number of PFC increases linearly (Shore D = 0.8271x + 71.67) with increase in reprocessing. Shore D hardness increases from an average hardness number of 72.10 to 77.89 after the sixth reprocessing. The increase in hardness may have resulted from the reduction of micro-voids and the increase in composite density with increased number of reprocessing. This increase in composite density is also due to the fiber shortening.

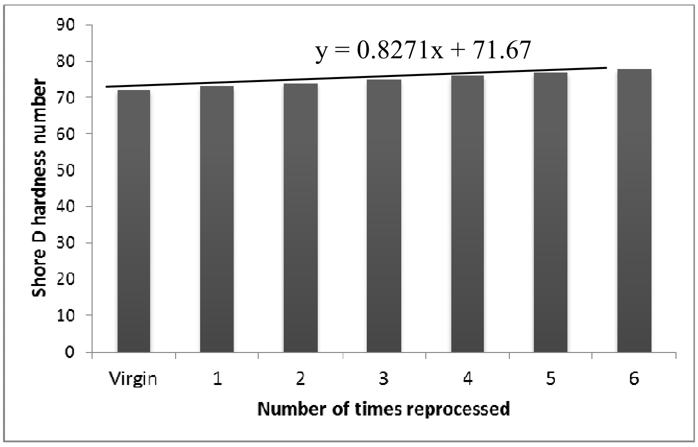

Fig.4. Shore D hardness of Virgin and Reprocessed Composite

Conclusions

As conclusion, this research focused on investigating the effect of reprocessing on the mechanical properties of oil palm fiber reinforced polypropylene. Polypropylene (PP) is used as matrixes and 30 wt% palm fiber as the reinforcement with 3wt% Maleated polypropylene (MAPP) as a coupling agent to produce palm fiber composite (PFC). The tensile strength of the palm fiber composites were found to decrease with increased number of reprocessing. The reprocessed palm fiber composite shows a reduction of 9.6% from an average tensile strength of 23.21MPa to 20.99MPa after going through six stages of reprocessing. The reprocessed palm fiber composites show an average Young's Modulus of 1524MPa which reduced linearly by 4.7% after being reprocessed six times to 1453MPa. The flexural strength of the reprocessed palm fiber composites showed an average flexural strength of 55.77Mpa which reduced linearly by 23.8% after being reprocessed six times to 42.47MPa. The reduction of tensile strength, Young's modulus and flexural strength was considered to be due to fiber damage that occurred during reprocessing process. The fiber length also was found to decrease after the palm fiber composites were reprocessed six times. The reprocessing had influenced the hardness of the palm fiber composites. The hardness numbers of the composites were found to increase with increased number of reprocessing. The fiber composites showed an average hardness number of 72.10 which increased by 7.43% after being reprocessed six times to 77.89. The increase in hardness may have resulted from the reduction of micro-voids and the increase in composite density with increased number of reprocessing. In general the decrease in mechanical properties is small and PFC seems to be a good candidate for reprocessing.

Acknowledgements

The authors are grateful to Universiti Teknikal Malaysia Melaka for financial support in short-term grant research project no. PJP/2012/(41A)/S01045

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