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Effects of Particulate Types on Biomass Particulate Filled Kenaf/Polypropylene Composite

Mohd Abrar Abd Latif[a], Mohd Edeerozey Abd Manaf[b], Muhammad 'Izzat Syahmi Firdaus, Loganarrth Maslamany and Rose Farahiyan Munawar[c]

Carbon Research Technology, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, 76100, Durian Tunggal, Melaka, Malaysia.

[a]m051410022@student.utem.edu.my, [b]edee@utem.edu.my, [c]rosefarahiyan@utem.edu.my

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Abstract. The application of natural fibers in composite is very encouraging because of its many benefits such as more environmental friendly and cost reduction. Recently, there is an interest on the application of kenaf-based material for high-end uses such as in automotive industry. In this research, mechanical properties of kenaf fiber reinforced polypropylene (KFRP) composite added with two different types of bio-based fillers, i.e., oil palm shell particle (OPSP) and rubber seed shell particle (RSSP) are studied. The composites were prepared by melt mixing of the materials using internal mixer, followed by compression molding process using hot press machine. The tensile and flexural strength were found to increase with the addition of OPSP as well as RSSP. However, KFRP composite added with RSSP showed better tensile, flexural and impact properties as compared to the composite added with OPSP. From microscopic observation of the raw OPSP and RSSP particles, it was observed that OPSP showed a more granular shape, while RSSP particles were flakier in shape. The difference in particle shape is believed to affect the mechanical properties of the composites as demonstrated in this study.

Introduction

Natural fiber reinforced composites like kenaf fiber reinforced polypropylene (KFRP) composite have become a potential structural material with many attractive properties for instance low density, cost effective, higher deformability and less abrasive. In recent times, kenaf is used as an alternative to replace wood in pulp and paper industries. Besides, it can also replace synthetic fibers such as glass and metallic fibers. There are many studies have been carried out in the utilization of kenaf as well as other natural fibers such as bamboo, jute, silk, sisal and flax as composite materials [1].

Oil palm shell is an industrial waste produced by palm oil industry, which is one of the main sources in Malaysia's economy. Besides producing crude palm oil as the main product, it also produces a million of tonnes of oil palm waste in various forms such as fronds, trunk, empty fruit bunch and shell [2]. Oil palm shell (OPS) has been studied as a potential material to replace conventional aggregates in structural elements and road construction utilizing its low density with the potential to remarkably reduce the cost [3]. However, little study has been done on OPS potential as reinforcement or filler in polymeric composite.

Rubber seed shell (RSS) is an agricultural by-product of rubber plantation. Currently, rubber seed shell offers almost no economic value and left to rot without being fully utilized. Some studies reported the use of untreated and carbonized rubber seed powder as reinforcement in polymeric composites. [4] It was reported that carbonized rubber seed shell had the potential as reinforcing filler for natural rubber compounds [5]. In the study of PP- and HDPE-based composites added with RSSP, it was shown that with higher RSSF content, the higher thermal stability, initial degradation temperature, degradation temperature, and total weight loss became. Furthermore, water resistance ability of the composites reduces as the filler loading increases for both matrices [6].

Hybrid composites refer to the composites made by combining two or more different types of fibers in a common matrix [7]. A right combination of the reinforcing fillers or fibers, could lead to significant improvement in the mechanical properties as well as substantial reduction in the material cost. Hybrid reinforcement offers various potentials that cannot be obtained with a single type of reinforcement. It was reported that, the hybrid effect of nanoparticles and hemp fiber, not only increased the stiffness but also flexibility of the PP based hybrid composites [8].

Up till now, there are still not many studies reported on hybrid composites that use a combination of bio-based fibers and particles as reinforcements. In this study, effects of OPSP and RSSP addition on the mechanical properties of kenaf fiber reinforced polypropylene composite are evaluated using tensile, flexural and impact tests as well as fracture surface analysis using scanning electron microscopy (SEM).

Experimental

Materials. Kenaf fibers used in this study were supplied by Kenaf Natural Fiber Industries Sdn. Bhd. The oil palm shells were obtained from Jugra Oil Palm Sdn. Bhd. Kenaf fibers were manually cut into short fibers of about 5~10 mm. The rubber seed shells were supplied by Rubber Industry Smallholders Development Authority (RISDA). The polypropylene (PP) was purchased from Polypropylene Malaysia Sdn. Bhd. The coupling agent used in this experiment was maleic anhydride grafted polypropylene (MAgPP) and produced by Sigma Aldrich.

Sample Preparation and Testings. Initially, oil palm and rubber seed shells were cleaned with water and dried under sunlight for 10 hours. The shells were then crushed and subsequently pulverized by using a variable speed rotor mill (Pulverisette, FRITSCH) to produce oil palm shell particles (OPSP) and rubber seed shell particles (RSSP). The OPSP and RSSP particles were sieved using a vibratory sieve shaker (Analysette, FRITSCH) to obtain particles with particle size of approximately 45 μm. The amounts of OPSP were varied at 0, 3, 5, 10 per hundred compound (phc), while the composition of kenaf/PP was fixed at 30/70 wt%. The formulations for the composites used in this study are shown in Table 1. The amount of MAgPP coupling agent used was 3phc.

Table 1 Formulations of the OPSP/kenaf/PP and RSSP /kenaf/PP composites.

Kenaf (wt%)	PP (wt%)	OPSP or RSSP (phc)	MAgPP (phc)
30	70	0	3
		3	
		5	
		10	

Fabrication of OPSP-KFRP and RSSP-KFRP composite samples involved melt mixing and hot compression molding processes. Initially, all the materials were mixed manually. The mixture was then melt blended using internal mixer and followed by extrusion, in order to compound the bio-based particles, i.e., OPSP or RSSP, with the kenaf and PP. Subsequently, the extrudites were crushed to obtain OPSP/kenaf/PP and RSSP/kenaf/PP pallets. The pellets were preheated in hot press machine for 10 minutes and then compressed for 10 min at 180 °C and 10 MPa to obtain a composite sheet. Finally, it was cooled at room temperatures for 10 minutes, before being cut into standard samples.

Tensile and flexural tests were performed using Universal Testing Machine according to ASTM D638 and ASTM D790, respectively. Izod impact test was performed using pendulum impact tester according to ASTM D256. For each composition, the average value for five measurements was taken as the result.

Morphological analysis was performed using scanning electron microscopy (SEM) machine (INCA X-sight EVO 50) to observe the microstructure of the fracture surface for each composition. The machine was operated at accelerated voltage of 10kV.

Results and Discussion

Mechanical Properties. The percentages of increase in tensile and flexural strength of kenaf fiber reinforced polypropylene (KFRP) composite are shown in Fig. 1. In general, addition of these bio-based fillers is found to increase both tensile and flexural strength of KFRP composite. Particularly, KFRP composite added with RSSP shows an increase as much as 13% and 14% for tensile strength and flexural strength, respectively. On the other hand, the maximum increases of tensile and flexural strength in the KFRP/OPSP are slightly lower at 2% and 10%, respectively. In general, it is found that the addition of RSSP is more effective to increase the value of tensile and flexural strength except for the 10phc RSSP, in which the increase in flexural strength is lower than that of 10phc OPSP as shown in Fig. 1(b).

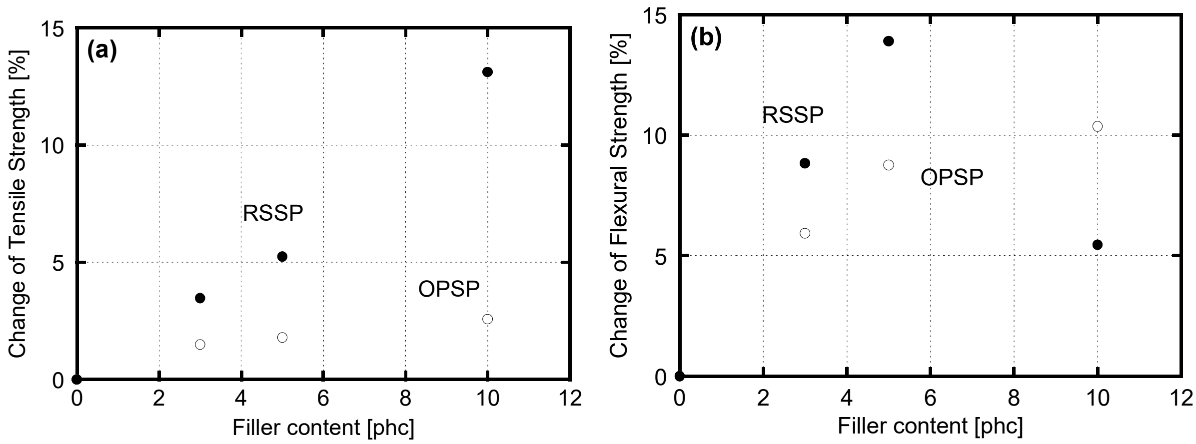

Fig. 1 Percentages of change in (a) tensile strength and (b) flexural strength of kenaf/PP composite added with various amount of OPSP and RSSP content.

As shown in Fig 1(b), flexural strength show a larger increase than tensile strength with the same amount of filler, however when the filler content is increased to 10phc, the percentage of increase in flexural strength of KFRP/RSSP lessens. This is probably due to reduced effectiveness of coupling agent as the amount of RSSP filler is increased that somehow is manifested in the slight drop in flexural strength, when stress is applied in bending mode. Moreover, at higher filler loading, the possibility for agglomeration to occur will increase. This could lead to a decrease in wettability and consequently affects the mechanical performance. The difference obtained between tensile and flexural tests suggests that the failures are governed by two different flaw distributions. Tension tends to produce a more catastrophic failure due to the uniform stress field, while flexure loading produces a more localized failure due to stress gradients [9]. From the results, it is thought that localized failure as produced by the flexural mode tends to be aggravated by the presence of agglomeration in the KFRP/RSSP composite.

Both KFRP/OPSP and KFRP/RSSP show a decrease in impact strength with the addition of the bio-fillers as shown in Fig. 2. Impact strength further decreases as the amount of bio-fillers is increased. When a crack occurs after the impact, it spreads towards a poor interfacial area. Hence, impact strength tends to decrease as the fillers content increase. Furthermore, KFRP composite added with RSSP shows a smaller decrease in impact strength compared to the composite added with OPSP.

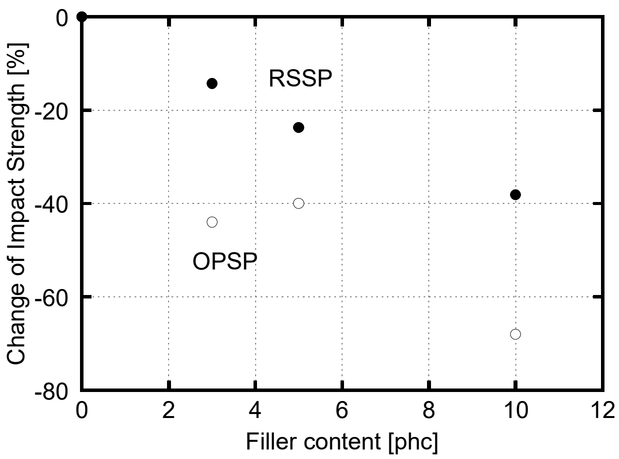

Fig. 2 Percentages of change in impact strength of kenaf/PP composite added with various amount of OPSP and RSSP content.

Morphological Properties. The scanning electron microscopy (SEM) images of the OPSP and RSSP particles prior to composite fabrication are shown in Fig. 3(a) and 3(b), respectively. The pulverized oil palm shell particles are found to be more granular, while the pulverized rubber seed shell particles appears to be flakier. The shape of these bio-fillers could explain the results of mechanical properties obtained in this study. The flaky shape of RSSP particles in the PP matrix are more prone to agglomerate compared to the more granular OPSP particles. This explains the decrease in flexural strength when the amount of RPSP is increased from 5phc to 10 phc. The flaky shape of RSSP also means higher surface area. At low filler content, the fillers are better distributed and have less agglomeration. The wettability between fillers and PP matrix is also better at low filler content due to the effect of MAgPP coupling agent. This enables the RSSP acts as better reinforcing agent as compared to OPSP due to its higher surface area.

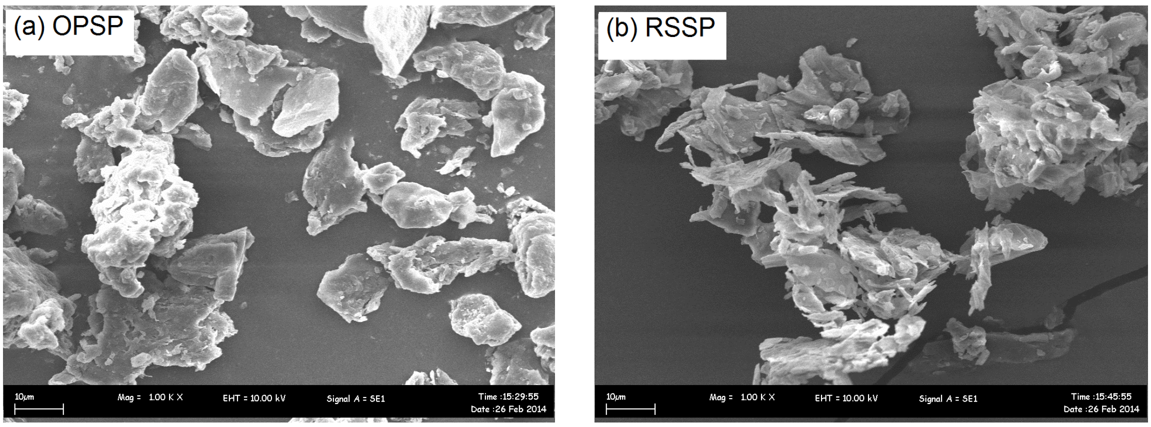

Fig. 3 SEM images of (a) OPSP and (b) RSSP particles prior to mixing with PP at 1000x of magnification.

The SEM image for fracture surface of KFRP composite without filler addition is shown in Fig. 4(a). The figure shows a good adhesion between kenaf fibers and PP matrix. The marks of good interfacial adhesion between kenaf fibers and the PP matrix can be observed. The addition of MagPP coupling agent contributes for better wetting of the kenaf fibers with the matrix, thus improves the adhesion. The image indicates the effectiveness of MAgPP as coupling agent between PP matrix and kenaf fibers in this study.

The SEM micrograph of fracture surface of KFRP added with 10phc RSSP is shown in Fig 4(b). The image shows a presence of voids due to fiber pull out. An increase in fiber pull out as compared to the KFRP composite with 0phc RSSP suggesting a decrease in the effectiveness of MAgPP as coupling agent as the amount of RSSP particulate is increased. However, there is no agglomeration of RSSP particles, indicating good particle distribution of RSSP in PP.

Overall, good particle distribution and wetting were observed in the SEM images of KFRP/RSSP and KFRP/OPSP, which contributes to the increases in tensile and flexural properties in the KFRP composite added with OPSP and RPSP particulates as shown by the results in Fig. 1.

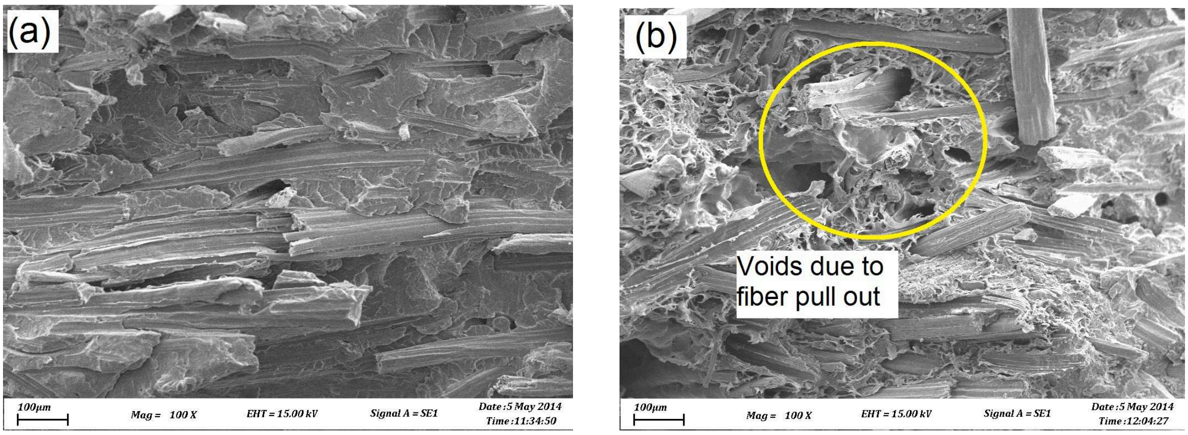

Fig. 4 SEM images of fracture surface of kenaf/PP (KFRP) composite (a) without RSSP or OPSP, and (b) with 10phc RSSP, at 100x magnification.

Conclusion

The effects of oil palm shell (OPSP) and rubber seed shell particle (RSSP) addition on the mechanical properties of kenaf/PP (KFRP) composites are studied. The addition of the bio-derived particulates are found to be effective as reinforcing filler in kenaf/PP composite as verified by the increase in the tensile and flexural strength values. Addition of the OPSP and RSSP however is found to decrease the impact strength of KFRP composite. Furthermore, composites reinforced with RSSP filler is found to produce higher tensile strength, flexural strength and impact strength than those reinforced with OPSP filler, which is presumably due to the flakier shape of the RSSP particles as opposed to the granular shape of OPSP particles. However, as the RSSP was increased to higher amount (10phc), the result in flexural strength showed a slight decrease, possibly due to the reduced effectiveness of the coupling agent.

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