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FGNF/EPOXY COMPOSITE FABRICATED USING CENTRIFUGAL SLURRY-POURING METHOD

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ABSTRACT

In this study, functionally graded natural fiber/epoxy (FGNF/epoxy) hybrid composite cylinders were fabricated using casting method. Coir husk and empty fruit bunch (EFB) were two type of natural fiber (NF) used in this work. The mechanical properties and microstructure of the composite were determined. Three different pouring height and compositions of NF were investigated i.e. 150, 250 and 300 mm and sample 1 (80% of epoxy, 10% of coir husk, 10% of EFB), sample 2 (80% of epoxy, 15% of coir husk, 5% of EFB) and sample 3 (80% of epoxy, 5 % of coir husk 15 % of EFB), respectively. As for comparison, the epoxy cylinder contains 100 % of epoxy was fabricated (Sample 4). In order to characterize the FGNF/epoxy cylinders fabricated, the hardness, density and compression test were carried out. From the observation, it is found that the NF particles can be graded from upper to lower surface of the FGNF/epoxy cylinders by casting. Many NF particles concentrated at the middle and bottom part rather than at the top part of composite. The hardness and density test results show that the hardness and density value along the cylinder vary from the highest value at the lower surface to the lowest value at the upper surface due to the differences of NF composition along the cylinder. Due to difference in density of NF causes the natural fiber particles move to downward by gravity during casting. The compression test result show that sample 1 and sample 2 has recorded the highest and the lowest Young's modulus, respectively. The Young's modulus and yield strength of FGNF/epoxy is higher than pure epoxy cylinder composite. It appears that FGNF/epoxy with a gradient in NF composition is superior to the homogeneous composite.

Keywords: functionally graded natural giber, voir husk, EFB.

INTRODUCTION

Functionally graded materials (FGM) are the advanced materials in the family of engineering composites made of two or more constituents phases with continuous and smoothly varying composition. These advanced materials with engineered gradients of composition, structure and specific properties in the preferred direction are superior to homogeneous material composed of similar constituents. The first FGM was developed in Japan in 1984 as the result of a space plane project (Mahamood *et al*., 2012). Later on, many researches were done with this novel material. The FGM constituents engineered by humans commonly involve two isotropic material phases; although any numbers of chemically and spatially compatible configurations are possible (Aysha C. P. M. *et al*., 2014).

Casting is one of methods to produce the FGM concept (Stabik and Dybowska, 2007). The FGM were successfully fabricated with continuous compositional gradients. This method divides two techniques, gravity and centrifugal casting. Gravity casting allowed particles to move under the gravitational force without external force (Jayachandran *et al*., 2013). Meanwhile, the centrifugal casting generated by a rotating cylindrical mold to throw molten against a mold wall to form the desired shape. Therefore, a centrifugal casting machine must be able to spin a mold, receive molten and let the solidify and cool in the mold (Wei and Lampman, 2008).

A recent year, natural fibre (NF) is a quite new material in the various applications such as construction and building industry compared to concrete and steel (Azwa and Yousif, 2013). NF is classified into two groups, man-made and natural. NF divided by the original source of fiber available from animal, vegetable, or mineral, and converted into a non-woven fabric (Saheb and Jog, 1999). NF derived directly and can be spun into filaments, thread, string or composite materials (Sivaraj and Rajeshkumar, 2014). The use of natural composites in the automotive industry started with Henry Ford. Around year 1942, he began experimenting, initially using compressed soybeans to produce composite plastic-like components (Drzal, *et al*., 2001).

During that period, new environmental regulations and the depletion of petroleum sources cause the scientists and manufacturers have revived their interest to derive a new generation of composite materials, from renewable sources such as NF (Furtado *et al*., 2014). NF reinforced polymer composite form a new class of materials which seem to have good potential in the future as a substitute for scarce wood and wood based materials in structural applications. NF are renewable, cheaper, no hazards and reduce environmental pollution by finding new utilization of waste materials (Verma, *et al*., 2013; Al-Oqla and Sapuan, 2014; Garcia-Espinel, *et al*., 2015).

In this study, the functionally graded natural fiber/epoxy (FGNF/epoxy) cylinders are produced by pouring method using the combination coir husk and empty fruit bunch (EFB) as NF and epoxy matrix. The purpose was investigating the effect of microstructure and mechanical properties of FGNF/Epoxy. The casting process applied to a mixture of reinforcement particle under the differential height of hollow tube. Based on

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studies by Jayachandran *et al*., (2013), it was concluded that the centrifugal slurry-pouring is a method to fabricate the continuous FGNF/epoxy cylinders. The sample was characterized by hardness, density and compression test for mechanical test and observed by optical microscope (OM).

METHODOLOGY

Preparation of FGNF/Epoxy hybrid composite cylinder

The FGNF/Epoxy hybrid composite cylinder was prepared by pouring method using coir husk and EFB. There are several processes that need to be conducted in producing the specimen. Firstly, the chemical treatment process for coir husk and EFB. The treatments are intended to remove a certain amount of lignin, wax and oils covering the external surface of the fiber cell wall. The fibers were immersed in sodium hydroxide (NaOH) with ratio 1:10 of water for 24 hours. The fibers were rinsed with clean water to remove dirt and chemical solutions at the fibers. After rinsed, the fibres were dried under the sun before inserted into an oven for 24 hours at temperatures of 50 °C. Finally, the fibers crushed using a grinder machine to get the average fiber length of 5 mm. The procedure of the treatment process is shown schematically in Figure-1. Meanwhile, Table-1 shows the three compositions and parameter that used in this study.

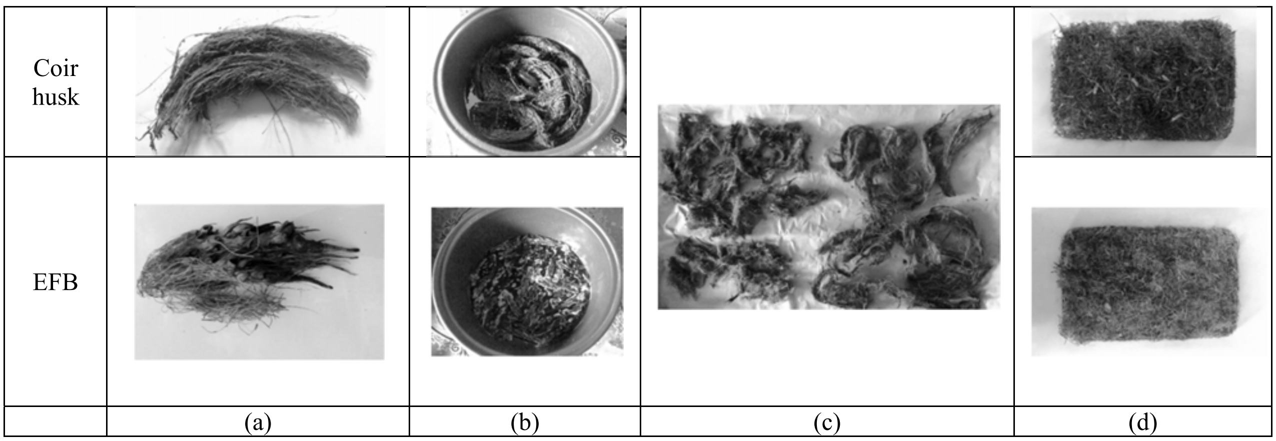

Figure-1. The procedure of the treatment process; a) Natural fiber used, b) Immersed NF in NaOH, c) Dried before insert NF in oven machine and d) NF after crusher machine.

Table-1. Material composition.

Pouring height (mm)	**Sample**	**Epoxy** (%)	**Coir** (%)	**EFB** (%)
150	1	80	10	10
	2	80	15	5
	3	80	5	15
	4	100	0	0
250	1	80	10	10
	2	80	15	5
	3	80	5	15
	4	100	0	0
300	1	80	10	10
	2	80	15	5
	3	80	5	15
	4	100	0	0

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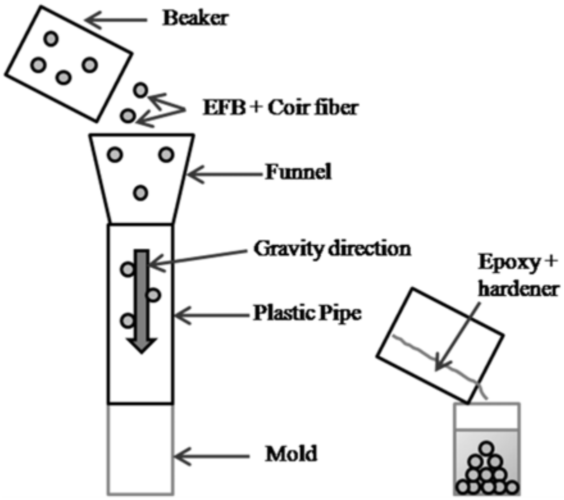

Figure-2. Slurry-pouring schematic.

The combination fiber (coir and EFB) and the epoxy and hardener were stirred manually for two or three minutes. The mixture of NF and epoxy was then poured into pipe. There are three different height of pipe used as shown in Table-1. The wall of pipe and mold were covered with wax as a release agent before casting. The mixture the flow in pipe and filled the mod. The sample was then removed from the mold after 24 hours. The sample cut according the ASTM standards for observation and mechanical test. Figure-2 shows the schematic diagrams of gravity slurry-pouring method. Meanwhile, Figure-3 shows that schematic of sample geometry and the sample produced.

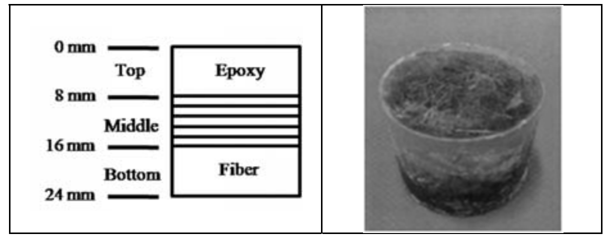

Figure-3. a) Schematic of geometry; b) Sample of FGNF/epoxy composite.

Characterization of sample

Hardness test was conducted on the sample by using ASTM D2240 Durometer Type D. The data were taken three times to get an average. Density of sample was done by using Mettler Toledo machine. The microstructure of the samples was observed by using 100x magnification optical microscope (OM). The compression strength of the composites was measured by Testometric universal testing machine (UTM) in accordance with the speed of the machine was about 5 mm/min. The shape of specimen for compression test was a cylinder with diameter of 30 mm and 24 mm height. The sample was compressed up to 40% from the original height.

RESULT AND DISCUSSIONS

Analysis of microstructure

The observation on samples separated by three parts; top, middle and bottom. From the observation of the overall samples, found that most of the NF concentrated at the bottom part of the composite. The reason is the NF particle is moving downward following by gravity and density since the density of NF is higher than epoxy. Based on Figure-4 (sample 1 with different pouring height), there are similarities in the patterns of the three diagrams at the top part of the sample. At the top part of the sample showed, only epoxy matrix observed and mixture of epoxy and NF is concentrated at the middle and bottom of the sample in which the casting by force of gravity. The similar microstructure patterns as sample 1 were observed in sample 2 and 3.

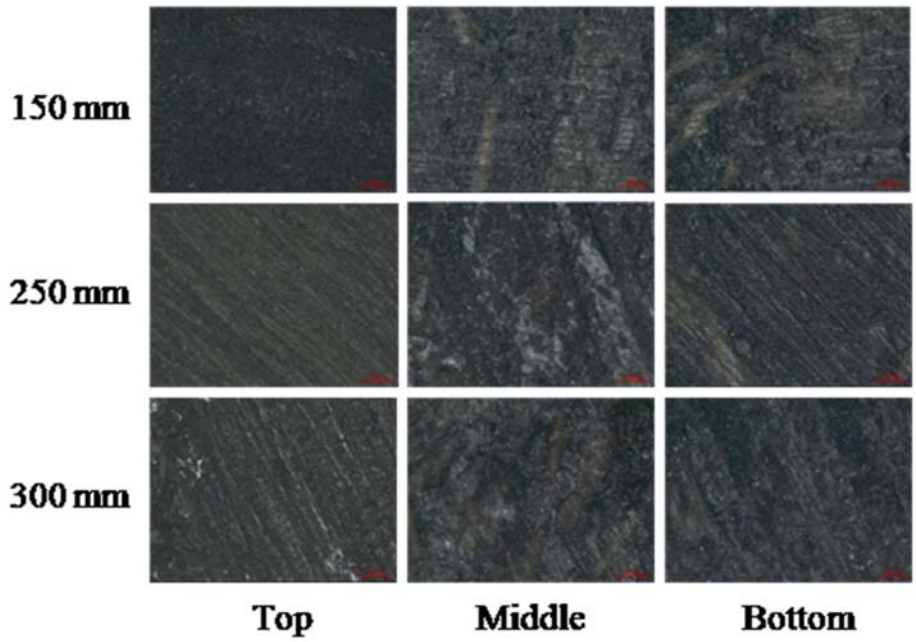

Figure-4. Microstructure of sample 1 at different part.

Hardness test

Figure-5 shows the result of the average value of hardness obtained for all samples. It is found that the average value of hardness is significantly depend on the pouring height. Sample 2 with 300 mm pouring height records the highest hardness value which is 85 shore D. Meanwhile sample 3 with records the lowest value of hardness. However, the hardness value of sample 3 is higher than sample 4 which contains 100% epoxy. The result shows that the hardness of sample increases with the increasing of NF contents and pouring height. The fiber serves as catalyst for the reinforcing the bond between the matrix and fiber.

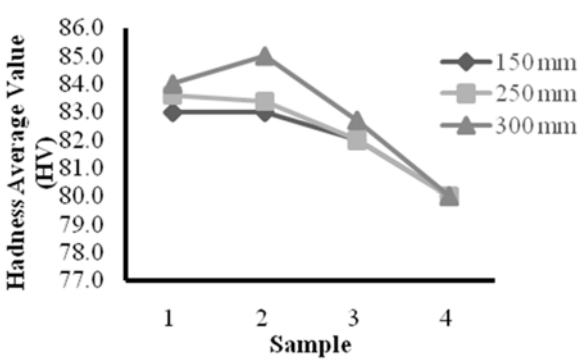

Figure-5. The average hardness value.

Density test

Figure-6 shows the average density value of the overall samples. Similar to hardness value, the average density value changes depend on the composition of natural fiber and epoxy. The average density value of sample 3 with 150 mm pouring height parameter is the highest (1.163 g/cm^3). Sample 3 contains more EFB fiber than sample 1 and 2 which is 15 %. In overall, it is observed that the density is increases with the increasing of pouring height. It is found that air bubbles are existed in the specimen which content high volume of fiber the existence of air bubbles makes the density value of FGNF/Epoxy cylinder drops. It also makes the weak bond between the matrix and the fiber.

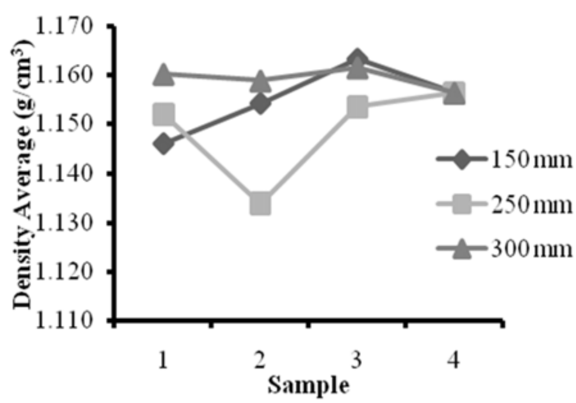

Figure-6. The average density value.

Compression test

The compression test is done to see the effect of composition of NF and epoxy and the pouring height on the strength of composite. The results of compression test are tabulated in Table-2. As can been seen in Table-2, the Young's modulus and yield strength increases with the increasing of pouring height. will be increased when the height parameter is increased. Sample 1 with pouring height 300 mm records the highest Young's modulus and yield strength value which is 7.736 N/mm^2 and 73.809 N/mm^2, respectively. The stress-strain relationship of sample 1 with different pouring height is shown in Figure-7.

Table-2. Compression test data.

Height (mm)	Sample	Yield strength (N/mm^2)	Young's Modulus (N/mm^2)
150	1	68.712	5.701
	2	36.200	2.728
	3	63.917	3.676
	4	69.221	7.650
250	1	68.772	7.720
	2	57.910	6.071
	3	56.963	4.157
	4	69.221	7.650
300	1	73.809	7.736
	2	54.800	6.875
	3	51.903	5.517
	4	69.221	7.650

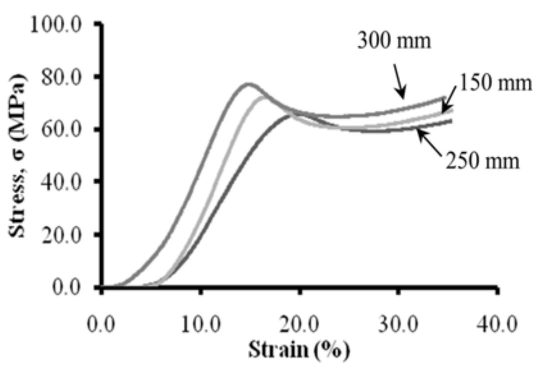

Figure-7. Sress-strain relationship of sample 1.

CONCLUSIONS

In short, the FGNF/Epoxy hybrid composite cylinders with different composition of epoxy and NF and pouring height were successfully fabricated by using slurry-pouring method. The cylinders were characterized by hardness, density and compression test. It is found that the hardness and density value of the specimen is increasing as the fiber content increased. The strength of composite is enhanced with addition of NF. Besides, the pouring height affects the mechanical properties and the microstructure of the sample. In conclusion, it appears that FGNF/epoxy with a gradient in NF composition is superior to the homogeneous composite.

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