Mechanical properties of coconut shell reinforced polymer composite

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Keywords: coconut shell; composite; mechanical properties; natural fiber

ABSTRACT – The utilization of natural fibers in composites has been increasing to save the environment by using biodegradable materials. Therefore, the aim of this study is to develop natural fiber composite that reinforced with coconut shell and analyze their mechanical properties. The powder particle size of 500 µm and below is produced from coconut shell by using crusher machine and sieved using vibratory shaker machine. This coconut shell powder is used as filler to natural composite material. The weight percentage composition of filler concentration varies by 10%, 15%, 20%, 25% and 30% into polyester matrix. Polyester Resin and Methyl Ethyl Ketone Peroxide (MEKP) hardener are mixed to form a solid. The mechanical properties of this coconut shell reinforced polymer composite is determined from the tensile test, which is conducted based on ASTM D3039 standard. The finding results showed that their mechanical properties are influenced significantly by the filler composition. The maximum tensile strength achieved at 15% weight of filler.

1. INTRODUCTION

The studies in natural fiber has increased insignificantly around the globe. Coconut shell is an organic natural plant fiber that is widely found nowadays in many industries such as building structure, furniture, packaging, agriculture, medicine and sportswear [1]. Natural fiber is also renewable source which can be extracted from leaf, seeds and grass. Coconut also have unlimited availability in many countries, it can be found abundantly in many countries such as India, Thailand, Indonesia, Malaysia, Sri Lanka and also Bangladesh. Lately, there has been escalation of interest and demand for natural fiber in many industries. The renewability of the biodegradable bio-composite makes it a highly interested attribute. It is also known that natural fiber show better mechanical properties compared to conventional synthetic fibers [2].

Conventional synthetic fibers that are utilized these days such has few disadvantages. Utilizing lignocellulose fibers provides a more salubrious working environment than the synthetic fibers. The glass fiber dust from the trimming and mounting of glass fiber components causes skin vexation and respiratory diseases among workers. For examples, there was some evidence of an 'asbestos type' condition arising from handling fiber [3]. As an alternative to conventional reinforcing fiber, lignocellulosic natural fiber is utilized since it is cost efficacious and environmental cordial through utilization of natural fillers or reinforcement in polymer composite [4]. The environmental friendliness and low cost production are among the most highlighted advantages offered by natural fibers [5-6].

Coconut fiber is additionally incrementing in agro waste. This designates that coconut shell will be discarded after it was utilized in agriculture. Hence, it is important to fabricate sample set of composites is consequential to analyze the mechanical properties using coconut shell as an agro waste, which is to ensure healthy environment by using agro waste in composite in the future. In this study, coconut shell powder with particle size 500 µm and below is used as a reinforcement, which is randomly distributed into polyester matrix. The filler weight percent varies from 10% to 30% into polyester matrix. It is expected that, the mechanical properties of this coconut shell reinforced polymer composite influenced significantly by the filler contents. The results finding is indispensable for the future development of composites that will be utilized in the future in many fields such as furniture and household appliances.

2. RESEARCH METHODOLOGY

The raw materials used for fabrication of the composites are coconut shell, unsaturated polyester and hardener. The coconut shell was broken with hammer to remove coconut milk and flesh inside the shell. The crushed coconut shell is then dried at room temperature for 24 hours. The crushed coconut shell was grinded by using crushing machine and then sieved using Vibratory Shaker Machine with 0.7mm amplitude to separate larger coconut shell tiny pieces from the powder size less than 500µm.

The coconut shell powder is mixed with polyester after measuring the mass of each constituents in composite, until it is homogenously mixed. The weight percent of the coconut shell powder (filler) is varies from 10% to 30% in order to study the effect of filler composition to the mechanical properties of the composites, as shown in the Table 2.1.

Table 2.1 Weight percentage of filler and matrix

Weight %	Filler content				
	10%	15%	20%	25%	30%
Filler	2.66 g	3.99 g	5.32 g	6.65 g	7.98 g
Matrix	23.95	22.61	21.29	19.96	18.63

The hardener is then added into the mixture which is act as catalyst and poured into mold to produce the composites plate. Tensile tests were performed to provide information on the mechanical properties in terms of the strength and ductility of the materials under uniaxial loading [7]. The test was performed according to ASTM D3039 standard using Universal Testing Machine model Instron 8872, as shown in Figure 2.1.

Figure 2.1 Universal Testing Machine, Instron 8872

3. RESULTS AND DISCUSSION

Figure 3.1 showed the stress-strain curve of the coconut shell reinforced polymer composite material with different percentage of filler. The plotted graph showed that the composite specimen breaks with brittle failure with sudden fracture at the maximum loads. For 10 % filler, the maximum tensile stress is 15.4 MPa, the Young's modulus is 2.6 GPa and extension break at 0.61 mm. For 15% filler, the maximum tensile stress is 18.3 MPa, the Young's modulus is 3.1 GPa and extension break at 0.62 mm. For 20% filler, the maximum tensile stress is 17.6 MPa, the Young's modulus is 3.2 GPa and extension break at 0.44 mm. Meanwhile, for 30% filler, the maximum tensile stress is 13.7 MPa, the Young's modulus is 3.9 GPa and extension break at 0.28 mm.

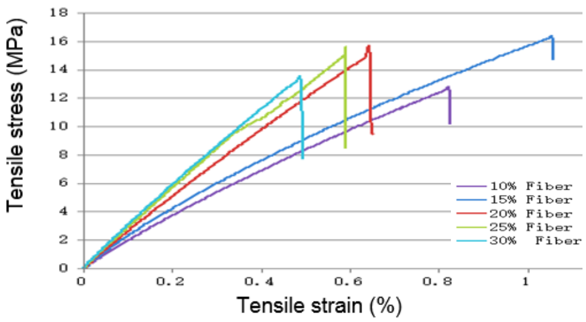

Figure 3.1 Stress-strain curve of the coconut shell reinforced polymer composite specimens

It is clearly shown that the maximum tensile strength of coconut polymer composite influenced significantly by the filler composition as shown in the Figure 3.2. The result showed that tensile strength of the composite increased 15.91% from 10% to 15% of the filler. This increment contributed by the increase of the surface area, good distribution and dispersion of the reinforcement in the matrix that results in greater ability to restrain deformation [8]. As the weight percentage further increased from 15% to 30% of the filler, the tensile strength value was reduced 25.52%. The reduction of tensile strength may be caused from poor adhesion of filler when the composition of the filler is too much within the matrix and contributed to poor dispersion [4]. Therefore, 15% content of the filler produced the best tensile strength for this coconut shell reinforced composite specimen.

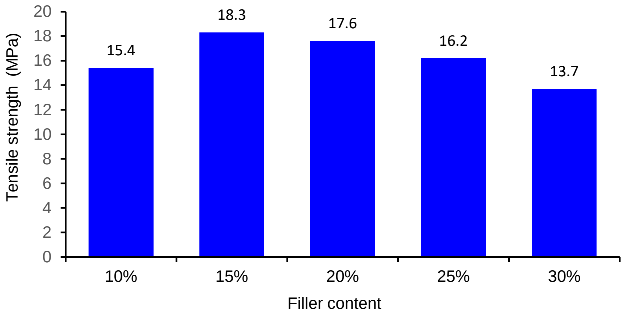

Figure 3.2 Maximum tensile strength with various filler content

Figure 3.3 showed the variation of magnitude Young's modulus with filler content. The experimental results showed that the Young's Modulus increases 33.26% when the weight percentage of the filler increased from 10% to 30% weight percentage. The magnitude of Young's modulus at 10% and 30% of filler contents are 2.6 GPa and 3.9 GPa, respectively. The increment of this Young's modulus value is incorporation with the filler restrains. When the quantity of the filler increased, there is less motion of the matrix phase in the proximity of each particle which consequently contributes the enhancement in modulus and stiffness [4].

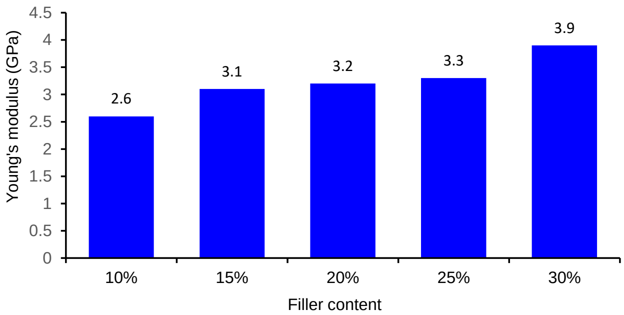

Figure 3.3 Variation of Young's modulus with filler content

4. SUMMARY

In this study, the natural fibers composite is successfully developed from the coconut shell, which is can be used as an alternative material to composites. The composite material from coconut shell waste is a biodegradable material that can contributed to better environment. Experimental results showed that the strength and the Young's modulus of this composite are influenced significantly with the filler contents. Higher weight percent of filler content produced higher elastic modulus. However, it is also reduced the tensile strength if the weight percentage of filler increased more than 15%. Therefore, the best composition of filler and matrix for this coconut shell reinforced composite specimen is

15%. The mechanical properties obtained from this study can be used as reference for further improvement in future.

REFERENCES

[1] Vasu, A.T., Reddy, C., Danaboyina, S., Manchala, G.K. & Chavali, M. (2017). The Improvement in Mechanical Properties of Coconut Shell Powder as Filter in HDPE Composites. *Journal of Polymer Science & Application*, 1(2), 1-6.

[2] Dayo, A.Q. (2017). Natural Hemp Fiber Reinforced Polybenzoxazine Composites: Curing Behavior, Mechanical and Thermal Properties. *Composites Science and Technology*, 144,114-124.

[3] Chereminisoff, N.P. (1990). Handbook of Ceramics and Composites: Mechanical Properties and Specialty Applications, CRC Press.

[4] Salmah, H., Marliza, M. & Teh, P.L. (2013). Treated Coconut Shell Reinforced Unsaturated Polyester Composites. *International Journal of Engineering & Technology*, 13(2), 94-103.

[5] Ng, L.F., Sivakumar, D., Zakaria, K.A. & Selamat, M.Z. (2017). Fatigue Performance of Hybrid Fibre Metal Laminate Structure. *International Review of Mechanical Engineering*, Vol. 11(1)1, pp.61-68.

[6] Ng, L.F., Dharmalingam, S., Zakaria, K.A. & Selamat, M.Z. (2017). Investigation on the fatigue life characteristic of kenaf/glass woven-ply reinforced metal sandwich materials, *Journal of Sandwich Structures and Materials*, 00, 1-16.

[7] Zakaria, K.A., Abdullah, S. & Ghazali, M.J. (2013). Comparative study of fatigue life behaviour of AA6061 and AA7075 alloys under spectrum loadings, *Materials and Design*, 49, 48–57.

[8] Durowaye, S.I. (2014). Mechanical Properties of Particulate Coconut Shell and Palm Fruit Polyester Composites, *International Journal of Materials Engineering*, 4(4), 142-147.