VOL. 11, NO. 18, SEPTEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

STUDY ON THE MECHANICAL PROPERTIES OF PMMA COMPOSITE USING RIDGE GOURD FIBRE

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ABSTRACT

Nowadays researchers are motivated by Environmental issues caused by several synthetic materials. These issues carved a path for the studies of natural fibers reinforced polymer composite and an option to have cost effective, light weight, high strength to weight ratio material. The ease in availability and fabrication process have attracted many researchers to use locally available natural resources as filler in composites, and to study their different properties for mechanical applications. Ridge gourd fibers were used at different weight percentages in Polymethylmethacrylate (PMMA) matrix. Fibers were pre-treated with alkaline solution to improve the interfacial adhesion. Tensile, Flexural and Impact behaviour of composites were analysed to study the stress transfer in fiber matrix phase. Optimum tensile strength values of the fabricated composites were found at 10wt% of fiber loading and similar results were obtained for flexural strength. Increment in tensile, flexural and impact strength in comparison to neat PMMA was found to be 17.2%, 5% and 600%.

Keywords: ridge gourd, Polymethylmethacrylate matrix., tensile properties, flexural properties, impact properties.

INTRODUCTION

In present scenario, increasing need for eco-materials with relatively high strength to weight ratio, cost effective and easy to process, made researchers to study natural fibers as an option for synthetic fibers in polymer composites [1]. Nowadays, the most commonly used natural fibers as reinforcement are flax, hemp, sisal and jute due to their specific strength, modulus and availabilities. These natural fibers are plant based and are lignocellulosic in nature. They are composed of cellulose, hemicelluloses, lignin, pectin and waxy substances [2]. The natural fiber reinforced composites are comparably strong, lightweight, cost effective and free from health hazards. Despite the advantages, they undergo water absorption especially moisture absorption which hampers their overall properties. However, major factors that presently restrict the large-scale manufacturing of green/natural fibers composite are poor interfacial adhesion between the fiber and matrix and the hydrophilic nature of fibers. A weak interfacial adhesion at the matrix interface which acts as a binder with the fibers, does not results in desired mechanical properties in the composite [3]. Luffa fiber is a light-weight material with high specific energy absorption capacity. However, up to now small fraction of research has been conducted on the luffa fiber as a source of bio-fibres and bio-composites due to the lack of information on the mechanical properties [4, 5].

In a study of composites consisting hybrid combination of sisal- coconut spathe, sisal-ridge gourd and coconut spathe-ridge gourd with fibers varying from 5% to 30 Wt%. Tensile properties showed an optimum value of 22 MPa at 25% weight fraction of natural fibers [6]. This study unveiled the alternative usage of natural fibers over synthetic fiber. Pannerdhass *et al.* [7] tested the mechanical properties of luffa fiber and ground nut reinforced epoxy at varying volume fraction. Mechanical properties of the composite showed enhancement and optimum results were observed at 40% fiber. In an another study the effect of reinforcement, chemical modification and weight ratio over flexural proprieties of matrix reinforced with a Luffa mat of fibers, a short Luffa fibers and a short Luffa fibers and fabricate it by different fibers treatments and weight fractions. The weight ratio effected the flexural properties of composites, and optimum strength values were evaluated at 105 weight ratio [8].

The non-biodegradable nature of synthetic polymer composites is a serious issue, as of today. Natural fiber reinforced polymer composites can solve both the environment and performance related issues. In a research work by Murali *et al.* [9], they study the possibilities of reinforcing new natural fibers as fillers in polymers, to develop economic, improved and light-weight materials. Earlier, techniques were formulated for extraction of fibers from plants like vakka, date and bamboo fibers, by researchers. The properties of these fibers were comparable to those of established fibers like sisal, coconut, banana and palm.

Sapuan *et al.* [10] investigated the mechanical properties of coconut fiber reinforced epoxy composites and study their potential to become successful materials in engineering applications. Tensile strength and flexural strength of the composite laminates ranged from 7.9 MPa to 11.6 MPa and 25.6 MPa to 67.2 MPa respectively. These values were less as compared to that of composites reinforced with cotton, coir and banana fibers. The coconut fiber reinforced composite reinforced with chemically treated fibers showed improved fiber matrix adhesion and hence showed better mechanical properties. Mohd zuhri *et al* [11] study the mechanical properties of short oil palm randomly oriented fiber reinforced epoxy (OPF/epoxy) composites. In this study, composite sheets with different volume fractions (5, 10, 15 and 20 vol%) of

ARPN Journal of Engineering and Applied Sciences

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fiber were fabricated. The tensile and flexural properties show degraded properties with increasing fiber fraction. The optimum tensile strength was obtained for the specimen with 5% volume fraction of fibers and beyond that there was no significant change. From this research, it is obvious that oil palm fiber is not suitable for structural applications. Boyand *et al.* [12] also estimated the effect of alkali treatment of ridge gourd fibers on the flexural properties of polyester matrix composites. Experiment results showed an increase of flexural strength by 14%.

In this work, PMMA based polymer composites were prepared with single luffa fiber as the reinforcing materials. The tensile, impact and flexural tests of the composite were performed and are discussed in detail.

MATERIALS AND METHODS

The raw materials involved in the fabrication were Polymethylmethacrylate (PMMA) and Ridge Gourd Fiber. Ridge gourd fiber were collected from farmland in Dehradun district of Uttarakhand, India. Samples are to be prepared with alkali treated fibers.

Table-1. Chemical composition of ridge gourd fiber.

Component	%
Holocellulose	82.4
α -Cellulose	63.0
Hemicellulose	19.4
Lignin	11.2
Extractives	3.2

FIBER PREPARATION

Initially they were air dried for 4 days to remove excess moisture. Fibers than uniformly cut equal to length of 5mm.

ALKALI TREATMENT OF FIBER

Uniformly cut fibers than initially cleaned with distilled water and then dried in sunlight. The dried fibers then alkali treated with 9% NaOH solution (9% NaOH with 91% distilled water) and left for 4hours. After soaking of fibers in NaOH solution, they were again dried in sunlight for 4-6 hrs.

PREPARATION OF COMPOSITE

PMMA is classified as a hard, rigid, but brittle material, with a glass transition temperature of 105°C. PMMA has good mechanical strength, acceptable chemical resistance, and extremely good weather resistance. Poly(methyl methacrylate) (PMMA) can be produced using a variety of polymerization mechanisms. The most common technique is the free radical polymerization of Methyl methacrylate (MMA). PMMA, with Molecular weight of 1,10,000 (Make: LG Corporation) was used as matrix material. For the fabrication of composites, initially PMMA granules were heated at 210ºC in mixer till the PMMA granules were thoroughly melted. To this melt, ridge gourd fiber at different weight percentages (0, 5, 10 & 15) was slowly added and mixed for 20 min at the same temperature. The mixture was taken out from the mixer and pressed to obtain a sheet of 200mm x 200mm with 3.2$\pm$0.4 mm in thickness.

Figure-1. Fabricated sheets of eco-composite at different wt% of ridge gourd fiber.

PREPARATION OF SPECIMENS

Before performing mechanical tests, the composite specimens were prepared as per ASTM standard and conditioned on ambient values of 23 $\pm$ 2^o C and 50 $\pm$ 5% relative humidity for 48 hrs.

Tensile testing specimens were having dimensions165mm×20mm×3.2mm as per standard ASTM D 638 with gauge length 53mm, using a Universal Testing Machine of model LR 100K, Lloyd U.K., at a crosshead speed of 2mm/min.

The flexural strength of the samples was measured by Universal testing machine of model LR 100K, Lloyd, U.K., according to ASTM D790. The crosshead speed was 2 mm/min. The dimensions of the rectangular shaped flexural specimens were 80mm×20mm×3.2mm with span length 48 mm. The flexural testing was done using a three-point bending test. Flexural strength and flexural modulus were calculated by the following equations.

$$F.S. = \frac{3FL}{2bd^2} \qquad (1)$$

Where; F is ultimate failure load in N, L is span of the supporting center in mm, b and d are the width and thickness of specimen for flexural test correspondingly in mm.

Izod impact test specimens were prepared as per standard ASTM D 256 of had dimension 65mm×13 mm×3.2 mm and 2.5 mm V-shape notch.

VOL. 11, NO. 18, SEPTEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Table-2. Nomenclature.

Short Forms	Description
RE	Ridge gourd Eco-composite
RE00	Neat epoxy
RE05	Fibers at 5% by weight
RE10	Fibers at 10% by weight
RE15	Fibers at 15% by weight

RESULTS AND DISCUSSION

Use of Natural fibers as a potential filler in polymer matrix composites are well cited in numerous literatures. However, the natural fiber-reinforced polymeric composites are highly polar and hydrophilic nature of lignocellulosic fibers, which shows poor interfacial adhesion compatibility with hydrophobic polymer matrix, which led to degraded mechanical and thermal properties [13]. Therefore, fibers were initially treated with alkali to remove lignocellulosic content and to reduce hydrophilic nature.

TENSILE TEST

Figure-2 show the results of tensile test performed on ridge gourd based epoxy composites. From the above graphs, it is clear that under increasing fiber content, the performance of the RE10 is much superior to the other three samples. This signifies that the tensile properties of the composite improve with increase in fibers till 10% weight fraction and then on further increasing to 15% weight fraction, it decreases. It may be due to insufficient stress transfer from PMMA to the fiber because of poor adhesion between fiber and matrix. RE10 sample showed 17.2% improvement than neat PMMA and 26.9%, 74% than RE05 and RE15. Similar trend was observed by Sakthivel *et al.* [14], they investigated mechanical properties of luffa and coir fiber reinforced with polypropylene matrix.

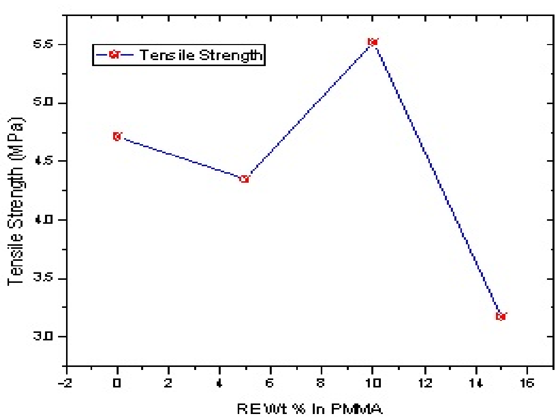

Figure-2. Tensile strength of eco-composite.

FLEXURAL TEST

The Flexural test used to measure the stress required to bend under three-point loading conditions. Flexural strength of PMMA and Ridge Gourd reinforced composites are plotted in Figure-3. The result of flexural test shows the effect of Ridge Gourd fiber reinforcement into the PMMA matrix. The value of flexural strength was found maximum for the composite RE10. The flexural strength of RE10 was found 05%, 10% and 6.4% more than RE00, RE05 and RE15 respectively. Impact strength decreases by further increasing the weight fraction of fiber from 10% to 15%, due to the non-homogeneous filling of reinforcement in matrices, which reduces the support to bending stress. The interfacial adhesion would be much less due to uneven distribution and bundle formations of fibers in the matrix, and this leads to poor stress transfer between epoxy and particle fibre [15,16].

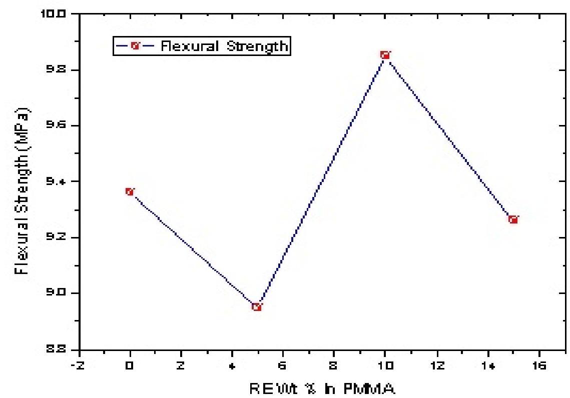

Figure-3. Flexural strength of eco-composite.

IMPACT TEST

Fiber content and fiber strength parameters influences the impact strength properties of the composite. Hence the improvement in strength with different weight fractions of fibre loading show varying properties. This variation in impact strength of the composites with 0%, 05%, 10%, and 15% of fibre content are shown in Figure-4. These figures clearly indicate the sudden increase in impact strength for fibre content. Optimum results were obtained for RE15 with maximum fiber content by weight. RE15 showed approximately 600% increment in impact strength from neat PMMA.

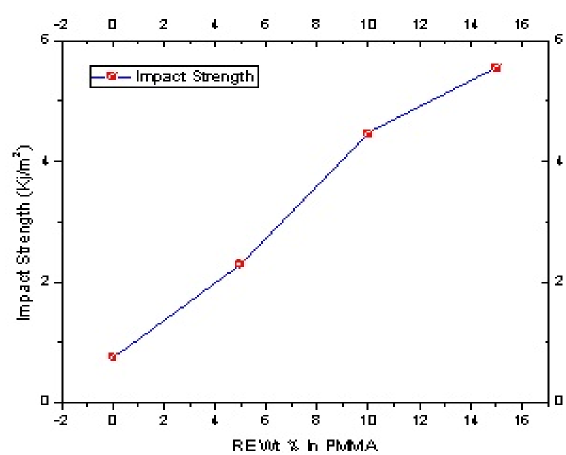

Figure-4. Impact strength of eco-composite.

ARPN Journal of Engineering and Applied Sciences

CONCLUSIONS

The mechanical testing was performed on the neat PMMA (E) and ridge gourd reinforced composite (RE00, RE05, RE10, and RE15) and following conclusions are made.

- Tensile strength of epoxy was improved by the reinforcing of ridge gourd fibre and further decreases with increase in fiber content.
- Flexural properties and impact properties were found to be improved.
- Tensile properties of the composite RE15 were seen maximum compared to those of other specimens.
- Flexural strength was also found maximum at RE15.
- Impact properties of ridge gourd fiber composite were found maximum for the composite RE15.

ACKNOWLEDGEMENTS

The Authors are grateful to and CIPET, Govt. of India, Amritsar, Punjab for their support in the characterization of the natural composites and DIT University for funding the research.

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