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Impact and hardness behaviour of epoxy resin matrix composites reinforced with banana fiber/camellia sinensis particles

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ABSTRACT

In this article, the impact and hardness properties of the epoxy resin matrix, banana fiber-reinforced, and Camellia Sinensis particles, filled bio-composites were established. Four composite specimens for Izod impact test and Rockwell hardness test were prepared as per the ASTM standards by keeping weight percentage of the matrix material as constant (65%) and varying the weight percentage of banana fiber (35, 33, 31, 29%)/Camellia Sinensis particles (0, 2, 4, 6%) respectively. Izod impact test and Rockwell hardness tests are performed on the four composites specimens as per ASTM standards. Experimental results reveal that by adding Camellia Sinensis particles with epoxy resin matrix/banana fiber composites enhances the hardness and diminishes the impact of energy and impact strength of the composites considerably.

1. Introduction

Due to biodegradable, completely or partly recyclable, and renewable, natural fiber-reinforced polymer composite materials are quickly increasing both in accordance with the conditions of their fundamental research and industrial applications. Investigators have come about with new product developments for composite utilizing natural fibers to decrease the damage of the environment and to create cost-efficient polymer reinforced composites, that are partly recyclable [1–4]. Initially, natural fibers were utilized 3000 centuries back in composite methods in ancient Egypt, in which clay and straw have been integrated together to create walls. During the past decade, natural fibers reinforced with polymer composite materials have been receiving ever-growing attention, both from different industries and from the university. The interest in polymer composite material reinforced natural fiber is increasing every day [5–8]. Their plentiful ease of use, low price and intensity, and reasonable mechanical characteristics are making them a very attractive environmentally friendly option for the production of composite materials.

The natural fiber in accordance with the composite materials is more ecologically friendly and has a wide range of applications in the area of transport (aerospace, railway coaches, automobiles) construction and building industries (partition boards, ceiling paneling), consumer products, packaging, and so on [9–12]. There is a broad range of various natural fibers that can be applied as fillers or reinforcement. Because of ease to use and characteristics, the most essential kinds of natural fibers utilized in composite materials are sisal, kenaf, jute, hemp, and flax. Additionally, ecological appropriateness can be accomplished by utilizing post-consumer reused plastic instead of virgin polymer matrices [13–15]. Polymer utilized as a matrix material for those composite materials is usually categorized into two categories, thermosetting and thermoplastic. Thermoplastic materials presently stand out, as matrices for bio fibers; the most widely utilized thermoplastic for this objective are polyvinyl chloride (PVC), polyethylene, polypropylene; at the same time as polyester resins, epoxide and phenolic are the most frequently utilized thermosetting matrices [16–18]. The main obstacle discovered with natural fibers is the inconsistency among the hydrophilic thermoplastic matrices and the hydrophilic natural

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fibers throughout integration, which results in detrimental characteristics of the resultant composite materials. Consequently, it is needed to improve this challenge by a variety of fiber-polymer interface variations to enhance the adhesion among matrix and fiber, which leads to an enhancement of efficiency of the resultant composite [19,20]. Contemplating the environmental dimensions in the selection of material, substituting synthetic fibers with natural ones is just an initial step. Limiting the exhaust fumes of greenhouse impact triggered by gases like CO2 into the environment and improving the perception of the finite nature of the fossil fuel resources that are prominent to create new substances that are based completely on renewable resources [21–23]. In this experimental work, an attempt has been made to establish the impact and hardness properties of the banana fiber reinforced, Camellia Sinensis particles filled-epoxy resin matrix composites.

2. Materials and methods

In this experimental work, matrix materials i.e. epoxy resin of one liter and hardener of 200 ml was procured from Covai Seenu and Company Ltd, Coimbatore, Tamilnadu, India. Filler material i.e. used Camellia Sinensis powder of 1 kg was collected from the tea stalls and bakeries. After the collection of used Camellia Sinensis powder, the collected powders were washed with distilled and then normal water. The washed Camellia Sinensis particles are dried at atmosphere temperature (36 °C) for 48 h to remove the moisture content. The reinforcement material i.e. pure white banana fibers were obtained as long fiber (10 cm length) from Tessma Natural Fiber Mills, Annur, Coimbatore, India. The obtained long banana fiber was cut into the short fiber with 3 cm length to enhance the mixing range with matrix and filler materials. By using the above matrix and reinforcement materials, four composite boards were prepared by keeping the matrix material weight percentage as constant (65%) and varying the reinforcement /filler material weight percentages. Normal hand layup technique was adopted to prepare the four composite boards with the help of a square molding box (150 mm width, 150 mm length and 6 mm thickness). The well-fabricated composite boards were named as C1 (65 wt% of epoxy resin, 35 wt% of short banana fiber and 0 wt% of Camellia Sinensis powder), C2 (65 wt% of epoxy resin, 33 wt% of short banana fiber and 2 wt% of Camellia Sinensis powder), C3 (65 wt% of epoxy resin, 31 wt% of short banana fiber and 4 wt% of Camellia Sinensis powder) and C4 (65 wt% of epoxy resin, 29 wt% of short banana fiber and 6 wt% of Camellia Sinensis powder) respectively. The compositions for the four composite plates were given in table.1.

Test specimens for impact and hardness tests were cut away from the composite boards by using a portable wood cutting machine as per ASTM standards. ASTM D-256 standard was used for the Izod impact test and the specimen dimensions were taken as 65 mm in length, 13 mm in width and 3 mm in thickness correspondingly. An Izod impact test specimen for C1, C2, C3, and C4 composites was shown in Fig. 1. Izod impact tests were conducted on the specimens by using Impact test machine. ASTM D785 [4] standard was adopted for Rockwell hardness test, the test specimen size is taken as 50 mm in length, 50 mm in width and 6.6 in mm thickness respectively. Test specimens of C1, C2, C3 and C4 composites for Rockwell hardness test were illustrated in Fig. 2.

Table 1
Composition details of composites.

Composites	Epoxy resin (wt %)	Banana fibe (wt %)	Camellia Sinensis powder (wt %)
C1	65	35	0
C2	65	33	2
C3	65	31	4
C4	65	29	6

A 1/16″ ball type indenter was used to make an impression on the hardness test specimens, 60 kgf loads was applied on the test specimens and that load was kept for 15 s, then the major applied load was removed. Rockwell hardness values were directly taken over from the dial in B scale. The same procedure is repeated for the remaining two trails.

3. Results and discussions

The following results have been attained from the experimental studies on the composites. Izod impact test [9] results of the composite specimens were illustrated from Figs. 3 to 8. correspondingly. Izod impact energy absorbed by the composite specimen C1, C2, C3, and C4 during the test was shown in Figs. 3–8, from that figure it was noticed that the Izod impact energy values for the C1 composites in trail-01, 02 and 03 were in the range of 40, 30 and 40 Joules respectively. The average impact energy magnitude of the C1 composite specimens was observed as 37 Joules. The composite specimens C2 were in the range of 30, 35 and 30 Joules during the test trail-01, 02 and 03 correspondingly. An average Izod impact energy value C2 composites is noted as 32 Joules. It was also found that the impact energy of C3 composites were observed as 25, 15 and 25 Joules during the test trail-01, 02 and 03 accordingly.

The average Izod impact energy of C3 composite specimens is observed as 22 Joules and the 25, 20 and 20 Joules of impact energy were obtained from the C4 composite specimens under the test trail-01, 02 and 03 correspondingly. The C4 composite specimens revealed an average Izod impact energy of 22 Joules. Average Izod impact energy observed by the C1, C2, C3 and C4 composites during the test were depicted in Fig. 4. Composites C1, C2, C3 and C4 exhibit an average Izod impact energy of 37, 32, 22 and 22 Joules correspondingly. It was found that the increased filler content and decreased fiber amount with the epoxy resin matrix leads to the reduction of composites impact energy. The composite C2, C3 and C4 attain less impact energy values than C1 composite specimens because of the excess filler material. Improper bonding of the filler material with epoxy resin and banana fiber causes the reduced impact energy of the composites. The lower load transfer capacity of the filler material is also the reason for the reduced impact energy of the composites during the test.

Izod impact strength absorbed by the composite specimen C1, C2, C3, and C4 during the test was shown in Fig. 5, from that figure it was noticed that the impact strength values for the C1 composites in trail-01, 02 and 03 were in the range of 1.03, 0.77 and 1.03 J/mm^2 respectively. The average impact strength magnitude of the C1 composite specimens was observed as 0.94 J/mm^2. It was observed that impact strength by the composite specimens C2 were in the range of 0.77, 0.90 and 0.77 J/mm^2 during the test trail-01, 02 and 03 correspondingly. An average Impact strength value of 0.81 J/mm^2 was noted for C2 composites and the C3 composites were observed an impact strength of 0.64, 0.38, and 0.64 J/mm^2 during the test trail-01, 02 and 03 accordingly. The C3 composite specimens observed an average Impact strength of 0.56 J/mm^2 during the test.

It was also noticed that the 0.64, 0.51, and 0.51 J/mm^2 of impact strength were obtained from the C4 composite specimens under the test trail-01, 02 and 03 correspondingly. The C4 composite specimens revealed an average Impact strength of 0.56 J/mm^2 during the test. Average Impact strength observed by the C1, C2, C3 and C4 composites during the test were depicted in Fig. 6. Composites C1, C2, C3 and C4 exhibit the average impact strength of 0.94, 0.81, 0.56 and 0.56 J/mm^2 respectively. It was found that the increased filler content and decreased fiber amount with the epoxy resin matrix leads to the reduction of composites impact strength. Reduced impact strength values were found in the C2, C3 and C4

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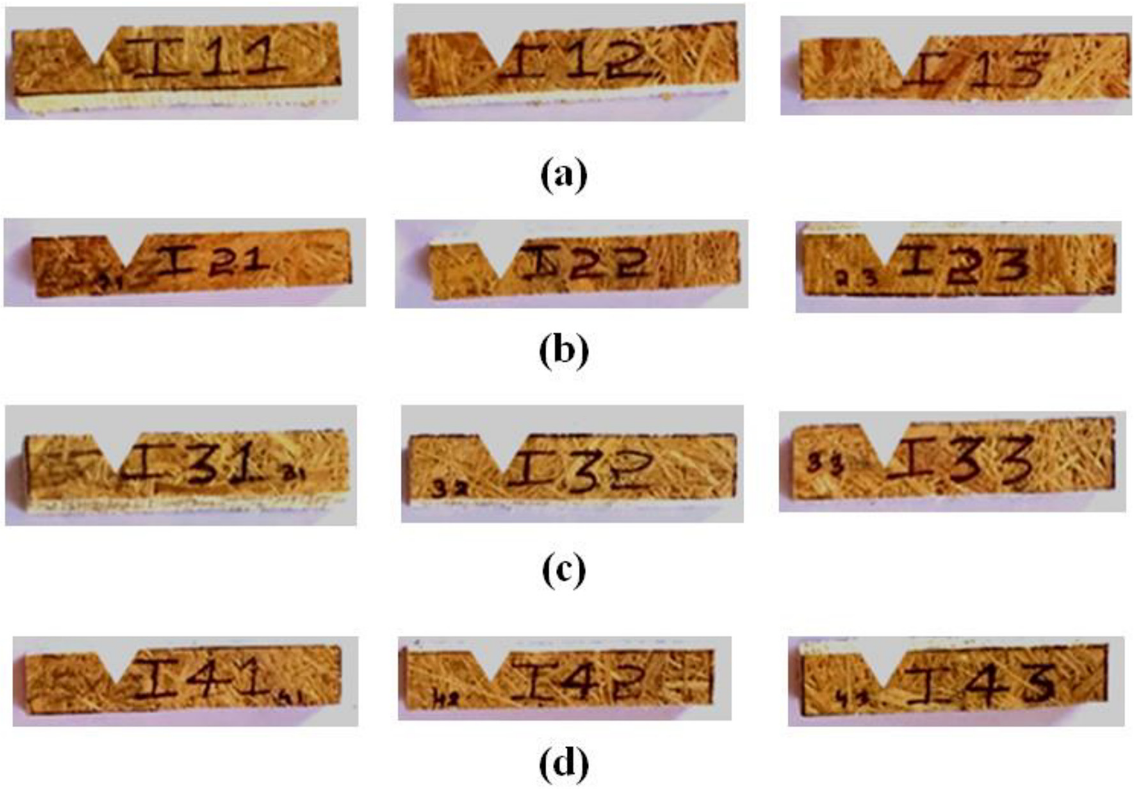

Fig. 1. Izod impact test specimens of (a) C1 composites (b) C2 composites (c) C3 composites (d) C4 composites.

Fig. 2. Rockwell hardness test specimens of (a) C1 composites (b) C2 composites (c) C3 composites (d) C4 composites.

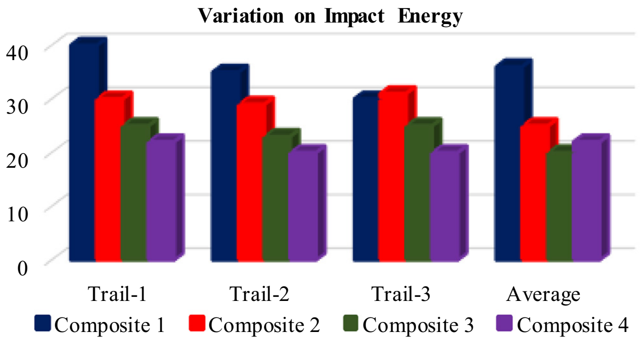

Fig. 3. Variation on Impact energy of Composite C1, C2, C3 and C4.

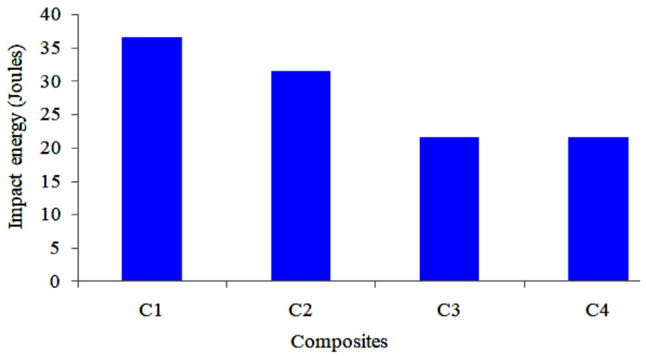

Fig. 4. Variation on average impact energy of C1, C2, C3 and C4 composites.

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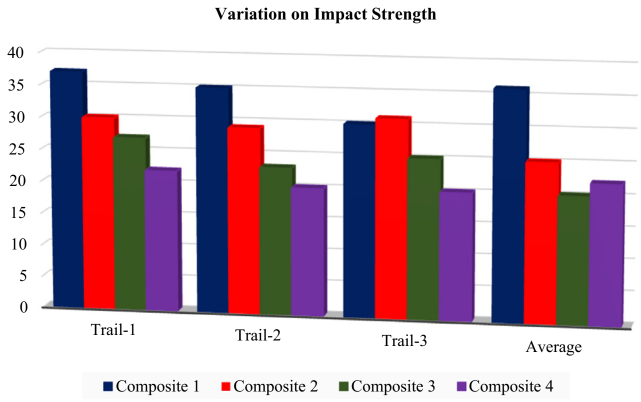

Fig. 5. Variation on the Impact strength of Composite C1, C2, C3 and C4.

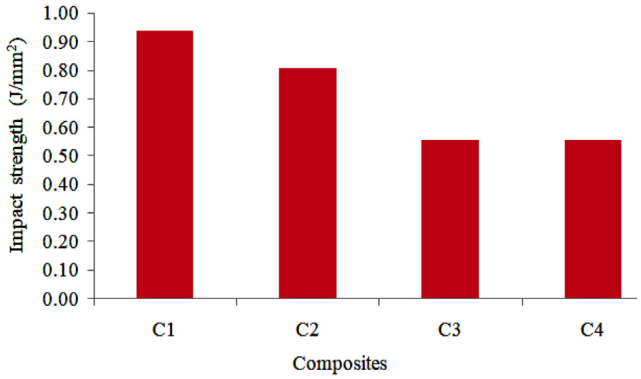

Fig. 6. Variation on average impact strength of C1, C2, C3 and C4 composites.

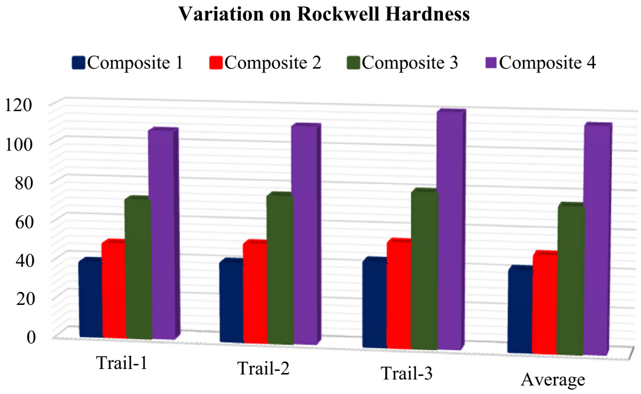

Fig. 7. Variation on Rockwell Hardness of Composite C1, C2, C3 and C4.

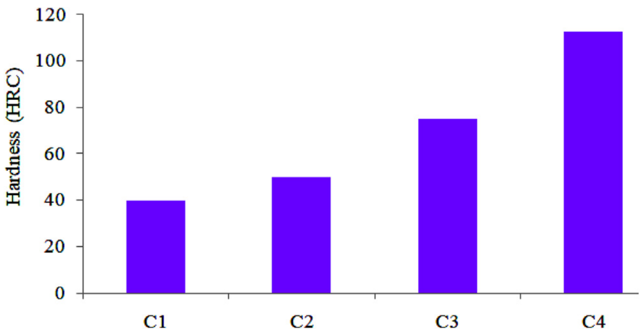

Fig. 8. Variation on average Rockwell hardness of C1, C2, C3 and C4 composites.

composites than C1 composite specimens because of the excess filler material. Improper bonding of the filler material with epoxy resin and banana fiber causes the reduced impact strength of the composites. The lower load transfer capacity of the filler material is also the reason for the reduced impact strength of the composites during the test.

The hardness of the composite's specimens that are exhibited during the Rockwell hardness test was illustrated in Fig. 7. From this figure, it was noticed that the C1 composite specimens Rockwell hardness value for trail-01, 02 and 03 were in the range of 38, 40 and 42 HRC respectively. The average Rockwell hardness values for the C1 composite is 40 HRC. It was found that the Rockwell hardness values for C2 composites were in the range of 48, 50, and 53 HRC respectively. An average Rockwell hardness value of 50 HRC was observed in C2 composites.

From the figure, it was observed that the hardness value for the three trails was observed in the range of 71, 75, and 79 HRC correspondingly. An average Rockwell hardness value of 75 HRC was observed in C3 composites and the hardness values of composite C4 for the trail tests were noticed in the range of 107, 113 and 118 HRC respectively. Average Rockwell hardness value of 113 HRC was observed in C4 composites. Average Rockwell hardness values for C1, C2, C3 and C4 composites were shown in Fig. 8 and the corresponding hardness values were found in the range of 40, 50, 75 and 113 HRC.

The experimental resuls shows that the composite specimen with higher filler material contents (C2, C3 and C4) exhibits better hardness behaviour than the C1 composites due to the addition of higher weight percentage of filler material to the banana fiber and epoxy resin. The complete accomplishment of the filler material into the resin matrix and banana fiber leads to the improvement in the hardness of the composites significantly.

4. Conclusions

In this experimental work, four composite specimens were prepared by varying the weight percentages of the epoxy resin and banana fiber with Camellia Sinensis powder. Izod impact test and Rockwell hardness tests were performed on the specimens. Impact energy, impact strength and Rockwell hardness values for the composites were evaluated and compared with each other. The following conclusions were made from the above experimental studies on the composites. Impact energy and impact strength of the C2, C3, and C4 composites are comparatively low when compared with C1 composites. Impact energy and impact strength of the composites were found minimum with respect to the addition of higher weight percentage of Camellia Sinensis particles in the epoxy resin matrix and banana fiber composites. Rockwell hardness values of the C2, C3 and C4 composites are considerably higher than that of C1 composites. The addition of higher weight percentage of Camellia Sinensis particles with epoxy resin matrix and banana fiber composites enhances the hardness of the composites considerably. Camellia Sinensis particles can be used as filler material in natural as well as in polymer-based composites.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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