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EFFECT OF EGGSHELL PARTICLES ADDITION ON MECHANICAL PROPERTIES OF JUTE FIBER REINFORCED EPOXY RESIN MATRIX BIO-COMPOSITES – AN EXPERIMENTAL STUDY

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Abstract

In recent years, natural fibers have considered as the new category of material for the replacement of the synthetic fibers. In this experimental study, bio-composites have developed with epoxy resin, fine eggshell particles and jute fibers. Six composite mates have prepared through the compression-moulding machine by changing the weight percentage of eggshell particles (0, 2, 4, 6, 8 and 10%) with epoxy resin and jute fibers respectively. The water jet machining process has adopted to prepare the composite specimens as per ASTM standards from the composite mats. The tensile, flexural and impact tests have been carried out on the composites specimens to establish the different mechanical properties under the standard testing environment. The test results reveals that the composites containing of 4% of fine eggshell particles in weight percentage enhances the tensile and flexural properties of the composites significantly. Conversely, composite specimen's impact energy and impact strength have reduced with respect to the increasing weight percentage of the fine eggshell particles.

Keywords: Experimental studies, mechanical properties, epoxy resin, jute fiber, eggshell, bio-composites.

1. Introduction

In latest years, research focus on biodegradable composites has significantly increased to develop the pollution free green composites and the replacement of the polymer materials for commercial applications. Abundant research investigations are focus on the usage of natural resources as reinforcement materials to develop the various varieties of natural composites [1]. Different organic fiber composite materials reach the mechanical characteristics of fiber optic composite materials, and applied in the automotive and furnishings industries. Up to the date, the most significant organic fibers are Coir, Jute, and flax. Organic Fibers are renewable resources and they have been biodegradable [2]. Several researchers have aimed at their work towards defining abundant combinations of biodegradable matrix/natural fillers in order to promote new classes of biodegradable composites with enhanced mechanical properties, as well as to attain products with lower cost. Among several investigated natural fibers in this area, different fillers have the significant importance [3]. Due to the increasing concern about the environment, a lot of research is going on in the field of developing new materials. Natural fibers are being used to create composites as they have less density, easily available and have less weight to strength ratio [4]. It has revealed that the inclusion of groundnut shell powder into the epoxy-based banana fiber gives the superior bonding between the matrix and reinforcement material. Adding up the groundnut shell powder to the epoxy/banana fiber enhances some mechanical properties of composites [5]. The effect of hybridization of jute/kenaf/E-glass fabric reinforced epoxy composites were studied and found that there was only 2% voids and also the physical properties were enhanced and has reduced moisture absorption [6]. 2% Degraded polypropylene and maleated polypropylene are used as compatibilizer to improve the surface adhesion between jute fibres and polypropylene matrix, as a result the composites show higher mechanical properties and also the study showed that there is no degradation of fibres during chemical treatments [7]. Jute, bamboo fibers and glass fiber reinforced polymer composites provides enhanced mechanical properties, wear and moisture absorption resistances [8]. In a hybrid composite, which consists of bamboo fiber as an outer layer and jute fiber as the inner layer gives enhanced mechanical properties [9]. The tensile behavior of Kevlar, Jute fiber is studied by reinforcement with Epoxy, the material is prepared with various combination of the Kevlar and jute fiber. The hand-

layup method is used and the material is tested in Tensometer. The thickness of the composite enhances the tensile strength due to the addition of Kevlar, which is required for dynamic loading application [10].
Distinctive designing properties, for example, physical and mechanical, imperviousness to abrasive wear, weathering and fire, etc. of plant fibers, for example, jute and sisal alongside industrial wastes (fly ash and red mud) which have been utilized for composite fillers. The study uncovers that the created polymer regular fiber modern (inorganic) waste composites appear to have far better mechanical properties and resistance to abrasive wear, fire, water absorption, weathering, and chemical attack, when contrasted with traditional materials, for example, wood, medium density fiber (MDF) sheets, particle board, and so forth [11]. Mechanical Behavior of Eggshell and Coconut Coir Reinforced Composites and fabricated by hand layup method. The created composites are having increased tensile and compressive strength [12]. Fabricated and tested the composite with slag and eggshell powder filler. The strength of the slag and eggshell reinforced epoxy composite increased as in the case of flexural and impact strength as the weight increased. Tensile strength of the composite increased gradually up to 18% of slag in weight and gradually decreased [13]. Mechanical properties of egg shell powder reinforced with polymer composites, polyamide/ nylon block composite prepared in injection molding and its tensile, flexural, impact strength are more as compared with polyamide composite [14]. Mechanical properties, morphology and water absorption behavior of chemically modified low-density polyethylene/eggshell powder composites. It was found that the chemical treatment of eggshell powder has a positive effect on mechanical properties, water absorption and morphology of composites [15]. Adding malefic anhydride and eggshell nanoparticles instigate an improvement in mechanical properties as well as better adhesion among polymer, starch and corn particles [16]. It has observed from the various researches, addition of eggshell particles into the fibers and matrix has enhanced the mechanical properties of the composites considerably. In this experimental study, mechanical properties of the epoxy resin-jute fiber reinforced which have filled with fine eggshell particles were established through the different mechanical tests under the standard testing environment.

2. Materials and methods

Epoxy resin -LY556 (figure.1D) and hardener - HY991 (figure.1E) was used as matrix materials, which are procured from Covai Seenu and Company, Coimbatore, Tamilnadu, India. The epoxy resin and hardener has mixed by using a mechanical stirring machine in the ratio of 10:01 to obtain the good bonding with fibers filler materials. The required amount of jute fibers have procured in the form of mates (figure.1F).
The waste eggshells which are used as filler materials were collected from hotels and restaurants in and around the erode region of Tamilnadu, India. The collected waste eggshells were cleaned first by normal water and then it has washed again with hot water to remove the presence of dust particles completely. After the washing process, it has allowed to dry at atmospheric temperature in an open space for 6 hours. After the drying process, the well-dried eggshells have put in a home use mixer to get the eggshell particles (figure.1A).

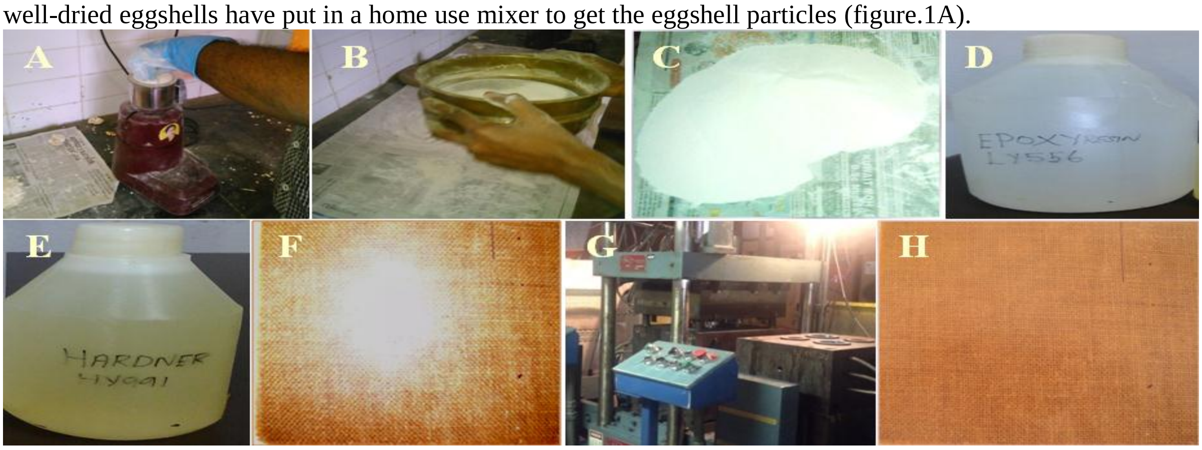

Figure 1. (A) Egg shell's grinding process (B) Grinded egg shell powder separation process (C) Grinded and filtered egg shell powder (D) Epoxy resin – LY556 (E) Hardner – HY991 (F) Jute fiber mate (G) Compression moulding machine (H) Jute fiber/Epoxy Resin/Egg shell composite plate

The mixer has converted the irregular shaped eggshells into the powder form of eggshells (figure.1B). After the grinding process the powder form of eggshells with irregular size particles have separated as 75 microns size by using manual sieving process (figure.1C). Required amount of fine eggshell particles have obtained through this process. A compression moulding machine (figure.1G) has used in this research work to produce the composite mates from the jute fiber, epoxy resin and fine eggshell particles. Initial stage of composite mates starts with the arrangement of jute mates inside the compression-moulding machine. Mates of jute fibers have placed on the compression-moulding machine surface table. After this arrangement, suitable amount of eggshell powders have dispersed on the jute mates surface completely. Epoxy resin/hardener solution has applied over the eggshell particles dispersed surface for particular thickness.

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After the application of epoxy resin/hardener solution over the jute mate and eggshell powders, again the jute mate has placed on the same eggshell powder dispersed surface. The combined mate form of jute fiber, epoxy resin-hardener and eggshell has allowed to heat up to 100°C for thirty minutes duration time at the compression-moulding machine under the specific hydraulic pressure. After the processing time of 30 minutes, the required composite mate (figure.1H) has obtained and it has allowed for cooling at room temperature. After the cooling process, the composite mate has taken over to the water jet machining process and the required composite specimens have cut away from the composite mate as per the ASTM standards. The same process has repeated for the remaining five compositions. The well-prepared composite specimens are allowed for tensile, flexural and impact tests to establish the mechanical properties of the composites. A computerized universal testing machine (UTM) of 400 kN capacity has used to carry out the tensile test (ASTM D638) and flexural test (ASTM D790-10) of the composites with a loading rate of 2 mm/min. An Izod impact test also carried out on the impact test composite specimens as per the ASTM D256-10 standards in a Impact testing machine. The composite specimens for tensile, flexural and impact tests have illustrated in figure.2 and figure.3 respectively. The outcomes of the mechanical tests like, peak tensile load, breaking tensile load, ultimate tensile strength, yield strength, percentage of elongation, peak flexural load, breaking flexural load, flexural strength, flexural modulus, impact strength and impact energy for all composite specimens have represented as graphical color plot in results and discussions chapter.

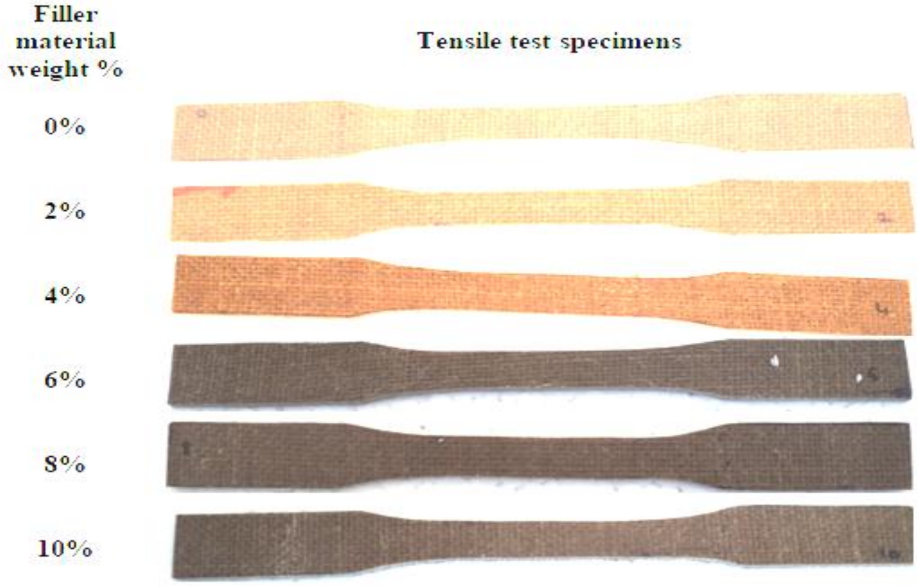

Figure 2. Tensile test specimens as per ASTM standards

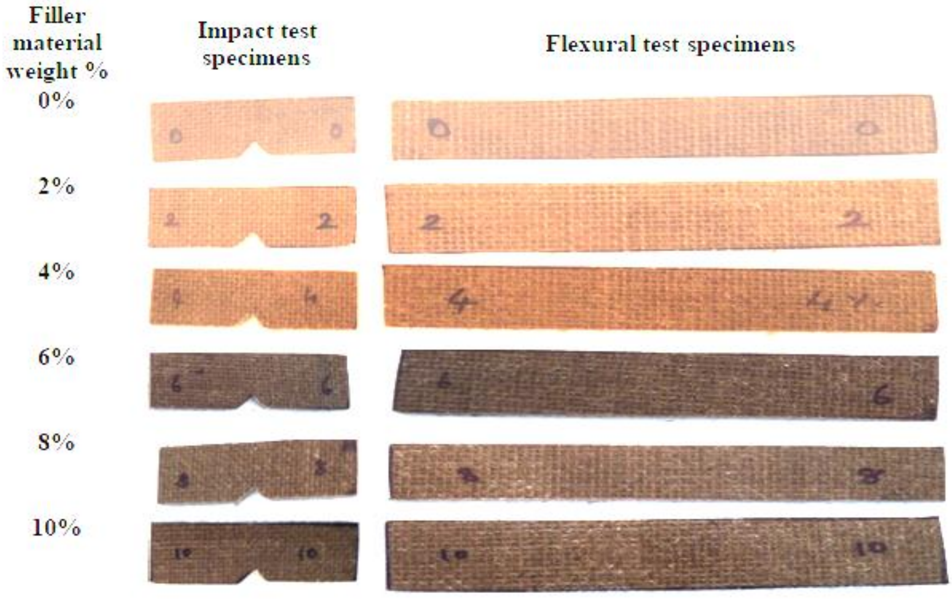

Figure 3. Impact and flexural specimens as per ASTM standards

3. Results and discussions

Experimental studies on epoxy resin matrix, jute fiber reinforced, and eggshell powder filled bio-composites was successfully carried out and the following results were acquired for the all bio-composite specimens.

3.1 Peak tensile load and breaking tensile load

Effect of increasing filler material weight percentage with epoxy resin-jute fiber composites for peak tensile load and breaking tensile load has evidently illustrated in figure.4. It has observed that the overfed weight percentage of filler material (eggshell powder) is enhancing the peak tensile load of the composite during the tensile test. Maximum peak tensile load of 2201 N was found in 4% filler composite specimen and the minimum value of 1432 N peak load was observed in 10% filler composite specimen respectively. Peak tensile load has increased with respect to the increased weight percentage of filler material up to 4% of eggshell powder contribution on the composites. Unlikely the peak tensile load was in receipt of lower values for the increasing weight percentage of eggshell powder after the 4%. The peak load magnitude for 0%, 2% 6%, and 8% filler material on composites were in the range of 1562N, 1656N, 1810N and 1667N respectively. Load observed by the specimens in tensile test during the rupture also represented in figure.4. It was found that the breaking load exhibit by the composite specimen were maximum at 4% filler material composites with the magnitude of 2901 N.

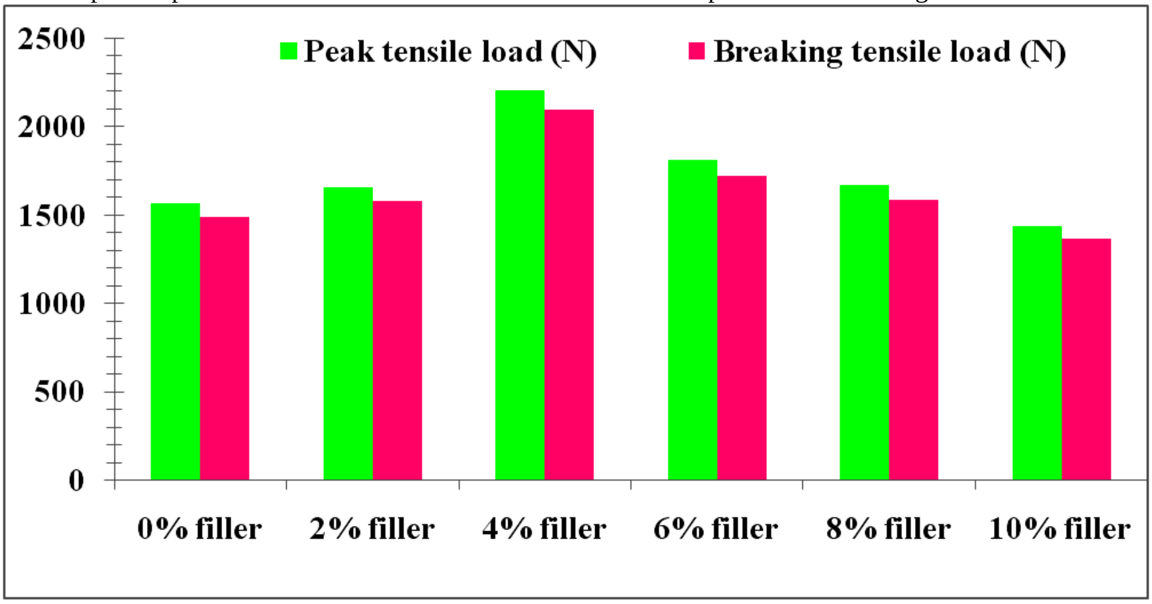

Figure 4. Variation on peak and breaking tensile load of composites for increasing filler material weight percentage

The minimum breaking tensile load has observed in 10% filler material composite with the magnitude of 1360 N respectively. On the other hand the composites filled with 0%, 2%, 6% and 8% were reveals the tensile breaking load of 1484 N, 1574 N, 1720 N and 1584 N respectively. Effective load shifting between the fiber, filler and matrix are the indication of the maximum tensile load and breaking load on the composites.

3.2 Ultimate tensile strength and yield strength

Strength exposed by the composites during the tensile test and the stress released by the composites during the yield conditions has illustrated in figure.5 correspondingly. Ultimate tensile strength of 56.45 MPa has noted in 4% filler composites due to the most favorable availability of eggshell particles inside the composite specimens. The minimum tensile strength of 40.05 MPa has observed in 0% filler composites due to the absence of eggshell particles. The tensile strength of composites filled with 2%, 6%, 8% and 10% eggshell particles were in the range of 46.41 MPa, 48.92 MPa, 44.53 MPa and 42.75 MPa respectively. Strength exposed by the composite specimens at plastic deformation stage during the tensile test is shown in figure.5. Addition of optimal weight % (4%) of egg shell particles into the epoxy resin matrix-jute fiber reinforced composites were accomplish the maximum yield strength of 47.98 MPa and the lowest yield strength of 34.05 MPa is noticed in 0% filler material composites due to the complete absence of egg shell particles.

Composites with 2%, 6%, 8% and 10% filler material exhibits the moderate yield strength in the range of 39.45 MPa, 41.58 MPa, 37.85 MPa and 36.34 MPa correspondingly.

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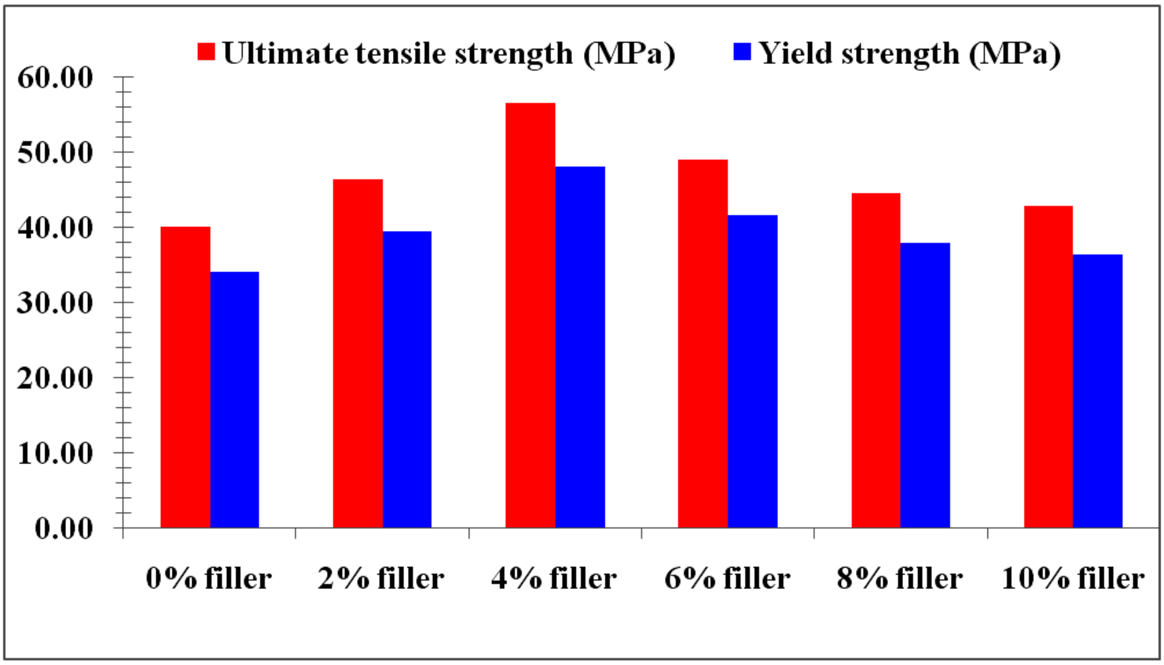

Figure 5. Ultimate tensile strength and yield strength variation of composites for the different filler material weight percentages

3.3 Percentage of tensile elongation

Elongation in composites during the tensile test in terms of percentage has shown figure.6. Four % of eggshell particles dispersed composites reveals the better tensile elongation percentage of 4.89% than other composite specimens. Applied tensile load on the composites were shifted from the matrix to the fiber and the load was transferred into the filler material. Highest tensile elongation percentage was found in 4% filler material composites due to the above said cause. Minimum elongation percentage (2.51 %) of due to tensile load has noticed in 0% filler material composites, due to the nonexistence of the eggshell particles. The tensile elongation percentage for 2, 6, 8 and 10 % filler composites has found in the range of 2.94, 2.98, 2.67 and 2.32 % respectively.

3.4 Peak flexural load and breaking flexural load

Ability of the composite specimens to withstand the maximum lateral loads and load at which the composite specimens letdown were established from the three point bending test and it was illustrated in figure.7.

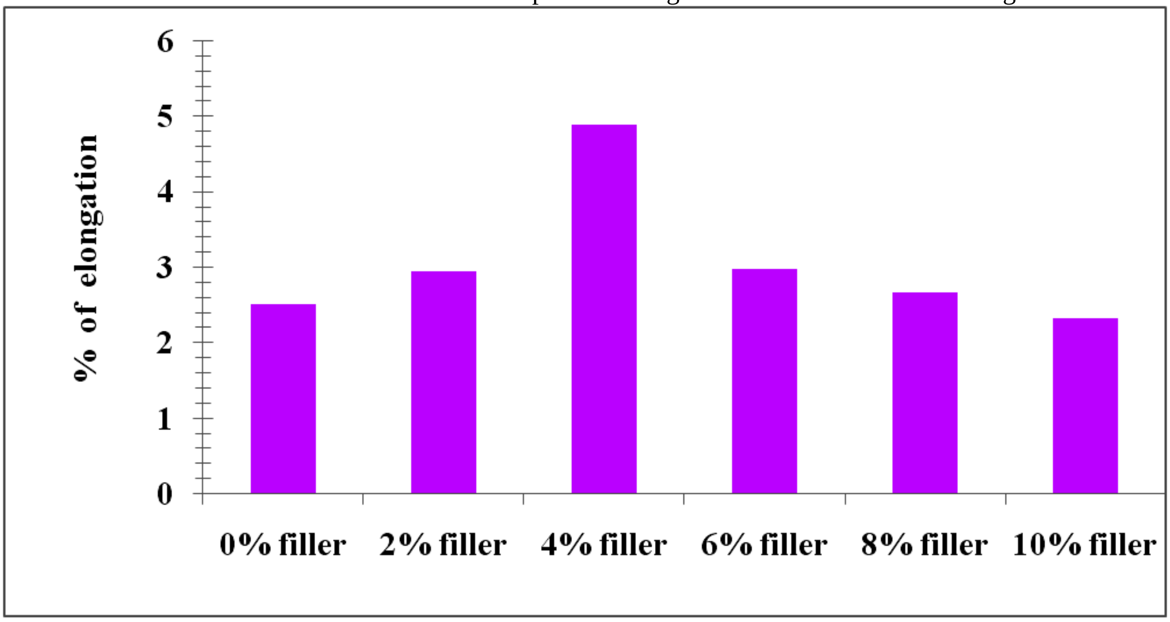

Figure 6 Effect of elongation percentage on composite specimens for various weight percentages of eggshell particles

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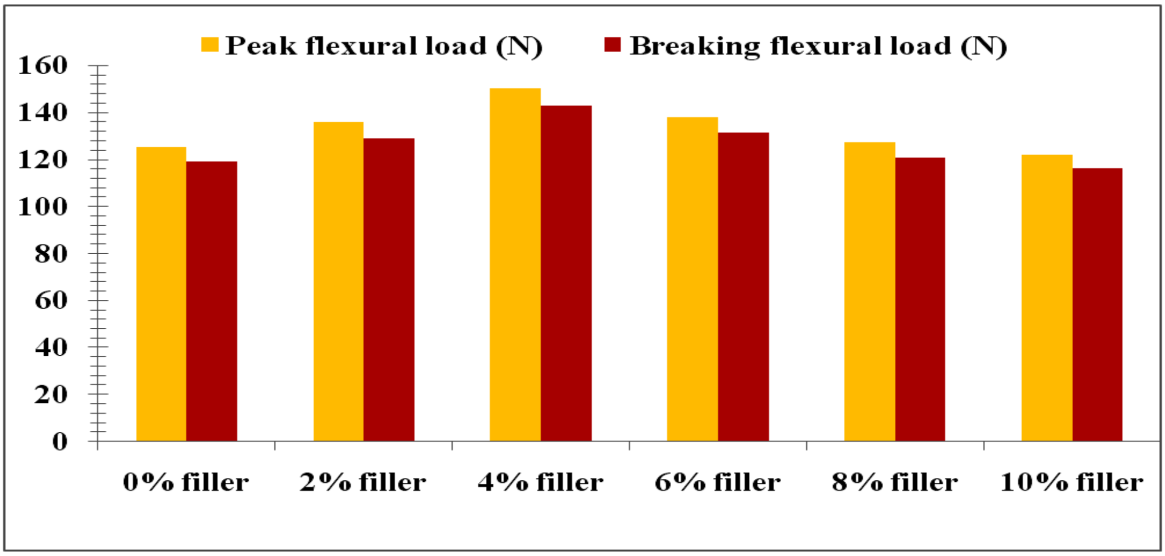

Figure 7. Peak flexural load and breaking flexural load for dissimilar weight percentages of eggshell particles in composites

Peak flexural load of 150 N were found in 4% eggshell particle dispersed composites. Lower value of peak flexural load was observed in 10% filler eggshell particle dispersed composites. Ability of the optimal eggshell particles to observe the lateral load, which is applied on the composites specimens, is the source for the enhanced flexural load than other composite specimens.

Peak flexural load of 125, 136, 138 and 127 N are observed for composites specimens, which are dispersed 0%, 2%, 6% and 8% of eggshell particles respectively. Failure load established by the composite specimens during the three point bending test results were represented and maximum breaking flexural load of 143N were noticed in 4% filler material composites. The minimum flexural load of 116N, which has exposed by the composite specimens during the three-point bend test, has found in 10% eggshell particles mixed composites. Excess amount of eggshell particles in the epoxy resin-jute fiber reinforced composites leads to the reduction of flexural properties. Composites filled with 0%, 2%, 6% and 8% egg shell particles were established the breaking flexural load in the magnitude order of 119, 129N, 131 and 121N respectively.

3.5 Flexural strength and flexural modulus

Flexural strength of the composite specimens exhibited during the three-point bend test has shown in figure.8. Composite specimens filled with 4% eggshell particles reveals the superior flexural strength of 125 N, due to the best possible amount of eggshell particles presence inside the composites.

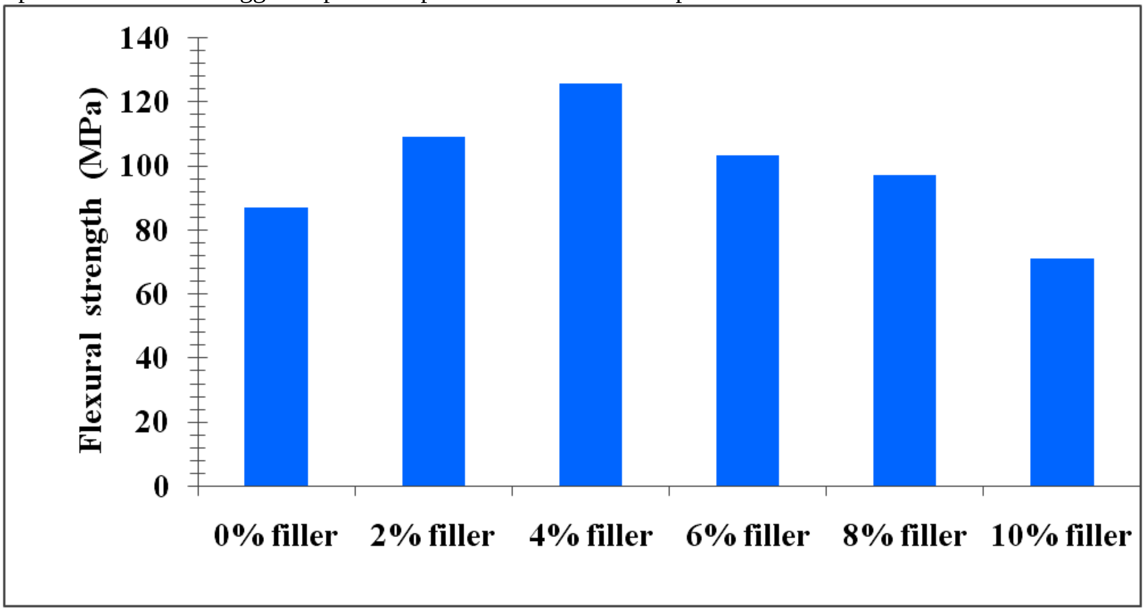

Figure 8. Flexural strength of composite specimens under a variety of eggshell particles weight percentage

The minimum flexural strength of 87N were obtained in 0% eggshell powder filled composites because of the absolute absence of the egg shell particles inside the composite specimens.

Eggshell particles filled with epoxy resin matrix-jute fiber reinforced composites in the weight percentage of 2, 6, 8 and 10% were exhibits the flexural strength of 109, 103, 97 and 71 MPa respectively. Distribution of ap-

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plied load on the composite specimens in lateral directions are carried out by the finest amount of eggshell particles causes the enhanced flexural strength in the composite specimens. Bending or flexural modulus for the composite specimens are shown in figure.9.

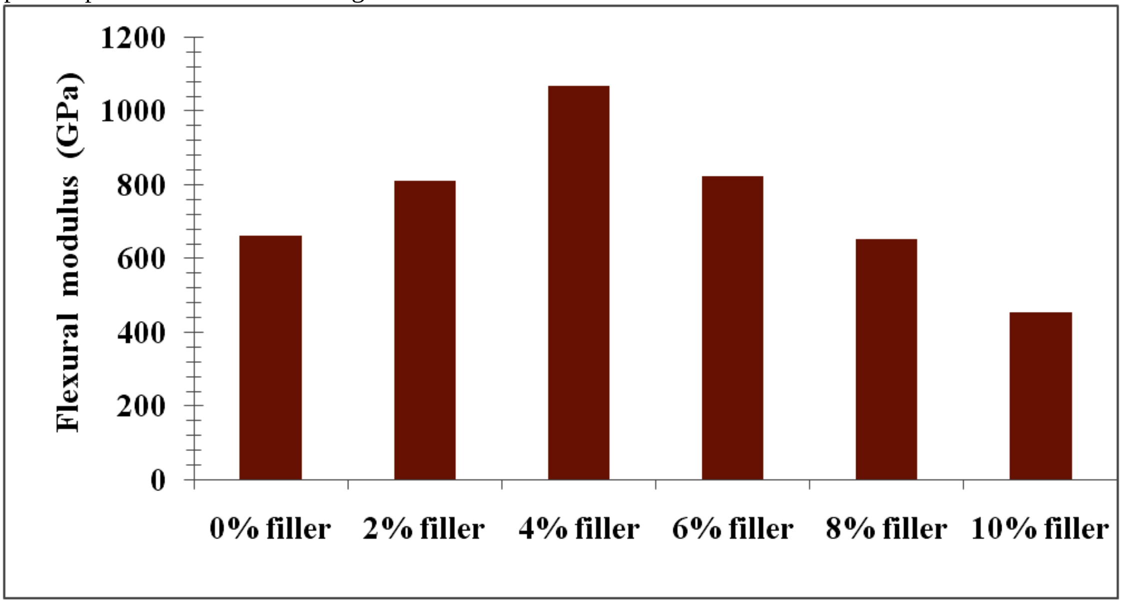

Figure 9 Flexural Modulus of composite specimens for diverse weight percentage of eggshell particles

Maximum and minimum three point bending test modulus are observed in the range of 1067 and 453 GPa in 4 and 10% eggshell particles filled composites respectively. The flexural moduli for other eggshell filled composites are in the range of 660, 809, 821and 651 GPa at 0, 2, 6 and 8% eggshell filled composites correspondingly. Best possible weight percentage of eggshell particles added with the epoxy resin matrix and jute fiber reinforced composites were significantly enhances the flexural modulus of the composite specimens significantly.

3.6 Impact energy and impact strength

Energy absorbed by the composite specimens during Charpy impact test has illustrated in figure.10. Energy observed by the composites specimens are in the range of 60, 48, 41, 36, 30 and 24 Joules for 0, 2, 4, 6, 8 and 10% egg shell particles composites. Improbably, impact energy of the specimens has decreased relating to the increasing weight percentage of eggshell particles, which has dispersed with the epoxy resin-jute fiber reinforced composites.

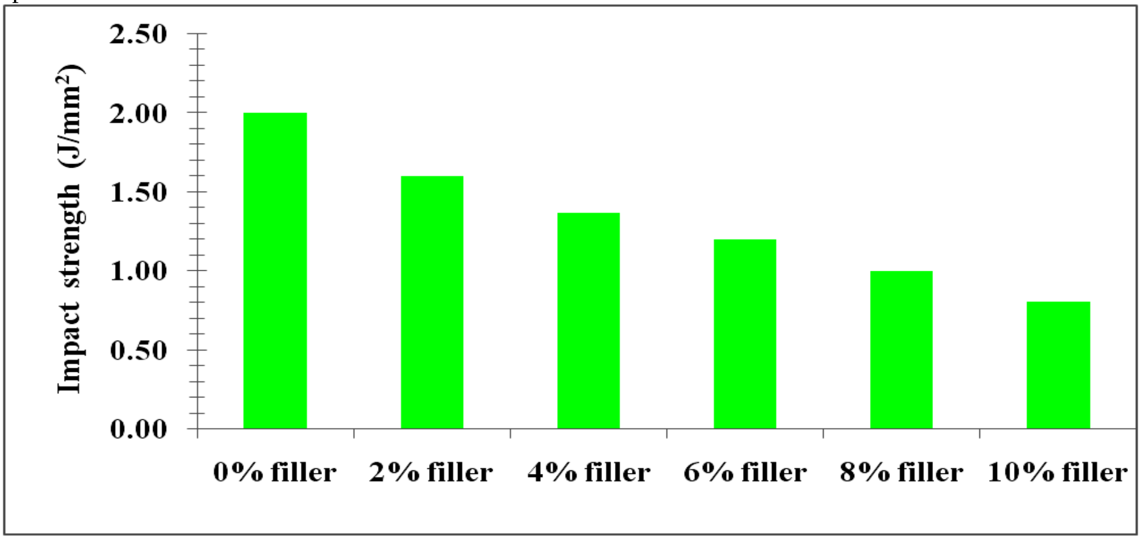

Figure 10 Variation on impact strength of composites for increasing eggshell particles weight percentage

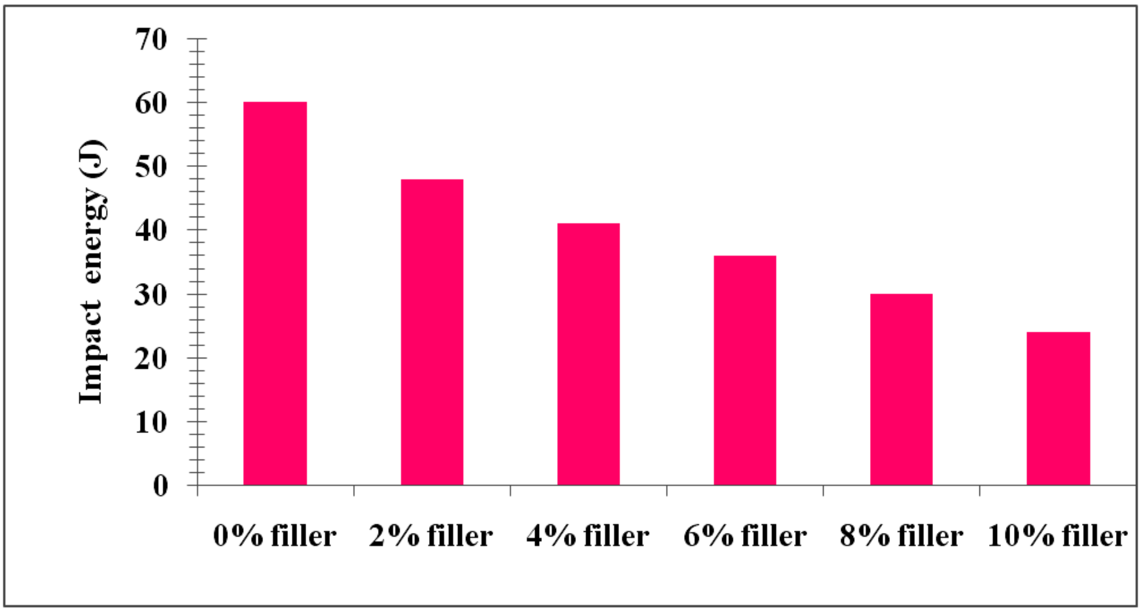

Figure 11 Impact energy observed by the composites intended for increasing eggshell particles weight percentage

Maximum impact energy of 60 J has revealed by the 0% eggshell filled composites and the minimum impact energy of 24 J has obtained in 10% eggshell filled composites respectively. Strength exposed by the composite specimens during the Charpy impact test has depicted in figure.11. Impact strength exposed by the composite specimens has noticed in the range of 2.00, 1.60, 1.37, 1.20, 1.00 and 0.80 J/mm^2 for 0, 2, 4, 6, 8 & 10% eggshell particles filled composites respectively. On the contrary, strength exposed by the composite specimens has gradually reduced with reference to the increasing weight percentage of eggshell particles to the epoxy resin-jute fiber reinforced bio composites.

Inopportune impact energy and impact strength exposed by the eggshell filled composites during the Charpy impact test has caused due to the uneven distribution of eggshell particles in the composites.

4. Conclusions

The influences of different weight percentages of fine eggshell particles as a filler material on the mechanical properties of an epoxy resin matrix-jute fiber reinforced biocomposites have investigated. Composites containing 4% of fine eggshell particles showed the improved tensile and flexural behavior when compared to other weight percentages of the fine eggshell particles. The enhanced tensile and flexural properties of the composites have obtained due to the existence of fine eggshell particles and the good bonding between the matrix, fibre and eggshell particles. The poor impact energy and impact strength has accomplished by the composites for the increasing weight percentage addition of fine eggshell particles due to the inappropriate bonding between the fiber, matrix and filler materials.

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