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Effect of mechanical properties on banana macro particle reinforced epoxy composites

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Mechanical properties of banana macro particles reinforced epoxy composites have been evaluated in this study. Composites have been prepared with 25, 30, and 35 wt % of banana macro particles using compression moulding machine. Mechanical properties (tensile, flexural, and impact) of banana macro particles reinforced epoxy composites have been obtained as a function of content of banana macro particles. The results show that the mechanical properties are found to increase substantially with increasing banana macro particles with epoxy composite. Composite with 35 wt% have the highest mechanical properties, *i.e.*, the tensile strength of 24.36 MPa; the flexural strength of 67.16 MPa; the impact strength of 0.32 J. Scanning electron microscope analysis has shown the failure mechanism and the damaged behaviors occurred in the composites after tests.

Keywords: Banana macro particles, Epoxy resin, Mechanical properties, Scanning electron microscope

1 Introduction

The increasing demand in environmental protection has confined the use of natural resources or products in the field of composite. The natural plant fibers can be a suitable replacement to synthetic fibers such as glass, carbon, and aramid[1-3]. Nowadays, the most commonly used natural fibers as reinforcing agents in polymer composites are sisal, kenaf, hemp, roselle, flax, cotton, pineapple leaf fiber, jute, coir, flax and banana fibers. The main concept of reinforcing the polymer with natural fibers is to enhance the properties of the polymers[4,5]. The mechanical properties of natural fiber reinforced composites, highly depend on the interface adhesion property between the fibers and the polymer matrix[6-9]. One or more discontinuous phase is embedded in a continuous phase to form a composite. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement, whereas, the continuous phase is termed as matrix[10-12].

The matrix materials used in the preparation of composites are classified as metallic, ceramic and polymer. Among these, the polymer matrix composite is a composite material which contains a polymer resin matrix and reinforcing agents (fibers or particles). The reinforcing agents may be synthetic or bio natural materials. These composites can be prepared by a simple manufacturing methods with low cost. Fiber reinforced polymer composites consist of fibers of high strength and modulus embedded in or bonded to a matrix with a distinct interface between them. In this form, both fibers and matrix retain their physical and chemical properties. Normally, the fibers are the principal load carrying members, while the matrix keeps them at the desired location and orientation. The matrix also acts as a load transfer medium between them and protects the fiber from the environmental damage[13-16].

The main parameters, which affect the physical and mechanical properties of the natural fiber-reinforced polymer composites, are fiber length, weight ratio, fiber orientation and interfacial adhesion between the fiber and the matrix[17]. The mechanical properties of the polymer such as impact, tensile, flexural and impact properties are enhanced by reinforcing the polymers with the fiber[18]. Mechanical properties of natural fiber reinforced composites are mostly based on the adhesion between the fibers and the polymer matrix[19, 20]. The mechanical properties of Agave fiber-reinforced polystyrene matrix composites have been studied based on the fiber dimensions (particle, short

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and long) and found that particle reinforcement gives better mechanical properties than short and long fiber reinforcement[21]. Tensile load withstanding capacity of natural fiber reinforced composites is identified to be increasing the fiber content up to an optimum wt% and then, starts decreasing[22].

The optimum weight percentage of the fiber content in the composite also determines its mechanical properties[23]. Agave fibers have better mechanical properties with the particle reinforcement rather than short and long fiber reinforced composites[24]. Now days, cultivation of banana fiber has been drastically increased. Hence, it is easy to procure with low cost input for industrial purpose. When Banana fiber is reinforced with thermosetting resin, it becomes strong. The objective of the paper is to study the tensile, flexural and impact properties of the banana fiber macro particle reinforced epoxy composites.

2 Experimental Details

2.1 Materials

Banana fibers are extracted from the pseudo-stem of the banana plant (*Musa Sepientum*) and they are clean manually. The chopped fiber is crushed into Then, they are crushed into particle by crushing machine and separated by sieving machine. The macro particles with the size of 10-100 microns are separated to be used as reinforcing materials for the composites. Table 1 gives the mechanical properties of banana fiber[25]. The SEM image of macro particle is given in Fig. 1, to represent the size of the particles. The epoxy resin (LY 556) and the hardener (HY 951) are used as matrix materials. All the chemicals used in this study are procured from GVR Enterprise, Madurai, Tamilnadu, India.

2.2 Fabrication of Composites

The BMPs reinforced epoxy composites are fabricated using a compression moulding machine with the metal mould size of 290 × 290 × 3 mm. The top and bottom surfaces of the mould are coated with wax as a releasing agent to ensure the easy removal of composite plates after curing. The epoxy resin and the hardener are mixed in the ratio of 10:1 by weight for the preparation of composites. Keeping the different weight ratio of BMPs, epoxy resin and hardener, the mixture is stirred mechanically using a mechanical stirrer. The mould is compressed at a constant pressure of 103 bar and allowed to cure in 80 ºC for 45 minutes in a hot press. After cured, the composite plates are removed from the mould and cut into specimen size according to the ASTM standard for the mechanical tests.

Table 1 — Mechanical properties of banana fiber [25]

Properties	Banana Fiber
Density g/cm^3	1.35
Flexural Modulus (GPa)	2-5
Tensile Strength (MPa)	54
Young’s Modulus (GPa)	3.49

2.3 Testing of Composites

The tensile properties of the composite specimens are measured on the DTRX-30 KN universal tensile tester (DEEPAK POLY PLAST Pvt., Ltd.,) in accordance with the ASTM D3039 at a constant crosshead speed of 2 mm/min. The three point flexural tests on composite specimens with the size of 125 mm × 13 mm × 3 mm is carried out on the KALPAUK universal testing machine according to the ASTM D 790 at a constant crosshead speed of 2 mm/min. The impact strength of the specimen (65 mm x 13 mm x 3 mm) is tested in the Izod impact test rig according to the ASTM D 256 standard. Five samples are taken for each test and the average values are noted.

The SEM is used to study the morphology of the fractured specimen after tests are carried out. The entire fracture specimen is coated with gold and kept in an ionizer. Images of the fracture specimen are subjected to a voltage of 10 KV.

3 Results and Discussion

3.1 Tensile Properties

The banana macro particle composite tensile test results are shown in Fig. 2 to 4. From Fig. 2, it clears

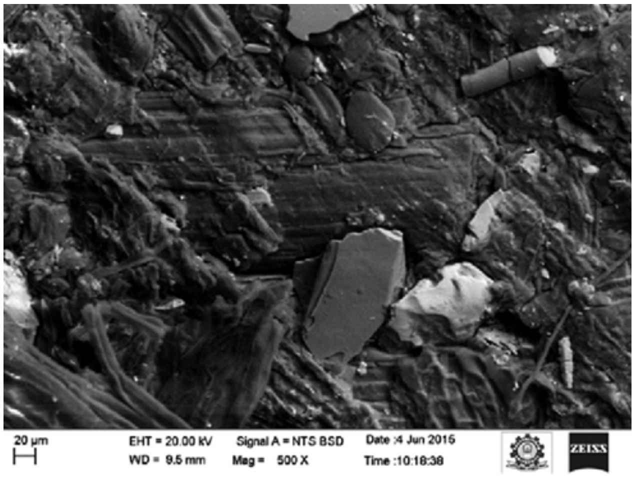

Fig.1 — SEM image of macro particle, which shows the size of the particle .

that the maximum tensile strength is obtained at 35 wt% composite. This is having a 14.9 % higher than the 30 wt % of composites. The tensile strength of 25 wt% composite shows the 7.4 % less than the macro particle of 30 wt% composite and 23.4 % less than the composite having 35 wt%. This is the reason of adhesion between the macro particle and the matrix because the macro particle and the matrix are evenly distributed. Therefore, the composite having 35 wt% shows the better tensile strength. Figure 3, shows the tensile modulus of the composite. Figure 4, shows the stress vs strain graph for the composites and is used to find out the tensile modulus of the composites. It is clearly shown that the 35 wt% of the composite has the better modulus. It is clearly seen that the tensile modulus values are linearly increased with the particle wt%. The 35 wt% of composites shows the 36.08 GPa, which is 13.9 % higher than 30 wt% composites and 24.7 % higher than the 25 wt% of composites. From the result point out that the addition of the macro particle content increase the toughness value.

3.2 Flexural Properties

The flexural strength of the macro particle reinforced epoxy composites are shown in Fig. 5 to 8. Figure 5, indicates that the flexural strength of the

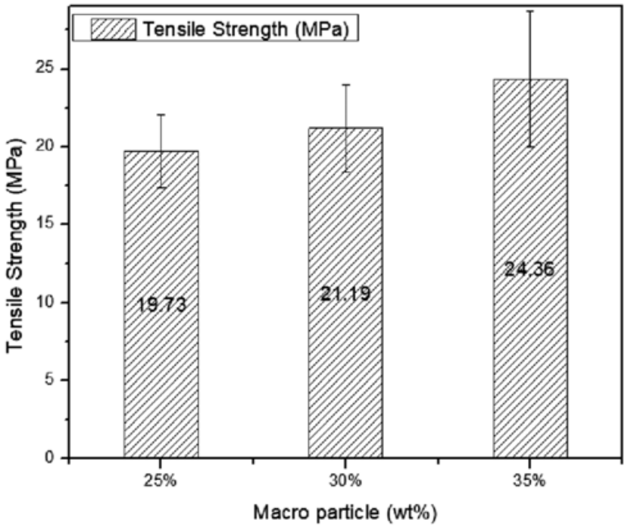

Fig. 2 — Variation of tensile strength of macro particle/epoxy composites based on the particle loading.

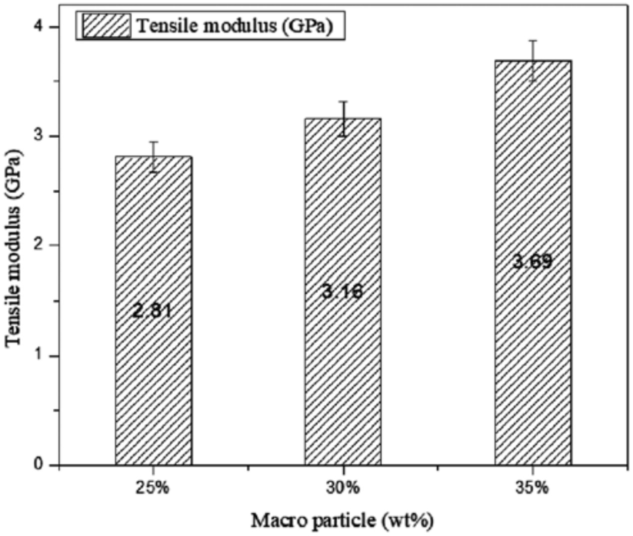

Fig. 3 — Variation of tensile modulus of macro particle/epoxy composites based on the particle loading.

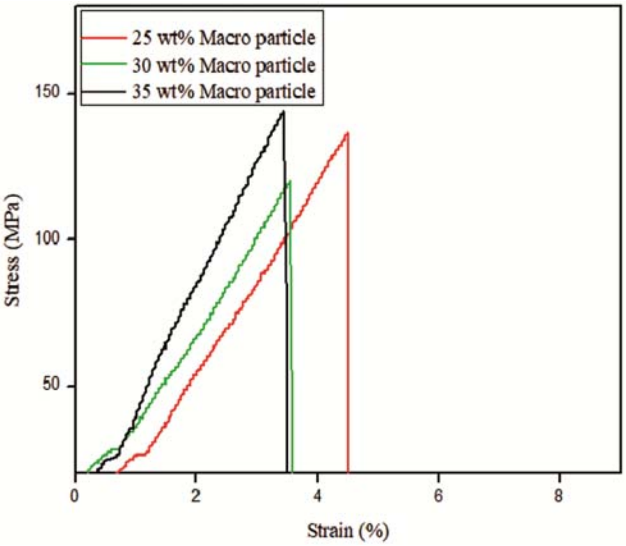

Fig. 4 — Stress versus strain curve for tensile test.

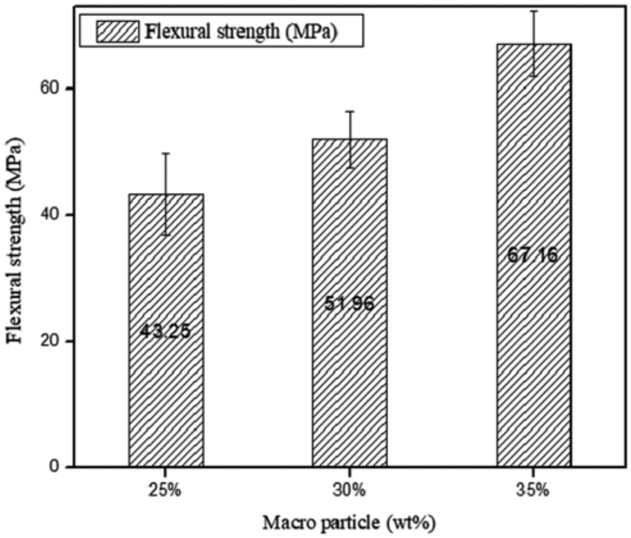

Fig. 5 — Variation of flexural strength of banana macro particle/epoxy composite based on the particle loading.

composite of 35 wt% has high flexural strength of 67.16 MPa which is 29.25 % higher than the composite of 30 wt% and 55.24 % higher than the composite of 25 wt%. So the flexural strength of the composite increases with the particle loading and the resin penetrates evenly throughout the composites. Figure 6, shows the flexural modulus of the composite. Figure 7, shows the load vs length graph used to calculate the flexural modulus of the composites. Figure 8, shows the model graph for the load vs deflection for the composites. It clearly indicates that the composite having 30 wt% shows the highest flexural strength (2.31 GPa) which is 7.7 % higher than 25 wt% of composites and 73 % higher than the composite of 35 wt %. The 25 wt% of composite is 27.12 % higher than the composite of 35 wt%.

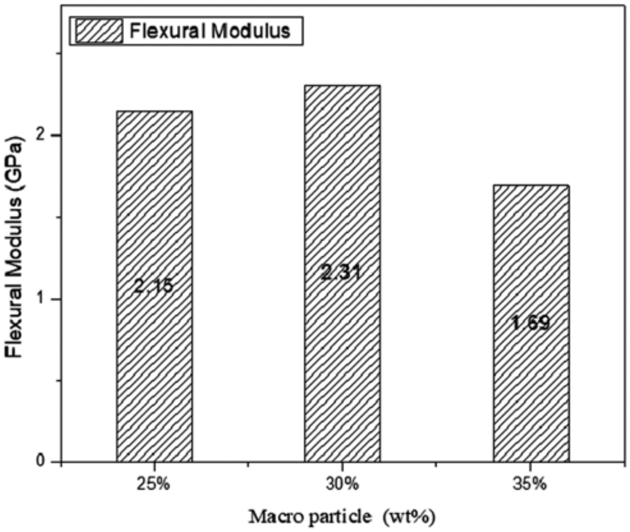

Fig. 6 — Variation of flexural modulus of banana macro particle/epoxy composite based on the particle loading .

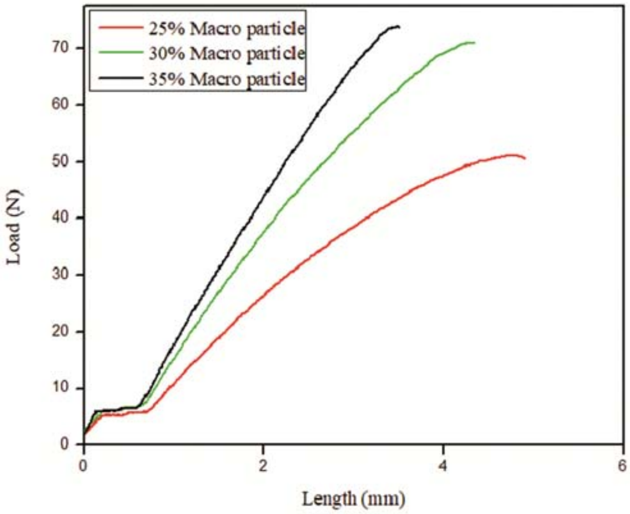

Fig. 7 — Load versus length graph for flexural test.

3.3 Impact Properties

The energy absorbed, while a sample is impacted by a heavy blow. The composite of 35 wt% absorbs more energy (38.13 %) higher than composite of 25 wt% and (28 %) more than the composite of 30 wt%, as shown in Fig. 9. It is also observed that the composite 35 wt% is much better than the other two composites (25 and 30 wt%). The increasing particle content and size of the particle are also influencing the energy absorption. Hence, the composite of 35 wt% does not initiate crack easily.

3.4 Scanning Electron Microscopy (SEM)

The fractured surfaces of composite specimens after the tensile tests are examined using SEM images. Figure 10(a), shows the SEM image of the fracture surface of the composite specimen having the particle content of 25 wt%. It is observed that the voids and crack propagation is initiated through the matrix. The hollow portions are also identified in Fig. 10(a),

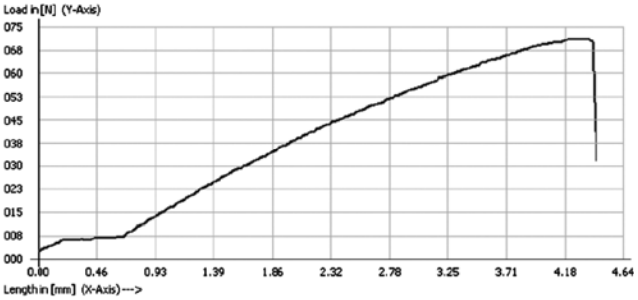

Fig. 8 — Sample graph obtained from UTM for load versus deflection (30 wt%).

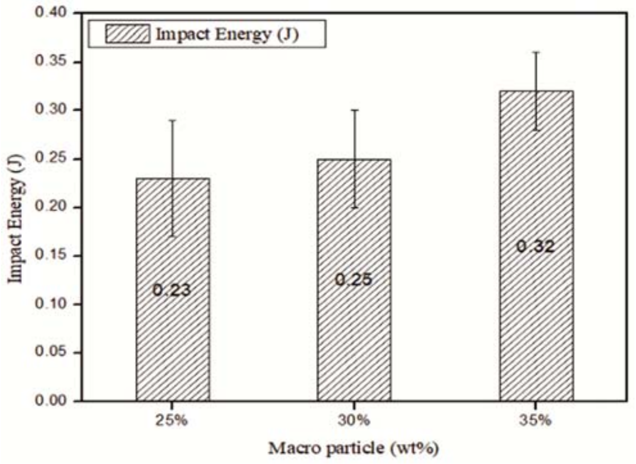

Fig. 9 — Variation of impact strength of banana macro particle/epoxy composite.

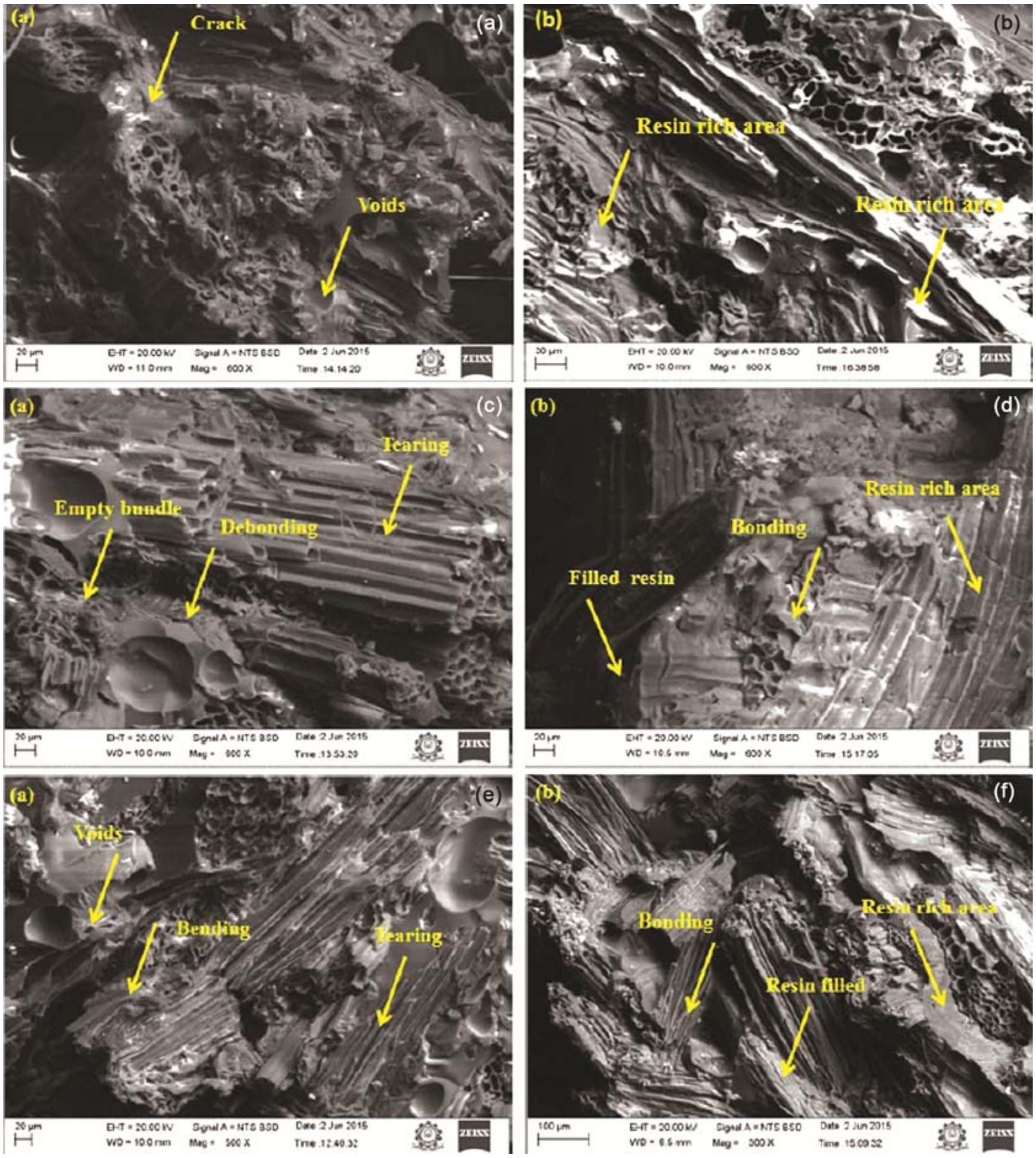

Fig. 10 — SEM images of banana macro particle/epoxy composites (a) 25 wt% composite after tensile test, (b) 35 wt% composite after tensile test, (c) 25 wt% composite after flexural test, (d) 35 wt% composite after flexural test, (e) 25 wt% composite after impact test and (f) 35 wt% composite after impact test.

which indicates the phenomenon of less penetration of the resin content between the macro particles. Due to this, the interfacial adhesion strength is reduced between the particles and the resin matrix. Figure 10(b), shows the SEM image of a fractured surface of the 35 wt% composite. From the Fig. 10(b), it is indicated that a closely packed interfacial bonding between the resin matrix and the particle is obtained. Moreover, the smooth surface is observed after tests which indicate the absence of crack propagation due to the better packing of materials.

The SEM micrograph of a fractured surface of the composite specimen (25 wt%) is shown in Fig. 10(c). From the Fig. 10(c), it can see that the detachment and de-bonding of the macro particle from the resin matrix, which indicate the poor interfacial adhesion of the macro particle with the epoxy resin matrix. The lack of epoxy content in the inner space of the macro particle is observed, which causes the tearing in the inner macro particle. A good interface bonding strength between the macro particles and the epoxy resin matrix is observed in the composite specimen

(35 wt%) as shown in the SEM image (Fig. 10(d)). From the Figure 10d, it is also understood that the mechanical interlocking between macro particle and epoxy resin matrix is becoming stronger.

Figure 10(e), illustrates the SEM image of the composite specimen (25 wt%) after impact test. The tearing is noticed as shown in Fig. 10e, which initiates the failure of the composite specimen during impact loading. The voids over the surface of the composite specimen is also noticed which may be due to the poor interfacial bonding between the macro particle and the epoxy resin matrix. The SEM image (Fig. 10(f)) of a fractured surface of the composite specimen (35 wt%) shows a strong mechanical interlocking between the particles and the resin matrix, *i.e.*, better interfacial strength, the results increase in impact energy.

4 Conclusions

The banana macro particle reinforced epoxy composites have been prepared with three different wt% in the compression moulding machine. The following conclusions are drawn:

(i) The tensile strength increases with the increase of weight percentage of macro particles. It is observed that the composite having the particle content of 35 wt% is able to withstand more load which results in better tensile strength and modulus.

(ii) The values of flexural properties are also higher in the composite of 35 wt% (67.16 MPa). It may be due to the better interfacial boding between the particles and the resin matrix.

(iii) The high impact strength value is also obtained at composite having the particle content of 35 wt% (0.32 J) which may be due to the more energy absorption.

(iv) The SEM images show the fracture behavior of the composite specimens after mechanical tests.

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