Track1: Machine Design

Tensile, flexural and impact behavior of Tamarind seed (Bio-waste) particulate reinforced polymer composite

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Abstract

Designing of lightweight materials in house hold, construction, automobile and aerospace sectors is attracting researchers to replace conventional materials. In this regard environment friendly materials are the focus point. Development of bio composites is one of the solutions for this. In this paper, effort has been made to design and develop a material from Tamarind seed (a biowaste). To fulfill the objective Tamarind seed particulate composite of varying weight fraction (10, 20, 30 and 40 wt.%) has been fabricated with epoxy as the matrix material. The characterization study of tamarind seed particulate was carried out using Scanning electron microscope (SEM), Fourier transform infrared spectroscopy (FTIR), energy dispersive X-ray spectroscopy (EDX) and X-ray diffraction (XRD) analysis to find its suitability as reinforcement material. Tensile, flexural and impact behavior of the developed composites has been carried out as per ASTM standard. Morphology of fractured samples were carried out with SEM to ascertain the failure behavior.

Keyword: Natural fiber composite, fiber characterization, bio-waste, mechanical behavior, SEM

1. Introduction

Composites materials are improving the design process and end products across industries, from aerospace to renewable energy. Composites materials continuously substituting existing traditional materials like mild steel, copper, aluminium. As design flexibility improves and composite fabrication costs goes down, new design opportunities for researchers and engineers have opened up. Global concerns on environmental and sustainability issues lead rapid growth in area of sustainable materials emerging from biobased plastics and their composites (bio composites). Bio composite can be an alternative to traditional composite materials (glass, carbon) to reduce the carbon footprint and strain on the environment. Advantages of bio composite over traditional composites are their low cost, low density, high toughness, good specific strength, non-toxic to human body, enhanced energy recovery, CO_2-neutrality when burned, and biodegradability [1-3]. Bio composite have natural reinforcement in polymer based matrix. Agricultural waste like rice husk, corn can be used as the fiber reinforcement.

[4]H.S Yang.et.al investigated mechanical properties of rice husk flour reinforced polypyrene composite. As the filler loading and cross head speed increases the tensile strength decreases but have acceptable strength up to filler loading of 40 weight percentage. As the filler percentage increases interfacial bonding between filler and polypyrene matrix become weak which causes strength to decrease.[5]R. Prithivirajan.et.al uses coir pitch in addition to rice husk as the reinforcement in the epoxy composite. The experimental results shows that the average tensile, flexural and impact strength values for coir pith and rice husk bio-particle reinforced epoxy composite were 12.7 MPa, 24.3 MPa and 2.6 J, respectively. [6]J. Sarki studies the mechanical and morphological properties of coconut shell particle reinforced epoxy composite. SEM of the fabricated composite indicates that there is very good interfacial bonding between coconut shell particles and epoxy composite. Tensile strength, tensile modulus and hardness values are improved but impact strength of the composite decreases, as compared to pure epoxy. [7]Vinay K. Singh investigates mechanical property of walnut shell particle reinforced epoxy composite. SEM of the different wt.% of composite shows that walnut shell particle was uniformly dispersed in epoxy matrix. Addition of wall nut particulate decreases tensile, flexural strength of composite decreases but in a permissible range. Composite with 10% walnut shell particle shows maximum strength. As the wall nut particle concentration increases beyond 10% both tensile and flexural strength of composite decreases, this is due to agglomeration of

walnut particles in epoxy matrix. The modulus of elasticity and hardness values of epoxy increases significantly by addition of walnut particles.

A review of literature suggests that a lot of research has done on biowaste particulate reinforced composite but research on tamarind seed particulate (TSP) reinforced epoxy composite is not done. Taking this in account, the study is aimed to explore the possibility of tamarind seed as a filler in epoxy and to study mechanical behaviour of tamarind seed particulate reinforced composite.

2 | Materials and Methods

2.1 | Materials

Tamarind is a hardwood tree, known scientifically as Tamarindus indica. It is large evergreen tree and produces pods filled with paste-like, sweet-sour fruit. It basically belongs to Africa but grows in many other countries also like India, Sri Lanka. Thailand, Indonesia. India is the world largest producer of tamarind; it is estimated that 300,000 tons are produced annually. A typical fruit/pod contains 55% pulp, 34% seeds/kernel, and 11% shell (seed coat) and fibres [8]. Fresh tamarind seed were collected from locally available trees. The seeds were roasted to a temperature about 130 -135°C and after some time the shell cover is removed from pulp by hammering. The tamarind seeds grinded in ball mill to obtain powder form. The obtained tamarind powder was boiled with distilled water for time period of 3 hours, mixture is stirred constantly to avoid layer formation on the surface. The polysaccharide part was removed by drying up the entire mixture. The tamarind seed consists of 47.50% hemi-cellulose, 19.22% of cellulose and 18.80% of lignin. Hemi – cellulose is strongly bound to the cellulose fibres, presumably by hydrogen bond. Lignin acts as the cementing agent in the fiber, binding the cellulose fiber together.

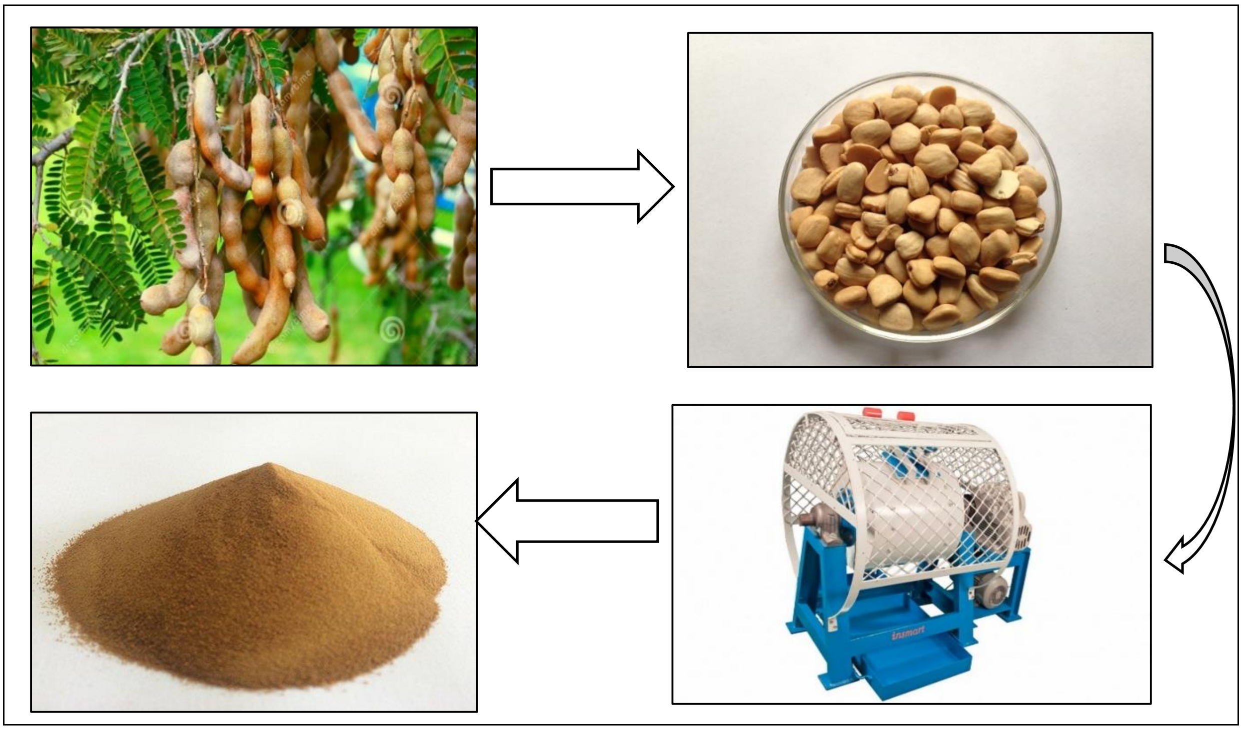


Figure 1. Preparation of tamarind seed particulate (TSP) form tamarind seeds by ball milling

2.2 | Characterization study of fibre

2.2.1 | X-ray diffraction (XRD) analysis

X-ray diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline and amorphous material and can provide information on unit cell dimensions. The XRD test is carried out in an XPET-PRO diffractometer at wave length 0.154 nm, voltage 40mV and current 40mA. The crystalline index can be calculated by following formula:

$$I = \frac{Ic - Ia}{Ic}$$

where I = crystallinity Index, Ic = intensity of crystallographic plane, Ia = intensity of amorphous plane.

2.2.2 | Energy-dispersive X-ray (EDX)

EDX quickly generate information about the chemical composition of a sample, including what elements are present as well as their distribution and concentration. In this process electron beam strikes the spot size of few microns on sample surface and generates X-ray signal, which creates elemental composition maps.

2.2.3 | Fourier transform infrared (FTIR) spectroscopy

FTIR analysis is done to study the structure of inter and intra -molecular hydrogen bond in cellulose.

2.2.4 | Scanning electron microscopy (SEM) analysis

Scanning Electron Microscopy used to find morphological features of tamarind seed particulate (TSP) by high magnification, high-resolution images. The tamarind powder was platinum coated to make the surface conductor of electrons. The image results were analysed to investigate the distribution of tamarind seed particulate and their interactions within the epoxy matrix.

2.3 | Composite Fabrication

The fabrication of composite is done by hand lay-up method using heat gun technique. A mold with dimensions (270*130*5 mm^3) was prepared from wood. The mold is then glued on clean, smooth per -pex sheet. The epoxy and hardener used for fabrication is “LY556”and “HY951” respectively. The amount of epoxy and hardener and tamarind seed powder for different weight fraction of tamarind seed particulate(TSP) obtained with the law of mixture of composite materials. The epoxy and hardener are mixed in the ratio of 10:1 by weight. Then required amount Tamarind seed powder is added to mixture of epoxy and hardener. The mold releasing agent is applied on the mold surface for easy removal of composite from mold after solidification. The epoxy, hardner and TSP mixture continuously stirred with minimum turbulence to avoid bubble formation. The mixture is carefully poured in the mold to avoid voids. The mold is closed with the help of per-pex sheet and proper load is applied to avert any voids formation. The composite with 10 ,20, 30 and 40 percent weight fraction of tamarind seed filler in epoxy were fabricated by the same method along with samples of pure epoxy.

2.4 | Density and void fraction

The actual and theoretical density of fabricated composites with different filler weight percent (0, 10, 20, 30 and 40) were calculated by Archimedes and rule of mixture, respectively, as per ASTM D792 standard. The composites with void fraction less than 4% were selected for tests. Void fraction of the fabricated sample as following equation:

$$V_v = (\rho_t - \rho_a) / \rho_t.$$

Where V_v is the volume fraction of void and ρ_t and ρ_a theoretical and actual (experimental) densities respectively.

2.5 | Tensile test

The tensile test of composite was carried out as per ASTM D638 standard by maintaining cross head speed of 2mm/min. Standard dog bone shape of 165*13*4 mm^3 were prepared for tensile test. For each composition 5 samples were tested and average property is calculated.

2.6 | Flexural test

The flexural test was carried out as per ASTM D790-03 standard. It is three-point bending test, load being applied centrally. Cross head speed of 2mm/min is maintained. For each composition 5 samples of size 80*13*4 mm^3 are prepared.

2.7 | Impact test

Impact test was carried out as per ASTM D256 standard. It is also called as Izod impact test. For each composition 5 samples were prepared and average property is calculated.

3 | Result and Analysis

3.1 | XRD analysis

The XRD analysis was done to study crystalline structure of TSP. The crystallinity index of the TSP is 31.68% and the remaining content of filler is amorphous. The maximum intensity was found at 22.8°. The XRD mapping of TSP is shown in figure 2(a).

3.2 | EDX analysis

The EDX analysis shows that the carbon, oxygen and potassium are constituent of TSP (figure2(b)).The weight percent of carbon ,oxygen and potassium is 53.02 %,45.20% and 1.77% respectively. The atomic percent of carbon, oxygen and potassium is 60.60 %,38.78% and 0.62% respectively.

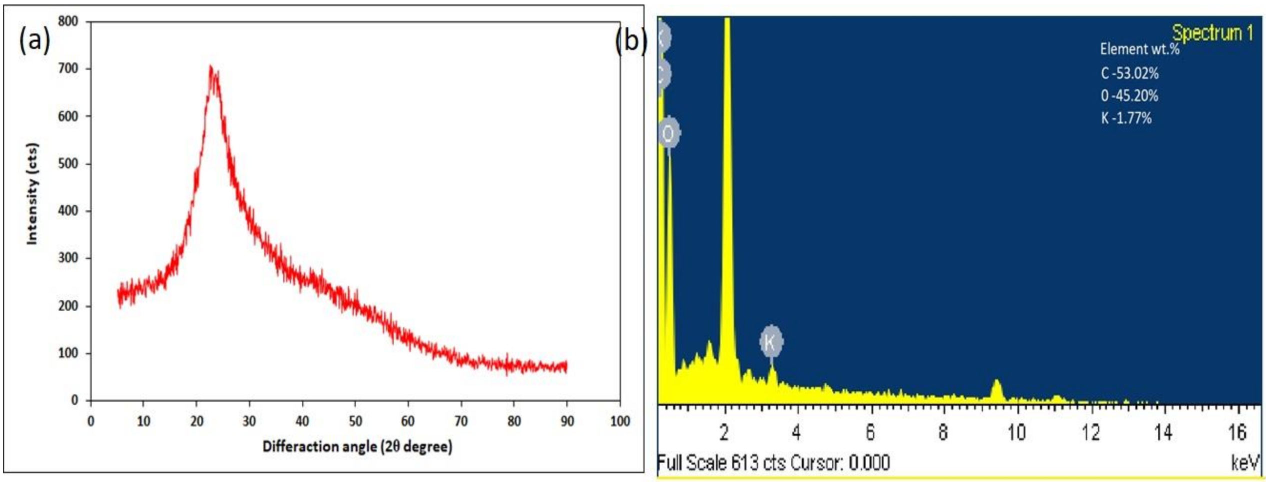


Figure2. (a)Plot of intensity Vs diifraction angle in XRD analysis of the tamarind seed particulate (b)Energy dispersive spectra of tamarind seed particulate surface

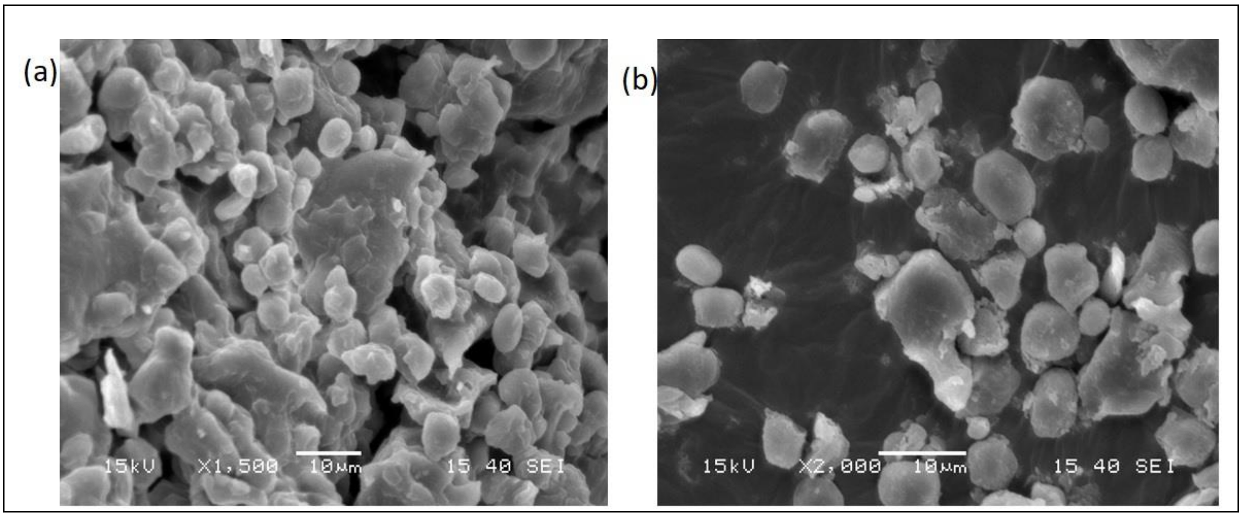


Figure4. SEM images of tamarind seed particulate (a)with lower magnification and (b) with higher magnification

3.3 | Scanning Electron Microscopy (SEM) observation

The SEM images (figure 4) of TSP at very higher magnifications 1500X and 2000X reveals that the surface of TSP is porous. The size of TSP is in the range of 3 – 9 µm. The average particle size is 6 µm.

3.4 | FTIR analysis

FTIR analysis results are shown in figure5 confirms presence of C- , C-O-C and OH bonds. Peaks at 2920.99 cm^{-1}, 1016.13 cm^{-1} and 555.75 cm^{-1} attributed to alkane C–H stretching (C–O–C) stretching of cyclic ethers and OH bending respectively.

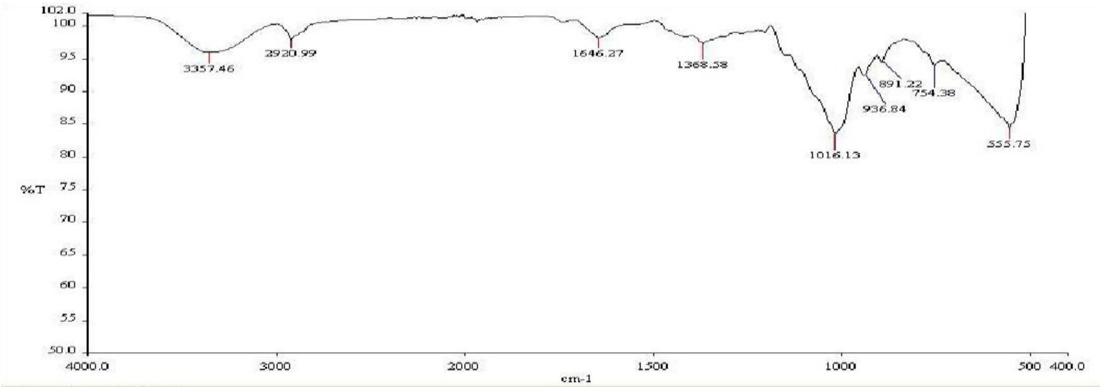


Figure5. IR spectra of TSP sample

3.4 | Density

Density is very important property of particulate reinforced composite. The density of different weight fraction of TSP in epoxy matrix are shown in the figure6(a). Both theoretical and actual density decreases as the TSP filler content increases. This is because the density of TSP reinforcement is less than the epoxy.

3.5 | Tensile test

The tensile strength of fabricated composite with 0, 10% ,20%,30% and 40% weight fraction of TSP are shown in the figure6(b). It can be noticed that for all specimens the ultimate tensile strength is highest for the 10 wt.% of TSP and is 24 MPa. this is due to the uniform distribution of TSP in the composite. This leads to efficient stress transfer from matrix to the filler under the tensile loading, which is important in obtaining high tensile strength. The ultimate tensile strength increases as the weight percentage of TSP increases from 0 to 10%. However, the ultimate tensile strength decreases beyond 20%.

3.6 | Flexural Strength

The tensile strength of fabricated composite with 0, 10% ,20%,30% and 40% weight fraction of TSP are shown in the figure7(a). The flexural strength of composite increases by the addition of TSP. The composite with 20% of TSP shows maximum flexural strength.

3.7 | Impact test

The result of Izod impact test is shown in the figure7(b). the impact strength increases as the weight percentage of TSP increase. The composite with 20% of filler shows highest impact strength among all the composites. The impact strength initially increases with increasing filler content up to 20 wt.% then decreases with increasing filler weight percentage. Poor dispersion of the TSP is the reason for decrease in the impact strength.

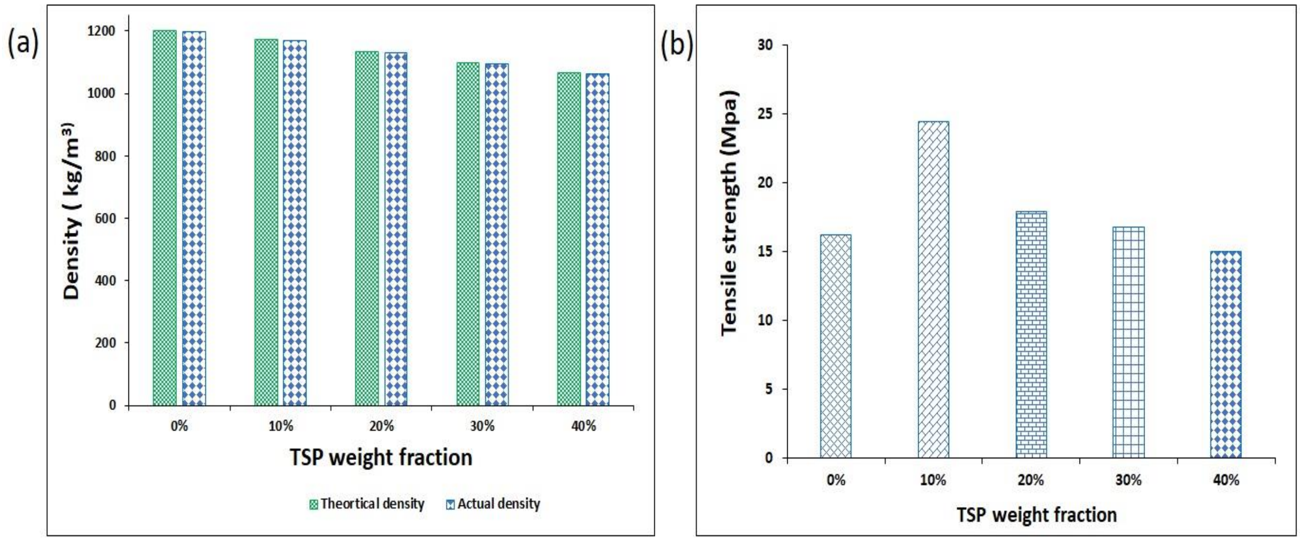


Figure 6. Variation of (a) theoretical and actual density and (b) tensile strength of different wt.% of TSP reinforced epoxy composites

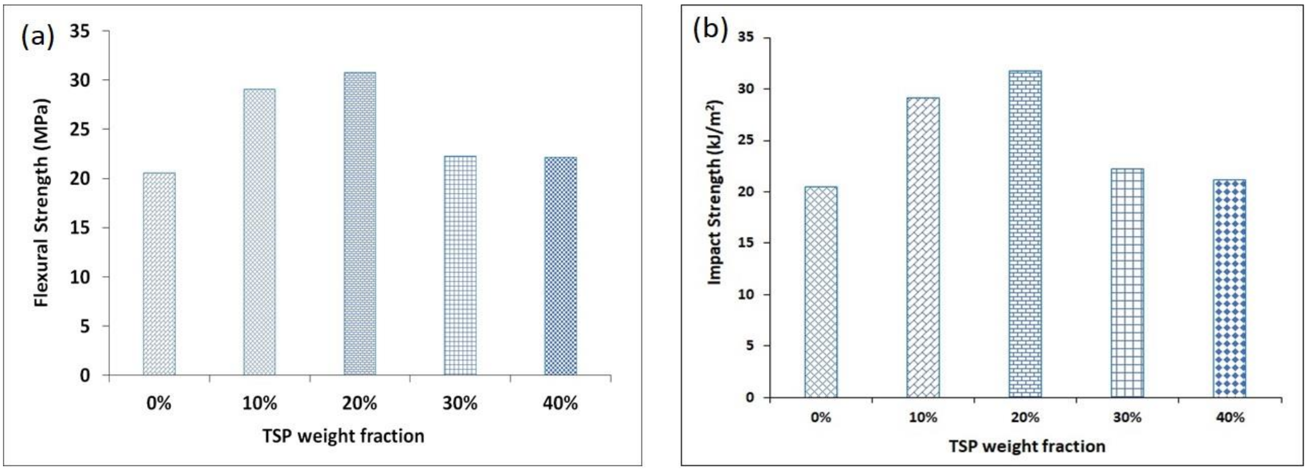
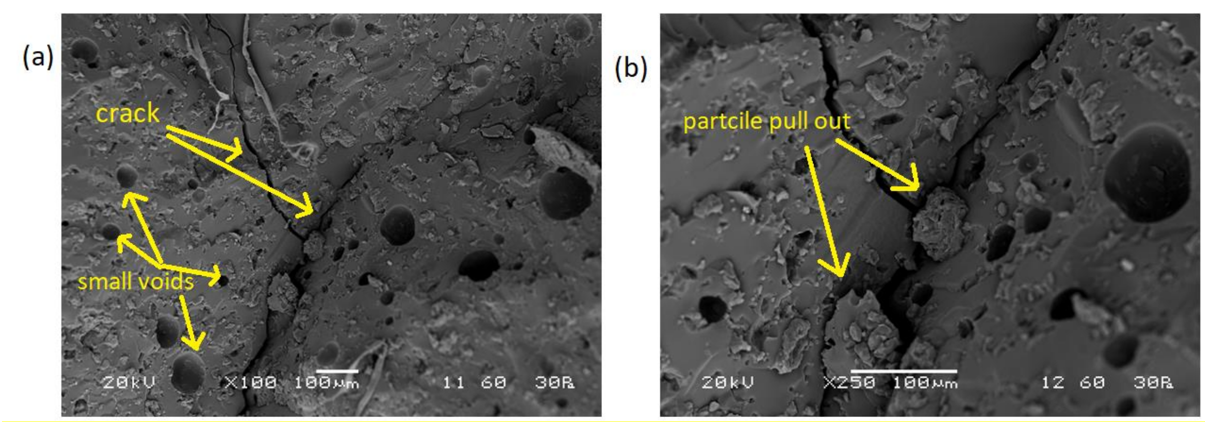
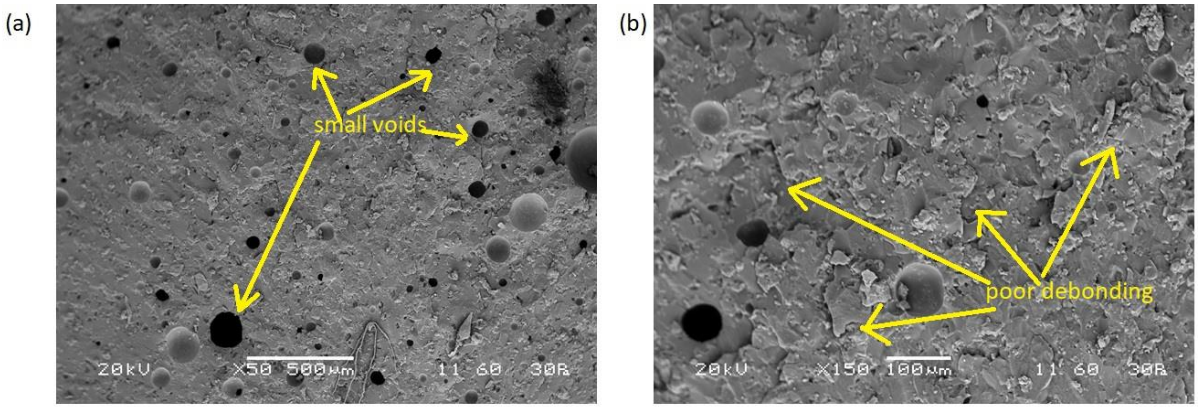


Figure 7. Variation of (a) Flexural and (b)impact strength of different wt.% of TSP reinforced epoxy composites

4 | Morphological analysis



Fiigure 8. SEM images tensile sample of 20 wt.% of TSP (a) lower magnification (b) higher magnificaton



Fiigure 9. SEM images flexural sample of 20 wt.% of TSP (a) lower magnification (b) higher magnificaton

SEM images of figure 8 shows the failure of TSP (20 wt.%) content in the composite samples during tensile test at lower and higher magnification. SEM images confirms presence of cracks which are evident due to the brittle failure. TSP are deboned from the epoxy matrix. Tensile strength decreased as the filler content increases beyond 10%, this is due to the clustering of TSP in the composite.

Figure 9 shows SEM images of TSP (20 wt.%) content in the composite samples during flexural test at lower and higher magnification. SEM images confirms the presence of small voids and craters. Poor debonding leads to failure.

5 | Conclusion

The following conclusions can be made out of experiments.

The characterization studies of the Tamarind seed particulate shows it can be used as a reinforcement in the epoxy based composite. The inherent surface roughness and porous structure of the tamarind seed particulate imparts better bonding between the filler and matrix. The mechanical properties i.e., tensile, flexural and impact strength increases by the addition of tamarind seed particulate. The composite with 10 wt.% shows maximum tensile strength among all the compositions. Flexural and impact strength are maximum of 20 wt.% of TSP composite. However tensile strength decreases after 10 wt.% and flexural and impact strength decreases after 20 wt.% , this is due to the agglomeration of filler in the matrix and debonding of filler with matrix.

6 | References

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