Static investigation of almond shell particulate reinforced *aquilaria agallocha roxb* blended *epoxy* hybrid matrix composite

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Nowadays, the use of recyclable, eco-friendly materials in automotive industries are growing due to the environmental concerns in place of synthetic polymers. Natural filler materials are increasingly used to reduce the usage of the polymer matrix and to improve the mechanical, thermal properties of the composite materials. Natural fiber and filler incorporated hybrid composite materials are used in places where the load requirements are low. This study focuses on the use of Almond shell as a particulate reinforcement in the *Aquilaria agallocha Roxb* reinforced Epoxy composite with different volume fractions. The specimens were fabricated using hand layup process and the mechanical properties were investigated. The results had shown that the composite with 20% v/v Almond shell particulate reinforced composite had shown better mechanical properties. While the Visco elastic properties had shown minor improvement due to the incorporation of natural filler in the hybrid composite material.

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1. Introduction

Natural fiber and filler incorporated polymer Composites are currently considered as a suitable replacement over conventional polymer composites by the investigators [1-5] in the world. Due to the adverse environment impact cause by the use of synthetic fibers and polymers in the composite materials, several natural fibers and filler are being investigated in view of their eco-friendly nature, recyclability, low cost and safety. Khalil et al [6] had investigated the use of carbon Black produced from the natural resources as filler in the Epoxy composite. Three varieties of carbon black produced from oil palm empty fruit bunch (EFB), bamboo stems (BS) and Coconut Shells (CS) were used at 5% v/v in the composite. The test results indicated an improvement in the tensile strength, modulus for the EFB and BS derived carbon black incorporated composite materials. X Ray Diffraction (XRD) patterns of the composites showed nonlinear crystalline and amorphous structure of the CB. The effect of inorganic fillers such as kaolin, talc and zinc borate on the mechanical and water absorption properties of the wood powder incorporated epoxy was studied by Gwon et al [7]. The results indicated that the addition of filler materials resulted in better performance in water absorption properties. Among the fillers used in the experiment the kaolin filler had shown better mechanical strength and better moisture resistance due to the stacked plate shape and small particle size. The influence of particulate fillers

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such as talc, silicon carbide, aluminium flake and steel fibers on the mechanical properties of the polymer matrix composites were evaluated by Bigg et al [8]. The studies showed that the Noryl exhibited better properties than the other types of filler materials. The properties of PVC nanoclay composites was analysed by Awad et al [9]. It was reported that nanoclay exhibited excellent dispersion in the PVC matrix which lead to better mechanical properties and also a minor reduction in the thermal stability was observed. The effect of fillers on the epoxy resin composite was studied by Jin et al [10]. Nano fillers such as alumina and silicon carbide were used ass particulate fillers in DGEBA known as Epoxy resin. The curing behavior, thermal stability and dynamic mechanical properties were analyzed and the results had shown that the decomposition temperature increased from 630 degrees to 853 degrees for Al_2O_3 composite and it is 858 degrees for the SiC composite. The glass transition temperature was increased by a value of 10 degrees than neat Epoxy resin. Bleach et al [11] had studied the effect of Biphasic Calcium Phosphate filler on the bio absorbable Polylactic acid. The filler content was incorporated upto 25% v/v. SEM analysis revealed the agglomeration of the filler content was observed at higher volume fraction. The glass transition temperature of the composite was reported as increased due to the addition of filler material. Khalil et al [12] made use of natural filler material as the particulate reinforcement in the recycled polypropylene. Wood saw dust was used as the filler at different loadings and at different particle sizes. The mechanical and water absorption properties were analysed, the results indicated that the particle loading of 30% and filler size of 100mm produced better mechanical properties. Santos et al [13] also studied the effect of wood plastic composites by using saw dust powder ass the filler and polypropylene as the matrix. It was stated that the addition of the filler reduced the tensile strength of the wood plastic composite (WPC) at all compositions. The water intake also increased with increase in sawdust filler. Sarki et al [14] made use of coconut shell powder as the natural filler for the epoxy composites. The effect of filler content on the on the mechanical properties of the composite was studied. The test results indicated that the addition of the filler content improved the tensile properties of the composite due to the better interfacial interaction between the filler and the matrix. Similarly the use of coconut shell powder [15], potassium titanate whisker [16], Snail shell powder [17], wood flour [18], flyash [19] as the filler had been investigated by several researchers. Many studies [20-23] indicated that filler materials can be effectcively used to improve the mechanical properties of the composite materials to some extent. Very few researchers have reported the *Almond Shell* Particulate Reinforced *Apuilaria Agallocha Roxb* Hybrid Matrix Composite. The effect of the mechanical, behavior of the *Almond Shell* Particulate Reinforced *Aquilaria Agallocha Roxb* Hybrid Matrix Composite material with different vol % was analyzed.

2. Materials and methods

Almond Shell Particulate Reinforced *Aquilaria Agallocha Roxb* Blended Epoxy Hybrid Matrix Composite was used as the filler and matrix materials respectively. Powdered *Almond Shell* and *Aquilaria Agallocha Roxb* resin materials were procured from PV fibers, Kanchipuram. Composite samples were fabricated using hand layup moulding method followed by light compression. Composite specimens were fabricated with different volume fraction percentage of *Aquilaria Agallocha Roxb* Blended Epoxy Hybrid Matrix as shown in table 1. Experiments were conducted to investigate the mechanical and dynamic mechanical properties of the composite specimens as per ASTM standards.

Table 1. Volume and mass fraction of particulate reinforcement and polymer.

	Mass %		
Specimen ID	Almond Shell powder	*Aquilaria Agallocha Roxb* Blended Epoxy Hybrid Matrix	Mass of Almond Shell powder (gm)
AS5	5	95	24
AS10	10	90	48
AS15	15	85	72
AS20	20	80	96
AS25	25	75	120
AS30	30	70	144
AS35	35	65	168
AS40	40	60	192

3. Results and discussion

3.1 Mechanical properties

Tensile test was performed as per the ASTM D638 standard with a test speed of 2 mm/min. Flexural test and Impact tests were conducted as per ASTM D790 and ASTM D256 standards respectively. The mechanical properties of the *Aquilaria Agallocha Roxb* Blended Epoxy Hybrid Matrix composite with different volume fraction of Almond Shell powder is shown in Fig. 1 to Fig. 3. It can be noted that the incorporation of filler material improves the mechanical properties of composite material to some extent. Maximum value of tensile strength of 29.2 MPa was witnessed for the composite specimen with the composition of 20% v/v Almond shell powder incorporated *Aquilaria Agallocha Roxb* blended Epoxy composite. Similarly the flexural and impact properties were higher for the composite with 20% v/v Almond shell powder incorporated composite material.

Impact test is used to determine the toughness of a material which is defined as the energy absorbed during the fracture. Natural fillers are usually added to develop the stiffness (modulus) and toughness of the polymer composites. When the load is applied, the matrix and natural filler are separated which requires energy, this energy required depends on the bonding strength between the filler and hybrid matrix material.

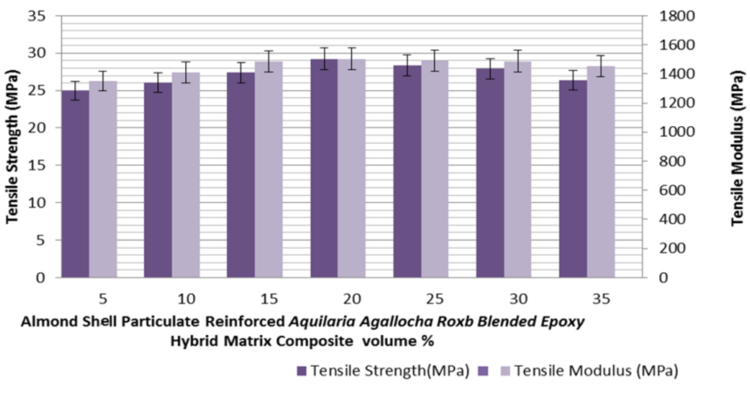


Fig. 1. Tensile properties of Almond Shell powder with Aquilaria Agallocha Roxb Blended Epoxy Hybrid Matrix.

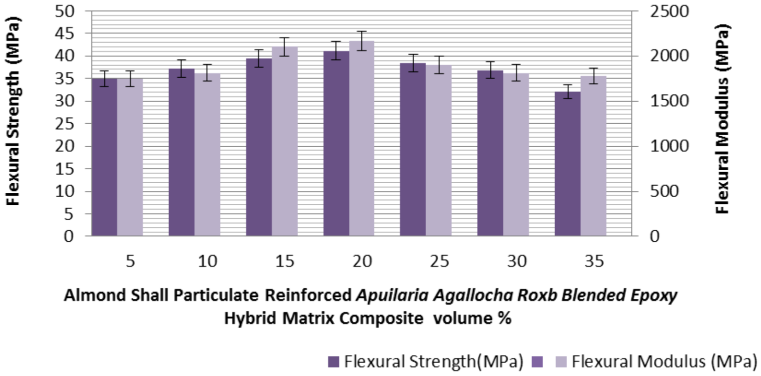


Fig. 2. Flexural properties of Almond Shell powder with Aquilaria Agallocha Roxb Blended Epoxy Hybrid Matrix.

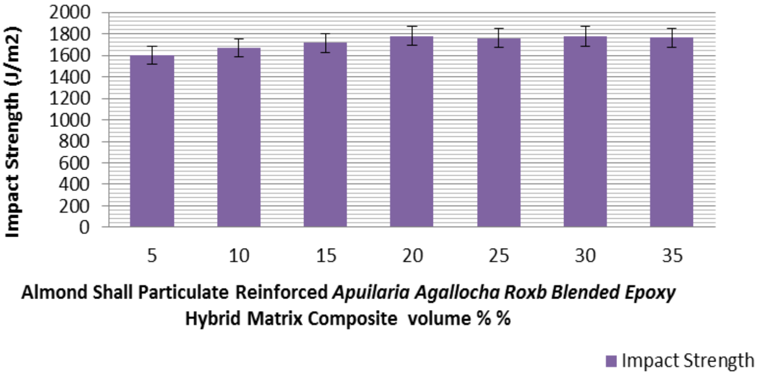
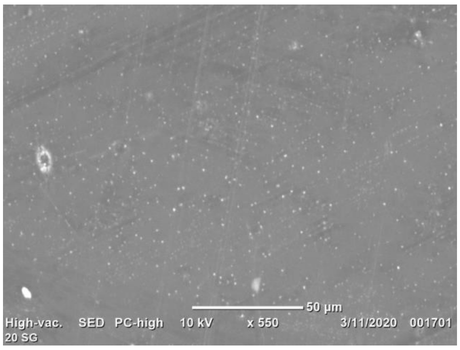
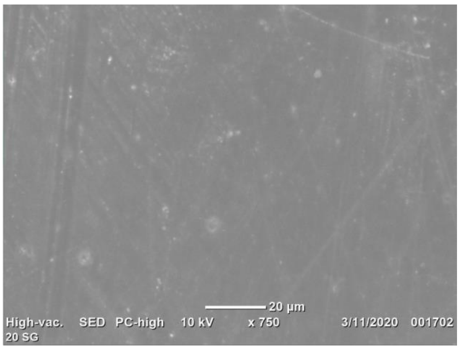


Fig. 3. Impact strength of Almond Shell powder with Aquilaria Agallocha Roxb Blended Epoxy Hybrid Matrix.

3.2 SEM Analysis

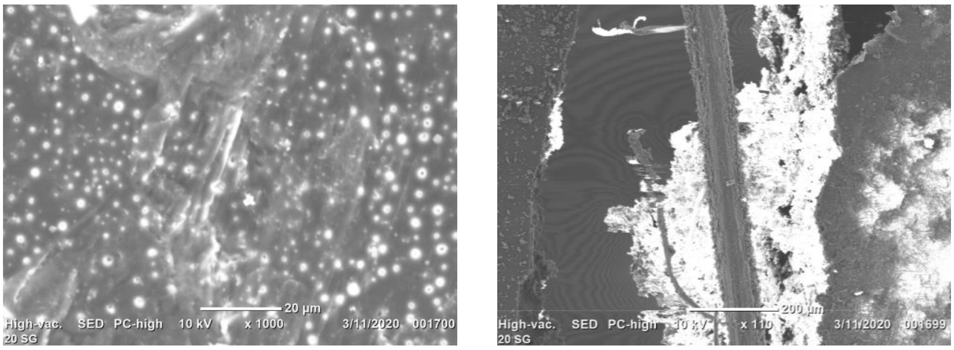
The Addition of Almond Shell powder with *Aquilaria Agallocha Roxb* Blended Epoxy Hybrid Matrix more than 25 vol% resulted in decreasing of the tensile properties. This is due to the agglomeration of the natural filler in the epoxy matrix this is evident from SEM images presented in Fig. 4 and Fig. 5. The agglomeration of the filler materials increases the brittleness of the composite material which is evident from the lower strain to failure. In addition, the filler may suppress necking and initiate yielding in agglomerated zones as if the particles were treated by an anti-adhesive and their bonding with the polymer was weakened.





(a) (b)

Fig. 4. SEM Image of 20vol% Almond Shell powder with Aquilaria Agallocha Roxb Blended Epoxy Hybrid Matrix (a) tensile Specimen (b) Flexural Specimen



(a) (b)

Fig. 5. SEM image of 35vol % Almond Shell powder with Aquilaria Agallocha Roxb Blended Epoxy Hybrid Matrix (a) tensile Specimen (b) Flexural Specimen

3.3. Dynamic Mechanical Analysis

Dynamic mechanical analysis is used to determine the visco elastic properties of the composite. The effect of temperature and filler content on the storage modulus of Almond Shell powder with *Aquilaria Agallocha Roxb* Blended Epoxy Hybrid Matrix Composite was investigated in this work which is shown in Fig. 6 the test temperature is range from 35° C to 180° C and frequency in the range of 10 Hz.

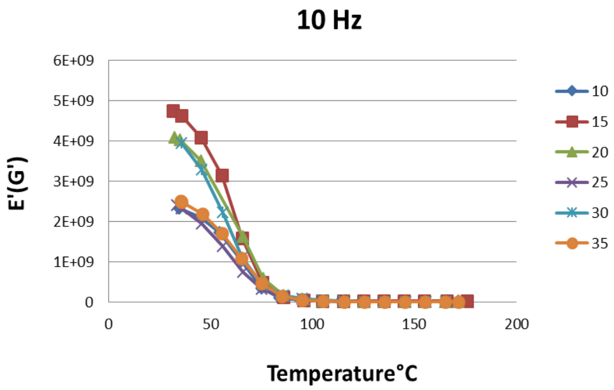


Fig. 6. Storage modulus of Almond Shell powder with Aquilaria Agallocha Roxb Blended Epoxy Hybrid Matrix Composite at 10 Hz Frequency.

Fig. 6 shows that the storage modulus of the composite is better for the specimen with 15% v/v filler until 90° C. Further increase in the testing temperature the energy absorbed by both the resin and composite are almost same. This indicates that until 90° C the almond filler is transferring the load effectively. Afterwards the filler tends to loosen its bonding with the matrix and results in failure in their function they are intended. Researchers suggested that incorporation of almond filler in the Blended Epoxy Hybrid Matrix enhances the storage modulus or stiffness value of the composite. This molecular rearrangement of the material causes the material reduction in localized stress. At low temperatures, the molecules are so immobile that they are unable to resonate with the oscillatory loads and therefore remain stiff. The thermoset polymers have cross-link between every 20 atoms, this link is retained at all temperature, and hence they are strong.

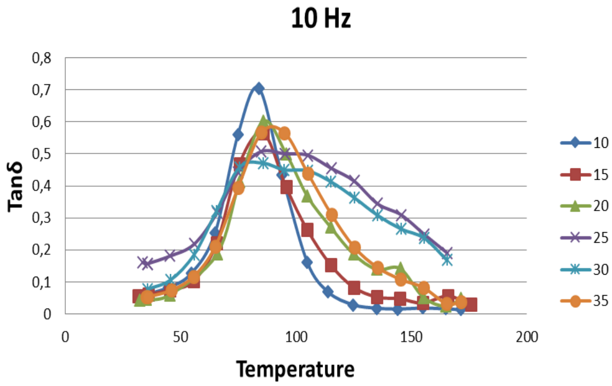


Fig. 7. Effect of filler content on the damping factor Tanδ at10 Hz Frequency.

3.4. Damping Factor (Tanδ)

Damping factor in general is described as the ratio of loss modulus to storage modulus of the material. This indicates the energy dissipation of the material during loading and shows the degree of molecular movement in the polymer chain. Fig. 7 shows the plot of damping factor of the almond shell powder incorporated composite material. The results show that the addition of reinforcements decreases the Damping factor of the composite material. This indicates that the composite possesses better energy dissipation mechanism than matrix. At low temperature, the material is said to be in the glass state or energy elastic state, as the temperature increases material phase changes to rubber or entropy elastic state a change from the glass state into the rubber-elastic state is called the glass transition. The glass transition temperature is often taken to be the temperature of the maximum loss modulus (E”). In this work, the glass transition temperature is calculated using peak of tan δ value. Irrespective of magnitude of applied force, the peak of tan δ reduces when compared with epoxy resin whereas a clear shift in the glass transition temperature (T_g) is seen along. This shows that there exists a synergetic effect between almond shell powder filler with *Aquilaria Agallocha Roxb* Blended Epoxy Hybrid Matrix Composite

The peak of damping is associated with the glass transition region where the material changes from a rigid to plastic state. Initially, the molecules are stable, as with the rise in temperature the movement of small groups and chains of molecules within the polymer structure is set to begin. Therefore, higher the tan δ peaks, higher the degree of molecular mobility. The decrease in the peak height and increase in the width signifies the lowering of mobility of molecules and increase in the inhomogeneity phases. The lowering of peak height indicates the better interfacial adhesion between matrix and reinforcement. As the material changes its phase, the degradation of property occurs due to breakage in polymer chain.

4. Conclusions

In this research, the influence of different volume fractions of Almond Shell powder with *Aquilaria Agallocha Roxb* Blended Epoxy Hybrid Matrix reinforced composite on the mechanical and DMA properties were investigated. It was observed that the incorporation of filler material enhanced the mechanical properties of composite material to certain extent. It was noted that the 20 % volume fraction of Almond Shell powder with *Aquilaria Agallocha Roxb* Blended Epoxy Hybrid Matrix resulted in maximum tensile strength, flexural strength and impact strength, while better visco-elastic properties were achieved with 15% v/v filler material. However further addition of Almond Shell powder with *Aquilaria Agallocha Roxb* Blended Epoxy Hybrid Matrix resulted in reduction of the mechanical properties which may be due to the non-uniform dispersion in filler in the epoxy matrix. SEM images revealed the accumulation of the filler at higher volume fractions.

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