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Variation of Tensile, Hardness, Impact and Natural Frequency in Jute/E-Glass Epoxy Composite For Varying Fiber Loading and Addition of Shear Thickening Fluid

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ABSTRACT

In the recent decade composite materials plays a significant role in the manufacturing sector of many industries contributing towards the social and economic development of a country. This is because of flexibility to combine different set of materials to bring out the desired properties in developed material. Many researchers performed experimental investigation on potential use of composite in various engineering application viz. structural components of automobile and aerospace application. In this regard current investigation is intended to tailor a hybrid fiber reinforced composite material constituting Jute, E – Glass and Epoxy matrix material. Traditional hand layup technique is adopted to cast the composite based on weight fraction. Thus casted composites are tested for Mechanical properties and vibration characteristics. Also the composites are tested for the effect of addition of Shear Thickening Fluid (STF). Scanning Electron Microscope (SEM) images were captured for the composites developed to validate the test results. Mechanical and dynamic test result indicates that addition of STF to composite improved the mechanical properties and vibration characteristics and has potential to be used in automobile application.

Keywords: Hybrid composites, Shear thickening fluid, Mechanical testing, Jute, E-glass, Epoxy

I. INTRODUCTION

Hybrid composite materials are those when two or more fibers combined together with the aid of a polymer resin [1]. The purpose for combining two or more fiber in composite is to develop the desired mechanical properties so as to be used in a specific application. In this regard many researchers performed research for the true worthiness of the developed composite. Also researcher tries many natural fibers as replacement for synthetic fiber to improve the degradability to make composites eco – friendly by not compensating with properties of material [2]–[6].

K Abdurohman et al. investigated the effect of different casting technique on the tensile properties of composites made of E – glass and epoxy. Techniques involved in the casting of composites are hand layup, vacuum bagging and vacuum infusion. American Standard for Testing Materials (ASTM) D 3039 was adopted as testing procedure. Results indicates that the composites processed using vacuum infusion with 60 wt % fiber and rest as resin possess higher tensile modulus and Ultimate Tensile Strength (UTS) of 10673.4 MPa and 346.15 MPa respectively compared to 8660 MPa and 260.986 MPa for hand layup method [7].

Abhishek et al. experimented the tensile and hardness properties of hybrid composites having jute, e-glass and epoxy resin. Composites were casted using conventional hand layup method. Composites were tested for the effect of addition of Shear Thickening Fluid (STF). Fibers and resins were maintained in the ratio of 60 wt % of fibers and 40 wt % resins. Jute fibers were varied to examine the effect of jute fiber variation. Results concluded that tensile modulus and UTS of the composite increased with the increase in the jute wt %, but the percentage elongation of the composite decreased. Addition of STF to the composite further increased the strength and UTS. The tensile modulus and UTS recorded were around 1300 MPa and 200 MPa for composites with STF [8].

Joselin et al. in their investigation attempted to improve the impact resistance in high performance Kevlar fabrics by impregnating the fabrics using STF. Results indicated that the fabric with impregnated STF exhibited better impact resistance, also the depth of penetration in the fabrics with STF was lesser compared to fabrics without STF [9].

Davoodi et al. tested composite material comprising of Kenaf – Glass fiber bonded with epoxy resin for bumper beam application in passenger car and found that above said composite has a greater potential to be used in bumper beam application since its strength was on par with the requirement, but its impact resistance was on lower side [10]. Raghavendra et al. tested hybrid composites made of Jute and glass, epoxy as polymer for mechanical properties to be used in automobile application and concluded that combination of natural and synthetic fiber hybrid composite had greater abilities to replace conventional materials in automobile application with improvement in impact strength [11].

Kunkun et al. carried out their research on effect of shear thickening fluid on energy absorption capacity and transverse impact strength in sandwich composites. Sandwich composite panels were prepared using carbon fibers facing with shear thickening fluid filled in composite. Thus prepared composite were tested for low velocity impact loading. It was found from results that composite made of shear thickening fluid as core material exhibited higher energy absorption capacity than aluminium foam as core material. Also the depth of penetration in the composite panel was less compared to aluminium foam sandwich composite panels [12].

Kejing et al. [13] evaluated the stab resistance of fiber by coating with silicon based shear thickening fluid. Glass fibers were soaked in STF and dried before fabrication. The evenly distribution of STF was established by SEM photographs. Quasi – static stab resistance test was conducted on fiber with and without STF. Fiber coated with STF indicated superior stab resistance compared to fibers without STF.

It can be summarized from the literature that the composite with the addition of STF improves the Strength and impact resistance. In the current investigation, it is intended to process a hybrid composite consisting of e-glass, jute as fibers and epoxy as resin. Also the developed composites are tested for the effect of addition of STF.

II. MATERIALS AND METHODS

As discussed in the previous section in the current investigation a hybrid composite are developed with e-glass and jute as fibers and epoxy as matrix materials. Figure 1 depicts the jute. E-glass and epoxy used in the casting of composites. Composites are fabricated using hand layup method [14]–[17]. In this method the woven fibers are placed in a flat mould and the measured quantity of matrix material is added with constant rolling to remove any trapped air gaps in the composites. Thus prepared composites are allowed to cure in the room temperature for one day. Cured composites are then processed according to ASTM standard for evaluating tensile, hardness, impact and dynamic properties. Also the composite are tested for the addition of STF, which are made of corn starch suspended in water in the ratio of 10:1. This mixture is then added to resin. Mechanical properties of the jute, e-glass and epoxy are listed in Table 1, 2 and 3 respectively.

Table 1. Mechanical properties of Jute

Density (g cm^{-3})	Tensile strength (MPa)	Youngs modulus (GPa)
1.3	393	26.5

Table 2. Mechanical properties of E - Glass

Density (g cm^{-3})	Tensile strength (MPa)	Youngs modulus (GPa)
2.55	1750	70

Table 3. Mechanical properties of Epoxy

Density (g cm^{-3})	Tensile strength (MPa)	Youngs modulus (GPa)
1.2 -1.3	50-125	2.5-4.0

Hybrid composites are prepared with varying jute fiber loading viz. 5 – 20 wt % i.e. in steps of 5 wt %. Also composites are tested for the effect of addition of shear thickening fluid; the details of the composition in the composite are tabulate in Table 4 and 5.

a b c

Figure 1: (a) Jute (b) E-glass (c) Epoxy

Table 4. Composition of the composite without STF

Composition	Jute Wt%	E-Glass Wt%	Epoxy Wt%
C1	5	45	50
C2	10	40	50
C3	15	35	50
C4	20	30	50

Table 5. Composition of the composite with STF

Composition	Jute Wt%	E-Glass Wt%	Epoxy Wt%
CS1	5	45	50
CS2	10	40	50
CS3	15	35	50
CS4	20	30	50

Tensile Test

Material of any form, assessment of tensile properties is very important since, materials to be used in structural application requires mechanical properties, one such property is tensile strength which are assessed through tensile testing. In this test materials are subjected to axial loading. Gradually load is increased till the failure of the material. standards are adopted for testing is ASTM D638 type I [18]. Mechanical properties such as UTS and percentage elongation are determined for the composites defined in previous section.

Rockwell Hardness Test

Surface property is one of the key factors to assess the wear in materials. Here composites are tested for Rockwell hardness testing for M Scale with ASTM D785, size of the ball indenter being 6.35 mm. Composites are subjected to minor load of 10 kg and major load of 100 kg. The hardness of the materials is evaluated using Equation 1.

Rockwell hardness number = $130 - \frac{h}{0.02\,mm}$ ... Equation 1

Charphy Impact Test

Resistance against sudden load is as important property for structural application like in automobile/aerospace industry. This charphy impact test characterises the strength of the materials against impact. The ASTM D 256 standards are adopted for the conduction of test. Figure 2 indicates the tailored composites according to ASTM standards.

Figure 2: Composites according to ASTM standards

Dynamic Mechanical Test

Fast Fourier Transform (FFT) analysis are performed to evaluate natural frequency of the materials [19]–[23]. Dynamic vibration analysis were conducted to evaluate the natural frequencies of the passenger car components [24]–[26]. In this test a specimen of dimension 300 * 300 mm are held as cantilever beam, specimens are subjected to excitation force to record FRF variation in the material which are utilized to compute natural frequency of the components. Figure 3 illustrates arrangements made in dynamic mechanical testing to assess natural frequency of the composites for different modes.

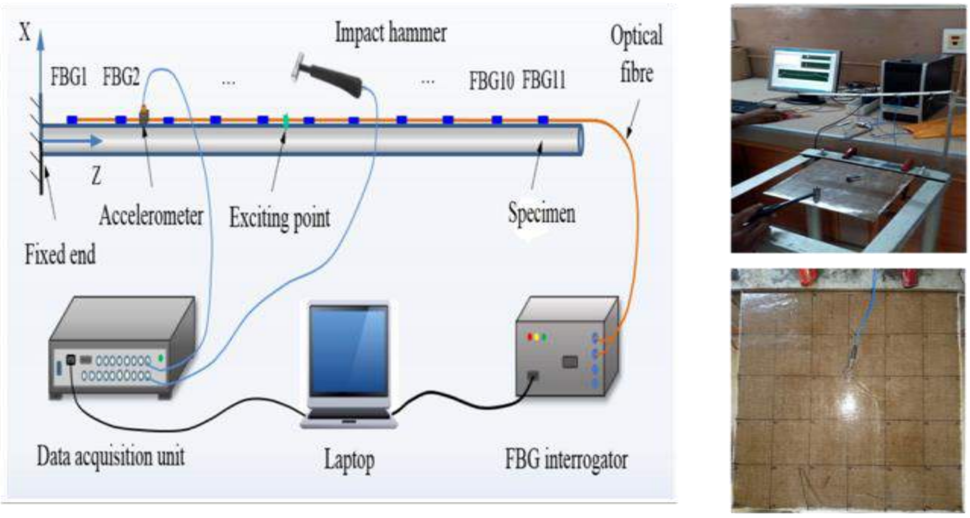


Figure 3: Dynamic mechanical testing setup

SEM Analysis

SEM photography of composites with and without STF is captured in order to validate the bonding between fibers and fiber-matrix by using Hitachi SU 3500 machine. Initially composites are subjected to Gold sputtering process as surface preparation.

III. RESULTS AND DISCUSSION

Tensile Test

Mechanical properties such as UTS and percentage elongation are recorded for the hybrid composites with and without STF and the Table 6 reveal the results.

Table 6. Results for Tension test

Composite	UTS (MPa)	% Elongation	Composite	UTS (MPa)	% Elongation
C1	96.49	2.09	CS1	211.06	4.79
C2	81.83	3.34	CS2	147.42	2.83
C3	137.89	4.31	CS3	97.74	1.87
C4	61.27	4.36	CS4	100.04	1.43

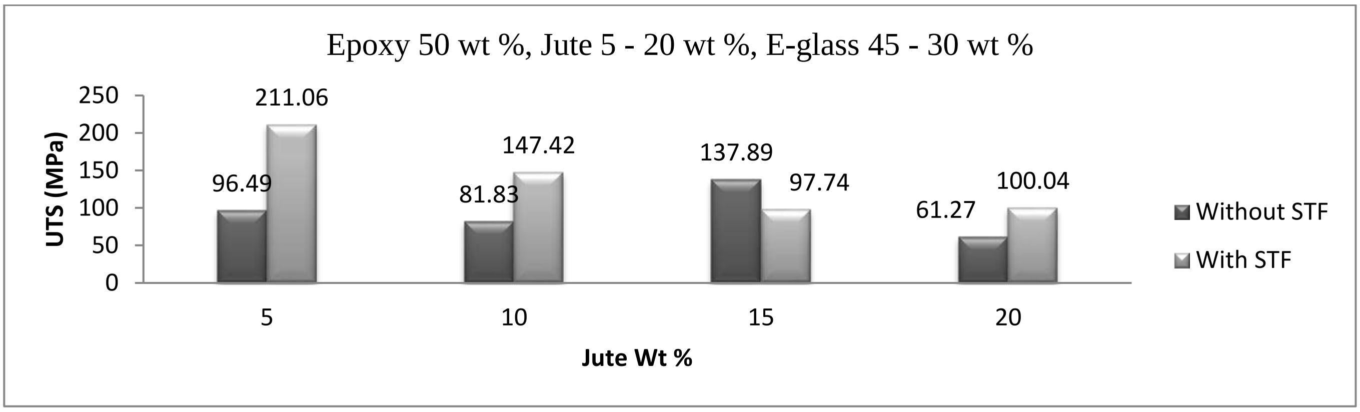


Figure 4: UTS vs jute wt % in composites with and without STF

The variation in the UTS for the change in the jute wt % in composite with and without STF is depicted in Figure 4. It indicates that the UTS in composite C3 are higher compared to composite C1, C2 and C3, but a decreasing trend is observed except in C3 composites this is argued later with the morphology images that the bonding in composite C3 is better compared to rest of composition. Similar variations are recorded for the composites with STF. This decrease in the UTS is because of increase in the jute wt % i.e. e-glass is stronger compared to jute as shown in Table 1 & 2. This is supported by the work carried out K Abdurohman et al. in the application of alkali treated rice straw fiber composite in bumper beam application [7] .

The highest UTS are recorded for the composite without STF is 137.89 MPa for C3 and for composite with STF it is 211.06 MPa in CS1. Results also indicates that the addition of STF to composites enhances the UTS in C1, C2 and C4 but in C3 it decreased as a result of poor bonding between fibers and fiber-matrix by SEM morphology.

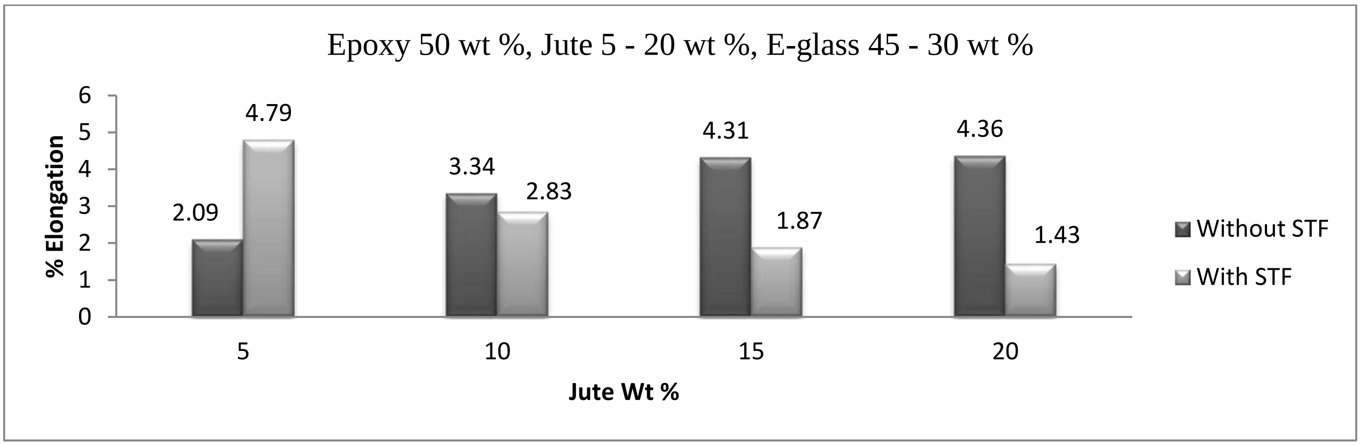


Figure 5: Percentage elongation vs jute wt % in composites with and without STF

Effect of varying fiber loading and addition of STF to composite on percentage elongation is shown in Figure 5. On comparing the stiffness of jute and e-glass as listed in Table 1 & 2, jute is less stiffer then e-glass, this is distinctly visible in the results of percentage elongation for varying jute fiber loading in composites i.e. as the jute wt % in composite increases, the percentage elongation increases. The highest percentage elongation of 4.36 % is noted for the composite C4 and lowest of 2.09 % for C1.

In composites with STF this trend is overturned, percentage elongation decreased with the increase in the jute wt %. The formation of tenacious like substance due to the addition of STF to composite is one of the reasons, which improves bonding between fibers and matrix to increase the strength and decrease in percentage elongation as revealed in SEM images.

Hardness Test

Surface hardness of the composites are measured using Rockwell hardness and test results are shown in Figure 6. It indicates that the variation in the hardness between composites has not varied significantly for varying jute wt % in both composites with and without STF this is because of the reason that the resin is kept constant and the facing layers of composites comprises of e-glass. But composites with STF revealed lower HRM compared to without STF. Highest HRM is noted in composite C1 with 82 HRM while lowest of 61 HRM in CS4.

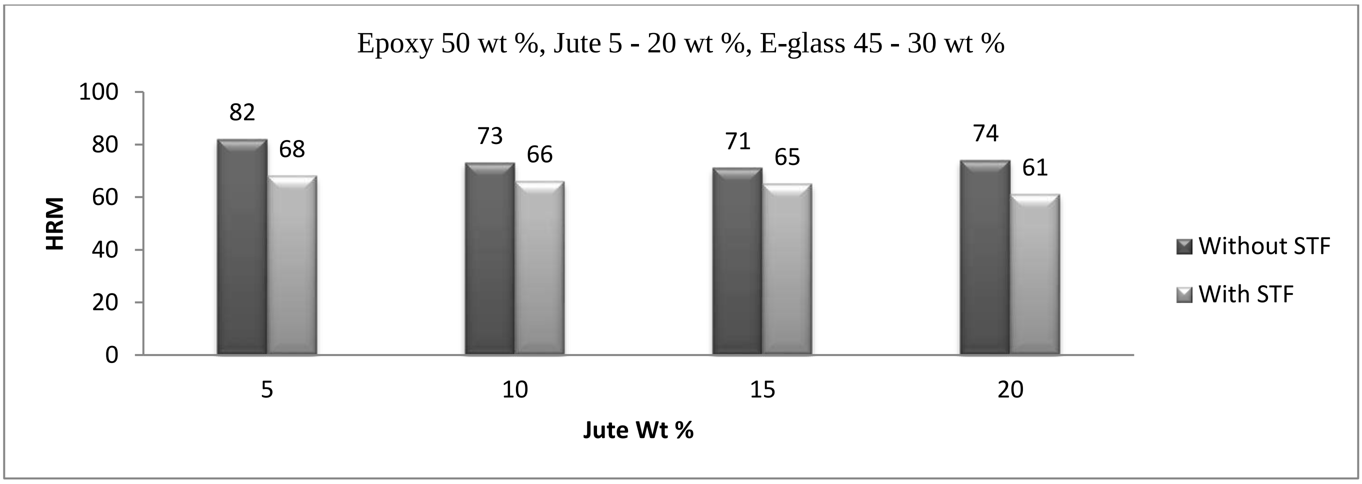


Figure 6: HRM vs jute wt % in composites with and without STF

Impact Test

Effect of Adding STF and varying fiber loading on charphy impact strength are depicted in Figure 7. Results indicated that increase in the jute wt % in composite increases the impact strength in both composites with and without STF, but the effect of increment in impact strength is not that significant for composites with STF and for 15 and 20 jute wt %. M K Guptha et al. [15] in their investigation proved that the combining jute with sisal increased the impact strength in the composites. Similar results are noticed in the composites without STF.
Kejing et al.[13] in their investigation proved that the addition of STF increases the impact strength of the composite, similar observation are noticed in the current research that the addition of STF increased the impact strength in composite with STF compared to the composites without STF.

Dynamic Mechanical Test

The results for the dynamic mechanical test are illustrated in Figure 8, 9 and 10 for mode 1, 2 and 3 respectively for composites with and without STF. The effect of adding STF and varying jute wt % in the composite is not significant for the 10, 15 and 20 jute wt %. But in composite with 5 wt % jute natural frequency increased in mode 1 and decreased noticeable in mode 2 and 3. Results concluded that a range of natural frequency can be obtained by varying jute wt % and addition of STF to composite.

SEM Analysis

Surface morphology for the composites with and without STF for varying jute fiber loading is illustrated in Figure 11 and 12 with 500X magnification. Figure 11 reveals the presence of voids in composite C1, C2 which reduced the strength in the composite as seen for UTS. Also from Figure 12, it is noticed that the addition of STF transposes resin into sticky which hold the fibers and matrix to higher strength and reduced the formation of voids in the composites.

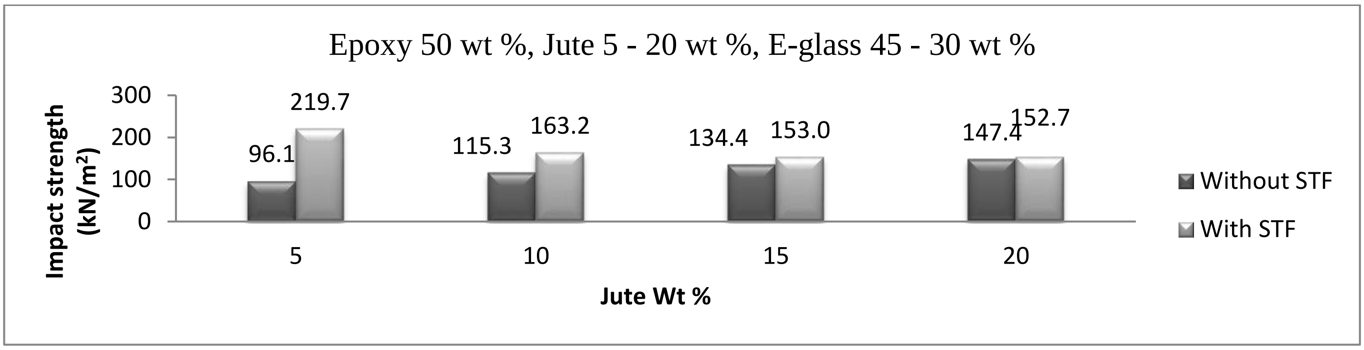


Figure 7: Impact strength vs jute wt % in composites with and without STF

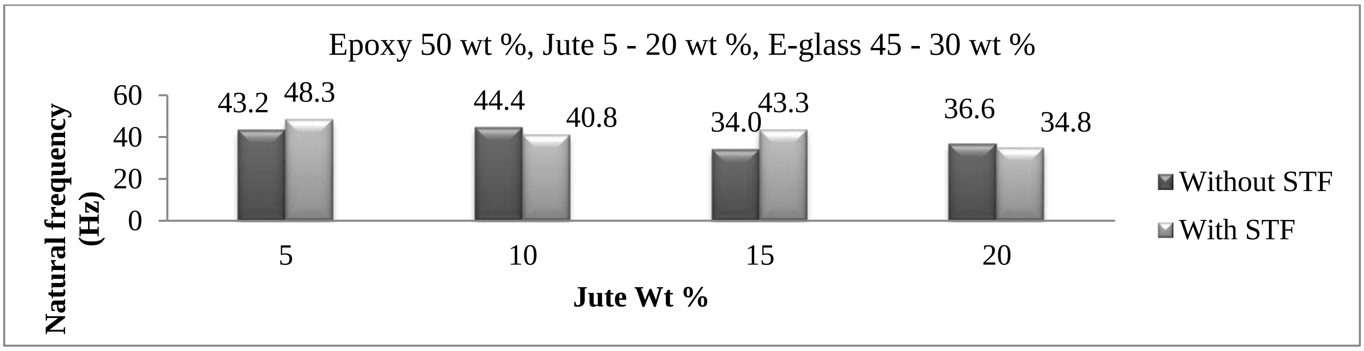


Figure 8: Natural frequency vs jute wt % in composites with and without STF for mode 1

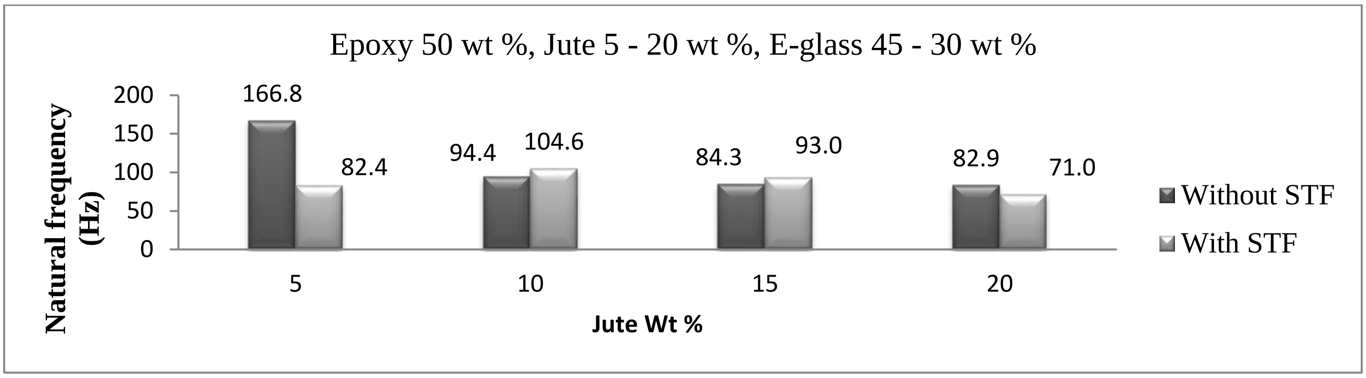


Figure 9: Natural frequency vs jute wt % in composites with and without STF for mode 2

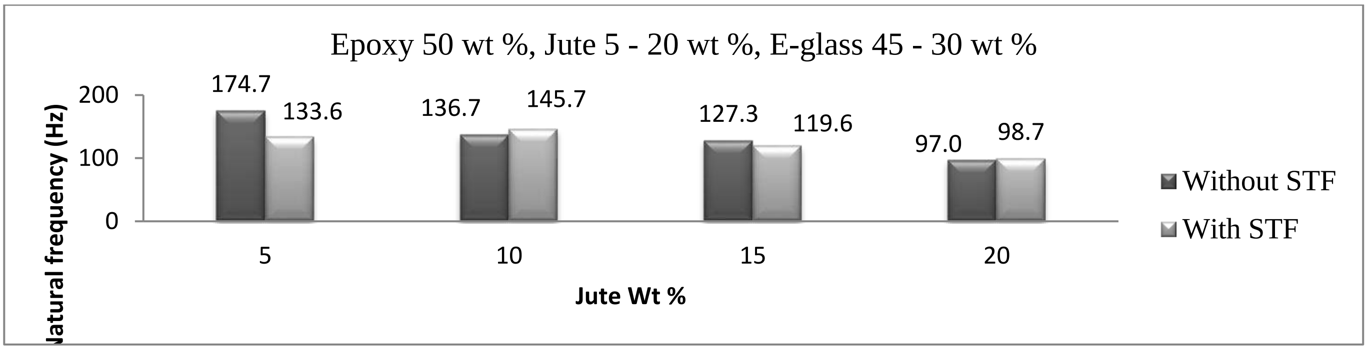
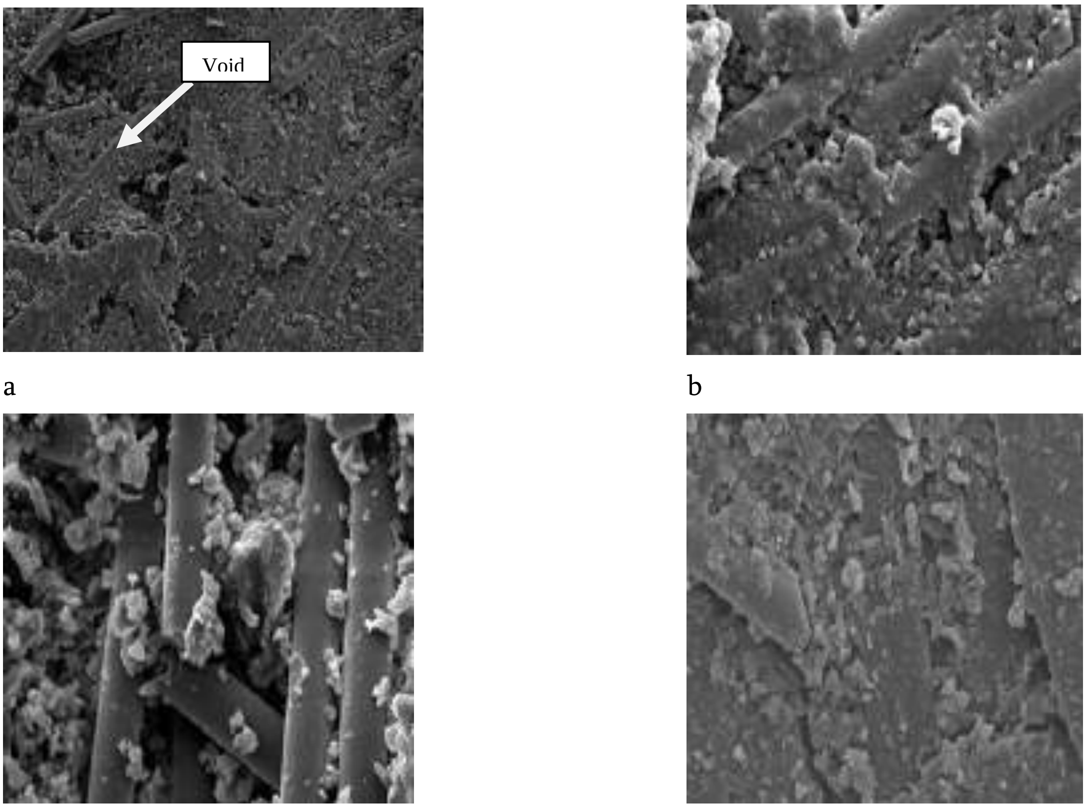


Figure 10: Natural frequency vs jute wt % in composites with and without STF for mode 3



a b

c d

Figure 11: SEM images of composites without STF (a) C1 (b) C2 (c) C3 (d) C4

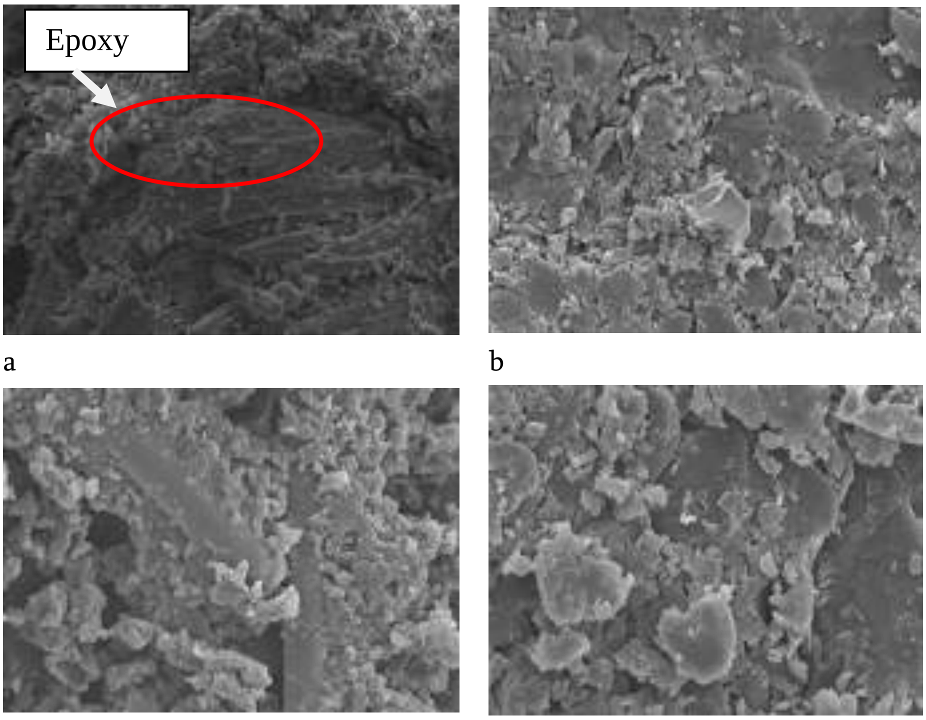


Figure 12: SEM images of composites with STF (a) CS1 (b) CS2 (c) CS3 (d) CS4

IV. CONCLUSION

Mechanical Properties such as tensile strength, percentage elongation, hardness, impact strength and Vibrational characteristic like natural frequency for the composites for varying fiber loading and effect of STF are studied and following conclusion were drawn: the hybrid composite CS1 shows better ultimate tensile strength, percentage elongation, hardness, impact strength and natural frequency in mode 1 indicating addition of STF increased mechanical properties. But the addition of higher jute wt % fiber to composites reduced the UTS, increased the impact strength making the composite potential to be used in automotives with impact application.

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