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Evaluation of Mechanical properties of Jute Reinforced Epoxy Resin

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Abstract: In modern day scenario, epoxy resin matrix composites are widely used due to their desirable high strength, better durability and low corrosion property. Epoxy resin is a commonly used resin matrix composite that is adhesive and stable. In the current analysis the matrix of epoxy resin was reinforced using jute strains, which are widely used in gunny bags and sacks. The tensile strength was measured using UTM machine and impact strength was measured using Izod impact test. Also Scanning electron microscope(SEM) is used to view the grain structure. Both the samples (with and without) the reinforcement was tested and the results are evaluated. This study aims to evaluate the benefit of bio reinforcement in the epoxy resin compound which are commonly referred as bio-composites. The mechanical properties of epoxy resin are affected by the ratioof curing agent to epoxy resin; this mixing ratio has very importantpractical implications.

Keywords: epoxy resin, UTM, Izod test, SEM

1. Introduction:

Epoxy resin (EP) is one of the important types of high-performance thermosetting organic polymers and has been widely used as adhesives, coatings, and composite materials for a wide range of advanced applications such as in the field of aerospace, marine, and electronics, wear-resistant slide joints, tribological field, etc. Although epoxy resin has excellent adhesion strength, acid and alkali resistance, green environmental protection and so on, it is brittle in comparison with the metals. The presence of matrix compound can help increase the strength of the compound.In modern engineering applications, fiber reinforced plastics are used widely in aircraft and spacecraft structural parts due to its mechanical and physical properties like high specific strength and specific stiffness. (Hemnath et al., 2021)
Though there are different thermoset materials available as resin, still epoxy remains as a choice due to its ability to obtain desired chemical and mechanical properties.(Biswas et al., 2015) The composites are usually made using artificial and natural fibers. Artificial fibers such as glass, carbon, and aramid offer the advantages of higher stiffness and strength to weight ratio.

Natural fiber composites gained attention due to low cost, low density, eco-friendliness, acceptable specific properties, ease of separation, enhanced energy recovery, CO_2neutrality, biodegradability and recyclable nature. (Unnikrishnan, 2019). The uses and applications of jute and banana fiber composites are discussed in detail. Jute fiber, due to its easy availability and commercial nature revealed moderate mechanical properties. Tensile strength of oriented discontinuous fiber composites was evaluated by single fiber pull out showed the fiber/matrix adhesion was good due to the natural waxy surface
The literature study shows that the composites importance in numerous diverse areas such as automobile, structural, aerospace and marine applications.(Gopinath et al., 2018) Reviews confirm very few researches have been carried out in the effects of fiber properties on the mechanical performance of the polymer composites.

2. Literature Review

S.No.	Citation	Resin Mixed	Matrix Used	Ratio of mixing	Outcome
1.	Mechanical Properties of Epoxy and Its Carbon Fiber Composites Modified by Nanoparticles(Liu et al., 2017)	DGEBA resin + peperidine hardener	Carbon fiber	100:5 by weight	Flexural strength 10-15% increase Compressive strength 4-5% increase
2.	Evaluation of Mechanical Properties and Microstructure of Polyester and Epoxy Resin Matrices	Epoxy+ polyester	E-glass and coconut fiber	18:82 by weight	Flexural strength 40-50% increase SEM – Better bond between atoms

	Reinforced with Jute, E-glass and coconut Fiber(Gopinath et al., 2018)				
3.	Characterization and Evaluation of Mechanical Behavior of Epoxy-CNT-Bamboo Matrix Hybrid Composites(Thakur et al., 2018)	Epichlorohydrin + Bisphenol	Bamboo and carbon nano tubes	Variable ratios of CNT	Tensile strength 10% increase Flexural strength 7% increase SEM – Better grains
4.	Experimental determination of the true epoxy resin strength using micro-scaled specimens(Hobbiebrunken et al., 2007)	RTM6 resin with heating	-	-	-
5.	The mechanical properties of epoxy resin composites modified by compoundmodification(Li et al., 2018)	GCC135 resin + GCC 137 hardener	Viscose fiber	Variable ratios	Tensile load 13.83% increase Tensile strength 20.2% increase Bending stress 104 % increase
6.	Novel, low-cost jute-polyester composites. Part 1: Processing, mechanical properties, and SEM analysis(Dash et al., 1999)	Jute Polyester Hot Curing (control), and JPH (B) Jute Polyester Hot Curing (bleached)	Jute fibers	Variable ratios	Tensile load 15% increase Bending stress 20.5%increase
7.	Production and Properties of Short Jute and Short E-Glass Fiber Reinforced Polypropylene-Based Composites(Khan et al., 2012)	Polypropylene based resin	Short jute fiber (2-3mm)	20% by weight	Tensile load: Increase Flexure Load: Increase Impact strength: Increase
8.	Mechanical properties of kenaf fibers and kenaf/PLA composites(Ochi, 2008)	Poly lactic acid(PLA) resin	Kenaf fibers	Increased linearly to 50% by weight	Tensile strength: 223MPa Flexural Strength: 254 MPa
9.	Tensile and flexural behaviour of rice husk and sugarcane bagasse reinforced polyester composites(Hemnath et al., 2021)	Polyester resin	Rice straw fibers	Increased to 40% by weight	Tensile modulus: 1.66 times Specific tensile modulus: 2.17 times
10.	Experimental Investigations on Mechanical Properties Of Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices(Gopinath et al., 2014)	Polyester and epoxy resin	Jute fiber With NaOH	18:82 fiber-resin	Tensile strength – 17% increase Flexure strength – 18% increase
11.	An Experimental And Numerical Investigation Of Mechanical Properties Of Glass Fiber	Polyepoxide resin with polyamine hardener	Glass fiber mat	As per ASTM standard	Tensile strength – 14.5% increase Flexural strength – 123% increase

	Reinforced Epoxy Composites(Singh &Kumar;S.K. Jain, 2013)				
12.	Study on the mechanical properties of alkali treated screw pine root fiber reinforced in epoxy matrix composite material(Naik et al., 2021)	Epoxy LY556	Screw pine root fiber	Varying ratios from 10-30%	Tensile strength- 15% increase Impact strength- 30% increase Water absorption- 0.8% increase per 10% increase in matrix
14.	Chemically functionalized alumina nanoparticle effect on carbon fiber/epoxy composites(Shahid et al., 2005)	Lysine-alumoxane (L-alumoxane) and *para*-hydroxybenzoate-alumoxane (*p*-HB-alumoxane)	Carbon fiber + alumina nanoparticles	Varying 5-16%	SEM – better grain structure Tensile strength –Increase Thermal stability – Increase
15.	Natural fiber-mediated epoxy composites – A review(Mittal et al., 2016)	Epoxide resin	Natural fibers – vegetable, animal, fiber	Varying	Tensile strength – 300% increase Tensile modulus – 13% increase
16.	Low velocity impact tests of laminate glass-fiber-epoxy matrix composite material plates(Belingardi&Vadori, 2002)	Epoxy resin	Glass fiber	As per ASTM standards	Impact energy- Increase absorbed Damage degree – Increase
17.	The mechanical properties of epoxy resins(Yamini & Young, 1980)	Bisphenol-A (DGEBA) with various amounts of triethylene tetramine (TETA)	-	-	Evaluation of mechanical properties of epoxy resins
18.	Mechanical, Interfacial and Thermal Properties of Different Chemical Structures of Epoxy Resin(Su Shin et al., 2017)	Bisphenol-A type epoxy and novolac type epoxy	Glass Fiber	30% by weight	Thermal properties of novolac type epoxy were generally better than those of the bisphenol-A type epoxy resin. The novolac type epoxy and composites had superior strength under all three modes of loading.
19.	Physical, Mechanical and Thermal Properties of Jute and Bamboo Fiber Reinforced Unidirectional Epoxy Composites(Biswas et al., 2015)	Epoxy resin cured with vacuum	Jute and bamboo fiber	Jute (52%by weight) Bamboo (57% by weight)	Bamboo fiber has better tensile strength but jute fiberhas higher Youngs modulus. Jute fiber show better thermal behaviour than bamboo.
20.	High performance aligned short natural fibre – Epoxy composites(Pickering & Le, 2016)	Nuplex resin R180 and Nuplex standard hardener H180 (mixing ratio 5:1 by weight	Harakeke fibre (New Zealand flax)	12,27,32,46 and 52% by weight	Tensile strength increases by 78.5%. Young modulus increases by 46%.
21.	Mechanical Properties of Reinforced Banana Fibre / Bio-Fibre Hybrid Polymer Composites on Review(Unnikrishnan, 2019)	Epoxy resin with hardener	Banana/hemp /kenaffibers	Variable 10-25% by weight	Tensile strength increases Flexure strength increases

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3. Experimental Procedure:

Epoxy resin is a thermosetting polymer. Thermosetting polymers are irreversibly hardened and cannot be extracted back into their original constituents. Thermosetting polymer are usually mesh or cross-linked polymer structure joined by covalent bonds. The polymers can be cured by heating, applying pressure etc. However, epoxy resins are usually cured using chemical reactions –

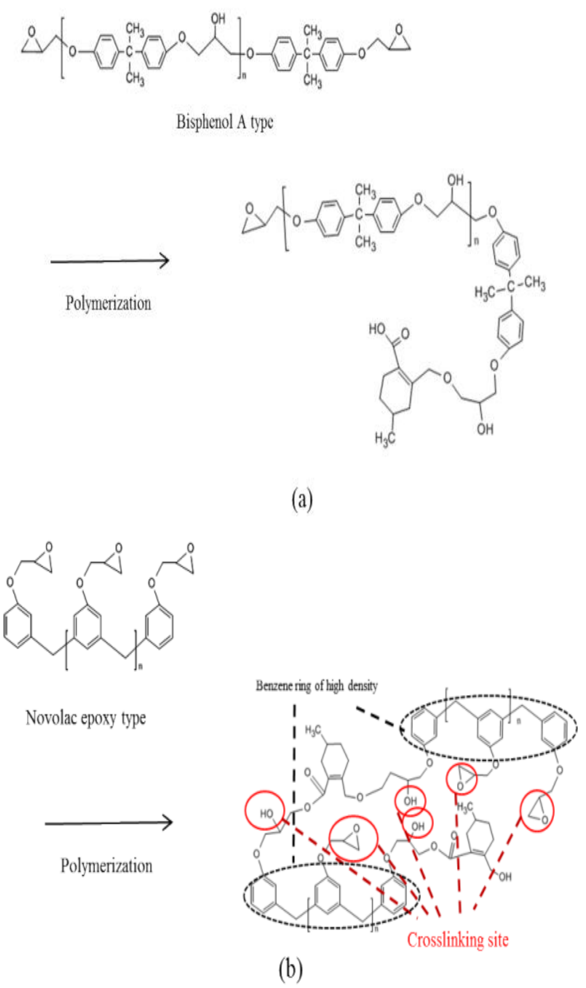

Fig. 1: Schematic plot of chemical reactions in different epoxy resin: (a) bisphenol A type (b) novolac type(Su Shin et al., 2017)

Epoxy resin is a chemical compound with two or more epoxide C-O-C per monomer. During polymerization, the hardener opens the C-O-C rings, and the bonds are rearranged to join monomer into 3-D network of cross-linked molecule.

The epoxy resin are cured usually by reaction of bisphenol-A (or F) and epichlorohydrin. The ratio of resin and hardener can be varied as the we decrease the epichlorohydrin causes the increase in molecular weight of resin composite.

Jute fiber of length 5-6 mm were prepared from gunny bags for preparation of the samples. Tri-ethylene tetra amine (TETA) is used as hardener for the epoxy resin. The epoxy resin is mixed in the ratio 3:1 by weight. The mixture was mixed thoroughly for at least 10 minutes to avoid any bubble formation. Thereafter the mixture was poured into a silicon mold with aluminium foil partition and cured for a period of 24 hours. For the other specimens, fibers in required weight percentages were added to the resin and poured into mold for curing 24 hours.

The specimen were prepared as per ASTM test standards. After curing, the sample was conditioned and prepared into 10cmx1.3cmx0.7cm which were later subjected to testing. The testing was conducted in Central Institute of Petrochemical Engineering and Technology (C.I.P.E.T), Lucknow.

Sample	Compositions	
	Epoxy wt %	Jute wt%
Sample 1	100%	Nil
Sample 2	90%	10%
Sample 3	80%	20%
Sample 4	70%	30%

The samples were subjected to flexure strength testing, tensile and impact testing.

4. Results and Discussion

The short 5-6 mm jute fiberswith variable weight ratios are mixed with epoxy resin which are subjected to testing, tensile and impact testing. The results obtained are analyzed, tabulated and inferences are made based on the test results. The results displayed that as the weight ratio of jute fibers are increased in the matrix the mechanical properties gets enhanced. This is due to the fact that jute contains high proportion of cellulose which binds with the epoxy to enhance its mechanical properties. The results obtained are written separately.

Tensile Strength

The mechanical tensile testing of the composites as per ASTM D3039 standards. The test was carried out by universal tensile strength measuring machine. As per the results obtained it is evident that tensile strength without jute matrix was 21 MPa. The tensile strength increase was 20-30% for increase in the quantity of jute. The results obtained are tabulated as below:

Sample	Composition		Tensile strength (MPa)
	Epoxy wt %	Jute wt%	
Sample 1	100%	Nil	21
Sample 2	90%	10%	27
Sample 3	80%	20%	34
Sample 4	70%	30%	38

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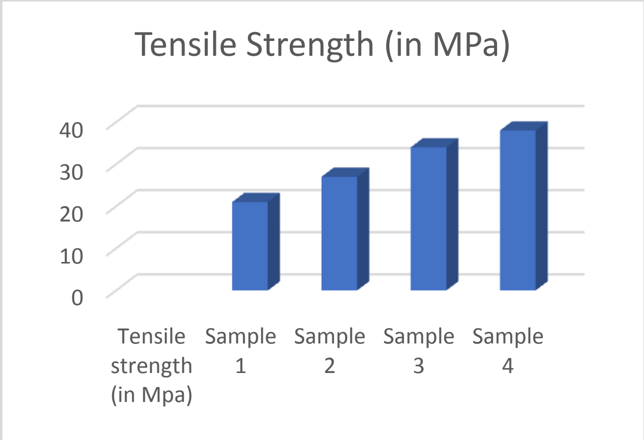
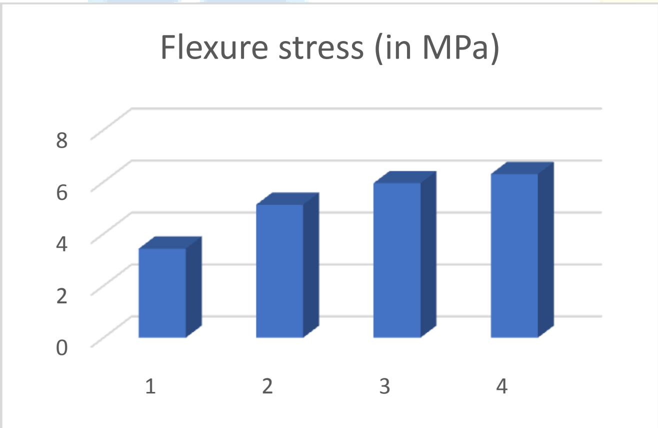
It can be seen from the results that an increase in tensile strength of biocomposite is observed with increase in jute weight percentage.



Flexural Test

Flexural test estimates the strength of the material to withstand the twisting moment in a material and characterises protection of material from flexing and bending. Flexural quality aides in the plank of bars, cantilever, shafts etc. The jute-epoxy bio composite was subjected to flexure load as per ASTM D790. The test samples were placed according to three point method to ensure evenness of the sample. The dimensions of the sample are 13mm(width)x7mm(thickness). The crosshead speed is 2mm/min.

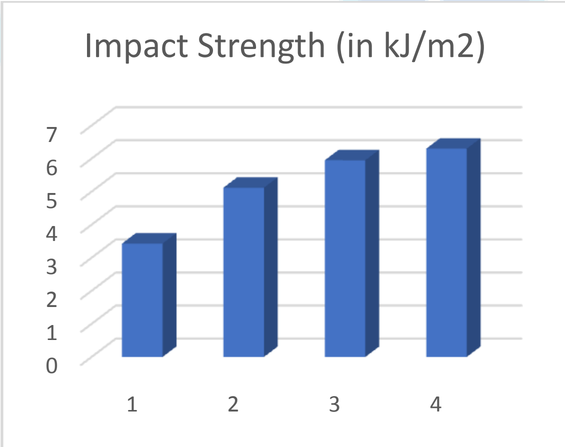
Sample	Composition		Flexure stress (MPa)
	Epoxy wt %	Jute wt%	
Sample 1	100%	Nil	29
Sample 2	90%	10%	35
Sample 3	80%	20%	41
Sample 4	70%	30%	49



Impact Strength Testing

The test was performed using Izod impact strength test. One of the main concerns of epoxy composite is their low impact strength. The main are of concern is to enhance the impact of bio composites. Various research takes place to increase the impact strength of the bio composites. For the current test the sample of width 10mm and thickness 7mm of the material was made with a 45^0 degree notch for clean impact. The results of the Izod impact tests are tabulated below –

Sample	Composition		Impact Strength (kJ/m^2)
	Epoxy wt %	Jute wt%	
Sample 1	100%	Nil	3.43
Sample 2	90%	10%	5.12
Sample 3	80%	20%	5.95
Sample 4	70%	30%	6.30



5. Conclusion

Through the experiments conducted in the laboratory, it can be concluded that the jute reinforced epoxy resin has better mechanical properties. The enhanced properties help the reinforced resin to have better use and results in all the industrial and architectural applications.

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