EXPERIMENTAL TESTING OF TENSILE PROPERTIES, ILSS AND IS PROPERTIES AND OF ACRYLIC FIBER-REINFORCED EPOXY COMPOSITE: COMPARISON BETWEEN UNIDIRECTIONAL, BIDIRECTIONAL AND MAT FIBER FORMS

Rambabu Pulla[1] Dakey Suman[2]

[1]PG Scholar, M. Tech scholar, Department of Mechanical Engineering, Godavari Institute of Engineering and Technology, Rajahmundry, India.

[2]Designation, Department of Mechanical Engineering, Godavari Institute of Engineering and Technology, Rajahmundry, India.

Abstract: *In this work, the experimental investigation on flexural Properties and tensile properties of Acrylic Fiber-reinforced epoxy composite is done. The composite is prepared by using a hand layup method with 10, 15, 20 % weight of Acrylic Fibres into the epoxy matrix. Fibers are oriented in unidirectional, bidirectional and mat fiber forms. The tensile tests, ILLS tests and IS tests on the specimen samples are done as per ASTM D-638M-89 and ASTM D-256-97 standards. Among the proposed combinations of reinforcement patterns, the specimen combination with ID 12 showed excellent improvement in strength by 24.04%, improved by 28.01% in elasticity, 54.29% in IS and 64.88% in ICSS properties compared to ID 1.*

***Keywords**: Tensile, SEM, Flexural, Acrylic, Epoxy*

INTRODUCTION

Composites reinforced with polymers (FRP) have good specific characteristics such as stiffness, strength and anisotropic properties [1]. As a result, these are widely used in many engineering and industrial applications such as automobile, aerospace, marine, space, electronics and many more industries [2].

Nowadays these polymers reinforced composites are being used in restructuring the damaged concrete structures because of their excellent specific properties and easiness in using them [3]. Plastic fibers, carbon fibers, and aramid fibers are being used as reinforcement in the preparation of composites having polymer matrix [4]. The plastic fibers have excellent resistance towards chemicals, high strength and are suitable to use in automotive, aviation and electronics [5]. Effective fiber orientation and compositions of fibers will equalize the characteristics of acrylic fiber-reinforced composites with those of metals [6].

Omar, Andrzej Bledzki, Hans Fink, Mohini rev in their review paper [7] reviewed on the for the most promptly used natural fibers and biopolymers from 2000 to 2010 in their paper. The general attributes of reinforcing fibers utilized as a part of biocomposites, including source, type, structure, creation, and in addition mechanical properties, are also discussed. Moreover, the modification techniques; physical like corona and plasma treatment and chemicals like silane, basic, acetylation, maleated coupling, and catalyst treatment are examined. The most mainstream matrices in biofiber reinforced composites based on petrochemical and sustainable assets are also discussed. The wide assortment of biocomposite preparing procedures and the variables like moisture content, fiber type and substance, coupling operators and their influence on composites properties and influencing these procedures are also discussed.

Preceding the processing of biocomposites, semi-finished product manufacturing which is additionally fundamental also outlined. Processing advancements for biofiber reinforced composites are discussed based on thermoplastic matrices formed by pressure shaping, expulsion, infusion forming, LFT-D-strategy, and thermoforming, and thermosets by tar exchange shaping, sheet shaping compound. Another process, i.e., thermoset pultrusion and compression molding and their influence on mechanical properties like ductile, impact and flexural affect properties are also assessed. At long last, the review closed with recent improvements and future patterns of bio composites and in addition key issues is resolved.

Gurunathan, Mohanty, Nayak, in their review paper [8] gave a concise blueprint of work that spreads in the area of bio composites. The growing environmental and ecological awareness has driven them as many researchers for the advancement of new inventive materials for different end-user applications since polymers incorporated from natural resources, have increased significant research enthusiasm in recent years. Their review paper is planned to give a concise blueprint of work that spreads in the area of bio composites, a significant class of biodegradable polymers, natural fibers, and their manufacturing techniques and properties has been featured. They incorporated different surface modification techniques to enhance the fiber-matrix adhesion bringing about the enhancement of mechanical properties of the biocomposites. Additionally, an economic impact and future heading of these materials have been fundamentally checked on. Their review infers that the biocomposites frame one of the developing territories in polymer science that pick up consideration for use in different applications going from car to the building industries.

In the review paper [9] by Vaisanen, Oisik, Tomppo they discussed the effects of residues, waste materials, or by-products of many types of processes on NFPC and their constituents were evaluated. Composite materials based on sustainable agriculture and biomass feedstocks are progressively used as these items significantly counterbalance the utilization of non-renewable energy sources and decrease ozone-harming substance emissions in the examination with regular oil-based materials. However, the consideration of natural fibers in polymers presents a few difficulties, for example, overabundance water retention and poor thermal properties, which should be overcome to create materials with comparable properties to the conventional composite materials. Rather than utilizing rather costly materials and physical modification techniques to dispense with these previously mentioned challenges, another pattern of using waste, deposits, and process results in Natural fiber-polymer composites (NFPCs) as additives or reinforcements may acquire significant upgrades the properties of NFPCs in a practical and flexible way. In their paper, the impacts of waste materials, deposits or process results of various types of NFPC are fundamentally reviewed into and their potential as NFPC constituents is assessed.

In the review article [10] by Mohammed, Ansari, Grace, Mohammad, and Saiful M Islam provided a comprehensive review of the natural fiber reinforced polymer composites and applications of them in various industries and business sectors. Furthermore, it presented an outline of different surface treatments connected to fiber strands and their impact on NFPC properties. The impacts of different chemical treatments on the thermal properties and mechanical properties of characteristic natural fibers reinforcements thermoplastics and thermosetting composites were examined. Various disadvantages of NFPCs like higher water absorption, inferior resistance to fire, and lower mechanical properties restricted its applications. Effects of chemical treatment on the water retention, tribology, viscoelastic conduct, unwinding conduct, energy an ingestion flares retardancy, and biodegradability properties of NFPC were also featured. The uses of NFPC in construction industries and the automobile industry and different applications were illustrated. They concluded that chemical treatment of the natural fiber-enhanced adhesion between the fiber surface and the polymer matrix which eventually upgraded thermochemical properties and physicomechanical properties of the NFPC.

In the work [11] by Elanchezhian, Vijaya, Ramakrishnan conducted experimental studies on Abaca, Sisal, and Jute and reviewed their mechanical properties. Their experimental study aimed at taking in the mechanical behavior of natural fiber composites. A short review has been done to make utilization of common strands, like abaca, jute, sisal, banana, cotton, coir, hemp, and so forth copiously accessible in India. Their paper exhibits an audit on the mechanical properties of Abaca, Jute, Sisal.

From the literature review, it can be seen that only a little research work was done on acrylic/epoxy composites (which are also biodegradable materials) by taking fiber orientations and alignment patterns into consideration using hand layup procedure. The mechanical properties of the composites can be enhanced by a good reinforcement pattern. This work aims to study the effect of reinforcement fibers oriented in unidirectional, bidirectional and mat fiber forms in 10, 15, 20 % weight of Acrylic Fibres into epoxy matrix. Experimental evaluations are carryout to find the sustainability of the proposed models.

MATERIALS AND EXPERIMENTATION

Materials:

Reinforcement:

In this study, acrylic fibers are used as reinforcement. Acrylic fibers having 0.38 mm thickness are taken to prepare three different types of reinforcement patterns such as unidirectional, bidirectional and mat. The fibers were obtained from CF composites, New Delhi. Table 1 shows the characteristics of acrylic fibers.

Table 1

Parameter	Value
Density	1.18 g/cc
Tensile strength	221 MPa
Elastic Modulus	17 GPa
Elongation	28 %

Matrix

Araldite LY1564 epoxy resin produced by Huntsman corporation and Araldite 22962 hardener were used to prepare matrix material. These two compounds were also obtained from CF composites, New Delhi. Table 2 shows the properties of resin and hardener.

Table 2

Parameter	Resin	Hardener
Appearance	yellowish	Mild yellowish
Viscosity (MPa-s at 25°C)	1200.00	5.00-20.00
Density (gm/cc at 25°C)	1.11-1.21	0.81-0.91
Mix ratio	100.00	25.00

Release agent:

Mould releasing agent for epoxies, QZ13 which is also a product of Huntsman corporation was coated on the mold.

Specimen fabrication:

The composite specimens were fabricated by using an open die casting procedure. The dies are fabricated by using 3D printing in order to support the reinforcement pattern. These dies are designed in Solidworks and the fiber supports are modeled on walls of the dies. The reinforcements fibers meshed and pattered in the die as proposed in this study. The epoxy resin and hardener are mixed in the ratio of 4:1 by the percentage of weight and stirred well. The molds having reinforcement patterns are treated with the releasing agent. To these treated molds the stirred epoxy resins are added and are allowed to cure for 24 hours at STP.

After 24 hours the complete mold was cured in an oven at 75°C and 80°C for 1 hour in oven with air circulation. The prepared composite slab has dimensions of 200X20X12 mm3. The reinforcement pattern and the mix ratio are listed in Table 3. The details of the fiber ply pattern are shown in Table 4. Figure 1 shows the reinforcement fibers.

Table 3

ID	Layer I, II reinforcement alignment	Reinforcement %	Matrix %
1	θ_1, θ_3	10	90
2	θ_1, θ_3	15	85
3	θ_1, θ_3	20	80
4	θ_1, θ_2	10	90
5	θ_1, θ_2	15	85
6	θ_1, θ_2	20	80
7	$\theta_1 + \theta_2, \theta_2 + \theta_3$	10	90
8	$\theta_1 + \theta_2, \theta_2 + \theta_3$	15	85
9	$\theta_1 + \theta_2, \theta_2 + \theta_3$	20	80
10	$\theta_1 + \theta_3, \theta_2 + \theta_3$	10	90
11	$\theta_1 + \theta_3, \theta_2 + \theta_3$	15	85
12	$\theta_1 + \theta_3, \theta_2 + \theta_3$	20	80

Table 4

S.No.	Notation	Degrees
1	θ_1	0°

2	θ_2	45°
3	θ_3	90°

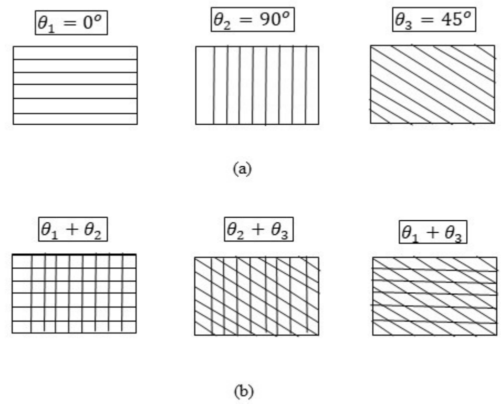

Fig. 1: Reinforcement fibre pattern (a) Unidirectional (b) Mat

The weave architecture of reinforcement plays a major role in composite sustainability. The transport of stress in the composite and the elastic deformation of the composite is affected and governed by the interference quality and architecture of the fiber.

Experimentation:

In order to evaluate the mechanical properties of the specimens propose in this study, many tests were conducted considering the ASTM testing standards. On K I P L - PC2000 UTM, at a speed of 10.0mm/min the tensile tests were performed on the twelve combinational specimens proposed in this study. By using ASTM D-638M-89 standard. Figure 2 shows the UTM testing machine. The stress-strain curves were obtained from the load-displacement curves during experimentation.

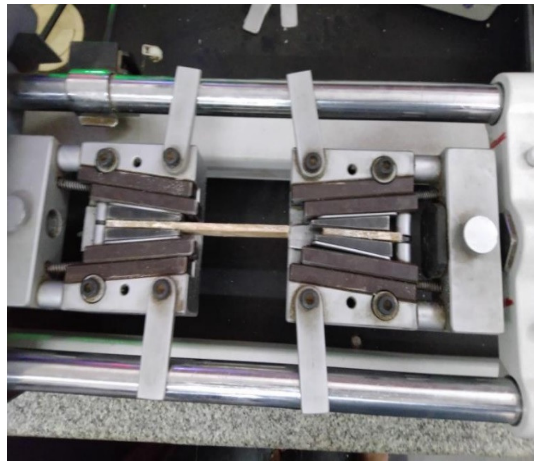

Fig. 2: Tensile testing

The impact tests are performed on the twelve impact test specimens having a V-notch by using the Izod impact testing machine having R3 hammer by using the ASTM D-256-97 standard to evaluate the impact strength (IS). The results are obtained from the indicator attached to it. The impact test is shown in figure 3.

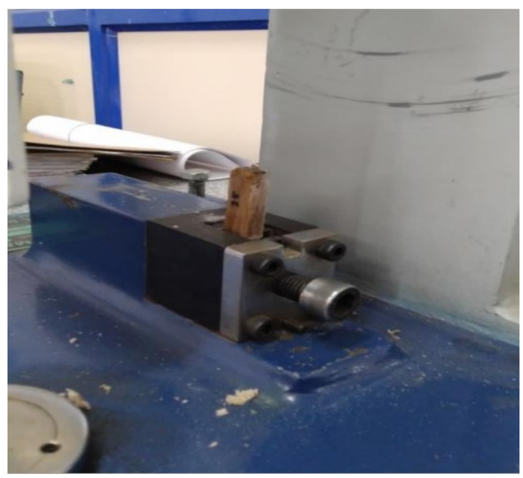

Fig. 3: Impact testing

The inter-laminar shear strength (ILSS) is evaluated for the specimens proposed in this study by using a three-point bending test using crosshead at 2.6mm/min. Figure 4 shows the ILLS test.

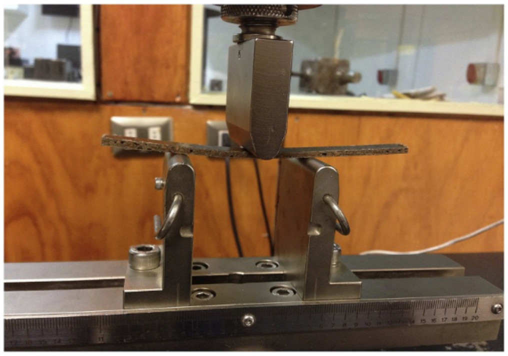

Fig. 4: ILSS testing

Analysis of microstructure:

The microstructure morphology specimen with the best mechanical properties was analyzed using SEM imaging. The fracture specimen surface samples are used to take the micrograph by using JOEL-JSM 648LV-SEM with a voltage acceleration of 20kV.

RESULTS AND DISCUSSION

The specimens proposed in this study are tested for their mechanical properties. The mechanical properties evaluated are tensile, ILSS and IS. The fiber architecture affected the mechanical properties in brief.

Tensile characteristics:

The tensile test results for the twelve specimen samples having various weave architecture of reinforcement are plotted and shown in Figure 5 and Figure 6. In figure 5 the stress-strain curves for the specimen samples are plotted to show the comparison. In figure 6 Young's modulus for specimen samples is compared in bar diagrams respective.

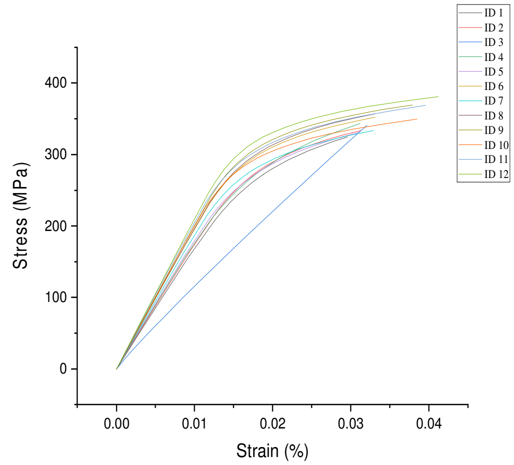

Fig. 5: Stress-strain comparison plot

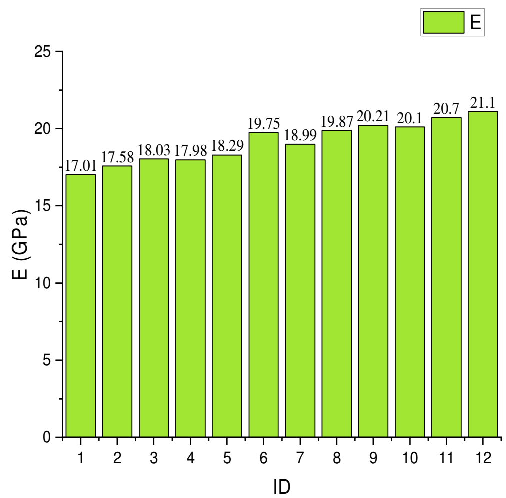

Fig. 6: Young's modulus comparison plot

From the figure 6, 7 it can be seen that the specimen with ID 12 i.e., the specimen with layer I, II reinforcement alignment having θ1+ θ3, θ2+ θ3 showed an excellent increase in its stiffness measurement (E, GPa) and elasticity.

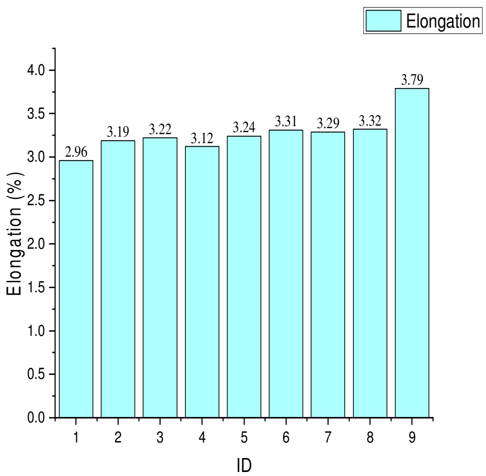

Fig. 7: Elongation (%) comparison plot

Compared to the ID 1 composite specimen, the ID 12 composite specimen showed a 24.04% improvement in strength (E, GPa) and improvement of 28.04% in elasticity.

ILSS properties:

The inter-laminar shear strength (ILSS) is evaluated for the specimens by using a three-point bending test using the crosshead at 2.6mm/min. The results obtained are plotted in a bar chart and are shown in Figure 8. From figure 8 it can be seen that the ILLS for the specimen with ID 12 is 64.88% higher than the specimen with ID 1. The remaining specimens showed lower ILLS because of less adhesive strength of matrix-fiber which may be due to void fraction increment of composites.

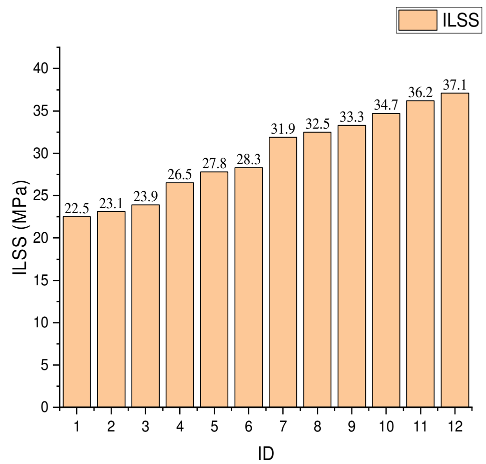

Fig. 8: ILSS (MPa) comparison plot

IS properties:

Figure 9 shows the bar graph for the results obtained from impact testing of composite specimens having proposed weave architecture of reinforcement. The impact strength of the specimen with ID 12 is 54.29% higher than the composite specimen with ID 1. The impact strength increased due to transport of stress in the composite and the elastic deformation of the composite by weave pattern of the reinforcement.

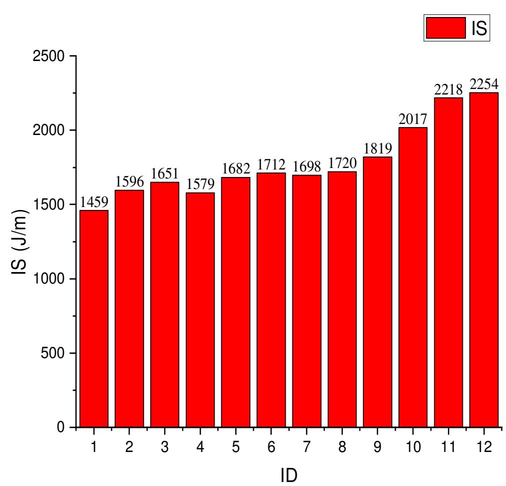

Fig. 9: IS comparison plot

SEM Analysis:

The mechanism of failure for the composite specimens having ID 12 was investigated. The SEM images of tensile fractured specimen surface and impact fractured specimen surface of composite with ID 12 were analyzed and are shown in Figures 10 and 11. From Figures 10 and 11 it can be observed that the reinforcement filaments are covered almost completely with the epoxy matrix. It can be seen that there isn't any interfacial de-bonding, cracking of matrix and delamination, etc.

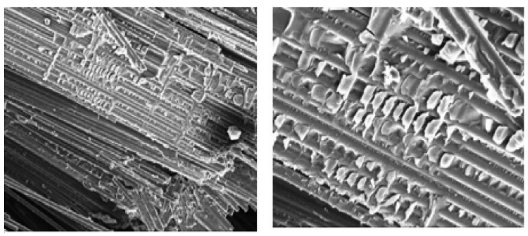

Fig. 10: SEM of the tensile fractured specimen surface

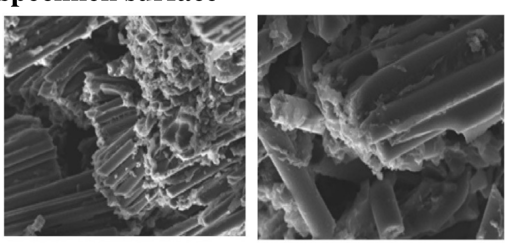

Fig. 11: SEM of impact fractured specimen surface

CONCLUSION

This study aims at studying the effect of weave architecture of reinforcement in composite sustainability since the transport of stress in the composite and the elastic deformation of the composite is affected and governed by the interference quality and architecture of the fiber. The following are the conclusions drawn from this study:

- There is a notable variation in the various mechanical properties of the composites' specimens from ID 1 through ID 12.
- Compared to the ID 1 composite specimen, the ID 12 composite specimen showed a 24.04% improvement in strength (E, GPa) and improvement of 28.04% in elasticity.
- The ILLS for the specimen with ID 12 is 64.88% higher than the specimen with ID 1.
- The impact strength of the specimen with ID 12 is 54.29% higher than the composite specimen with ID 1.
- From the SEM analysis, it is evident that there isn't any interfacial de-bonding, cracking of matrix and delamination, etc. in ID 12.

REFERENCES

[1] X. Liu, R. Wang, Z. Wu, W. Liu, Mater. Lett. 73 (2012) 21–23.

[2] L. Yang, X. Liu, Z. Wu, R. Wang, Compos. Struct. 152 (2016) 617–625.

[3] S.S. Karthick, R. Vetrivel, Vol. 5, Issue 5, May 2016.

[4] P. Feraboli, A. Masini, Compos. B Eng. 35 (2004) 323–330.

[5] Y. Ma, M. Ueda, T. Yokozeki, T. Sugahara, Y. Yang, H. Hamada, Open J. Compos. Mater. 7 (2017) 227–249.

[6] B. Patro, D. Shashidhar, B. Rajeshwer, S.K. Padhi, Open Mech. Eng. J. 11 (2017) 14–24.

[7] Layth Mohammed, M. N. M. Ansari, Grace Pua, Mohammad Jawaid, and M. Saiful Islam, "A Review on Natural Fiber Reinforced Polymer Composite and Its Applications," International Journal of Polymer Science, vol. 2015, Article ID 243947, 15 pages, 2015. https://doi.org/10.1155/2015/243947.

[8] "Review on mechanical properties of natural fiber composites," by C.Elanchezhian, B.Vijaya Ramnath, G.Ramakrishnan, M.Rajendrakumar, V.Naveenkumar, M.K.Saravanakumar Materials Today: Proceedings 5 (2018) 1785–1790

[9] Stuart T, Liu Q, Hughes M, McCall RD, Sharma HSS, Nor- ton A. Structural biocomposites from flax – Part I: Effect of bio-technical fibre modification on composite properties. Composites

Part A: Applied Science and Manufacturing 2006; 37:393–404.

[10] Liu Q, Hughes M. The fracture behavior and toughness of woven flax fibre reinforced epoxy composites. Composites Part A: Applied Science and Manufacturing 2008; 39:1644–52

[11] Santulli C, Caruso AP. Effect of fibre architecture on the falling weight impact properties of hemp/epoxy composite. Journal of Biobased Materials and Bioenergy 2009; 3:291–7.