MECHANICAL PROPERTIES OF FIBRE REINFORCEMENT PLASTICWITH E-GLASS EXPOXY RESIN-AN EXPERIMENTAL INVESTIGATION

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Abstract:

Now a days Glass Fibre Reinforced Plastics (GFRPs) find their application into various industries due to their better and distinctive properties. However, these properties can be improved further by incorporating different filler materials in the glass/epoxy polymer composite. The optimization techniques have a crucial role in developing advanced composites with enhanced properties. Present paper deals with a novel approach in finding mechanical properties of the different orientations of Fibre in Fibre Reinforcement Plastic (FRP) with E-Glass epoxy resin mould by vacuum infusion process and followed by low-temperature treatment. The work was then further divided into three different stages, i.e. preparation of three different orientation angles 0^o, 22.5^o and $45^o$of FRP samples with a thickness of 3 mm. A set of prepared samples was undergone at two different low temperatures cycles, one at 0^oC and another at -80^oC. Then, samples were tested for tensile, flexural, and shear strength to ensure epoxy fibre resin quality. Physical and mechanical tests were conducted as per the ASTM standards D3039, D695, D790. Results indicate that the transparent fibre ply angle 22.5^oFRP with 0^oC treated composites possess good physical and mechanical properties.

Key Words: E-glass, Epoxy Resin, Vacuum Infusion, Mechanical properties.

1.0 INTRODUCTION

Composite material is the combination of two or more materials with different physical and chemical properties to get a new desirable property, which is suitable for the required application A. Divya Sadhana et al [1]. The reinforcing can be in the form of fiber, particles, or sheets. The reinforcing material is embedded by another material, which is called the matrix. The matrix material is mainly a polymer, whereas the fiber material can be metallic, ceramic, or polymer. In a composite material, the fiber is stiffer and stronger than the matrix, which leads to the primary load carrying member S. S. Tomar, S. Zafar et al [2]. The composite material has been used other than the structural application. It has been used for electrical, thermal, tribological, and environmental application C. Elanchezhian et al [3]. Composite material has a new generation of materials that can be used as structural materials in the fast-growing industries of automobiles and aerospace. A composite material is a man-made material in which two or more materials with different properties are combined. A. Kalaiyarasan, P. Ramesh et al [4]. Hybrid composite materials must be composed of two or more different reinforcing materials and matrix materials. Due to the shearing effect of reinforcing fibers, this composite material has higher mechanical properties than simple reinforced fiber composite materials. Hybrid composites offer a wide range of applications, including aerospace interiors, naval, civil building, industrial, sporting goods and interior and exterior automotive applications B. Ravishankar, S. K. Nayak [5]. Hybrid composites are used for environmentally friendly applications like food packaging and furniture solar energy applications and epoxy-based hybrid composites are used in thermal interface materials and adhesives K. Majeed, M. Jawaid [6]. The needs of material development and research on different properties of composite materials have become indispensable. In many fields, such as medical care, automobiles, furniture, packaging, and construction, the use of composite materials is increasing year by year. Hence, a large number of discarded animal bones exist in our environment.

Matrix Material: The primary function of the resin is to transfer stress between the reinforcing fibers, act as a glue to hold the fibers together, and protect the fibers from mechanical and environmental damage. Resins used in reinforced polymer composites are either thermoplastic or thermoset. Epoxy resins have a well-established record in a wide range of composites parts, structures and concrete repair. The structure of the resins can be engineered to yield several different products with varying level of performance. A major benefit of epoxy formulated with different material or blended with other epoxy resins to achieve specific performance features. Epoxy are used primarily for fabricating high performance composites with superior mechanical properties such as resistance to corrosive liquids and environments, superior electrical properties, good performance at elevated temperature, good adhesion to a substance, or a combination of this benefits

2.0 LITERATURE REVIEW

Alcock et al [7] worked on the effect of temperature and strain rate on the impact performance of recyclable all-polypropylene composites. the relationship between the impact resistance of all-PP composite laminates based on these highly oriented co-extruded PP tapes, and the temperature and velocity of impact. Unlike isotropic PP, the highly oriented nature of all-PP composites means that a significant influence of glass transition temperature is not observed and so all-PP composites retain high impact energy absorption even at low temperatures. Ferreira et al [8] developed on Static and fatigue behaviour of glass-fibre-reinforced polypropylene composites. The composite was manufactured with a fibre volume fraction Vf of 0.338. The effect of layer design on the static and fatigue performance was investigated. The S-N curves, the rise in the temperature of the specimens during the tests and the loss of stiffness. The loss of stiffness was related to the rise of temperature and stress release observed in the material Mahmood Shokrieh et al [9] worked on strain rate behaviour of glass and carbon fibre reinforced composites at varying strain rates and temperatures. Material and structural response vary significantly under impact loading conditions as compared to Quasi-static loading. The strain rate sensitivity of both carbon fiber reinforced polymer (CFRP) and glass fiber reinforced polymer (GFRP) are studied by testing single laminate configuration. The dynamic responses of composite materials under dynamic loading at various strain rates, special testing machines are needed. Most of the researches in this field are focused on applying real loading and gripping boundary conditions on the testing specimens. Gilat et al [10] investigated on Experimental study of strain-rate-dependent behaviour of carbon/epoxy composite. The strain rate dependent behaviour of IM7/977-2 carbon/epoxy matrix composite in tension is studied by testing the resin and various laminate configurations at different strain rates. Tensile tests have been conducted with a hydraulic machine at quasi-static strain rates of approximately 10-5 s-1 and intermediate strain rates of about 1 s -1. Hosur et al [11] investigated on High strain rate compression of carbon/epoxy laminate composites. The response of carbon/epoxy laminated composites under high strain rate compression loading is considered using a modified Split Hopkinson Pressure Bar (SHPB). Yuan Qinlu et al [12] worked on Quasi-static and dynamic compressive fracture behaviour of carbon/carbon composites. To understand the dynamic compressive fracture behaviour of carbon/carbon composites, their compressive behaviour was investigated at a strain rate of 500/s using a modified split Hopkinson pressure bar. Marcus schobig et al [13] investigated on Glass fiber reinforced polypropylene and polybutene-1 materials in a high-speed tensile test. The glass fiber content especially the strain rate, influence the material behaviour. In this case, the stress strain behaviour, the tensile strength and the fracture appearance. Hao Yan et al [14] worked on compression-after-Impact failure in woven fiber reinforced composites. Compression failure of composite structures previously damaged by an impact event is due to the propagation of impact induced damage mechanisms such as interlaminar debonding, constituent, micro cracking, sub laminate buckling as well as the interactions between these mechanisms.

3.0 Methodology of VIP Set-up and Equipment

The Vacuum Infusion Process (VIP) is a cost-effective process for making high quality composite parts. Advantages of VIP include higher quality, better consistency, higher glass content (higher specific strength and stiffness), good interior finish, faster cycle time and lower cost The Vacuum Infusion Process (VIP) utilizes vacuum to infuse resin into the laminate. The first step is to load the fabric fibers and core materials into the mold. Also ribs, inserts and any other components can be added, and this is done without resin. Next the dry material is seal closed using a vacuum bag or a counter mold. High vacuum pump (25 in Hg or more) is used to remove all of the air in the cavity and consolidate the fiber and core materials. Still under vacuum, resin is infused into the mold cavity to wet out the fabric fibers and core. The vacuum infusion process is very simple in concept; however, it requires detail planning and process design so the parts can be infused in a reasonable amount of time without any dry spots. The rate of infusion depends on the viscosity of the resin, the distance the resin has to flow, the permeability of the media, and the amount of vacuum. Therefore, the choice of materials, flow media, resin flow layout, and location of vacuum ports are critical in making good parts. The advantage of the vacuum infusion process is to create a laminate with very high fiber content (up to 70%

fibers by weight), thereby creating a very high strength and stiff part at minimum weight. Vacuum Infusion is also an efficient manufacturing process for complex laminate with many plies of fibers and core materials.

Vacuum infusion, the pressure gradient is created by vacuum on the outlet portas shown in Fig.1. The major advantage of using vacuum is the absence of large forces on the mould than Standard RTM techniques which requires strong and stiff tooling. Vacuum infusion is a resin injection technique and is derived from resin transfer moulding (RTM). A resin injection technique generally consists of the following production:

- Dry reinforcement is placed in a mould.
- The mould is closed.
- Resin flows through the mould and impregnates the reinforcement.
- The resin cures.
- The mould is opened and the product is de-moulded.

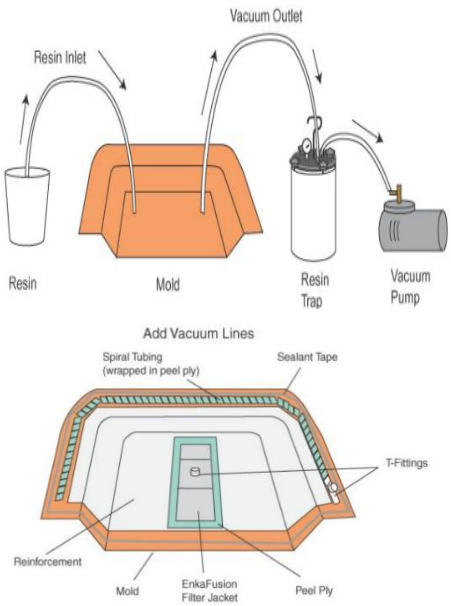


Figure 1: Vacuum Infusion Process Set-up

The Samples (studied component), representative of an aeronautic structural element, is a flat laminate stiffened by four stringers. The size of lay-up of the laminate and stringers are considered as $300x300x1.5mm^3$with fibre angle of orientation is $0^o/22.5^o/45^o$. Both the flat laminate and the stringers were made by resin infusion in intermediate modulus epoxy fibre performs obtained by a unidirectional. The following observations are made on development of Samples during Vacuum Infusion Process:

- Pressure Variation: 100 kPa
- While in Production: 35 kPa
- The resulting Pressure: 78 kPa
- Viscosity of resin: 220 mPa.
- Fiber: Satin-Criss Cross
- GSM: 160 g/m^2

4. Sample Preparation and Testing

The parameters ruling liquid resin infusion quality can be determined either by literature study or laboratory expertise in LRI processes. The layout of liquid resin infusion is shown in Fig. 4.1. The parameters are classified into three groups:

- Texture of reinforcement
- Process configuration
- Process temperatures

Texture of reinforcement the potential parameters are the preform architecture (woven, knitted, the presence of transverse reinforcements: stitched or nailed), the nature of the powder binder on the plies of fabric and finally the stacking sequence itself. The rate or type of thermoplastic powder (used as a binder) usually contributes to the quality of the material and has an effect on the properties of the composite, especially the impact properties.

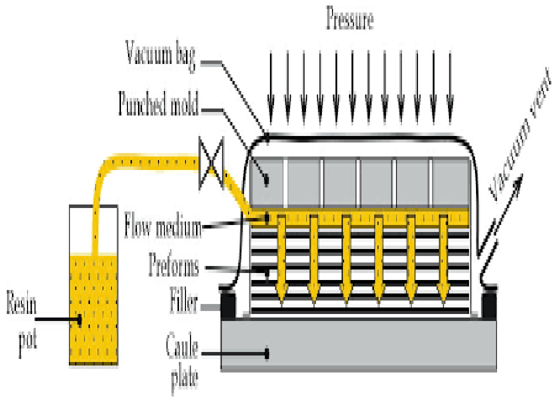


Figure 2: layout for liquid resin infusion

MATERIALS: Epoxy Resin with E-Glass Reinforcement

Material Selection Bi-directional E-glass and Carbon fibers with thickness 3 mm are used as ply direction of 0/90 reinforcements and Epoxy Resin (LY566) and hardener (HY951) are used as matrix material.

Epoxy Resin: YD128: TH 7222N-Aditya Birla group

Used for Self-levelling epoxy flooring, low-cost hardener, high gloss, high hardness, good chemical resistance, with mixed ratio of 100: 60, with mixed viscosity of 2500, gel time 25-35minutes and with TFST 3-5. A mould of 300x 300 mm with thickness of 3mm has been considered, process done at the temperature of input resin at 147^{o}C.

E-Glass Reinforcement: The composites used today in the industry are made of glass fibers. In fiber glass products the resin or 'matrix' transfers the shear and the glass fibers resist the tensile and compressive loads. The present study, E-Glass Reinforcement with YD128: TH 7222NEpoxy resin manufactured by M/s Aditya Birla group and the powder contained in the preform, manufactured by M/s SAERTEX, is intrinsic to the reinforcement. A very effective way to improve the low-velocity impact resistance of a composite (the extent of the dam-aged area and residual strength on compression) is to use reinforcement in the direction orthogonal to the plane of the composite The stitching of the preform has a great potential impact on the quality and mechanical properties of composites, both during the infusion process, through the flow of the resin in the vicinity of the stitching threads and also by displacement and weaving in plane threads.

Figure 3 : Development of Specimen

After completing vacuum infusion of 3 mm thick laminates with three different orientation0^{o}/22.5^{o}/45^{o} of E-glass fibre, two types of Specimens are prepared and undergone0^{0}Cand -80^{0}C low temperatures test for 15 minutes duration. The test Specimens are shown in Fig. 4.3 The thickness of the composite was measured at the point of failure by testing along with the maximum displacement of the composite at break load. The specimen was placed in the grip of the tensile testing machine and the test is performed by applying tension until it undergoes fracture. The corresponding load and displacement obtained are plotted on the graphs.

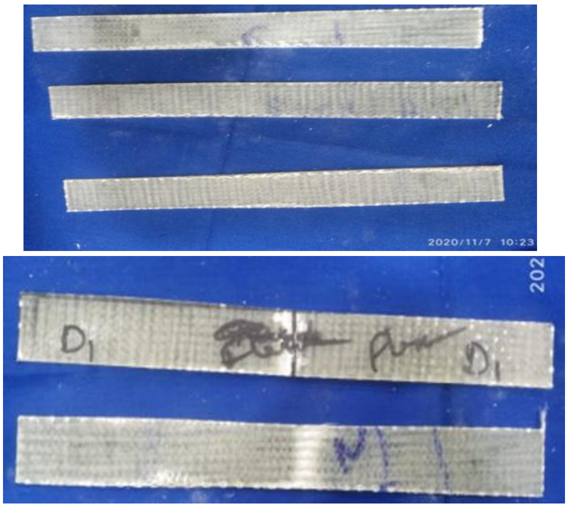


Figure 4: Shows the samples preparation 3mm thickness

Figure 5: **Specimens under flexural strength test**

All type of samples having different angle of fibre orientation $0^o/22.5^o/45^o$ are tested in bending machine to identify the flexural strength the laminates for better comparison- samples prepared at the middle portion of the mould sheet with 3 mm thick.

Figure 6: Specimens under UTS, flexural, Impact, and compression test

Flexural test: the composite materials are now cut by using a saw cutter to get the dimensions as per the ASTM D790 (50.8mmx12.7mm) standards as shown in figure-The 3-point flexure test is the most common flexural test for composite materials. Specimen deflection is usually measured by the cross-head position. Test results include flexural strength and displacement. The testing process involves, the placing of the test specimen in the universal testing machine and applying force on it until it fractures and breaks. The Flexural test were performed on the same universal testing machine, using the 3 point bending fixture according to the ASTM D790 with the cross head speed of 3mm/min

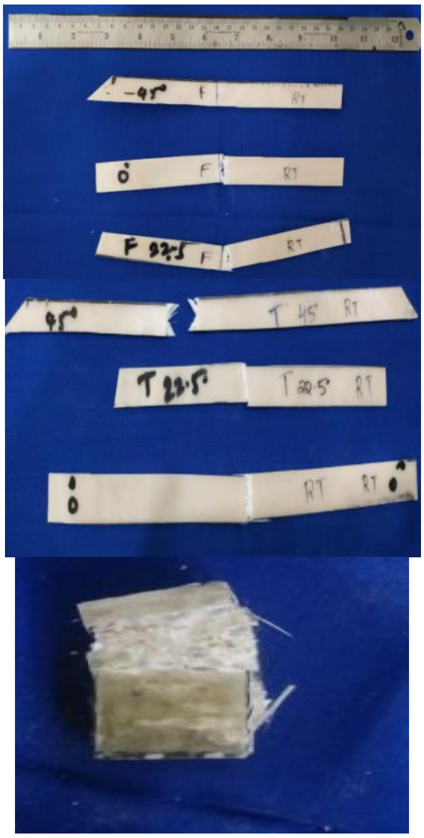


Figure 7: Tested specimens of UTS, flexural, Impact and compression

5.0 Results and discussions

Vacuum infusion process refers to be economic process of fibre laminates; work has been carried out for different Specimens at different parametric comparisons. E-glass fibre angle orientation, temperature are the variant parameters of the 3 mm thick Specimens and it is observed that Specimen which are treated under low temperature condition possess good mechanical properties as compared to room temperature Specimens. It is further observed that time taking for infusion process was more an approximately of 3-5% by increasing the laminate thickness. Mechanical properties investigation found to be good at the range of work done. There is no such impact energy changes found in the samples. The test results show the mechanical properties of lower temperatures treated Specimens are10 - 25% more as compared to Un-treated conditions (Room temperature) Specimens. The following Table shows the comparison of test data of Tensile, Compression, Flexural, Shear Strength and Impact energy for three different fibre orientations of Specimens treated under room temperature and low temperature conditions.

Table 1 - Ultimate tensile Strength (MPa) test results

Ultimate tensile Strength (MPa)					
S. No.	Temperature ^{0} C	Thickness	Angle of Fibre Orientation		
			0^0	22.5^0	45^0
1	Room (24^0C)	3	102.1	79.62	51.44
2	0	3	103.19	77.79	52.67
3	-80	3	101.40	73.10	49.80

Table 2 - Compressive Strength (MPa) test results

Compressive Strength (MPa)					
S. No.	Temperature ^{0} C	Thickness	Angle of Fibre Orientation		
			0^0	22.5^0	45^0
1	Room (24^0C)	3	130.42	140.22	142.34
2	0	3	153.40	149.30	145.90
3	-80	3	147.30	143.40	142.55

Table 3 - Flexural test results

Flexural Strength (MPa)					
S. No.	Temperature ^{0} C	Thickness	Angle of Fibre Orientation		
			0^0	22.5^0	45^0
1	Room (24^0C)	3	60.42	90.44	120.34

2	0	3	59.14	95.23	121.48
3	-80	3	61.30	98.54	129.58

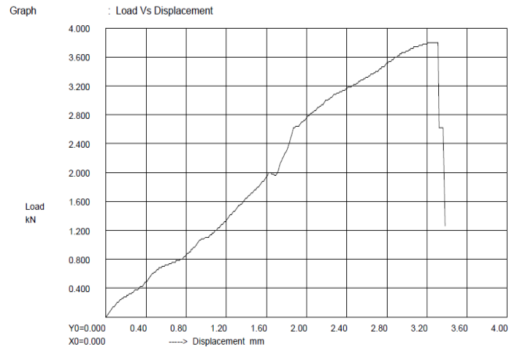
Table 4 - Shear test results

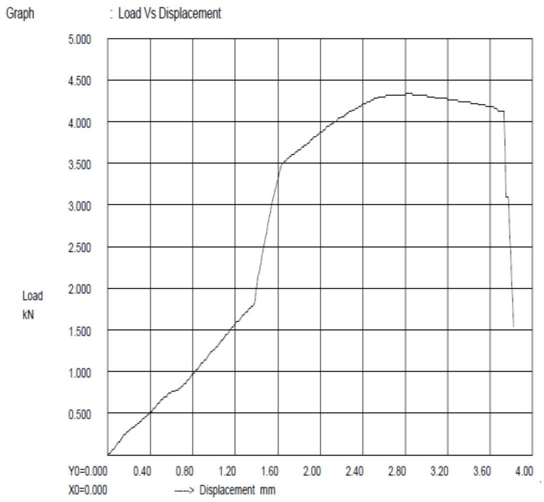
Shear Strength (MPa)					
S. No.	Temperature ^{0} C	Thickness	Angle of Fibre Orientation		
			0^0	22.5^0	45^0
1	Room (24^0C)	3	52.22	65.32	92.45
2	0	3	57.53	70.55	101.23
3	-80	3	60.30	69.55	104.59

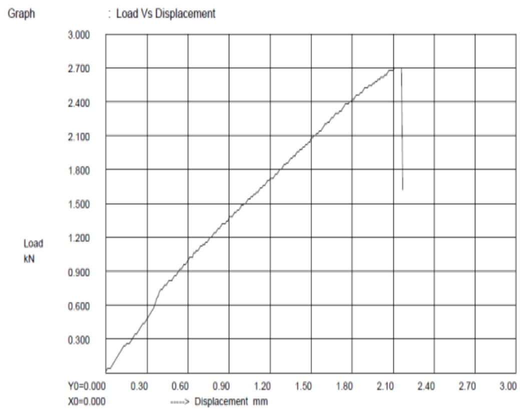
Table 5 - Impact Energy test results

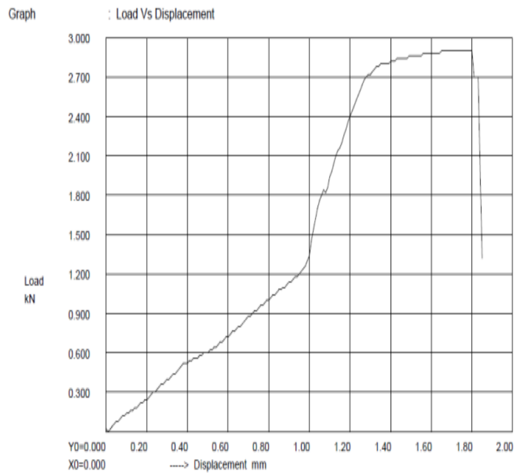
Impact Energy					
S. No.	Temperature ^{0} C	Thickness	Angle of Fibre Orientation		
			0^0	22.5^0	45^0
1	Room (24^0C)	3	6	6	8
2	0	3	6	8	10
3	-80	3	6	6	8

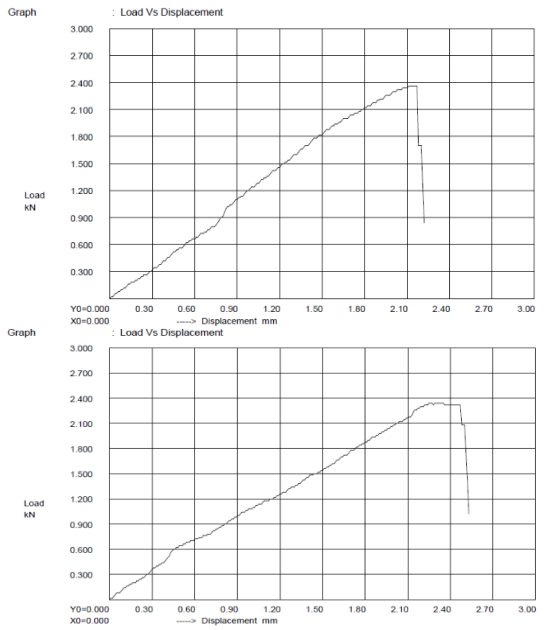
An impact testing machine with Charpy arrangement is employed to perform the test. It is done as per the ASTM D256 standards. The specimen is subjected to an impact blow by the pendulum until it fractures and the corresponding energy absorbed by the material is noted. This test gives the maximum energy that a material can absorb Impact energy normally referred for fracture the samples, the energy used to fracture the samples, even thickness proportionate to the fracture the samples mean to be same in all aspects fracture strength found to be increased.





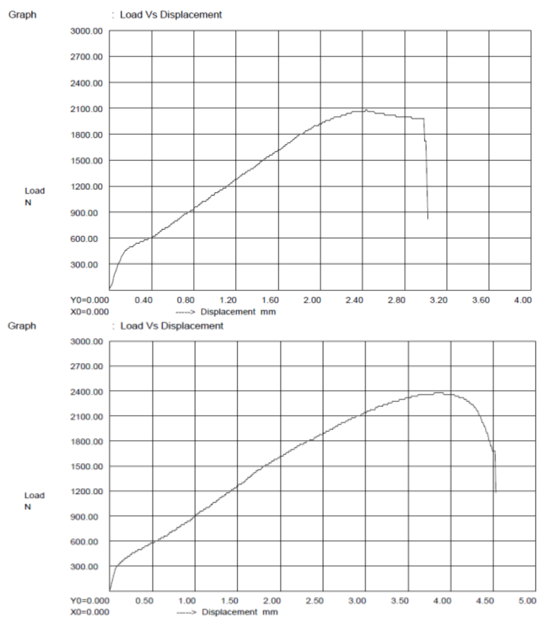


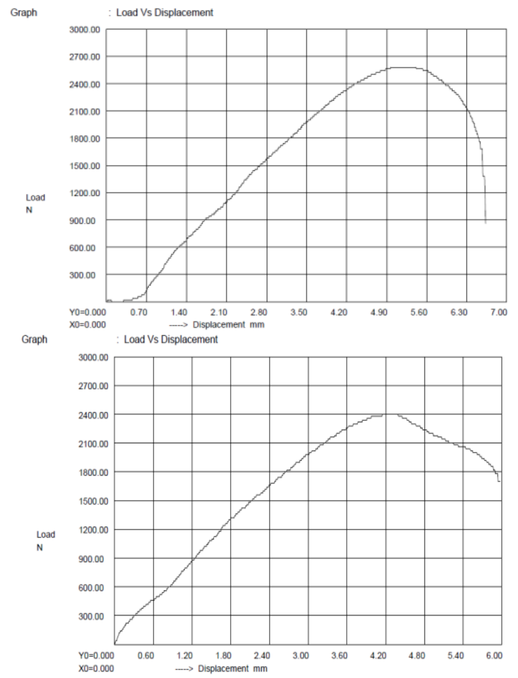


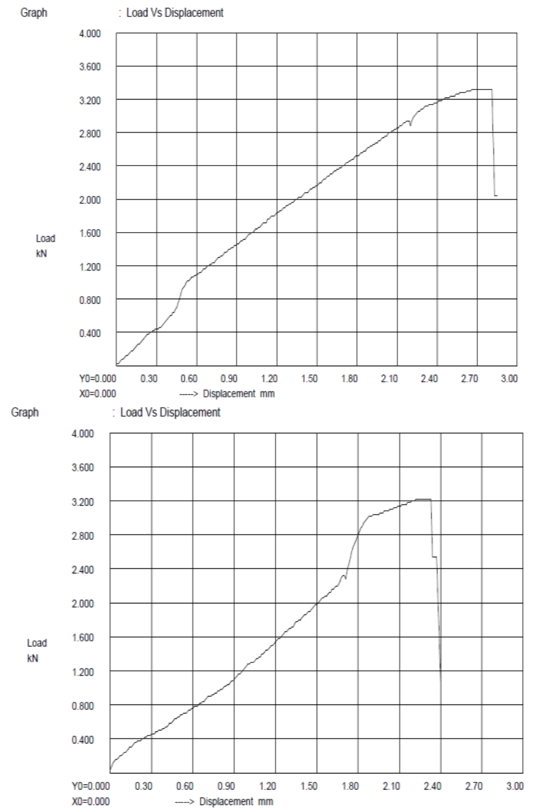


Graph 1 : Above graphs showing the results of 3 mm thickness samples at 0^{o}C

Graph 1&2 shows the comparison of tensile strength and compressive strength at different temperatures. Tensile strength decreases with the increase of angle, samples at -80^{0}C given good results. In compressive strength comparison results increase with the increase in angle at room temperature, decreased at zero and fluctuate in the primary that is up to 22.5 it is increased and then decreased.







Graph 2 : Above graphs showing the results of 3 mm thicknes samples at -80^{o}C

Graph represents the flexural and shear results, flexural strength increased with the increment of angle, better values found at -80 temperature. Shear strength increased at

0^0 temperature; the values decreased at primary angle increment in all the cases but a constant improvement when angle also inclined. It is observed that mechanical properties of E-glass FRP Specimen is increasing under low temperature treatment expect impact energy. The maximum Tensile strength is observed in 0^o Angle of fibre orientation treated at -80°C. The maximum Compressive strength is observed in 22.5° Angle of fibre orientation treated at -80°C. The maximum flexural and shear strength are observed in 45° Angle of fibre orientation treated at -80°C.

Conclusions

The mechanical properties of different angles of E-glass fibre orientation with Epoxy resin is studied under room temperature and low temperature treated Specimens are shows higher mechanical properties than the room temperature treated Specimens. It is observed and identified that the angle of fibre orientation of 22.5° has good mechanical properties and marginal difference between tensile and shear strength. Also, the maximum value of each property is achieved at 0°C treated Specimens as compared to -80°C treated Specimens. Since the angle of fibre orientation of 22.5° FRP possessing good mechanical property, it can be used as structural member of Airborne LRUs and Electronic housing Chassis in all defence applications. The paper is limited to the study of mechanical properties of FRP varying E-glass fibre orientation with low temperature treatment.

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