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Research

FABRICATION AND CHARACTERIZATION OF HYBRID FIBER REINFORCED COMPOSITE LAMINATED PLATES

Dhan Bahadur Chhantyal[1], Dr.Manohar HS[2]

[1]M. Tech Student, Department of Mechanical Engineering, Golden Valley Integrated Campus , Angallu , Madanapalle

[2]Professor, Department of Mechanical Engineering, Golden Valley Integrated Campus , Angallu , Madanapalle

Abstract *Fiber reinforced polymer composite materials are gradually substituting traditional metallicmaterials because of their high specific strength and better corrosion resistance. However, the cost of the composites is still higher than the traditional materials. Different fibres are used inpolymer matrix composites. Glass ,aramideand carbon fibre are one of the promising reinforcements inpolymer matrix composites*

In this thesis ,Glass, carbon and armidfibers are popularly used in polymer composites for their improved properties and lower weight.The influence of stacking arrangement on mechanical properties of hybrid composite containing glass ,carbon and armidfiber.Three hybrid composites of symmetrical pattern were fabricated; i.e. [GCGC]S ,[CACA]and [GAGA]S having a fixed proportion of carbon fiber and glass fiber. Mechanical characterization was done by hardness, impact, tensile and compression tests.

Key words;

1. INTRODUCTION

A composite material is made by combining two or more dissimilar materials. They are combined in such a way that the resulting composite material or composite possesses superior properties which are not obtainable with a single constituent material. So, in technical terms, we can define composite as a multiphase material from a combination of materials, differing in composition or form, which remain bonded together, but retain their identities and properties, without going into any chemical reactions. The components do notf dissolve or completely merge. They maintain an interface between each other and act in correct to provide improved, specific or synergistic characteristics not obtainable by any of the original components acting singly.

Composite laminates

A composite material can roughly be defined as a material with two (or more) distinct macroscopical phases. Often the morphology of the composite is such that one material, the matrix, surrounds the other. The surrounded material can for example have spherical, fibrous or disc shaped form, and when it comes to structural materials, fiber composites are most common. This has its origin in the fact that many materials can be manufactured with a much higher tensilestrength in fibrous than in bulk form. Glass for example has a relatively high stiffness-to-weight ratio but is virtually worthless as a structural

material. The reason is, as everybody knows, that glass is very brittle. One small imperfection within a body of glass can trigger instable crack growth, and for glass in bulk form this is critical, whereas the fracture of one fiber in a bundle is not. The advantages of surrounding the fibers with a matrix material are that the matrix keeps the fibers in place, distributes load among them and protects them from external damage. In the case of structural fiber composites, polymers, such as epoxy, are commonly used as matrix materials.

Laminates

A widely used geometry for continuous fiber composites is the laminate. Laminates are made of plies, in which all fibers often have the same direction. The fibers are usually much stronger and stiffer than the matrix so a ply is stiffer and stronger in the fiber direction - it is anisotropic. A laminate, such as the one shown in Figure 1, usually contains plies with different fiber directions even if the load is primarily in one direction. The reason is that a laminate with fibers in only one direction would be very weak in the direction transverse to the fibers, and small transverse loads due to uneven lateral contraction, for example, could trigger fracture of such a laminate.

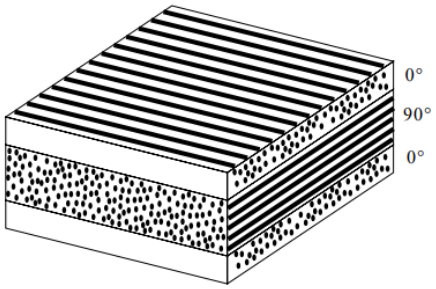


Figure 1: S laminate

Laminate geometry is described by the direction of the fibers in its plies. The laminate in Figure 1 would, for example be labeled [0/902/0]. The direction of the fibers in the outer plies are in this case chosen as the reference direction, the -direction, and the middle ply, which is twice as thick, has its fibers directed to the reference direction. Another way to label the laminate is [0/90]S where 'S' stands for symmetric. The anisotropic nature of the laminate opens a possibility of design and optimization on the material level, so the distinction between material and component or structure becomes less clear than it is for design with metals.

Damage in Composite

Laminates For safe and efficient use of composite laminates in structures it is important to understand inelastic material behavior. In metals, plasticity and creep are examples of such inelastic behavior. In polymer based fiber composites, an important type of inelastic behavior has its origin in the micro damage, that appears as the load on the material increases. In polymer based continuous fiber composites the development of damage often starts with matrix cracking transverse to the principal load direction, see Figure 2. This is followed by fiber fracture and delamination between plies, possibly aided by stress concentration at the tips of the existing matrix cracks. This scenario has been seen in many experiments.

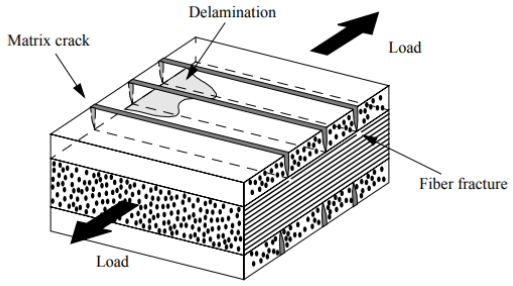


Figure 2: Common damage types in composite laminates

Mathematical models for predicting the behavior of damaged composite materials are of great value, and a lot of work has been done in this area. Ideally the model should have the character of a constitutive relation for the material. That is, component size and geometry, and preferably laminate lay-up (order of ply stacking), should not enter the material model directly. Real constitutive relations, like Hookes' law for linear elastic materials, have the advantage that material properties can be measured on one geometry and transferred to another. For example, the elastic deformation and stress in a pressure vessel of steel can be calculated using constitutive parameters (Young's modulus and Poisson's ratio) obtained from a uniaxial test of the steel.

2. LITERATURE REVIEWS

Jartiz [1] stated that "Composites are multifunctional material systems that provide characteristicsnot obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form".

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Kelly [2] very clearly stresses that the composites should not be regarded simple as acombination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them. The following are some of the reasons why composites are selected for certain applications.

K.V. Arun, S. Basavarajappa, B.S. Sherigara[3] carried out experimental analysis on glass/textile fabric reinforced hybrid composites under normal condition and sea water environments have been reported. The critical stress intensity factor, interlaminar shear strength and impact toughness have been evaluated, both in interlaminar and translaminar directions. The matrix material used was a medium viscosity epoxy resin and fibers are plain weave E-glass fabric and silk based textile fabric.

Yi Zou, Shah Huda, Yiqi Yang [4] studied the tensile strength, flexural strength, impact strength and sound absorption properties of laminas made of Whole and split wheat straws (WS) have been used with polypropylene (PP).

Aramide et al.[5] prepared the woven-mat GFreinforced unsaturated polyester composite using silicone rubber mould. The mould was cleaned and dried. The mould surface was coated with releasing agent of hard wax for easy removal of composites. Initially, unsaturated polyester resin containing curing additives was applied in the mould surface by using brush. The GF was placed on the resin and fully wetted. A steel roller was used to make full wetting of fiber in resin. A final sealing layer of resin was poured on the fiber. Over the period of time, the laminated composite was fully hardened and it was removed from the mould. The hand file was used to time the edges of the cured composites plate for obtaining the final size. The different fiber contents (5% to 30%) were used to prepare the composites plates.

3. METHODOLOGY USED

The above flow chart illustrates the methodology of problem of this project. At the beginning I selected Carbon fiber and LY-556 resin to fabricate fiber reinforced carbon laminate. Hand lay-up is the first method of many manufacturing processes of composites which is simple and takes less time to fabricate. In this projectlaminates were fabricated.

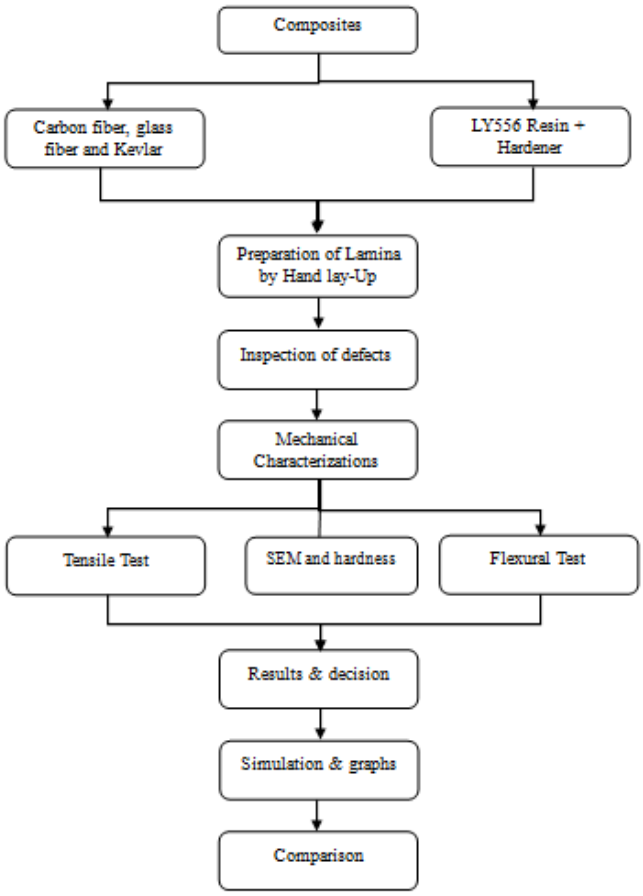


Figure 3: Methodology Chart

Release films and voids were used as defects in the laminate. To confirm that defects were present in the laminate. Ultrasonic inspection was performed on the laminate.

International Journal of Engineering Research and Science & Technology

To know the effect of defects on laminate and to obtain the mechanical properties of the laminates, two types of tests were performed on the laminates namely

1) Tensile Test.

2) Flexural Test

3) Shore D hardness

4) SEM

Further the results were discussed.

4. FABRICATION

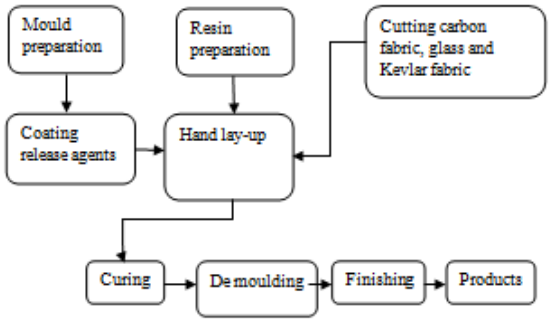


Figure 4: Fabrication chart

Preparation of laminate composite

The E-glass fibers, aramidefiber and carbon fibers with epoxy resin matrix were used to produce hybrid composites via hand layup technique .The weight fraction was determined by considering the density, specific gravity and mass. The fabrication of the composite was done at room temperature. The calculated weight ratio of epoxy resin and hardener are mixed using mechanical stirrer for 10 min.The required size of E-glass, aramideand carbon mats are cut as per the required size and each layer is coated by the resin mixture till the required thickness of laminates obtained.

The mould size taken –length (mm)-100 mm, Width (mm)-200 mm

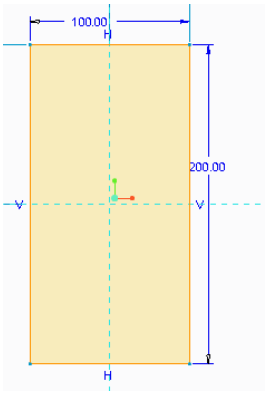


Figure 5: preparation of laminate composites

In this project, I conducting the three laminates

S. No	Layer 1	Layer 2	Layer 3	Layer 4
1	E-Glass fiber	Carbon fiber	E-Glass fiber	Carbon fiber
2	E-Glass fiber	Aramidefiber	E-Glass fiber	Aramidefiber
`3	Carbon fiber	Aramidefiber	Carbon fiber	Aramidefiber

Weight calculations

E-glass and carbon fiber fabric properties

Fabric Properties

Properties	UOM	Specification	Data	Test Method
Warp (0° Direction)	Type	HS 12K	HS 12K	-
Weft (90° Direction)	Type	HS 12K	HS 12K	-
Ends	Nos./cm	2.5	2.5	-
Picks	Nos./cm	2.5	2.5	-
Weave Style	-	Twill	Twill	-
Thickness	mm	0.43 ± 0.03	0.45	ASTM – D 1777
Width	mm	1000 ± 10	1005	ASTM – D 3776
Fabric Aerial Weight	g/m²	420 ± 3%	419	ASTM – D 3801

Aramide fiber fabric properties

Fabric Properties

Properties	UOM	Specification	Data	Test Method
Warp (0° Direction)	Type	3000D	3000D	-
Weft (90° Direction)	Type	3000D	3000D	-
Ends	Nos./cm	6.7	6.7	-
Picks	Nos./cm	6.7	6.7	-
Weave Style	-	Plain	Plain	-
Thickness	mm	0.56 ± 0.03	0.57	ASTM – D 1777
Width	mm	1000 ± 10	1005	ASTM – D 3776
Fabric Aerial Weight	g/m²	485 ± 3%	487	ASTM – D 3801

For each layer (E-Glass and carbon fiber) -

100mm*200mm*420g/m^2

-0.1m*0.2m*420 g/m^2

= 8.4 g

For each layer (aramidefiber) -

100mm*200mm*485g/m^2-0.1m*0.2m*485 g/m^2

=9.7g

International Journal of Engineering Research and Science & Technology

Laminate 1(G, C, G, C)

Layer 1: E-glass fiber -8.4 g

Epoxy resin -8.4 g

Hardener -0.84g

Layer 2: carbon fiber -8.4 g

Epoxy resin -8.4 g

Hardener -0.84g

Layer 3: E-glass fiber -8.4 g

Epoxy resin -8.4 g

Hardener -0.84g

Layer 4: carbon fiber -8.4 g

Epoxy resin -8.4 g

Hardener -0.84g

Total fabric weight -33.6g

Laminate2 (G, A, G, A)

Layer 1: E-glass fiber -8.4 g

Epoxy resin -8.4 g

Hardener -0.84g

Layer 2: Aramidefiber -9.7 g

Epoxy resin -9.7 g

Hardener -0.84g

Layer 3: E-glass fiber -8.4 g

Epoxy resin -8.4 g

Hardener -0.84g

Layer 4: Aramidefiber -9.7 g

Epoxy resin -9.7 g

Hardener -0.84g

Total fabric weight -36.2g

Laminate3 (C, A, C, A)

Layer 1: carbonfiber -8.4 g

Epoxy resin -8.4 g

Hardener -0.84g

Layer 2: Aramidefiber -9.7 g

Epoxy resin -9.7 g

Hardener -0.84g

Layer 3: carbonfiber -8.4 g

Epoxy resin -8.4 g

Hardener -0.84g

Layer 4: Aramidefiber -9.7 g

Epoxy resin -9.7 g

Hardener -0.84g

Total fabric weight -36.2g

5. FABRICATION PROCEDURE

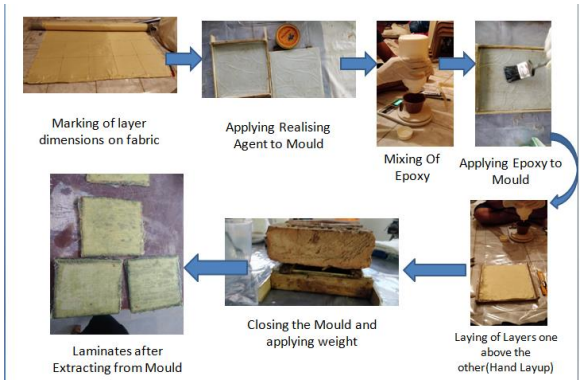


Figure 6: Fabrication procedure



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Figure 7: Cleaning the mould and applying univax



Figure 8: Applying plythene sheet to mould

The fabrication of the polymer matrix composite was done at room temperature. The required ingredients are LY-556 Resin and HY-951 Hardener were mixed thoroughly in beaker and the mixture so made was transferred to carbon fabric the carbon composite is fabricated using simple hand layup technique to the mould and the mould is tightened with the help of nuts & bolts.



Figure 9: LY-556 ResinFig 27: HY-951 HardenerFig 28: Univax

6. MATERIAL PROPERTITES OF RESIN

Property	Specification	Unit	Araldite® LY 556
Viscosity at 25° C	ISO 12058	mPa.s	10,000 – 12,000
Density at 25° C	ISO 1675	gm/cc	1.15 – 1.20
Flash point	ISO 2719	° C	> 200



Figure 10: Mill fiber carbon fabric



Figure 11: Mixing of Resin and Hardener



Figure 12: Applying mixture of Epoxy Resin and hardener



Figure 130: Layers are placed one after the other



Figure 14: Closing the Mould and applying weight

The layup assembly is pressed with the help of roller so that excess air between the layers is expelled out. The laminate is cured at ambient conditions for a period of about 8hrs. The laminate is prepared for different additive concentration of silica powder. Generally it takes 8-12 hours to cure and is completely done at atmospheric temperature. After that removing the nuts and bolts and peel off the polythene sheet from the specimen and mould.



Figure 15: Laminates after Extracting from Mould

Composite laminate of tensile specimen of dimensions 165 mm length, 19 mm width and 4 mm thickness and flexural specimen of dimensions 127 mm length, 12.7 mm width and 4 mm thickness are fabricated using hand layup method. Eight layers of bi- directional carbon fiber mat along with epoxy are employed forth purpose of fabrication of the laminates. The 12 tensile specimens of size 165×19×4 mm were cut from the laminate in accordance with ASTM D 638 standard. The 12 flexural specimens of size 127×12.7×4 mm were cut from the laminate in accordance with ASTM D 790 standard.



Figure 16: Specimens after preparation



Figure 17: Flexural Specimens

Tensile &Flexural tests were carried out using Universal Testing Machine respectively for samples of bidirectional oriented carbon fiber reinforced epoxy resin based polymer composite laminate beams of C-Section for different silica concentrations. Each test have 12 specimens for Tensile and flexural respectively and results were discussed.



Figure 18: Universal Testing Machine (UTM)



Figure 19: Tensile test



Figure 20: Flexural test



Figure 21: Tested specimens

Hardness:

Shore hardness is a measure of the resistance in a material to identify. The shore hardness scales foe measuring the hardness of the different materials (soft, rubber, fibers, rigid plates, and super soft gels, are the examples).

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Figure 22: Shore hardness testing machine

DESIGN

Designs the tensile and flexural specimen in software CREO are per the dimensions give by the standards

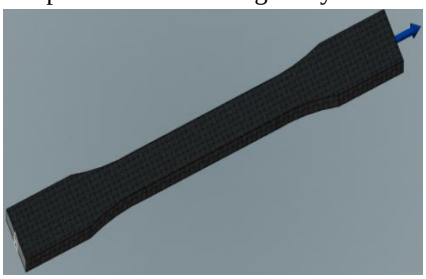


Figure 23: Design of tensile specimens

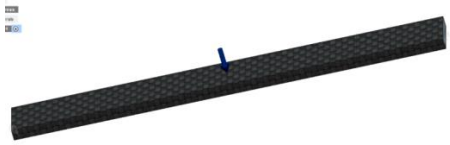


Figure 20: Design of flexural specimens

7. RESULTS AND ANALYSIS

Tensile test results

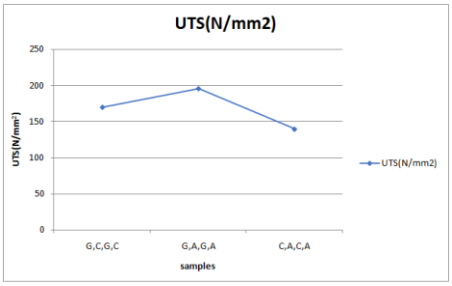


Figure 24: Tensile strength Vs different fabric materials

Above graph show the change in Tensile strength versus different fabric laminates.The Tensile strength was found to be maximum at [C,A,C,A] with 2.04 %.

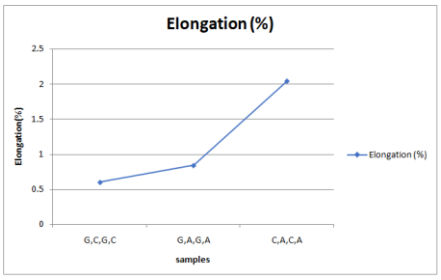


Figure 25: Elongation Vs different fabric martial

Flexural test results:

The three types of laminates with varying the fabric [G,C,G,C],[G,A,G,A] and [C,A,C,A], are tested by applying Flextural loads.The tables summarises the values of various tensile properties .The results show that there is significant change in flextural propertites with the change in fabric materials.

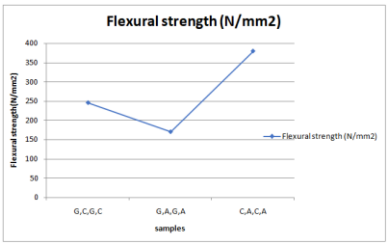


Figure 26: Flexural strength Vs different fabric materials

Shore D Hardness

Shore D Hardness is a standardized test consisting in measuring the depth of penetration of a specific indenter. Test methods used to measure Shore D Hardness are ASTM D2240 and ISO 868.

The hardness value is determined by the penetration of the Durometer indenter foot into the sample. Shore Hardness measures are dimensionless. It goes between 0 and 100. The higher number represents the harder material.

The resulting depth is dependent on

- Hardness of the material
- Its viscoelasticity
- Shape of the indenter

- Duration of the test.

One can clearly see the conceptual parallels between the Rockwell method and the Shore method. Today, off the shelf equipment, at least some of which is automated, can be purchased for immediate use and testing according to standardized ASTM/ISO procedures.

Table 3 shows the tabulated values of [G,C,G,C],[G,A,G,A] and [C,A,C,A] Shore D hardness values respectively.

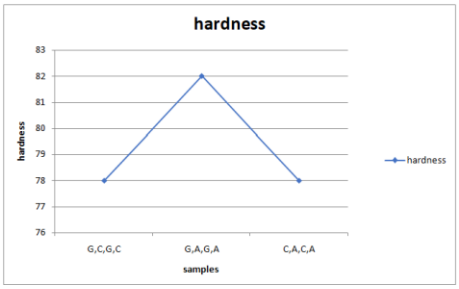


Figure 27: Hardness test results

SEM ANALYSIS

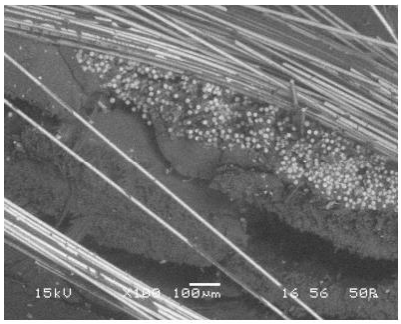


Figure 28: SEM image of [C,A,C,A]

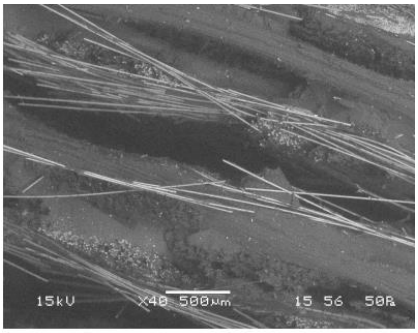


Figure 29: SEM image of [G,A,G,A]

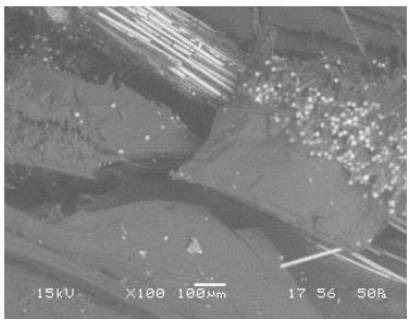


Figure 30: SEM image of [G,C,G,C]

The common feature of all the SEM micrographs shown above is fiber breakage.

The modes of failure are mainly matrix cracking fibre breakage and fibre pullout. The fibre breakage occurs when the fibres are unable to sustain the load applied. But matrix cracking occurs mainly due to the matrix hardening when subjected to cryogenic environments. But fibre pull out is a case which occurs due to improper bonding between the fibre and the matrix due to which there is ineffective load transfer to the fibres from the matrix and hence due to stress accumulation at the interface the fibres are pulled out of the matrix.

Extensive delamination along with fibre fracture which might have occurred due to high moisture intake or higher exposure to hygrothermal exposures. Delamination may also occur due to the presence of voids at the interface (due to fabrication error), when stress is applied, a triaxial state of stress is developed ahead of the void and hence crack propagates along the interface of fibre and matrix causing failure of the composite.

A case where the specimen is subjected to cryogenic environment, it can be seen that there is a high degree of adhesion at the fibre matrix interface which is mainly due to the free thaw effects or mechanical keying.

8. CONCLUSIONS

Based on the experimental results on Tensile ,hardness and Flexural properties of carbon /armide/ glass epoxy composite laminate with different fabric

materials ,the following conclusions are drawn. The tensile and flexural strength at breaking was found to be maximum at [G,A,G,A]Fabric materials.There is no significant changes in elognation percentage with the influence of additive. By observing the hardness results, the maximum haardness was found at [G,A,G,A]Fabric materials when we compared to other laminates .

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