

Structural Integrity of Glass and Basalt in Thermoplastic Laminates

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ABSTRACT: The glass is well known reinforced material for composite. Today the basalt fiber reinforcement, a renewable and natural resource based composite can be produced with good mechanical properties suitable for various engineering applications. Basalt fiber is a possible polymer reinforcing material and can be applied in polymer matrix composites instead of glass fibers in thermoset as well as in thermoplastic matrix composites. The present work is focused on hybridization of different Glass preforms structure with Polypropylene and basalt to study the structural integrity in Laminates.. The objective of this work is to investigate the applicability of different glass structure and basalt fiber combined in Laminates. The laminates have been prepared with different layers, which consist of either same material, different material or different structures. The preforms are consolidated to form thermoplastic laminates using polypropylene non-woven needle punched fabric as a matrix under hydraulic press. The mechanical properties of laminates like strength, flexural rigidity, shear strength and puncture resistance evaluated as per ASTM standards. This study gives the idea about the selection parameters of preforms to improve the quality and performance of laminates.

KEYWORDS: Thermoplastic, Basalt Fiber, Hybrid Structure, Hybridization, Laminates

I. INTRODUCTION

Thermoplastic composites are relatively more flexible compared to thermoset matrix. Due to this impact resistance is improved resulting in increased damage tolerance. Thermoplastic matrix currently that allows the new intermediate modulus, high-strength, high-strain carbon fibers to be used in addition to their fullest potential in composite. Thermoplastics has become the important part of the automotive industry the reason behind this is at the end of the product life the thermoplastic composite can be converted to the pellet size process able material, whereas major thermoset can only be ground and used as a filler material. Also the processing methods are having lower impact on environment than thermosets. [1, 3, 4]

Besides this there are few problems related to thermoplastic composites that are due to the higher viscosity the impregnation of the resin in the reinforcement is difficult. Another problem with it is natural form of occurrence that is in the solid state so for impregnation it has to be heated to its melting temperature and has to be applied with the pressure. So the resin will impregnate for this the whole assembly has to be kept for longer time for curing. So this process is tedious, time consuming and complex. The new research is mainly focused on making process simpler and to get homogenous mixing of the thermoplastic matrix with reinforced fiber. Hybridization concept is not new where basically two different materials are combined to get better performance of final product. This concept can be adopted in both type of composite but the work mainly focused here is related to thermoplastic composite. To understand the hybridization concept, it need to understand the different method and the stages where hybrid material can be incorporated. [2,3,5]

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II. CONCEPT OF HYBRIDIZATION

Hybridization is the process of combining different varieties of materials to create a hybrid material. Hybridization is proved to be a promising strategy for the toughening of composite materials. Appropriate combination of two or more fiber types these hybrid composites can offer a better balance in mechanical properties than non-hybrid composites. But their mechanical properties prediction is a challenge due to uneven distribution created between different fibers. The term “Hybrid-composite” is generally used to describe a matrix containing two or more than two types of reinforcements. [5, 7]

To take full advantage of individual fibers and realize an innovative structure with integrated and synthesized structural performances, one feasible way is to hybridize different types of fibers having different mechanical properties, stiffness, modulus, temperature resistance, etc. the damage. Damage tolerance and impact resistance have become key parameters for composite materials in structural applications. The hybridization concept is used for thermoset and thermoplastic but the hybrid materials used in thermoplastic composites are offering two functions.

- (1) The hybrid material used with the combination of high performance and thermoplastic material where thermoplastic material will melt during consolidation.
- (2) The high performance remains intact during consolidation due to the high temperature resistance improves impregnation and structural integrity. The stages of hybridization and the three main hybrid configurations are as shown in figure 1. [5-10]

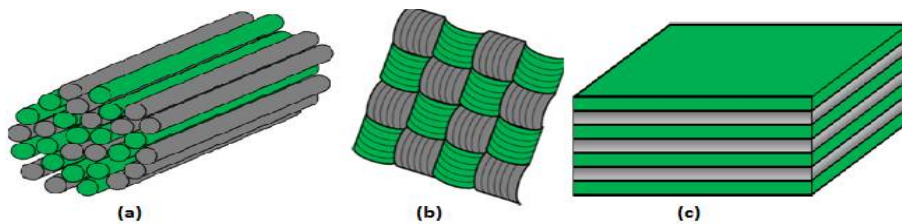


Figure 1: Stages of hybridization (a) At yarn stage (b) At fabric stage (c) At laminate stage

(a) HYBRIDIZATION AT YARN STAGE

The hybrid yarn is basically manufactured by two different types of material, where the one fiber gives performance properties and another gives cover. In thermoplastic composite the concept of hybrid yarn use by combining high performance yarns like glass, carbon, basalt, etc. with Polypropylene, polyester, nylon like thermoplastic material where the thermoplastic material will consolidate during the process as shown in figure 1(a).

(b) HYBRIDIZATION AT PREFORM STAGE

The textile fibers/yarns are integrated in single entity by interlacing in fabric as shown in figure 1(b). There are different fabric structures specially developed known as a preform used in composite process as a backbone structure this preforms having a different structures like woven, biaxial, multiaxial, 3D preform, etc. this structures are mainly constructed using single material in thermoset composite but for thermoplastic composite this fabric is constructed using hybrid yarn or combination of hybrid and thermoplastic yarn in new methods. Conventionally used process to manufacture the thermoplastic the preform used are same as what's used in thermoset. The hybrid preforms are specially designed structure based on the final requirement of the product.

(c) HYBRIDIZATION AT LAMINATE STAGE

In figure 1(c) interlayer configuration is shown, layers of two fibre types are stacked onto each other, this is the simplest and cheapest method for producing a hybrid thermoplastic composite. But main problem of this method is flow transfer from one layer to another gives variation in consolidated behavior with different materials. Another problem with this method is adhesion between layers (inter laminar strength). This process having wider scope if the percentage distribution of the thermoplastic material over reinforced material can be controlled; hence in this project attempt has

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been made to study the behaviour of the preforms in thermoplastic laminates and study the structural integrity of Glass/Basalt combination.

The main objective of this project is to study the effect of preform combination on thermoplastic laminates for this laminates were fabricated using different reinforced material combinations. The properties of laminates like thickness, GSM, strength, shear strength, flexural rigidity and puncture resistance has been studied with different reinforced material. Also the behaviour of reinforced material combination with PP Nonwoven needle punched fabric in thermoplastic laminates has been studied. SEM and DSC analysis has been done to study the performance of laminates. The study is mainly highlighting the consolidated method for thermoplastic laminates. The limitation of this study is the sample availability, machine limitation, sample size and preform manufacturing. It is difficult to get tailor made preforms as industries are making the preforms as per there requirements in mass scale. The process need to be standardized when the material parameters are changing. So the standard process is taken to produce laminates.

III. MATERIAL AND METHODOLOGY

The materials used to manufacture thermoplastic laminates were selected based on different preform structures and materials. The preform having glass and basalt with plain weave have been selected initially and then further for further investigation glass biaxial and multiaxial structures to make thermoplastic laminates in all above manufacturing of the laminate polypropylene fiber mat (non-woven fabric) has been taken as matrix material. The Table 1 gives the specification of reinforced material used in laminate. This consolidates during heat pressing. The preform material has been procured under GUJCOST MRP project.

Table1. Specifications of Preforms

Code	Specification	GSM	Thickness (mm)
SG _p	Glass plain woven fabric	300	0.38
SC _p	Carbon plain woven fabric	300	0.29
SB _p	Basalt plain woven fabric	300	0.27



Figure 2: Hydraulic Press

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The laminates comprising of different combinations of preforms were produced on the hydraulic press machine as shown in figure 2. The samples of polypropylene non-woven and the reinforced glass and basalt have been stacked as per sequence given in Table 2. Allow the plates to reach the 190 °c temperature and keep it for the decided time, in this the viscous matrix material binds with the reinforcement under 15kg/cm² pressure. The whole assembly has been kept for curing.

Table 2: Specifications and Coding of Fabrics

Code	Specification	GSM	Thickness (mm)
Laminates with different combination of materials			
L _{G2}	3layers of SG _p + 2layers of PP	1630	1.34
L _{B2}	3layers of SB _p + 2layers of PP	1450	1.25
L _{C2}	3layers of SC _p + 2layers of PP	1110	1.20
Laminates with combinations of Glass/Basalt preforms			
L _{GBG}	SG _{p2,90/0} + SB _p + SG _{p2,90/0}	1523	1.05
L _{GBGBG}	SG _{p2,90/0} + SB _p +SG _{p2,90/0} + SB _p + SG _{p2,90/0}	2204	1.65
L _{GBGBGBG}	SG _{p2,90/0} + SB _p +SG _{p2,90/0} + SB _p + SG _{p2,90/0} + SB _p +SG _{p2,90/0}	2928	1.89

IV. EXPERIMENTAL RESULTS

The laminate has been prepared using different combination of Glass and basalt reinforcement and PP as a matrix material. The number of layers of reinforcement ranging from two to seven and glass with different structure like plain biaxial and multiaxial has been has been tried. The comparative analysis and effect of different Glass/Basalt combinations are discussed below.

A. PROPERTIES OF LAMINATES WITH DIFFERENT MATERIALS

The laminate properties are greatly influenced by the preform properties like thread density, GSM, strength, thickness and structure of preform. The Figure 3 shows that out of all plain structure carbon is having the highest strength with respect to GSM because carbon is having inherent properties of high strength to weight ratio. The same reason rolls out for basalt also.

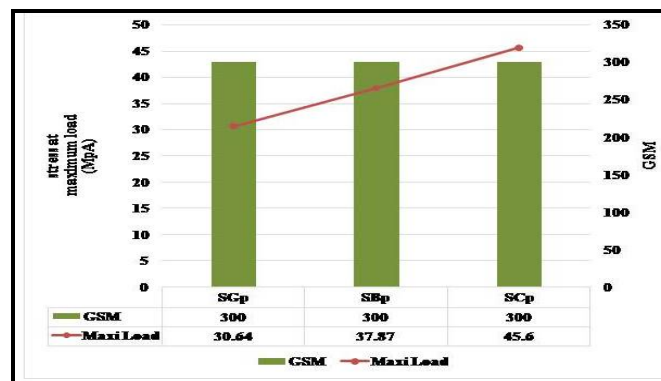


Figure 3: Properties of Preform From Different Materials

The laminates were prepared using three layers of reinforcement of glass, basalt and carbon and two layers of polypropylene matrix material (non-woven). It is very obvious that due to high content of reinforcement material and

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low pp % gives higher strength and puncture resistance. It also improves shear resistance but significantly deteriorates the flexural characteristics of the material the value shows in figure 4 is significantly low compared to three layer laminates.

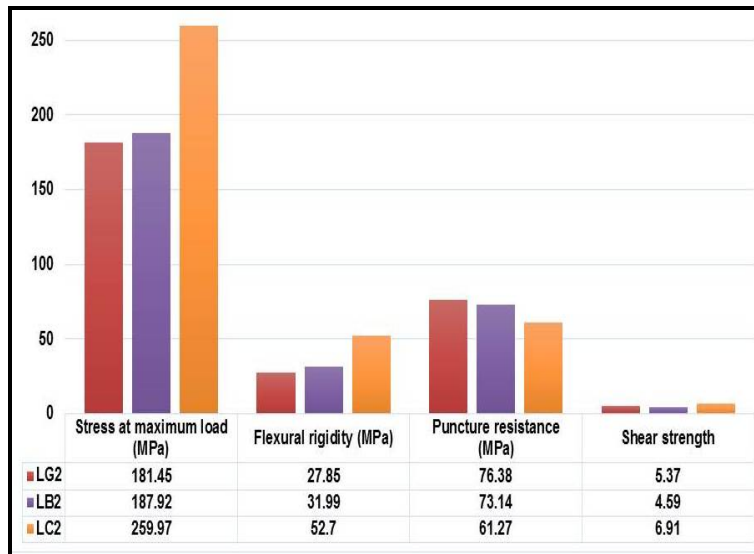


Figure 4: Properties of laminates from different materials

The figure 4 shows the comparative value of strength, flexural rigidity, puncture resistance and shear. It has been clearly observed that the carbon laminates gives maximum strength due to its inherent property. The flexural rigidity is defined as the resistance offered by a structure while undergoing bending. Higher the value less is the bending. The flexural rigidity of laminates mainly depends on the consolidation of the sample, adhesion between reinforced and matrix material and bending property of preforms (number of layers). The three laminate samples (glass, basalt and carbon) having around 30% resin content due to it shows nearer value of flexural rigidity. The basalt laminate shows lower value compared to glass and carbon that may be due to poor adhesion between basalt and polypropylene or inherent properties of basalt.

Similarly, puncture resistance is a measure of maximum force or energy required to penetrate the material. This is one of the major mechanical properties required as the composite exposed to different types of environment and impact forces. The puncture resistance of the laminates mainly depends on preform structure (unidirectional, bidirectional, multidirectional, etc) and stiffness of the laminates and percentage matrix material which helps in transferring the load. The puncture resistance of the carbon laminates shows the lower value in spite of having higher laminate strength that may be due to less compact preform structure and uneven distribution of matrix material between and within the layer.

The shear strength is the strength of the material or component which fails when the shear force applied parallel to the direction of the force. It is also a measure of inter laminar strength. This property purely influences by adhesion between two layer and the resin property. If the two layers of the fabric binds together at initial stage shows higher shear strength compared to stacking the layers one above the another. The carbon and Glass laminates shows higher shear strength compared to glass.

B. PROPERTIES OF GLASS/BASALT LAMINATES

The laminates have been prepared using different combinations of glass and basalt reinforcement and pp as the matrix material. The laminates prepared from glass and basalt the basalt shows higher strength than glass. The glass/basalt combination prepared with 3, 5 and 7 layers.

The 100% basalt shows highest strength compare to Glass and its combination. The flexural rigidity of laminates improves with Glass/Basalt combination compare to 100% glass and basalt laminates. The flexural rigidity of the L_GB_G laminate is superior amongst all the combination of different preforms. It has been observed that as the numbers of layers are increased in the combination the flexural rigidity gets decreased due to the subsequent increase in percentage of polypropylene, as polypropylene has elevated flexible property. The same effect has been observed amongst L_{G1}, L_{G2}, L_{B1} and L_{B2} laminates, L_{G1} and L_{B1} shows elevated flexural rigidity as it has less number of layers as compared to L_{G2} and L_{B2}.

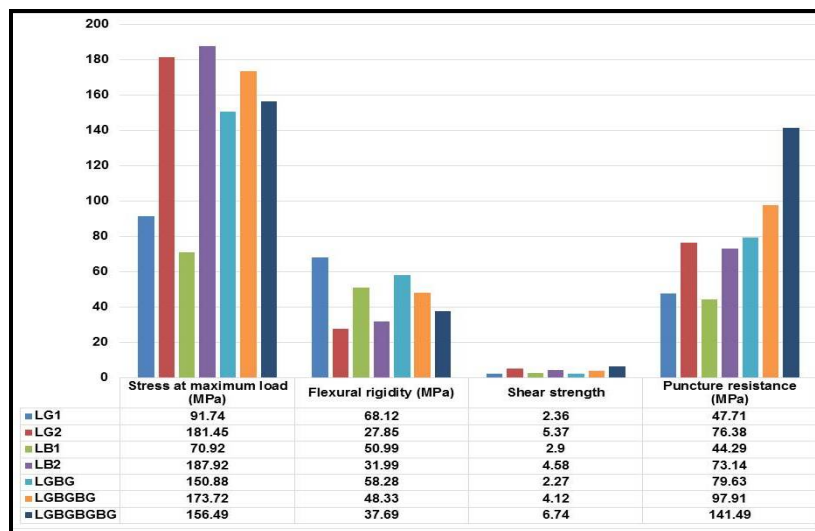


Figure 5: Properties of laminates with different combinations.

The shear strength is visibly high as the numbers of layers are increasing. Due to the contribution of seven layers the resultant value of shear increases due to resistance offered by the other layers which are under action and still the bond has not been break. The material breaks only once all layers fails. The puncture resistance is directly proportional to the number of layers in laminates. Hence, as the number of layers increases puncture resistance increases which is clearly indicated in figure 5.

V. CONCLUSION

During studies some of the behavior of glass preforms and laminate has been observed. The preform structure have a significant effect on final properties of the laminates. The strength of the preforms is greatly influenced by linear density, thread density, gsm value, stitch density and thickness of preforms. The Laminates are with higher thread density gives higher strength as more number of threads contributes in structure. Carbon and basalt laminates are having higher strength in comparison to glass of same gsm it is because of their inherent properties. The flexural rigidity of laminates mainly depends on the consolidation of the sample, adhesion between reinforced and matrix material and bending property of preforms (number of layers). As the numbers of layers are increased in the combination the flexural rigidity gets decreased due to the subsequent increase in percentage of polypropylene, as polypropylene has elevated flexible property.

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