

Structural Integrity of Glass Preforms in Thermoset Laminates

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ABSTRACT: The textile fabrics are generally having crimp structures, which deteriorate the mechanical properties of the textile composite. Hence conventional techniques are modified to develop non-crimp fabric for textile composites. New techniques are developed to produce non-crimp and multi-axial structures. In these project glass fabrics with different structures like woven, bi-axial, multi-axial has been used as textile reinforced materials. The properties like GSM, linear density, tensile strength, flexural rigidity etc. of glass material are measured by using suitable standards. The fabrication of glass preform structure has been done by using hand lay-up process and the mechanical properties like tensile strength, flexural and compression measured by standard recommended method as per American Standards for Textile Materials (ASTM). It has been observed that the properties of laminates greatly affected by the reinforcement (preform) structures. The textile preforms are designed such a way that it gives good mechanical properties, in-plane property, tailor ability, drapability, initial extension and bending properties to final products.

KEYWORDS: Integrity, Laminates, Biaxial, Multiaxial, Preforms

I. INTRODUCTION

The textile fabrics are generally having crimp structures, which deteriorate the mechanical properties of the textile composite. Hence conventional techniques are modified to develop crimpless fabric for textile composites. New techniques are developed to produce crimpless and multi-axial structures. The properties of laminates greatly affected by the reinforcement (preform) structures. The preform structures are back born structure of composite. The textile preforms are designed such a way that it gives good mechanical properties, in-plane property, tailor ability, drapability, initial extension and bending properties to final product. The geometrical aspects provide the information regarding maximum packing factor, shearing behaviour and bending behaviour of laminates. Textile preforms are subjected to the wide range of complex deformations, impact forces, during manufacturing process. The preform selection should be such a way that it should not generate the void, which propagates the cracks in final structures^{1,2}.

The main objective of this study is to study the effect of preform combination on thermoset laminates. The laminates were fabricated using different glass reinforced structures combinations. The properties of thickness, GSM, strength, shear strength, flexural rigidity and puncture resistance have been studied with different reinforced material. The SEM and DSC analysis has been done to study the performance of laminates. The hand laying method has been used to prepare the laminates. 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.

II. MATERIAL AND METHODOLOGY

The properties of high performances fibers like GSM, linear density, tensile strength, weight of fabric and thickness of fabric were measured on required instruments. In order to test the physical properties of Glass, Carbon, Basalt Preforms and Laminates the standard method has been used.

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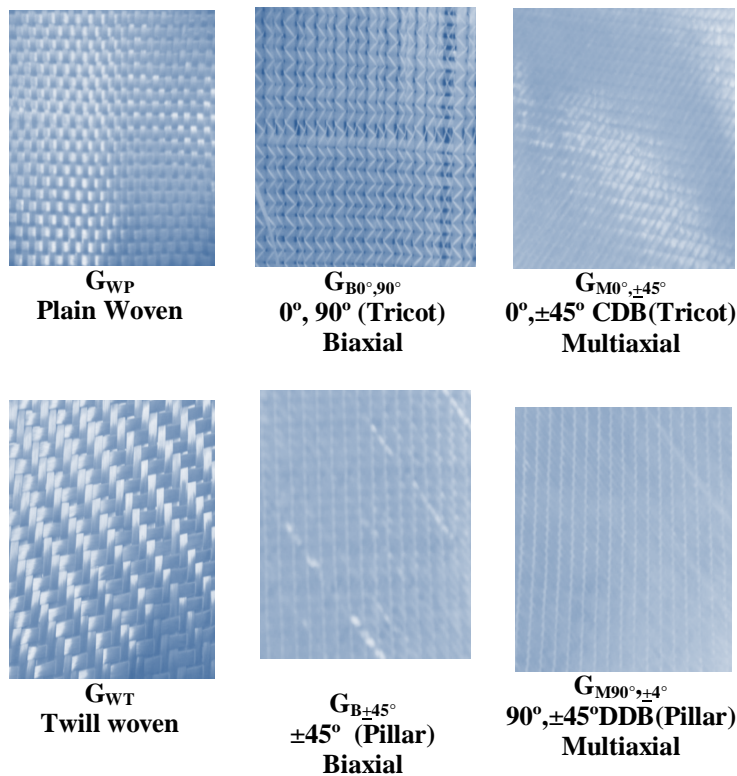


Figure 1: Different Structure of Glass Preforms

Table 1: Specification of Preform

Sample	Glass Preforms Structure	Coding	GSM	Thickness
1	Plain	G_{WP}	800	0.94
2	Twill	G_{WT}	902	0.85
3	Bi-axial	$G_{B0^\circ, 90^\circ}$	490	0.63
4	Bi-axial	$G_{B\pm 45^\circ}$	607	0.67
5	Multiaxial	$G_{M0^\circ, \pm 45^\circ}$	1192	1.14
6	Multiaxial	$G_{M90^\circ, \pm 45^\circ}$	1282	1.02

The Glass preforms with different structures like Plain, Twill, Bi-axial and Multi-axial has been studied. Also different material like Glass, Basalt and Carbon woven fabrics and its combination were used to prepare the Laminates. Glass fabric and its combination taken for study the thermoset Laminates. The preform material has been procured under GUJCOST MRP project. The Structure of glass preform as shown in figure 1. The paper describe only the behaviour of glass preform structure in laminates.

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III. EXPERIMENTAL RESULTS

EFFECT OF LINEAR DENSITY, THREAD DENSITY ON THICKNESS AND GSM ON PREFOMES

The thickness and GSM of preform plays important role to decide the final laminate properties. The studies have been done by keeping thickness constant for all laminates and the effect of different GSM preform in laminate structure has been observed. The thickness and GSM of glass preform has been measured according to ASTM D-5261. The thickness of the fabric depends on yarn linear density and number of layers. The variation in thickness changes GSM value, if the thread density is high it increase the GSM value.

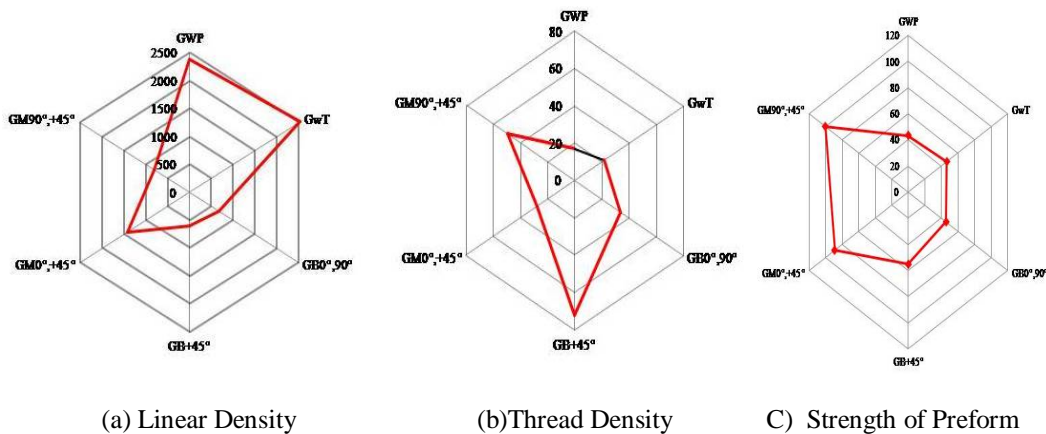


Figure 2: Properties of of Different Glass Preforms

In woven the plain and twill structure are having less difference between linear density and thread density as shown in figure 2 (a) and (b). The value of GSM of both sample is higher due to high value of linear density, hence the coarser roving also contribute in increasing the thickness. The thickness and GSM value of plain and twill found similar value as shown in Table 1 this behaviour indicates that weave of uncrimp woven structure have no much effect on thickness and GSM it directly depends on linear density of the roving. Due to uncrimp structure the weave have no much effect on thickness for similar GSM fabric.

Similarly in biaxial fabric in spite of high threads density the average value of thickness and GSM show lower value, due to effect of yarn linear density. The sample of biaxial GB+45°/-45° shows higher GSM value but no significant different in thickness in spite of higher thread density. In biaxial preforms the linear density roving seems to be quite less compare to woven and multi-axial in spite of high thread density and two layers of yarn is quite less compared to woven and multi-axial. Also GB0°/90° and GB±45° shows similar thickness as per Table 1 but GB±45° shows higher GSM value due to the combined effect of linear density and thread density.

In multi-axial preforms the larger difference in GSM compared to thickness variation. The main reason for this behaviour is due to correlation between linear density, thread density, number of layer and structure of preforms. The average value of linear density for both the multi-axial fabric found significantly low compare to plain, but due to the three layers in multi-axial it shows similar thickness and GSM value. The GSM values of preforms have direct effect on weight of laminate. During the processing of laminate the amount of resin pour depends on the GSM value. Also it decides percentage of glass distribution in laminates. In this work the glass percentage varies between 20-30 per cent. For a single layer of the woven preform the glass percentage comes around 20% and for similar GSM value multi-axial preforms give 30% of glass contain due to three ply in single layer.

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EFFECT OF PREFORM STRUCTURES ON TENSILE STRENGTH

The linear density and thread density of woven preform samples of plain (GWP) and twill(GWT) have almost similar value (Figure 2 (a) and (b)), hence the tensile value of the both samples shows no significance difference as shown in Figure 3. The weave have no significant effect on the strength of the preform due to no crimp structure. Similarly the tensile strength of the fabric depends on linear density, thread density orientation of the yarn and number of layers in fabric. The thread density of biaxial GB+45°/-45° have more thread density compared to GB0°/90°, hence the number of threads contributes more in strength gives higher value of tensile strength. It has been observed during experiment that the biaxial sample having yarn laying in 0°/90° direction shows less stable compared to yarn laying in +45°/-45° and also the GB+45°/-45° sample shows less distortion during testing.

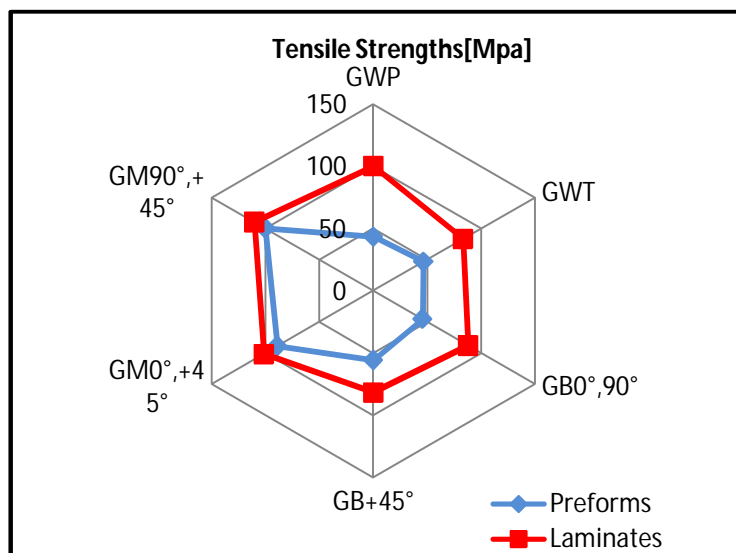


Figure 3: Strength of Preform v/s Laminates

The tensile properties of multi-axial fabrics also depend upon linear density, yarn orientation and number of layers. The GM90°/±45° shows the lower value of linear density and higher value of thread density as per figure 2 (a),(b), the trend is exactly reverse in case of GM0°/±45°. The tensile strength of GM90°/±45° shows significant higher value compared to GM0°/±45° due to the high value of thread density. The rovings are laid in different direction in preform also have effect on tensile strength of multi-axial fabrics.

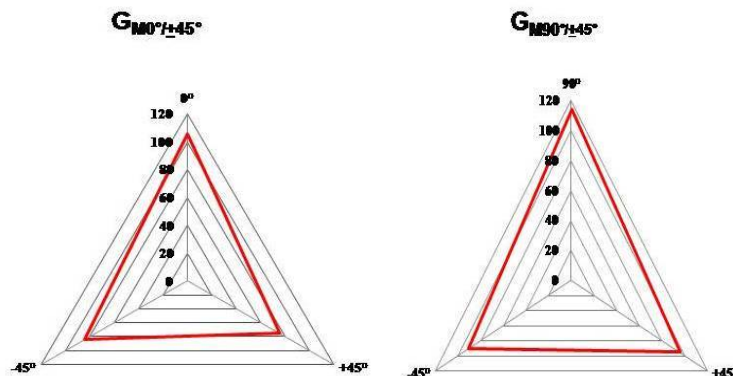


Figure 4: Tensile Strength of Multi-axial Preform

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In Figure 4 shows higher tensile strength in 0° compared to $+45^\circ$ / -45° , this behaviour is due to higher linear density of glass roving laying in 0° . The average value of tensile strength depends on cohesion between all three layers laid in different direction and binding force act on the layer due to stitch formation. Similarly in $GM90^\circ/\pm 45^\circ$ the tensile strength behaviour have similar trend in all three direction even though linear density of the roving laid in 90° direction is higher as compared to $\pm 45^\circ$, but due to less thread density it balance the structure as shown in figure 4.

COMPARATIVE ANALYSIS OF PREFORMS IN LAMINATES

The different preform structures and their physical properties has been analysed and then the preforms have been consolidated in laminate using polyester resin. The amount of resin added during the fabrication is equal to 2.56 times the weight of fabric. The amount of fibre contributes in laminate strength depends on preform structure and number of layers. The comparative analysis and effect of preform structure in laminates have been discussed, the properties of laminates along with preforms.

Figure 3 shows the comparative data of tensile strength of preforms and laminates. The tensile value of woven laminates have shown significant increase in strength compare to its preform strength. The woven laminates with plain weave gives more strength due its stable structure and less distortion in structure during process. The flexural rigidity and compression strength of twill preform depends on core material properties, bending and shear properties of preform, thickness and length of laminates on which load is apply. The flexible rigidity of the laminate shows the similar trend like preforms. Hence, the structure of preforms and the binding force acting between the preforms affect the flexural rigidity value of laminates but this statement can not be true as to understand the behaviour of laminates, more complex analysis is required. Compression strength value also not give clear trend to understand the preform behaviour. It is observed that woven preforms have lower value of tensile strength than laminated, due to consolidation of resin, GWP shows higher value of tensile strength as compared to GWT because the plain weave have stable and compact structure than twill. During fabrication of woven preform the twill structure gets more distorted than plain weave.

In biaxial $GB\pm 45^\circ$ shows higher value of strength in laminated, as $GB\pm 45^\circ$ have higher value of strength in preform itself as compared to $GB0^\circ/90^\circ$. The GSM of biaxial preforms have lesser value compare to woven but due to two layers and noncrimp non interlaced fabric. The strength of preforms and laminates give strength value similar to woven. The multiaxial preform shows higher value of tensile strength than woven, and biaxial. Though plain have stable structure but it has interlacement, which causes the distortion of yarn during the fabrication process, while in multiaxial the layers remain in contact with each other by the stitch formation. The resin get completely abounded between the layers in multiaxial preform. In multiaxial $GM90^\circ/\pm 45^\circ$ shows better value for strength than $GM0^\circ/\pm 45^\circ$, due to laying of yarn in 90° than in 0° , also the preform shows higher compression strength value for $GM90^\circ/\pm 45^\circ$.

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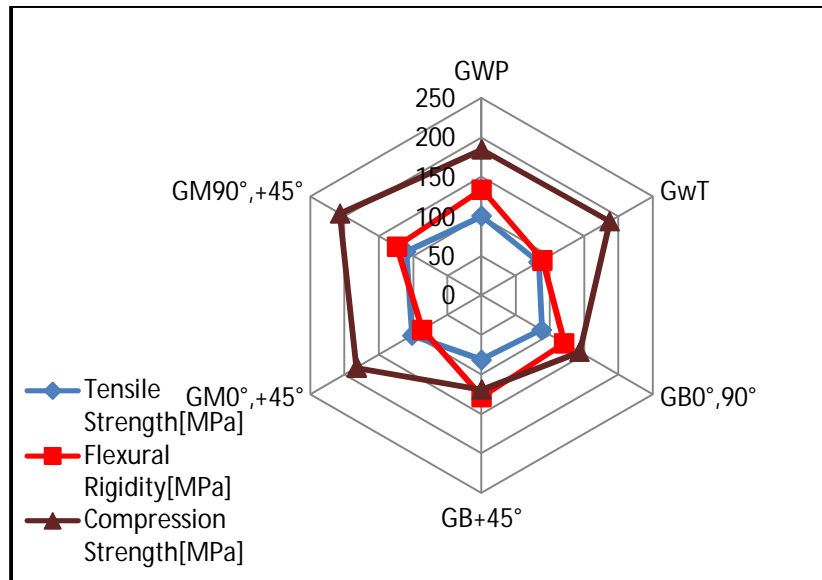


Figure 5 : Comaprative Properties of Laminates

Figure 5 shows the different physical propeties of laminates. In all three properties multiaxial laminate shows an increasing trend as compared to woven and biaxial laminates.

COMPARATIVE ANALYSIS OF DIFFERENT PREFORM STRUCTURES IN LAMINATES

Textile preforms play a key role in improving the mechanical properties of composites for various applications. In this project six samples of glass preforms having different structure and orientation have been selected for the fabrication. The Glass preform (woven, bi-axial and multi-axial) having different structural geometries, GSM and thickness of the fabric, also the number of layers are increased as per the requirement.

The six preforms structure has been consolidated in the laminate. The plain and $GM0^\circ/\pm 45^\circ$ taken for a SEM analysis to see the placement of preform in laminates. As shown in figure 6 (a) and (b) the plain and multiaxial structure of textile composite shows the glass preform which has been surrounded by the matrix material. The SEM images of plain and multiaxial glass preform have been taken from different magnification for a better focus. The internal structure of the samples reveals the uniformity of matrix material inside the laminate. In GWP structure the filaments are arranged in two directions, the dark portion indicates the matrix area while the white portion indicates the roving.

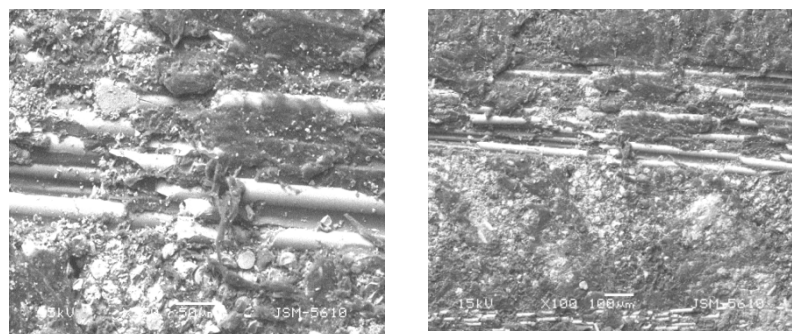


Figure 6 (a) : SEM Images of Plain Woven Preform in Laminate

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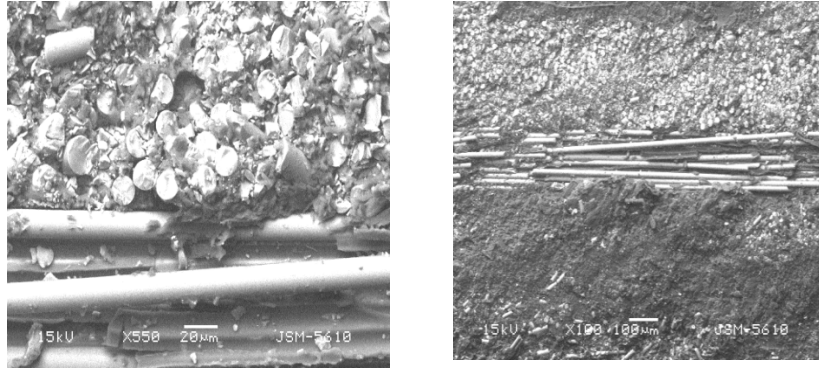


Figure 6 (b) : SEM Image of GM 0°/±45° Glass Preform in Laminate

In figure 6 (b) GM0°/±45° the filament yarn are arranged in three different direction and with a three layers .It clearly shows that rovings has been arranged in one direction and the edges of other two yarns laying at 45° and -45°. The consolidation seems to good as no void generation has been observed. Thus, from above study it clearly indicate that glass preform structure have a significant effect on final property of laminates

IV. CONCLUSION

It can be conclude from results that the mechanical properties of laminate greatly influence by structure of laminate. Hence designing accurate parameter of preform can give required quality of laminate. During process of the manufacturing of the laminate the woven preforms distorted more due to loss structure. The multi-axial remain intact due to the stitch bonding and give better handle.The fibre fraction ratio has been more in multi-axial then in plain woven. The multi-axial structure has been found more suitable structure within the same GSM value of plain. The strength of the preform greatly influence by linear density, thread density, GSM value and thickness of performs.In multi-axial due to the laying of yarn in different direction not having only the higher strength but also give higher load barring capacity in multidirectional.

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