Tensile Behavior Analysis on Different Structures of 3D Glass Woven Perform for Fibre Reinforced Composites

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ABSTRACT

Three common 3D (Three Dimensional) Glass woven structures were studied to analyze the tensile behavior. Each type of strand (Warp, weft and binder) of 3D woven structure was studied in detail. Crimp percentage of those strands was measured by crimp meter. Standard size samples of each 3D woven structure were cut in warp and weft direction and were stretched by Instron Tensile testing computerized machine. Results reveal that hybrid possesses lowest crimp in core strands and higher strength in warp as well as weft direction. Layer to layer woven structure appeared with lower strength and higher strain value due to highest crimp percentage in core strands.

Key Words: 3D Weaving, Tensile Analysis and Fibre Crimp.

1. INTRODUCTION

Weaving is one of the most commonly used process for producing 3D prefoms for composites because of high production speed combined with the flexibility to produce a diverse range of 3D fibre structures. In addition, 3D woven composites possess superior mechanical properties compared with conventional laminated composites [1,2]. 3D woven fabrics are used as reinforcements for the composite material including niche applications. Though, such materials are being utilized in high end applications such as in wing connectors, components of scramjet engines fuselage, frames missile nose cones and multi blade stiffened panels [3].

The potential of 3D woven preform has not been completely explored yet. There are some deformation mechanism helps to understand textile reinforcing material. However, in-plane shear, through- thickness compaction and tensile behavior appears very important testing. During mechanical properties analysis, tensile behavior analysis keeps great importance in order to understand the material properties. While fabric manufacturing, shear is key feature and low shear stiffness represents the largest source of energy indulgence in plane tensile behavior [4]. Lee et al examines the damage mechanisms and reductions to the tensile properties of E-glass yarns during weaving of 3D fabrics for polymer-based composites [5]. Chou has investigated and discussed mechanical properties of woven laminates of different types of fibres and structures made by diverse manufacturing techniques [6-10]. These data may help, however the success of textile composites rely on good prediction of composite material properties [11-13]. Due to three dimensional complex nature of fibre orientation, it has been very difficult to predict the properties of 3D composites end product. Therefore, it is necessary to develop the data with various parameters, fibre types and preform structures. Main objectives of present paper are based on the 3D weaving technique and focus on the tensile analysis of 3D woven preforms having different weave styles.

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2. METHODS

Three structures of 3D Glass woven preforms i.e orthogonal, Layer to layer and hybrid were used in this research. The crimp and tensile properties were measured with British Standard ISO 7211-3:1984 and British Standard BS EN ISO 13934-1:1999 by crimp tester and Zwick Instron testing machine with a load cell capacity of 10KN. Five specimens from each design of preform were cut parallel to warp and weft directions. The specimen dimensions for tensile testing were 20cm long and 5cm wide.

3. RESULTS AND DISCUSSION

3.1 Crimp analysis

Crimp plays vital role in mechanical properties of woven preforms. The force applied in fibre direction possesses optimum strength. The higher crimp of tows leads to decrease in mechanical properties of performs. Each 3D woven structure consists of warp, weft and binder yarns. Therefore, crimp of all types of strands of 3D woven structures was calculated as shown in Table 1. In orthogonal 3D woven structure, maximum crimp is taken by binder yarn and weft tows possesses least crimp as compared with warp tows as well as other 3D woven structures. In layer to layer 3D woven structures, warp tows possesses highest crimp among all 3D woven structures. Hybrid 3D woven structure appears as 3D woven structure having least crimp in warp as well as binder yarn. Only weft tows of this structure has slightly higher crimp.

3.2 Tensile Analysis

Figs. 1-2 presents the typical tensile force and strain curves of 3D woven perform in the warp and weft direction respectively for all the woven structures. It is seen that the force required for the preforrms are almost same as shown in Table 2. The hybrid 3D woven structure possesses highest strength which is mainly due to lowest amount of crimp present in weave. The hybrid 3D woven structure possesses slightly higher crimp in weft tows. Consequently, hybrid has taken higher load in warp direction as compared to weft direction. The orthogonal and hybrid weave has almost same strain value both in warp and weft direction.

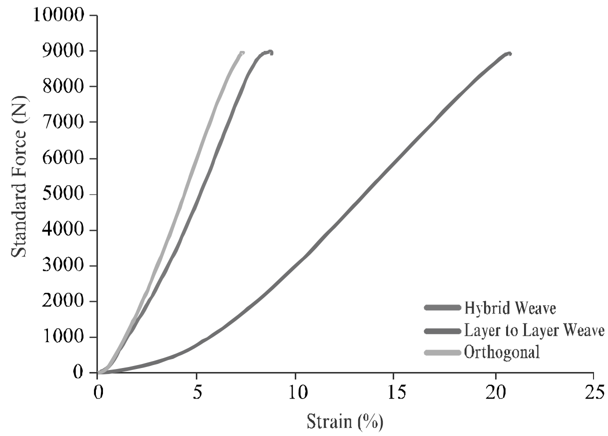

FIG. 1. TYPICAL FORCE-STRAIN CURVE OF 3D WOVEN STRUCTURES IN WARP DIRECTION

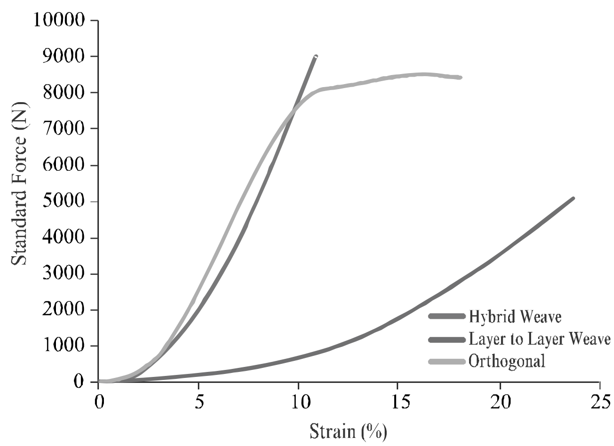

FIG. 2. TYPICAL FORCE - STRAIN CURVE OF 3D WOVEN STRUCTURES IN WEFT DIRECTION

TABLE 1. CRIMP STUDY OF 3D WOVEN PREFORMS

Fabric Structure	Warp Crimp (%)	Weft Crimp (%)	Binder Crimp (%)
Orthogonal	2.829190904	1.184236971	5.505952381
Layer to Layer	8.245243129	1.37837131	
Hybrid	2.192328483	1.528905877	3.830173

After Hybrid weave, orthogonal 3D woven structure occupies lower strain value. Though it posses almost similar strain value but has taken lower load to fail in warp as well as in weft directions.

The force- strain curve of layer to layer in warp and weft direction is observed different from both previous weaves. The standard force value is same like the orthogonal and hybrid weave. However strain value differs. This is because the construction of the layer to layer weave is bit different from other weave. Layer to layer 3D woven structure gains highest strain in warp direction. This may be due to highest crimp present in warp tows of layer to layer structure. Crimp possesses extra length of tows in curve form. As load increases, initially, fibres try to straighten itself and as a result it elongates and strain increases.

4. CONCLUSION

Tensile behavior of three common 3D woven structures: Orthogonal, Layer to Layer and Hybrid were analyzed. The behavior of each type strand of individual structure was studies. The results show that orthogonal, layer to layer and hybrid 3D weaves have almost similar standard force value in warp direction. However, layer to layer differs significantly in strain value due to higher percentage of crimp present in structure. Hybrid 3D woven structure appeared with higher strength and more or less similar strain value. It shows that if crimp is transferred from warp to binder or Z-direction yarn then it can improve the tensile property of textile preforms.

TABLE 2. FORCE APPLIED ON EACH 3D WOVEN STRUCTURE IN WARP AND WEFT DIRECTION

Fabric Structure	Orthogonal	Layer to Layer	Hybrid
Warp Wise	9000N	9000N	9400N
Weft Wise	8500N	8900N	9000N

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