Shear Deformation of 3D Carbon Woven Fabrics

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ABSTRACT

This study was to analyze the mechanism of shear deformation and yarn slippage in the 3D (Three Dimensional) carbon woven fabric. For this study three weaves orthogonal, layer to layer and angle interlock were tested in Kawabata shearing instrument and all the results were analyzed. The relationship between the shear load and shear angle was measured in both warp and weft directions. It is shown that the fabric having highly compact structure exhibits high shear rigidity and it can withstand high shearing load. The orthogonal weave has shown much higher shear rigidity as compared to other weave structures.

Key Words: **3D Carbon Woven Fabrics, Kawabata Shear Test Method, Shear Rigidity.**

1. INTRODUCTION

Textile composites are new scientific technique in the high-tech application used for high strength structures, which is expanding in the last two decades [1-2]. This rapid expansion is based on the unique physical and mechanical properties of the composite materials. 3D composites are a special class of materials with many unique properties [3]. 3D textile composites are responsible to withstand the high fracture toughness and spatial system of mechanical and thermal stresses and it has lower manufacturing cost than metals. Reduction in the manufacturing cost of the material can be accomplished by the highly efficient stamping process and also improving the reliability and reproducibility of textile composites [4-7].

The 3D textile composites are manufactured with fully integrated preforms. The preforms are made up with different techniques for fabric formation. These reinforcing preforms are generally made by interlacing, interlooping or intertwining. Most common textile techniques to manufacture the three dimensional preforms are knitted, braided, non-woven and woven [8].

There are numerous advantages of 3D textile composites. The significant advantage is the possibility to manufacture the different complex shaped parts such as pi or T etc with good mechanical properties. It is very important to get reliable engineering data for achieving improvement in the designs and methodology of these material and their products. Therefore to get these data, various mechanical properties including the shear property have to be examined by different techniques.

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In the woven perform manufacturing, the shear deformation and slippage of the yarns in the weave structure are very important [9]. Yarn slippage is mainly due to yarn deformation under the applied load which results in higher covering capacity of the fabric. Such fabrics have no wrinkles but low amount of fibres results the yarn slippage that reduces the fabric strength [10]. The determination of fabric shear property is one of key characteristics of advanced composites and difficult as well [11-12]. As a result, it is necessary to make sure that specimen may be subjected the constant shear stress. The shear sample may be small and easy to test. It has been assumed that the shear deformation is highly responsible for the tightness and looseness of the textile preforms. Therefore, authors examined the shear rigidity (G), and shear hysteresis at two angles (2HG and 2HG5) by using Kawabata shear instrument and analyze the data for different weave structures in detail.

2. MATERIALS AND METHOD

2.1 3D Woven Fabrics

Three structures of 3D woven fabrics made of carbon fibres were used in this study. These structures are orthogonal, Layer to layer and angle interlock. The specifications of carbon 3D woven fabrics used in this study are presented in Table 1.

TABLE 1. SPECIFICATION OF 3D FABRICS

Fabric Structure	Areal Density (g/m^2)	No. of Warp (cm)	No. of Weft (cm)
Orthogonal	1836.08	2	4
Layer to Layer	1960.72	2	4
Angle Interlock	1887.36	2	4

2.2 Methods

Kawabata shear evaluating system was used to test the fabric shear test. Five samples were cut in each direction of warp and weft of each structure. The sample size was 20x5 cm.

3. RESULTS AND DISCUSSION

3.1 Shear Rigidity and Hysteresis

When the fabric goes under shear deformation the warp and weft yarns were giving rotational movement and this movement gives the result of shear rigidity. Mahar, et. al. [13-14] examined the shear deformation of ends and filling yarns of woven fabric. In this paper, shear deformation is measured in both directions.

Fig. 1 represents the values of shear rigidity, 2HG and 2HG5 values in the warp direction. The Fig. 1 shows that the orthogonal weave have very high shear rigidity. This may be due to orthogonal weave is highly bound with the help of z-yarn so that because of the compact weave structure the yarn slippage is low and the fabric seems stiffer. On the other hand the angle interlock and layer to layer weaves show almost the same results because the z-yarn does not bind the fabric layers vertical through the thickness. However, it is bound at angular position. Only two layers are bound by the z-yarn. Thus these weaves have less shear rigidity as compared to orthogonal weave structure. The 2HG and 2HG5 values are very high in the orthogonal weave this may be because the fabric is much stiffer than other fabric structures. Layer to layer and angle interlock weave shows almost same values of 2HG and 2HG5.

Fig. 2 represents the shear rigidity, 2HG and 2HG5 values for weft direction. The Fig. 2 shows the same behavior as in the warp direction that the orthogonal weave structure shows high shear rigidity as compared to layer to layer and angle interlock weave structures. The 2HG and 2HG5 values also show same behavior.

3.2 Shear Load and Angle Analysis

Figs. 3-4 represents the relationship between the load in gf/cm and shear angle in degrees for different weave structures in warp and weft direction respectively. Fig. 3 it shows that the layer to layer and angle interlock weaves are giving almost same behavior. The z-yarn is mainly responsible for this rigidity because the interlacement/ binding of z-yarn is loose and the yarn can easily be slipped

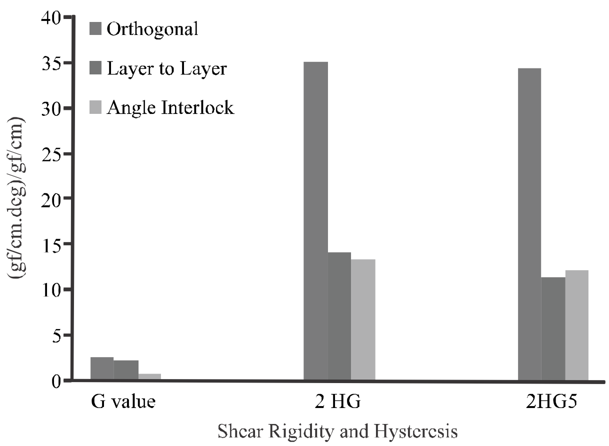

FIG. 1. SHEAR RIGIDITY AND HYSTERESIS VALUES IN WARP DIRECTION

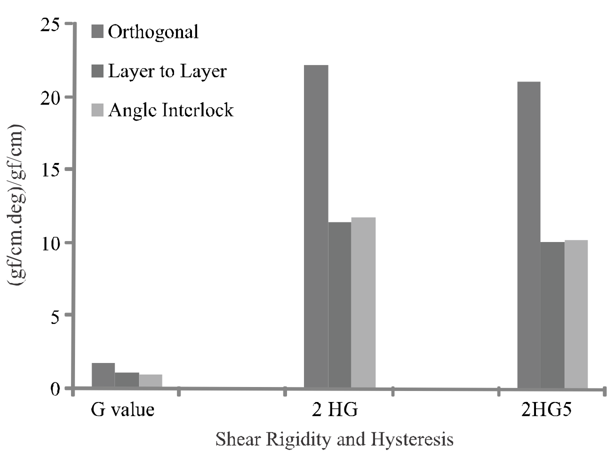

FIG. 2. SHEAR RIGIDITY AND HYSTERESIS VALUES IN WEFT DIRECTION

when the shear load is applied onto the fabric. On the other hand, the orthogonal weave structure shows completely change graph. It shows high load is applied to move the warp yarn this is probably due to warp yarns are compactly interlaced with the binder yarn.

Fig. 4 shows the orthogonal weave exhibits greater shear load and shear angle as compared to other weaves in weft direction. The weave structure and the movement of binder yarn are responsible of higher stiffness in orthogonal weave. Layer to layer and angle interlock presents same shear load and shear angle values in weft direction.

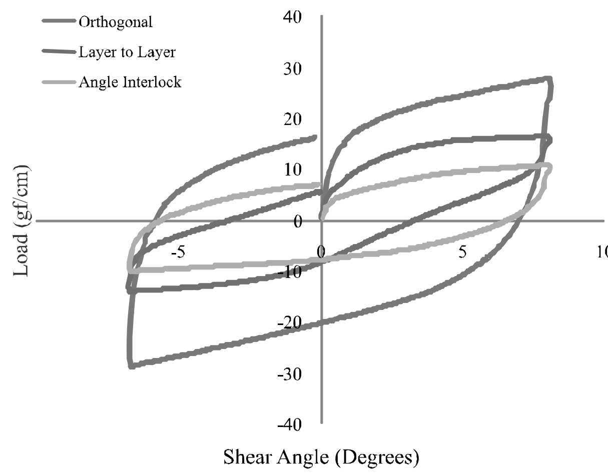

FIG. 3. STANDARD LOAD AND ANGLE CURVE OF 3D WOVEN STRUCTURES ALONG WARP DIRECTION

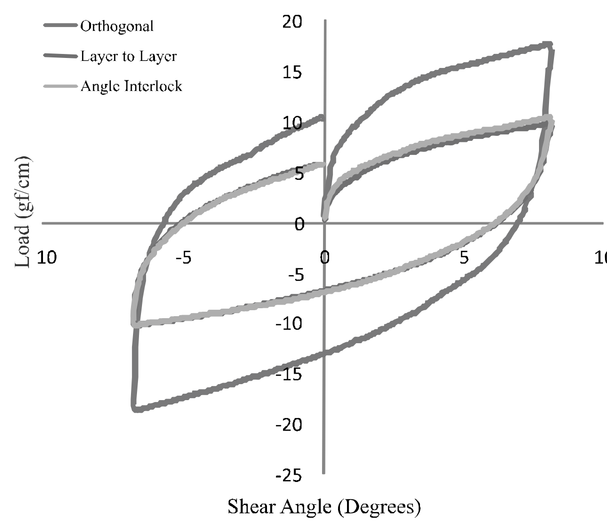

FIG. 4. STANDARD LOAD AND ANGLE CURVE OF 3D WOVEN STRUCTURES ALONG WEFT DIRECTION

4. CONCLUSION

Three different structures of 3D carbon woven preforms i.e. orthogonal, angle interlock and layer to layer structures were analyzed to understand the shear deformation and yarn slippage. Orthogonal 3D woven structures appeared with very high shear rigidity due to compact and all layers were tightly bound by z-yarn as compared with other structures. Layer to layer and angle interlock gave similar shear deformation behavior. Similarly, due to less interlacement in vertical direction, layer to layer and angle interlock has higher slippage and lower shear load as compared with orthogonal.

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