Analysis of Structure and Bending Behaviour of Quasi-Three-Dimensional Spacer Fabric Composite by Three-point Bending Tests

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Abstract: Glass-fiber fabric composites are widely used in various applications. Its usage is largely determined by the bending behaviour of fabric composites in through-thickness direction. In this work we have selected three types of quasi three spacer fabric made of glass fibres to analyze their structure and conduct bending experiments. The surface morphology in up, back and side views, as well as weaving/knitting structure were also observed. It exhibited that there existed much static atmosphere within fabric composite for a high porous structure. Moreover, the three-points bending properties were also measured by Instron tester. The bending load and deflection curve of fabric composite were obtained. The Typical Bending Stress and Strain Curves were calculated and studied for biaxial spacer weft-knitted fabric (named as sample #1), tuck stitch spacer warp-knitted fabric (sample #2) and spacer woven fabric composite (sample #3). The testing results show that sample #1 had the highest indexes in bending stiffness, maximum bending stress and maximum bending load, followed by Samples #2 and #3. This can be attributed to the yarn's orientation in fabric composite, i.e., the yarn's crimp shape in thickness direction.

Keywords: Quasi-three-point bending, flexural property, glass fiber, knitted, woven.

1. Introduction

Energy saving is one of the most important focuses in twenty-first century, especially in architecture field [1]. In architecture industry, glass fibers are widely adopted for high strength. Many researchers have been focusing on laminating fabric composite fabricated by resin or linking yarns in through-thickness direction. The former way of fixing the laminated fabric can be easily delaminated due to its weak shearing-resistant behaviour [2-4]. The latter uses linking yarns in the through-thickness direction, however, the traditional linking yarns are made by general polyester or polyamide yarns with good flexible property, which causes the strength to be low and the fabric can be easily damaged under high load [5,6]. The three-dimensional spacer fabric composites made of high performance fibers have high bending strength in three dimensional directions [7], while the mass per volume is heavier and results in increase of cost. It necessitates that the core part between the two faces of the layers are removed, which fabricates the spacer fabric with high porous structure. The spacer fabric decreases the mass per cubic meter and cost, and increases the thermal resistant ability, while it has low effects on the bending rigidity under small deflection deformation.

Therefore, glass-fiber spacer fabric composites are effective in saving energy with high bending rigidity in through-thickness direction under slight quake and collision if applied in architecture which is largely determined by the bending behaviour of fabric composites in through-thickness direction. The aim of this paper was to design three kinds of quasi-three-dimensional spacer fabric made by glass fibers, to analyze the structure and conduct bending experiments, where the yarns at the side edge were continuous to increase the bending strength. The quasi-three-dimensional glass-fiber fabrics consist of weaving or knitting structures of high porous volume and much static atmosphere within fabric composite. Then, it was to compare the bending properties of the three types of glass-fiber spacer fabric composite and to provide an effective structure for the spacer fabric composite to be applied in architecture field. It is helpful in designing the structure of high performance fiber yarns and acquiring high strength of fabric composites.

2. Structural analysis

The main content dealt with in the paper is to state structure of three kinds of quasi-three-dimensional glass-fiber spacer fabric preforms by observing face morphology and comparing bending properties. The spacer fabric preforms are laying-in weft-knitted spacer fabric composite (named as sample #1), astrakan stitch warp-knitted spacer fabric composite

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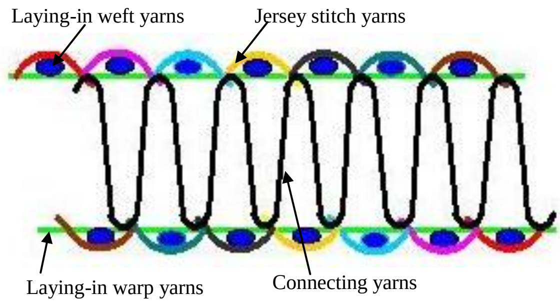
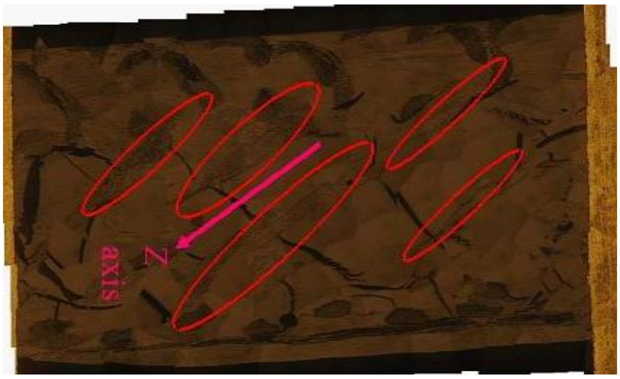
(sample #2) and spacer woven fabric composite (sample #3), respectively, all of which are opposing much static atmospheric capability for a high porous structure.

The first preforms are a biaxial weft-knitted spacer fabric whose upper and bottom face structures are two symmetrical jersey stitches (shown in Figure 1), and are strengthened by laying-in wale and course yarns. The jersey stitches are located in the outset layer, and the middle layer as laying-in course yarns, and the inner layer as laying-in wale yarns where the laying-in wale and course yarns are both straight and not locked with each other, it is used to increase the utilizing ratio of fiber strength; moreover, the both laying-in yarns are bound by the jersey. The face structures are linked by Z-axis yarns i.e., through-thickness directional yarns; and the side views in left and right as shown in in Figure 1 (b) and (d). It shows that the connecting glass-fiber yarns links the upper and bottom faces and burdens high strength in through-thickness direction for high straight line under external applied load. It is also proved by the microscopy picture in Figure 1(a) and (c), where the pictures are observed by OLYMPUS microscopy, and it shows the contour of linking yarns in the Z-axis direction, i.e., the through-thickness direction.

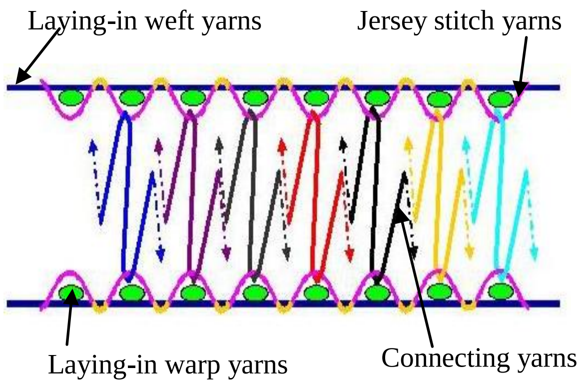
(a) Morphology of connecting yarns with resin cover



(b) Structure of side view



(c) Morphology of connecting yarns with resin cover



(d) Structure of side view

Figure 1 Morphology and Structure of laying-in weft-knitted spacer fabric in through-thickness direction.

The second preform is astrakan stitch warp-knitted spacer fabric whose faces and linking structures are shown in Figure 2. It can be seen from Figure 2 (b) and (c) that the upper face structure is a five-thread warp sateen stitch and the bottom surface is an open-chain stitch, and the linking yarns shape is obvious from the side view of fabric as shown in Figure 2(a). The connecting yarns are knitted with the upper face yarns into astrakan stitch and casting off to interknitting with the chain stitch in the bottom surface, which increases the rigidity in thickness direction. The chain structures are strengthened by the laying-in yarns in wale direction, and there exists a pair of thick laying-in yarns by two-thread fleecy between neighbouring chains, and then a pair of thin laying-in yarns by two-thread fleecy between neighbouring chains, as shown in Figure 2(b).