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Technical report

Tensile and bending behaviours of laminates with various fabric orientations

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Abstract

Woven fabrics are probably by far the most commonly used forms of textile composites in structural applications, they generally consist of two sets of interlaced yarn components, known as the warp and weft yarns according to the yarn directions in the fabric. One of the major factors which influences the mechanical properties of the woven fabric composites is the stacking orientations of the fabric layers in the composites. Vacuum assisted resin infusion technique was employed to produce two-layer laminates with various fabric crossing angles. The bending and tensile behaviours of the specimens were measured, the results showed that both bending character and tensile strength were highly influenced by the orientation of the fabric layers in the laminates. Parallel lay-ups of the fabric would increase both the bending and tensile strength in a definite direction, meanwhile, elongation at break in that direction was also increased greatly.

Distinctive fracture profiles were noticed when using different fabric orientations in the laminates.

Keywords: Laminate; Woven fabric; Lay-up; Glass fibre

1. Introduction

Textile composites are being used in advanced structures in aerospace, automobile and marine industry [1]. The application of textile composites in engineering structures has been driven by various attractive aspects such as ease of handling, high adaptability, light weight, high specific stiffness and tensile strength. Textile based composite materials have received considerable attention in the literature in recent years [2–9]. Therefore an in-depth knowledge of the mechanical properties is of fundamental importance.

Woven fabric is a two-dimensional material in which the warp and weft fibre tows are interlace to each other to form a layer. It is thought that if the laminate is constructed with fabric layers in which yarns in the same category (warp or weft) are parallel, excellent strength in orthogonal directions (e.g., the warp and weft directions) would be resulted. This implies that the tensile strength of the composite would vary greatly according to the orientation of the fibre tows in the laminate. In some cases, materials with isotropic properties are expected, in which the fabric stacking has to be carefully designed, usually a multi-directional lay-ups of the fabrics are recommended. Questions arise as how does the laminate behave when using different fabric orientations.

Vacuum assisted resin infusion (VARI) technique was employed to fabricate two-layer laminates with fabric crossing angles of 0°, 30°, 45°, 60°, and 80°, respectively. Three-point bending and tensile strength of the specimens were measured, differences were noticed among the samples using various fabric crossing angles, meanwhile different breaking modes were also revealed.

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2. Materials

Fabric used in the investigation was composed of E glass tows in both warp and weft directions. It should be noted that the fabric was balanced and presents the same number of yarns in both warp and weft directions. Table 1 presents the specifications of the fabric. The tensile strength of the fabric was tested with specimens measured 15 cm in length (the distance between the clamping jaws) and 5 cm in width. Each datum in the table was based on five determinations.

3. Testing and analysis

Fabric was cut into squares measured 30×30 cm. Each laminate sample was composed of two layers of fabric. For each specimen, there would be one layer (the bottom one) of fabric which was cut along the warp and weft directions; and another layer (the top one) was cut bias according to the predetermined cross angles of the laminates. The cross angles of the warp yarns in the two-layer laminate for the five specimen groups were 0°, 30°, 45°, 60°, and 80°, respectively.

Unsaturated polyester resin was selected as the matrix and corresponding hardener and promoter were included in the ingredient. VARI technique was used to fabricate the laminates. Forty hours after the fabrication, laminates were cut along the warp and weft directions of the bottom fabric, samples were 20 cm in length (warp direction of the bottom fabric) and 5 cm in width (weft direction of the bottom fabric). For each cross angle group 10 samples were prepared. Table 2 presents the characteristics of the samples, each datum in the table is the average of 10 measurements. In order to simplify the analysis, based on the crossing angles, hereafter samples No. 1 and No. 5 are included in group1, and samples No. 2, 3, and 4 in group2. Each group has the relatively closer cross angles (0°, 80° or 10° in group1; 30°, 45degr, 60° in group2).

Three-point-bending test was carried out according to the Chinese Standard GB3356/1982. The configuration of the test is schematically shown in Fig. 1.

The distance between the two pivots was 140 mm, a fixed load (0.2 N) was pressed at the middle of the sample during the test, the maximum deflection of the specimen was recorded. Fig. 2 illustrates the testing results.

Smaller deflections were noticed for the samples of No. 1 (0°)and No. 5 (80°); greater bending was resulted for the three other specimens. Statistic calculation revealed that the bending difference between the two groups (group1 with 0° and 80° ; group2 with 30°, 45°, and 60°) was highly significant. The author believes that when the fibre tows in the fabric are parallel to the line composed by the two pivots (Fig. 1), they would contribute the maximum resistance to the bending stress. Going to another extreme, if the fibre tows are perpendicular to the line mentioned above, they may provide little energy to resist the bending stress. In the cases of No. 1 and No. 5, warp yarns in the two layers are parallel (No. 1) or slightly bias (No. 5) to the line passing the two pivots, they would provide greater resistance to the bending of the laminates. No significant difference was noticed between No. 1 and No. 5 as far as bending strength is concerned.

Distinctive fabric cross angles existed in the laminates of group2. The warp yarns in this group can not contribute their entire strength to resist the bending stress, resulting in a smaller bending strength. No significant difference of bending strength was found among the samples No. 2, No. 3 and No. 4 in group2.

Table 1
Specifications of the fabric

Yarn fineness (warp and weft, tex)	114.8
Fabric structure	Plain weave
Warp density (ends/10 cm)	61
Weft density (picks/10 cm)	61
Warpwise strength (N)	681.5
Weftwise strength (N)	635.5
Weight (g/m^2)	140
Thickness (mm)	0.12

Table 2
Sample specifications

Sample No.	Group No.	Cross angle (°)	Thickness (mm)	Fibre volume fraction (%)
1	1	0	0.33	34.26
2	2	30	0.32	34.72
3	2	45	0.34	33.42
4	2	60	0.32	34.72
5	1	80	0.35	34.52

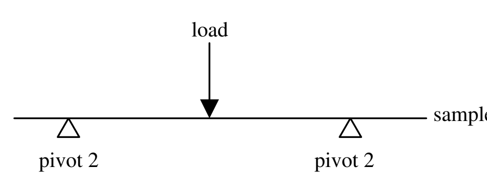

Fig. 1. Configuration of the bending test.

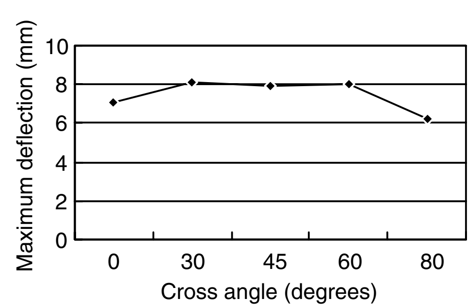

Fig. 2. Bending deflection of the laminates.