EFFECT OF STITCH YARN ON TENSILE PROPERTIES OF BIAXIAL WEFT KNITTED THERMOPLASTIC COMPOSITES

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Abstract
Within the scope of experiments, the effect of stitch yarn type, such as aramid and nylon, were investigated in the biaxial weft knitted (BWK) thermoplastic composites. Before fabricating of BWK thermoplastic fabric composite, 0 tpm and 20 tpm twisting of aramid / PA66 fibers were also studied in heat compression molding method. Two different types of composite panel, which include stitch fiber contents, such as aramid and nylon were fabricated by heat compression molding method. After production of composites, tensile tests were conducted on specimens. This study showed that BWK composites with nylon stitch fiber had higher tensile properties than this was with aramid stitch fiber composites.

1 Introduction
Due to the cost-effective manufacture offered by knitting technology, the using of knitting with advanced fibers, such as glass and aramid, to produce near-net-shape preforms has in recent years received increasing interest [1]. In order to improve the mechanical properties, such as strength and stiffness, of weft knitted fabric, straight yarns both in weft and warp directions can be integrated. These types of reinforcements are called biaxial weft knitted (BWK) structures. Weft and warp yarn layers are held together by a stitching yarn system in BWK fabrics. Reinforcing yarns, e.g. glass or aramid fibers, can be used within all yarn systems [2]. The tensile properties of BWK thermoset composites were reported by Demircan et al. [3]. They found that aramid-aramid-aramid type of composites showed the highest tensile properties.
Nowadays, thermoplastic composites are being used in various industries such, as automotive, wind turbines etc. The most important advantages of thermoplastics are their potential for rapid, low-cost and mass production of reinforced composites. On the other hand thermoplastic composites have very high viscosity (usually 500-5000 Pa s) which make difficult to the processing of thermoplastic matrix composites. Therefore some techniques, such as commingled yarn, were developed in order to improve process ability of thermoplastic composites. The matrix fiber will be mixed with reinforcing fiber in commingled yarn technique and this technique was proven to be a cost-effective method of

processing of thermoplastic composites [4-5]. Therefore, the commingled yarn technique was chosen in order to fabricate the BWK preforms. The tensile properties of knitted fabric reinforced composites made from GF-PP commingled yarn with different loop densities were investigated by Zaixia et al. [5]. They found that the tensile strength of the composites increase followed by light decrease as the loop density of preform increases.
In the literature, contributions about the mechanical properties of knitted composites were reported, which were explained above. However, only a few numbers of contributions were made about the mechanical properties of BWK composites with different stitch yarn combinations. The purpose of this research is to characterize the mechanical properties of biaxial weft knitted textile composites. Within this study we investigate tensile properties of BWK thermoplastic composites. The obtained results of this study can be used to design of new textile preforms during development of different composite materials.

2 Materials and testing methods

2.1 Selection of intermediate fiber of unidirectional composites

2.1.1 Materials

1670 dtex aramid reinforcement yarn (Kevlar-29, Dupont-Toray Co. Ltd., Japan) was commingled with nylon resin yarn (PA 66, 44 dtex x 31=1364 dtex, Asahi Kasei Ltd., Japan). During fabrication of BWK preforms on weft knitting machine, the commingled yarns were separated and could not be knitted. In order to overcome this problem, the commingled fibers were brought together by twisting (20 tpm, in S direction). Table 1 shows the processing conditions of intermediate fiber.

Table 1. Intermediate fibers for unidirectional composites

Intermediate fibers	**Twisting**
0 tpm	n/a
Twist 20 tpm	S dir. 20tpm

2.1.2 Experimental procedure of unidirectional composites

UD composites of twisted (20 tpm) and non-twisted (0 tpm) were fabricated on hot press compression machine. First, the fibers were wound 30 times on a metal frame and then, they were put on the mold and the hot press machine. The molding pressure, temperature and time were 6 MPa, 300^{o}C and 2.5 min. Later, mold was cooled under molding pressure until arriving the crystallizing temperature, 50^{o}C. After that, tensile properties of UD composites were studied in order to find effect of twisting process.

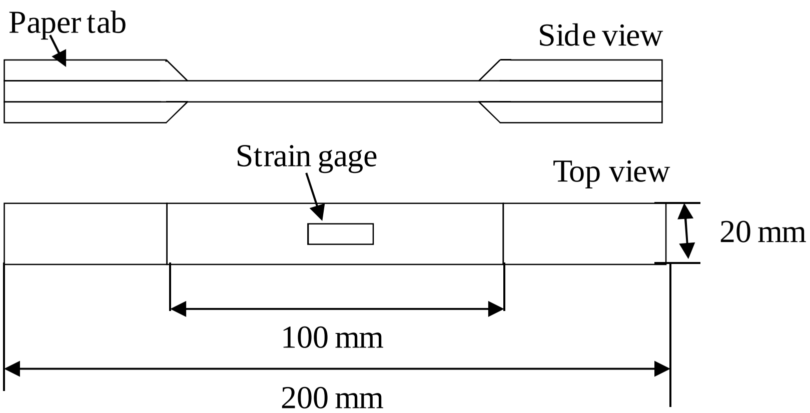

Figure 1. Geometry of the specimen; tensile test

The composites had 61% volume fraction. Fig. 1 shows the geometry of the specimen. The composite coupons had a nominal dimension: 200 x 20 x 0.6 mm. Tensile tests were conducted on the specimens according to ASTM-D303 standard using universal testing machine type 55R4206, Instron, under displacement control with speed 1 mm/min.

2.1.3 Results of selection of intermediate fiber of unidirectional composites

Fig. 2 shows the stress-strain curves of UD composites during tensile test. From these curves, it can be seen that tensile stress increase linearly with increase of the strain. This is followed by a sudden drop in a stress value corresponding to the ultimate failure of the composite. 20 tpm sample showed the higher tensile strenth and lower ultimate strain than 0 tpm sample.

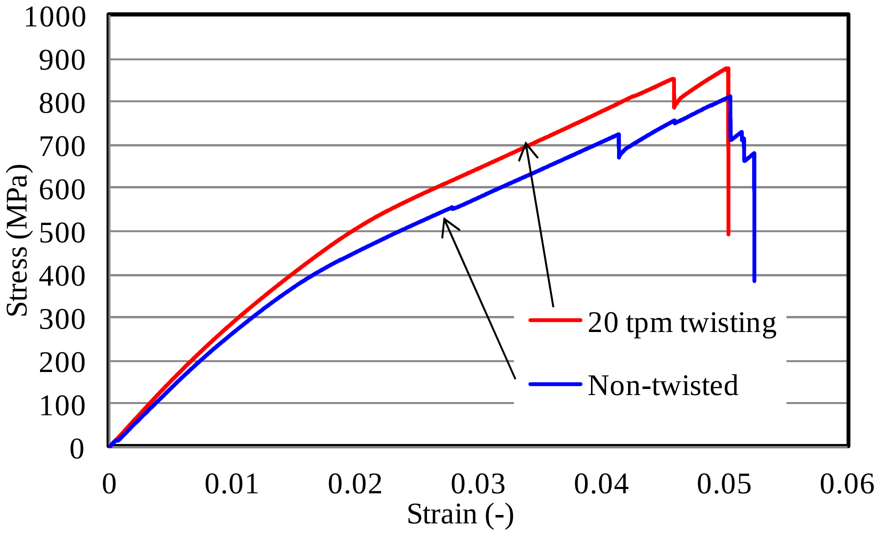

Figure 2. Stress-strain curves of unidirectional composites during tensile test

2.2 Biaxial weft knitted composites

2.2.1 Materials

Above mentioned commingled yarns with 20 tpm twisting were used as biaxial materials (warp and weft yarn). 440 dtex aramid (Kevlar-29, Dupont-Toray Co. Ltd., Japan) and 235 dtex PA 66 were used as stitch yarns. Table 2 shows the parameters of the BWK fabric. Two types of BWK fabric were produced on a flat bed knitting machine (Shima Seiki Mfg., Ltd., Japan). Fig. 3 depicts the fabricated BWK reinforcement fabrics.

Table 2. Parameters of the biaxial weft knitted (BWK) fabric

Sample name	Biaxial yarn		Stitch yarn linear density (dtex)	Density of warp yarn in fabric (end/cm)	Density of weft yarn in fabric (end/cm)
	Warp yarn linear density (dtex)	Weft yarn linear density (dtex)			
1) BWK with AR stitch yarn	AR/PA 66 1670/1360	AR/PA 66 1670/1360	AR 440	4.1	3.6
2) BWK with NY stitch yarn	AR/PA 66 1670/1360	AR/PA 66 1670/1360	PA 66 230	4.0	3.7

2.2.2 Experimental procedure of BWK composites

Two layers BWK composites were fabricated on hot press machine. The same molding conditions of UD composites were used during fabrication of BWK composites.

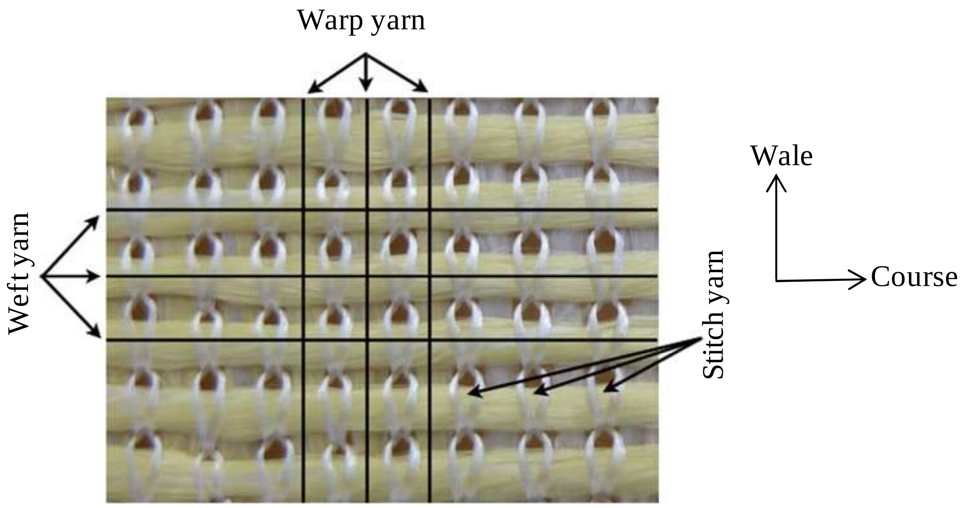

Figure 3. Structure of BWK fabric

The composite with NY stitch yarn had 46% total volume fraction and 0.54 mm thickness. The volume fraction of weft fibers was 22.1% and warp fiber was 23.9%. That with AR stitch yarn had 52% total volume fraction and 0.43 mm thickness. The volume fractions of weft, warp and stitch fibers were 16.8%, 19.1% and 16.1%. Above mentioned testing conditions and geometry of the specimens (paragraph 2.1.2) were used for tensile test. Tensile test were conducted on specimens in course (weft yarn) direction.

3 Results and discussions

The stress-strain curves of BWK composites during tensile test are shown in Fig. 4. From these curves, it can be seen that tensile stress with NY stitch increases linearly with increase in the strain and was followed by a sudden drop in a stress value corresponding to the ultimate failure of the composite. On the other hand tensile stress with AR stitch yarn increases linearly with increase of the strain and after maximum stress, it decreases and increases until to ultimate failure of the composite. The specimens with NY stitch yarn showed the higher tensile strength and the lower tensile ultimate strain compared to that with AR stitch yarn. The ultimate strain with AR stitch fiber was 3.6 times higher than that with the NY stitch fiber.

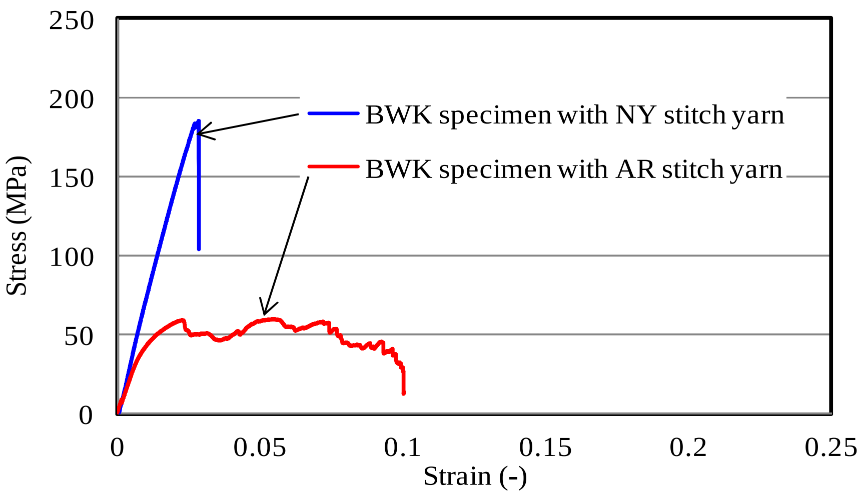

Figure 4. Tensile test results of BWK composites

During fabricating of composites with NY stitch fiber, the NY stitch fibers were melted and became resin. Only the AR warp and weft fibers were stayed in composites. That was with AR stitch fibers not happened. And AR stitch fibers were stayed after fabrication of composites with AR warp and weft fibers. The possible reason of obtained higher tensile strength results with NY stitch fiber would be higher weft fiber volume fraction (22.1%) than that with AR stitch fiber (16.8%).

4 Conclusions

This study showed that;

- UD composites with 20 tpm twisting showed the higher tensile properties than that with 0 tpm composites. 20 tpm twisting brings the fiber more closely each other compared to 0 tpm and this was probably increased the tensile strength of the fibers as well as the composites.
- BWK composites with NY stitch fibers had higher tensile properties than that with AR stitch fiber in wale testing direction. During tensile test of specimens with AR stitch fiber, the stress increased and decreased until ultimate failure of the composite. This showed that many small cracks occurred on the specimens with AR stitch fiber and this was reduced the tensile properties of the specimens. Also the lower volume fractions of weft fibers with AR stitch fiber compared to NY stitch fiber would be another reason of obtained lower tensile properties with AR stitch fiber.

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