TENSILE AND TEARING PROPERTIES OF BI-AXIAL WARP KNITTED COATED FABRICS

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Abstract:

Based on uni-axial tensile testing, the performances of bi-axial warp knitted PET/PVC flexible composites has been analyzed in seven in-plane directions, i.e., 0°,15°,30°,45°,60°,75° and 90°. The crack propagation of each sample has been observed and analyzed by evaluating the influence of the crack length and direction under uni-axial testing. The results show that bi-axial warp knitted coated fabrics present a strong orthotropic behavior and that the tearing strength depends on the initial crack orientation and length. Regardless of the crack length and orientation, the propagation is always perpendicular to the tensile loading direction.

Keywords:

Coated fabrics, flexible composite, bi-axial warp knitted fabrics, tensile

1. Introduction

Coated fabrics are widely used for permanent works in various applications such as sport stadiums, transportation and commercial constructions. Indeed, textile structures constitute an alternative to classical stiff roofs. Plain-woven fabric is the traditional reinforcement in flexible composites. Multiaxial non-crimp fabrics (NCFs) are a relatively new class of textile preforms for flexible composites that consist of multiple layers of fibrous yarns stitched together by warp knitting. The most commonly used types of NCFs are biaxial, triaxial and quadraxial fabrics in which straight, uncrimped yarns are aligned in the warp (0°), bias (30°< <90°) and/or weft (90°) directions to provide multidirectional in-plane properties. Some research work has been undertaken on the tensile and tearing behavior of flexible composites reinforced with woven-fabrics [1-3]. Only a few studies have been conducted on the mechanical performance of flexible composites reinforced with multiaxial NCFs [4,5].

This paper deals with the mechanical behavior of flexible composites reinforced by biaxial warp knitted fabrics for tents and outdoors purposes. The crack propagation strength of biaxial warp knitted fabrics of PET fiber coated with PVC is examined. Initially, based on uni-axial tensile experiments of bi-axial warp knitted PET/PVC flexible composites, tensile performance was analyzed in seven in-plane directions, i.e. 0°,15°,30°,45°,60°,75° and 90°. Then the failure mechanisms of samples, in particular evaluation of the influence of the crack length and direction under uni-axial test, has been observed and analyzed.

2. Materials and Experimental Methods

2.1. Materials

Three types of flexible composites reinforced with bi-axial warp knitted fabrics of PET fibers were studied. The structural parameters of the samples are listed in Table 1.

Table1. Structural parameters of samples

Parameter	Sample1	Sample 2	Sample 3
Fiber	Polyester	Polyester	Polyester
Yarn liner density (dTex)	500*500	500*1000	1000*1000
Density(warp*weft) (ends/inch)	9*9	18*12	12*12
Mass (g/m^2)	440	610	750
Coating material	PVC	PVC	PVC
Thickness(mm)	0.33	0.47	0.65

2.2. Experimental methods

Samples were cut in seven in-plane directions, i.e. 0°,15°,30°,45°,60°,75°and 90° with the weft direction as datum orientation (0°) for uni-axial tensile experiments (Fig.1). The tensile tests were carried out according to International Standard ISO1421, using a H100KS Hounsfield Universal Testing Instrument, with a cross-head speed of 100 mm/min. Three tests were carried out for each sample/angle. The dimensions of the samples are 400mm×50mm.

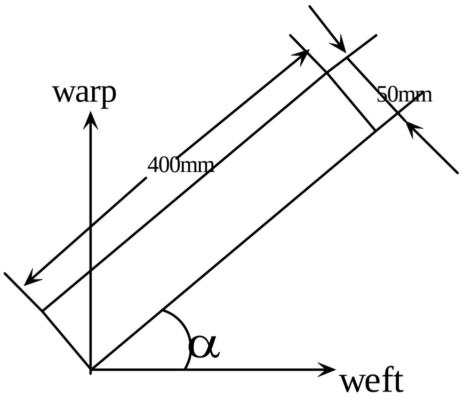
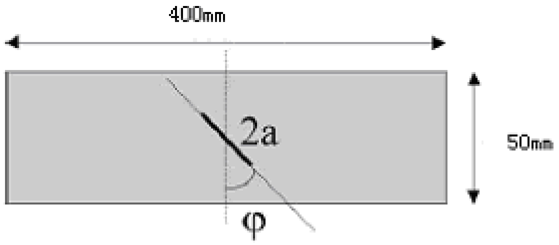


Figure 1. Samples for tensile testing

Tearing tests under uni-axial tensile were carried out on previously ripped samples cut in weft and warp direction and with a cross-head speed of 100mm/min. Initial crack lengths ranged from 5 to 20 mm (with a step of 5 mm) and their orientation ranged from 0° to 75° (with a step of 15°) (see Fig.2).



2a=5,10,15,20 mm, ϕ=0°,15°,30°,45°,60° and 75°

Figure 2. Tear sample configuration

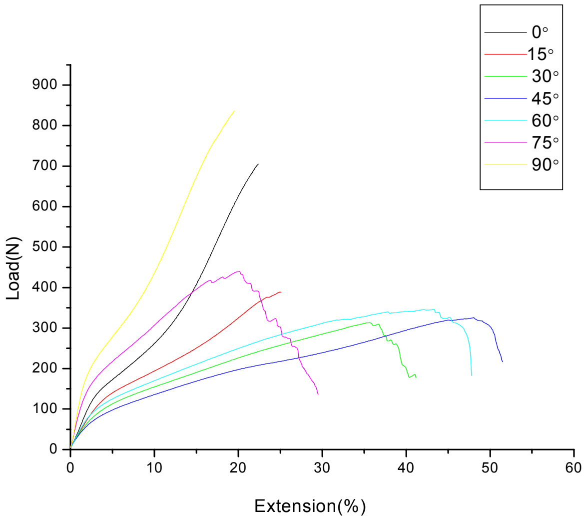


Figure 3. Stress-strain behavior of Sample 1 in different loading directions

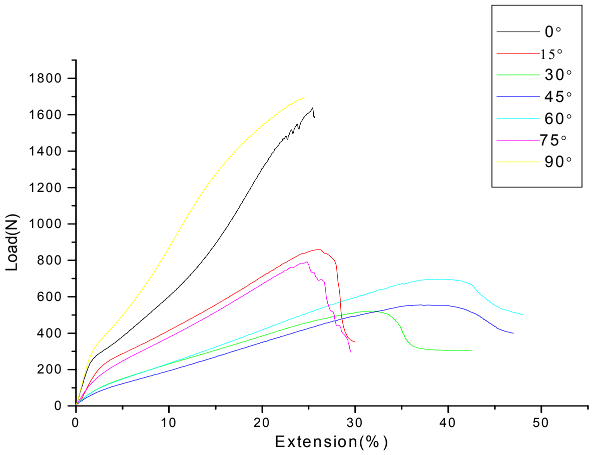


Figure 4. Stress-strain behavior of Sample 2 in different loading directions

3. Results

3.1. Tensile behavior

The typical stress-strain curves for samples 1 and 2 in different loading directions are shown in Figs. 3 and 4 respectively. It can be seen from these figures that the maximum stiffness is obtained at 90° (warp direction) and the lowest at 45°. The symmetry of the stress-strain curves for these flexible composite materials can also be seen in Figs.3 and 4. The load extension curves are quite similar at 0°and 90°, 15°and 75°, and 30°and 60° respectively. This can be explained by their quasi-equilibrium structure.

3.2. Tearing behavior under uni-axial load

The typical load-extension curves for tearing tests under a uni-axial load in the case of 2a=10mm and □=0° (warp direction) are shown in Fig. 5. Table 2 shows the results obtained in the tearing tests.

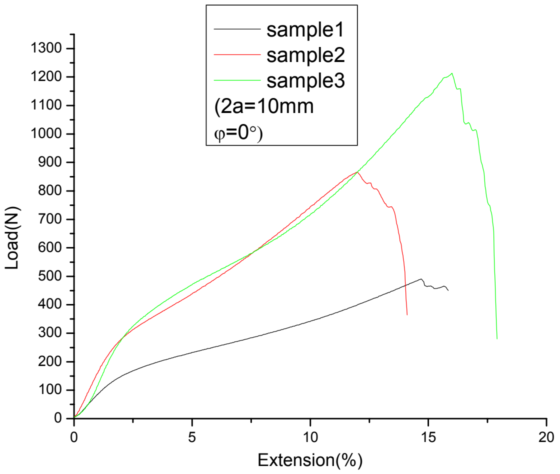


Figure 5. Tearing load-extension curves (warp direction)

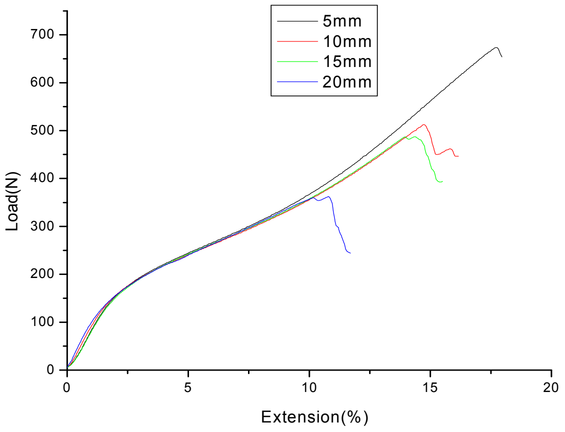


Figure 6. Tearing load-extension curves for different initial crack lengths for Sample 1

3.3. Influence of the initial crack length

The tearing load-extension curves for different initial crack lengths, oriented at zero degree, are given in Figs. 6 and 7 for samples cut parallel to the warp direction. The maximum force supported by a sample decreases with the increase of the initial crack length. The tearing strength of Sample 1 is lower than that of Sample 2 as the warp density of Sample 2 is higher.

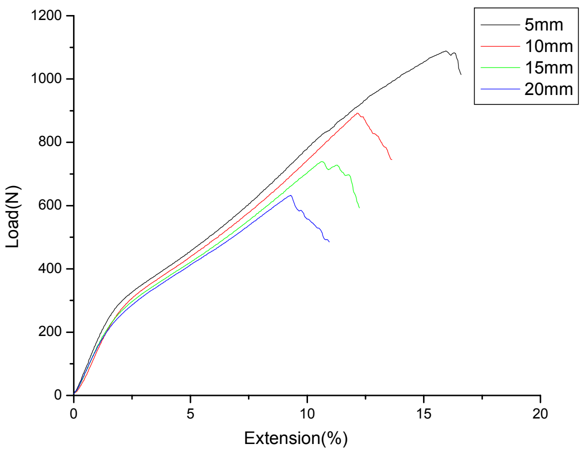


Figure 7. Tearing load-extension curves for different initial crack lengths of Sample 2

3.4. The influence of crack orientation

The influence of crack orientation is shown in Figs. 8 and 9. For a given crack length, it is observed that the maximum force supported by a sample increases with the increase in the crack angle. This is due to the fact that the number of cracked yarns decreases when crack angle increases Fig. 10 illustrates the crack propagation. For uni-axial tests, whatever the orientation of the initial crack is, the propagation is always perpendicular to the tensile loading direction. Consequently, only lengthwise yarns are broken, and the path is thus as energy- economical as possible.

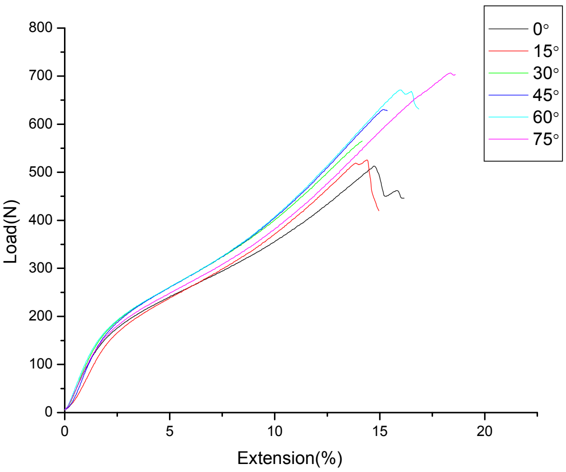


Figure 8. Crack orientation influence for Sample

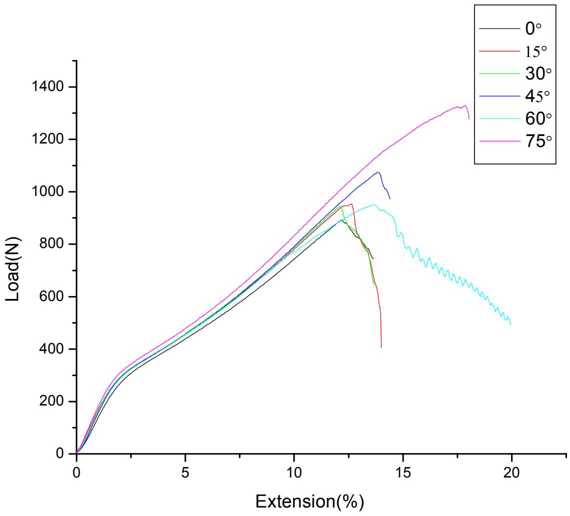


Figure 9. Crack orientation influence for Sample 2

Table 2. Tearing test results

Φ, °	2a, mm	Sample 1		Sample 2		Sample 3	
		Load, N	Extension, %	Load, N	Extension, %	Load, N	Extension, (%)
0	5	652.67		1096.67			17.62
	10	514.00	15.00	880.00	12.16	1218.00	15.87
	15	452.33	13.28	727.33	10.50	1037.33	13.77
	20	374.00	10.53	604.00	9.19	806.33	12.62
15	5	669.33	15.68	1170.67	14.11	1595.00	18.53
	10	525.67	14.33	945.67	12.45	1152.00	14.87
	15	437.18	11.62	792.00	10.41	1020.33	13.84
	20	360.13	10.22	650.00	9.37	848.00	12.66
30	5	687.00	15.77	1191.00	14.29	1564.33	18.45
	10	562.00	14.17	957.33	12.29	125.67	15.68
	15	462.00	12.06	836.33	10.52	1017.33	14.02
	20	375.87	10.47	695.67	9.49	877.33	13.41
45	5	699.00	16.15	1235.33	14.71	1628.00	21.30
	10	589.00	14.65	1026.00	13.32	1369.67	17.15
	15	511.83	12.49	889.33	10.97	1097.33	15.33
	20	444.50	13.06	757.00	9.81	1019.00	14.20
60	5	715.33	16.94	1384.00	16.83	1678.00	21.81
	10	654.67	16.02	1042.33	14.89	1489.33	17.65
	15	611.67	14.14	1026.00	12.20	1298.67	16.20
	20	548.00	13.11	929.00	11.44	1198.00	14.96
75	5	754.33	17.85	1518.67	20.37	1755.00	23.13
	10	718.33	18.02	1299.33	17.73	1623.00	20.81
	15	654.67	15.58	1201.33	14.68	1514.00	20.56
	20	652.33	15.35	1090.00	13.11	1481.00	18.73

Figure 10. Crack propagation

4. Conclusions

Tensile and tearing properties of PET fiber bi-axial warp knitted fabrics coated with PVC under uni-axial tensile loads have been presented. According to the experimental results and analysis, the following conclusions can be drawn:

(1) The tensile properties of PET fiber bi-axial warp knitted fabrics coated with PVC show strong orthotropic behavior. The highest stiffness and breaking strength occurs at 90° (warp direction), and the lowest at 45°.

(2) The tearing strength increases together with the increase of the initial crack orientation and decreases with the increase of the initial crack length.

(3) Regardless of the crack length and orientation, the propagation is always perpendicular to the tensile loading direction.

Acknowledgements

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References:

1. *D.Bigaud, C.Szostkiewicz, P.hamelin. Tearing analysis for textile reinforced soft composites under mono-axial and bi-axial tensile stresses, Composite Structure,62,129-137(2003).*
2. *C.Szostkiewicz, P.Hamelin. Numerical and experimental stiffness characterizations applied to soft textile composites for tensile structures. Mater Struct,31(206),118–25(1988).*
3. *Wei D, Wang C, Xiang Y, et al. Experimental study on material properties of structural fabric. Spatial Structures,8(1),37-43(2002).*
4. *Jiao W. H., and Chen N. L., Performance Advantages of Biaxial Warp Knitted Fabrics Used as Coated Substrates, Journal of Donghua University, 30 (6), 91-94 (2004).*
5. *Ning Y., Chen Nanliang, A Study on the Tensile Properties of Polyester Multiaxial Warp Knitted Flexible Composites, Technical textile Products, 8, 19-22 (2005).*

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