AUTEX Research Journal, Vol. 8, No1, March 2008 © AUTEX

TEARING PROPERTIES OF COATED MULTI-AXIAL WARP KNITTED FABRIC

Hong Hu and Ying Xu

College of Textiles, Donghua University
1882 West Yan An Road, Shanghai 200051, China
E-mail: huhong@dhu.edu.cn

Abstract:

In this paper, the tearing properties of a multi-axial warp knitted fabric produced with glass filaments and coated with PVC resin are presented. The typical tearing load-extension curves and influences of the different tearing testing conditions are analyzed. The results show that the tearing properties of the coated multi-axial warp fabric are different from those of the coated woven fabrics and that they depend on the tearing directions and tearing methods. The trapezoidal method and tearing tests along diagonal directions give higher resistance against tearing propagation.

Keywords:

Coating, tearing property, multi-axial warp knitting, tearing method

1. Introduction

Coated fabrics have widely been used in different fields such as transportation, protection, civil construction, sport, military and so on, due to their excellent flexibility and mechanical properties [5]. As a type of flexible composite, their resistance against tearing propagation is a very important property required by their end-uses, especially in some applications such as flexible roofing membranes, airship, inflatable boats, inflatable life-rafts, rescue tents, gas membranes, etc [4].

Traditional coated fabrics are based on woven structures. However, coated fabrics based on bi-axial or multi-axial warp knitted structures have been rapidly developing in recent years. Besides higher production compared to woven structures, the biaxial and multi-axial warp knitted structures also provide better mechanical properties in tension and tearing propagation resistance [1,3, 4].

In this paper, the tearing properties of a glass fiber multi-axial warp knitted fabric coated with PVC are presented.

2. Sample Preparation and Tearing Tests

2.1. Fabric

The fabric used was a multi-axial warp knitted structure as shown below in Fig.1. Its structural characteristics are shown in Table 1.

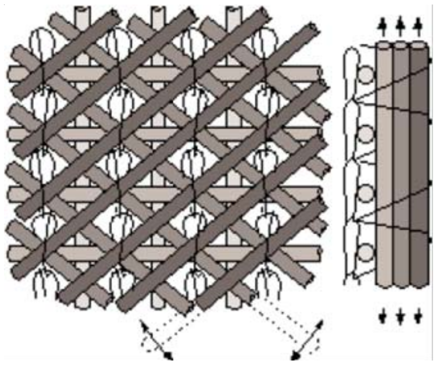


Figure 1. Multi-axial warp knitted structure

2.2. Coating

The coating was made on the laboratory coating machine JMU972, manufactured by the Beijing Textile Machinery Research Institute. The resin used was a commercial PVC P440 sold by Shanghai Tianyuan Chemical Company. The following coating conditions were used after a series of pre-tests in order to obtain the best coating quality:

Concentration of the resin: 80%
Coating thickness: 0.8 mm
Drying temperature: 160°
Time of drying: 10 min.

2.3. Tearing tests

Two tearing methods, trapezoidal and tongue tearing, as shown in Fig. 2, were used for the tearing tests. The

Table 1. Structural characteristics of the fabric used

Stitch yarn	Insertion yarns						Areal density g/m^2	Thickness mm
	Warp (0°)		Weft (90°)		Diagonals (±45°)			
	Fiber	Density bundles/cm	Fiber	Density bundles/cm	Fiber	Density bundles/cm		
150dtex PES filament	900 tex E-glass	4	750 tex E-glass	4	750 tex E-glass	5.6	923	1.20

trapezoidal and tongue tearing tests were respectively preformed according to the British Industrial Standard 3424 method 7A, and the Chinese Standard GB3918-83. The dimensions of the samples for these two kinds of tearing tests are respectively shown in Fig. 3, in which the clamping positions are presented by the discontinuous lines. Four different tearing directions, i.e. testing along 0°, 90°, ±45°, were selected. The testing machine used was a HD026N Dynamometer manufactured by the Nantong Hongda Textile Instrument Company. The rate of the mobile clamp was 100 mm/min. Five tests were carried out for each set of tests.

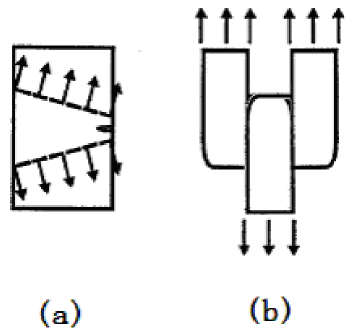
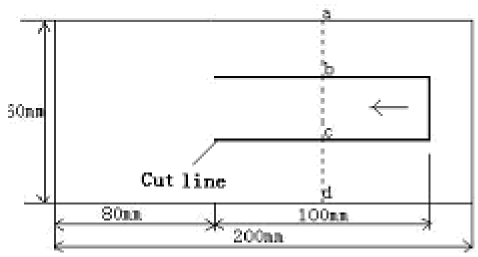
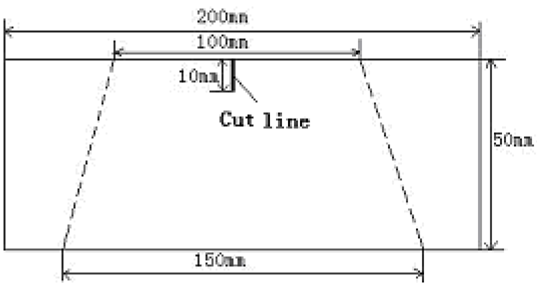


Figure 2. Different tearing methods (a)Trapezoidal, (b) Tongue Tearing



(a)



(b)

Figure 3. Dimensions of the samples (a) Trapezoidal, (b) Tongue Tearing

3. Results and Discussion

3.1. Typical tearing load-extension curves

The typical load-extension curves for the trapezoidal and tongue tearing tests are respectively shown in Figs. 4 and 5. Observing these figures, it can be seen that the loads for all the curves are not smoothly varied. They vary according to the saw tooth forms. This is normal because the yarns break one after other during tearing tests. Each time a breaking of the yarns takes place, a falling down of the loads cannot be avoided. It is necessary to point out that although the breaking of the yarn occurs, the general tendencies of the curves vary in an increasing fashion within a certain time after the commencement of the tests. The general tendencies of the curves only start to come down after maximal resistance has reached. This phenomenon is different from the previous tearing tests for coated woven fabrics, in which the general increasing tendencies of the curves were not observed following the first breaking of the yarns [3]. Because the insertion yarn layers in the multi-axial warp structure are not interlaced, they tend to bunch together during tearing action. The number of the yarns which can be bunched together directly influences the resistance of the structure against tearing propagation. Because the rate of the yarns bunching together is higher than that of the yarns breaking within a certain time after the commencement of the tests, a general increasing trend in the curves is obtained. However, after a certain time of testing, the number of the remaining yarns which can be bunched together in the sample is reduced. As a result, the resistance of the structure against tearing propagation begins to decrease. It is necessary to point out that the capability of the yarn layer to bunch together for a biaxial or multi-axial warp knitted fabric is strongly affected by the coating process. Coating will limit the slippage of the yarn during tearing tests. Previous studies have demonstrated that coating can result in a reduction of the tearing properties of both biaxial and multi-axial warp knitted fabrics[2,6].

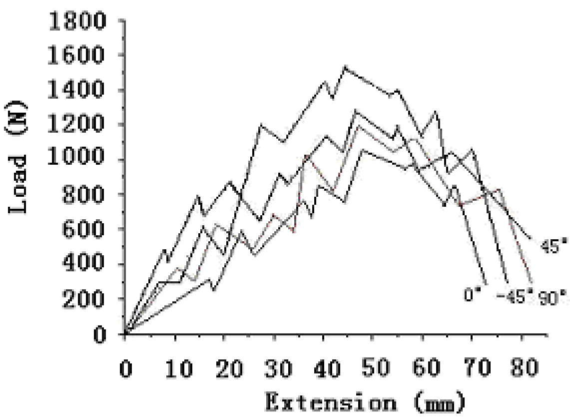


Figure 4. Typical load-extension curves under trapezoidal tearing testing condition

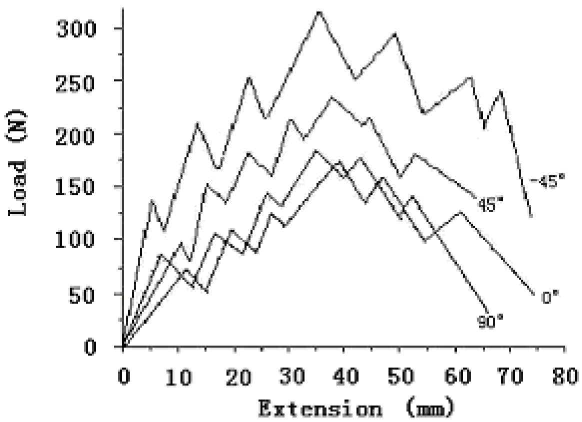


Figure 5. Typical load-extension curves under tongue tearing testing condition

3.2. Influence of the tearing directions

It can be also be seen in Figs.4 and 5 that the resistance against tearing propagation depends on the tearing directions. As stitch yarn is much finer than insertion yarn, the tearing properties of the coated multi-axial fabric mainly depend on the insertion yarn. As shown in Table I, the count and density of the insertion yarns are different in the warp, weft and diagonal directions. This leads to the difference of the curves along different tearing directions. The curves show that the maximum loads in the diagonal directions are higher than those in the warp and weft directions, especially in the case of tongue tearing testing. As shown in Fig.6 (a), when a tongue tearing test is made along the diagonal direction (+45°), the insertion yarns in the warp (0°), weft (90°) and other diagonal (-45°) will undertake the load. As the insertion yarns in the warp (0°) have a higher linear density, they will yield higher tearing resistance. The curves also show that even for diagonal directions a difference exists between +45°and -45°directions. Theoretically, the curves along +45°and -45°directions must be same because the tearing tests along these two directions are totally symmetrical. In fact, other factors in addition to the insertion yarns also influence the tearing properties, such as regularity of the yarn tension during knitting, quality of coated fabric, structural uniform of the yarn density, etc.

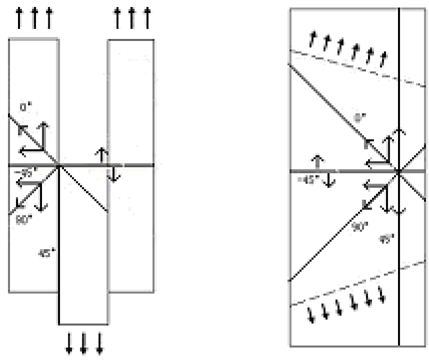
3.3. Influence of the tearing testing conditions

There is no doubt that the tearing properties also depend on the tearing testing conditions. Figs. 4 and 5 show that although the variation tendencies of the curves under the trapezoidal and tongue tearing tests are very similar, the tearing resistances are different in these two cases. The maximum tearing resistances under two tearing conditions along different directions are shown in Table 2. It can be seen from Table II that the maximum resistances under the trapezoidal testing conditions are much higher than those under the tongue tearing testing conditions. This reflects the fact that the manner by which the yarns undertake loads are different under the two tearing testing conditions. In the case of the trapezoidal testing condition, the insertion yarns parallel to the tearing direction can directly undertake the loads along the their axial direction, as shown in Fig. 6(b). This considerably increases resistance of the structure against tearing propagation.

Table 2. Comparison of the maximum resistance between the two tearing methods

Tearing method	0°	+45°	-45°	90°
Trapezoidal (N)	1069.45	1237.42	1539.63	1226.58
Tongue (N)	171.53	241.70	303.07	119.10

The failure modes are also different in the two tearing tests. As shown in Fig. 7, under the trapezoidal tearing condition the failure mode is characterized by breaking of all the yarns. However, under the tongue tearing condition, the failure mode includes, in addition to yarn breaking, separation of the yarn layers. In this case, the strength of the stitch yarn is important in order to enhance the resistance of the structure against tearing propagation.



(a) (b)

Figure 6. Tearing propagation resistance of the yarns in different directions (testing along +45º)
(a)Tongue tearing, (b)Trapezoidal tearing

(a) (b)

Figure 7. Tearing failure modes
(a) Trapezoidal, (b) Tongue Tearing

4. Conclusions

The tearing properties of glass fiber multi-axial warp knitted fabrics coated with PVC are presented. According to the experimental results and analysis, the following conclusions can be formulated:

1) The variation tendencies of the load-extension curves during tearing tests for coated multi-axial warp knitted fabric are different from those of the coated woven fabrics. Although the yarns break, the general tendencies of the curves vary in an increasing fashion within a certain time after the commencement of the tests, due to the yarn bunching together.

2) The tearing properties of coated multi-axial warp knitted fabric depend on the tearing testing direction and tearing methods. The trapezoidal methods and tearing tests along diagonal directions yield a higher resistance to tearing propagation.

Acknowledgement

The work reported here was funded by a project from the Ministry of Education of China designed to enable persons returning from abroad to implement their research work.

References:

1. *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).*
2. *Liu R. H., Study on the Mechanical Properties of the Multi-axial Warp Knitted Flexible Composites, Master Thesis, Donghua University (2005).*
3. *Ning Y., Chen Nanliang, A Study on the Tensile Properties of Polyester Multi-axial Warp Knitted Flexible Composites, Technical textile Products, 8, 19-22 (2005).*
4. *Raz S., The Karl Mayer Guide to Technical Textiles, edited by Karl Mayer Textilmaschinenfabrik GmbH, Obertsgausen (2000).*
5. *Sabit A., Wellington Sears Handbook of Industrial Textile, Western Hemisphere by Technomic Publishing Company, Pennsylvania (1995).*
6. *Xu Y., Mechanical Properties of the Directionally Oriented Warp Knitted Flexible Composites, Master Thesis, Donghua University (2006).*

∇∆