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PUNCTURE AND TEAR OF WOVEN FABRICS

Dr. Anthony Primentas
Associate Professor
Department of Textile Engineering, TEI of Piraeus

ABSTRACT

The quite often contact of textile goods with sharp objects, results in the puncture and in many cases the tear of the textiles. Thus, the determination of the tearing strength of textile articles occupies a very distinctive position among the various textile quality control tests. The existing device-method presupposes an initial cut in the testing area of the specimen. The lack of a device simulating the accidental combined puncture and tear of a fabric was fulfilled with the development of the apparatus COMPUTE. The impact angle and the mass of the falling puncture tool that causes the tear of the fabrics are the main variables that this apparatus possesses. In this project, the effect of these two variables on the tear propagation length of woven fabrics is investigated.

KEYWORDS: Puncture, Tear propagation, Woven fabrics, Quality control testing device

1. INTRODUCTION

It is well known that the textile quality control has become of increasing interest and the quality assessment of textiles is of vital importance for both manufacturers and consumers. An increased number of knowledgeable consumers with firm demands for specific performance behaviour and longer life textile goods, in combination with the numerous advances in technology, have made essential the better understanding of other, unknown a few years ago, properties of fibres, yarns and fabrics. This can be achieved by evaluating these properties in a more intensive kind. It is, therefore, necessary to develop and use suitable devices that obtain reliable testing methods of the quality characteristics of the various textile products.

1.1 Tearing of Fabrics

A common type of failure in textile fabrics and consequently a serious defect (with a few exceptions like bandages and adhesive tapes) is their tendency to tear easily. It may be described as the sequential breakage of yarns or groups of yarns along a line through a fabric. The tearing strength, that is usually measured as the force required to propagate a tear, may often be used to give a reasonably direct assessment of serviceability, and a fabric with low tearing strength is generally an inferior product. In contrast to the tensile strength, that involves the force required to break a large number of yarns simultaneously, and is relatively insensitive to yarn and fabric structural parameters, the tearing strength is considerably affected by changes in yarn and fabric geometry, the state of relaxation of the fibres and their frictional characteristics [1].

The ISO standard 4674 [2] specifies three methods used for the measurement of tearing strength. These methods, applicable mainly to coated fabrics are: the test using three-tongued test piece, the test using trouser-shaped test piece (well known in the USA as a “tongue tear”), and the tear with falling pendulum. In the “tongue tear”, an initial longitudinal cut is made part way down the centre of a strip and then the two “tails” thus formed are pulled apart, so that a tear proceeds through the uncut portion of the fabric. This test imitates quite closely the type of failure that occurs when one tears a piece of fabric or paper by hand.

A well-known fabric-tearing tester is the ballistic instrument Elmendorf (falling pendulum) that is based on the tear propagation of a specimen that was initially cut [3]. The recently developed Elmatear [4] device automatically calculates the tearing strength of the fabrics and presents the results in grams (g) or Newton (N). Its advantage is the operator’s safety that is assured with the special mechanism of pendulum release.

1.2 Puncture and Tear Testing

A frequent phenomenon that occurs during the use of the garments by the wearers is the accidental contact with sharp edged objects. Normally the wearer having had no clear sense of the incident, i.e., the catch of his garment by such an object, applies more power to be released. This action causes the sharp edged object to penetrate into the garment causing puncture and consequently tear of it.

For the determination of puncture and tear resistance of flat flexible materials, the only existing method is the ASTM D-2582. This method however has been designed for thin plastic sheeting and therefore it is not suitable for the complex variety of materials used in clothing and especially the protective ones.

Due to the lack of suitable specific test methods, simulating the combined dynamic actions of puncture and tear, the approach of protective clothing standardisation to date was to consider the mechanical actions of puncture and tear separately. This splitting up of mechanical hazards however is artificial and may thus lead to false results and unrealistic specifications of the materials.

The results of a textile literature survey, concerning a special device used for the examination of the fabric resistance to tear with no previous cut made by the operator, were not so encouraging. It is well known that in order tear to occur in a fabric, this has to start from its edges, unless a sharp edged object punctures the fabric. Therefore, it was considered as necessary to develop a new instrument and a suitable testing method for the determination of the behaviour of materials in the combined puncture and tear propagation in woven and non-woven fabrics. On this device, materials that are used for the manufacture of casual cloths as well special protective garments could be tested. The testing procedure as well as the principle of the device that is based on the ASTM D-2582 method is a simulation of the real risks and various conditions that garments are exposed.

2. COMBINED PUNCTURE AND TEAR APPARATUS (COMPUTE)

The “COMbined PUncture and TEar” device was developed under the framework of the European funded programme STM (Standard and Testing Measurement) during the years 1998-1999. Researchers from seven (7) European institutions (SATRA - England, CENTEXBEL - Belgium, ITF - France, FIOH - Finland, RICOTEST - Italy, ZS - Germany, ELKEDE - Greece) were collaborated for the development of the device and the testing method.

2.1 Description of the Apparatus

The apparatus consists of two main parts: the rigid frame (Figure 1) and the frame for holding the fabric specimen (Figure 2).

Figure 1: COMPUTE Apparatus

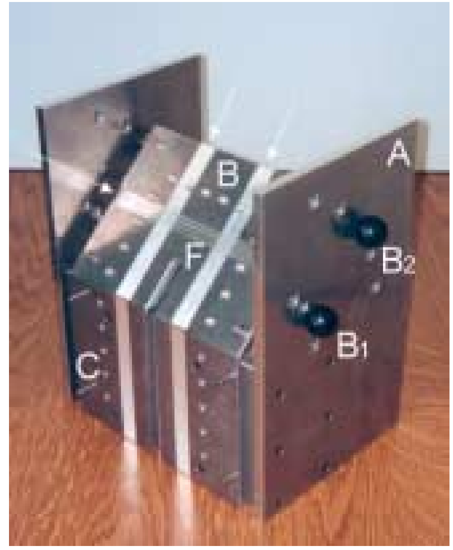

Figure 2: Specimen Holding Frame

2.1.1 Specimen Holding Frame

The front part of the frame (Figure 2) consists of two plates B, C. The plate C is fixed on the frame whereas the plate B can change angular positions of 15°, 30°, 45°, 60°, 75° ("impact angle"). The plate B is in position with the two rods (B_1, B_2) that passing through holes of the sides A of the frame. The specimen is placed on the surfaces of both plates. On the top of the specimen, two small plates are placed on the upper plate B, whereas another two similar plates are placed on the lower plate C of the frame. All the plates above and beneath the specimen have special grooves (white arrows) that assist the specimen to be tensioned evenly in both directions (lengthwise and width wise). An opening F on both plates B,C is made for the passage of the dropping edge of the puncture tool.

2.1.2 Rigid Frame of the Apparatus

In the front of the rigid frame (Figure 3) there are two cylindrical rods (U), parallel to each other, on which the puncture tool carriage (W) is travelling. Another two rods (T) are located in the front side of the rigid frame. On these rods, two sensors (S) have been placed in a distance of 40 cm apart. The lower sensor is placed very close to the region where the puncture tool comes in contact with the surface of the specimen. On the other rod, a scale has been placed for direct readings (in mm) of the tear length. For easier reading a metallic pointer (P) has been adjusted on the carriage.

The carriage (W) of the puncture tool (Figure 3) is made of light plastic material. There are two holes through which the two cylindrical rods are passing. Thus the loss in energy due to friction of the carriage on the rods is considered as negligible. Beneath the carriage the puncture tool is fixed. The two types of tools, the nail (I) and the knife (II) are shown in Figure 4.

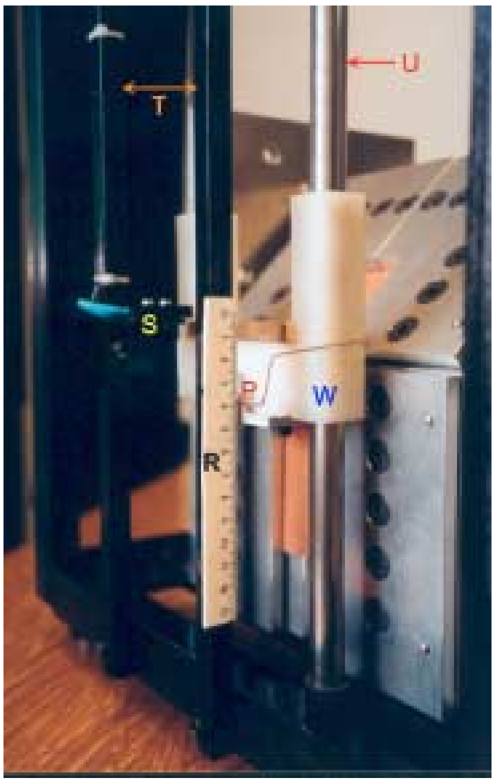

Figure 3: Front of Rigid Frame

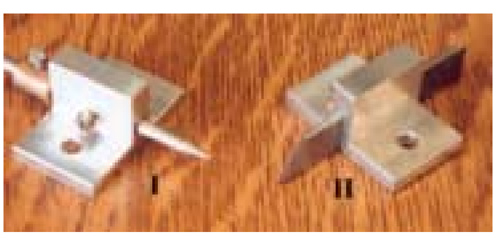

Figure 4: Types of Puncture Tool

2.1.3 Settings of the apparatus

For technical and practical reasons [5], the dropping velocity of the carriage was set at 3.5 m/sec for a falling height of 62.5 cm. (Tables I.) The time needed for the dropping carriage to cover the last 40 cm of this height was 0.14 sec.

Carriage **Velocity** at the impact	3.50 m/sec
Total **height** of carriage fall	62.50 cm
Time for the last 40 cm of height	0.14 sec
Mass of the falling carriage with the “knife” puncture tool	202.42 g
Energy of the falling carriage with the “knife” puncture tool	1.25 Joule

Table I: Settings of Device

2.2 Calibration of the Apparatus and Testing Procedure

Before testing it is necessary to calibrate (adjust) the pointer (P) on the right side of the carriage (Figure 3) on the scale of the device. The steps are:

i. The specimen to be tested is placed on the specimen frame (Figure 5). The frame is placed in its position in the rigid frame of the apparatus.
ii. With much care, the carriage (W) is lowered manually up to the point where the sharp edge of the puncture tool comes in contact with the surface of the mounted specimen (A) (Figure 6). Then adjustment of the pointer (B) on the zero (0) indication of the scale (R) of the device takes place. The carriage is returned to the starting position on the top of the rigid frame and secured for the testing.

After its release, the carriage drops and after the instantaneous puncture, it tears the specimen up to a point. The reading of the carriage pointer on the scale is recorded. The tests where either no puncture and tear, or a total tear of the lower part of the fabric specimen occur, are considered invalid. The proper adjustment of the weight placed on the carriage is made and the test is repeated.

Figure 5: Specimen on Holding Frame

Figure 6: Calibration of the Apparatus

2.3 Measuring Technique

Fabric specimens cut in warp and weft directions generally show **straight** tear whereas specimens cut in a bias direction mainly present a **V-shaped** tear. In the case of a straight tear, the measurement of its length can be obtained directly from the reading of the apparatus scale. In the event of a V-shaped tear, the total tear length is calculated by adding the two straight lengths of its sides [5] measured by a calibrated ruler, after the removal and relaxation for 24 hours of the specimen from its holder (Figure 7).

Nevertheless, the results of preliminary experiments [6] examining various coated and non-coated woven fabrics showed that there was an error in measuring the straight tear length from the scale of the instrument. Following the tear of the specimens, the puncture tool, by pushing down the fabric in the lowest part of the tear due to its carriage weight, was responsible for an increase of the tear length, resulting in wrong readings. Therefore it was considered as necessary to measure the straight tear length by a calibrated ruler, after the removal and relaxation of the specimen for 24 hours.

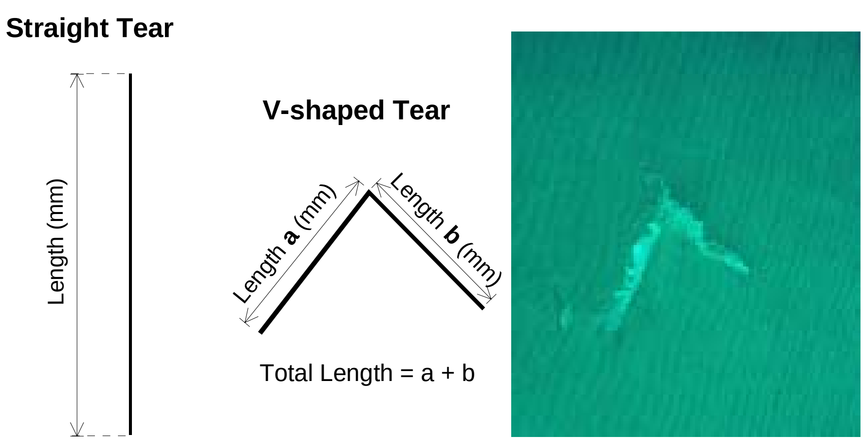

Figure 7: Methods of Tear Length Measurement and a V-shaped Torn Fabric

3. EXPERIMENTAL

For the purpose of an experiment concerning the effect of the impact angle and the weight of the puncture tool carriage on the tear propagation, specimens (210 mm × 105 mm) of a 24-hour normally conditioned lining fabric were cut. The five (5) different impact angles (15°, 30°, 45°, 60°, 75°) of the specimen holding frame were used. The puncture tool had the shape of a knife. In the first set of experiments, the total weight of the carriage was 202.42 g that corresponded to energy of 1.25 J. Using an extra suitable weight (42.77 g), the total mass of the carriage was 245.19 g, corresponding to energy of 1.50 J. For each of the ten (10) combinations obtained (five (5) different angles with the two (2) different carriage weights), five (5) fabric specimens cut in each of the warp, weft and a bias directions were tested. The results are shown in the Table 2 and Figure 8.

Energy (J)	1.25	1.50	Differ.	1.25	1.50	Differ.	1.25	1.50	Differ.
Angle	**Warp-wise**			**Weft-wise**			**BIAS**		
15°	*55.5*	*72.0*	***16.5***	*72.0*	*110.0*	***38.0***	*47.0*	*49.0*	***2.0***
30°	*52.5*	*67.0*	***14.5***	*83.0*	*103.0*	***20.0***	*55.0*	*56.5*	***1.5***
45°	*45.0*	*59.0*	***14.0***	*79.0*	*96.5*	***17.5***	*52.5*	*58.5*	***6.0***
60°	*46.0*	*52.0*	***6.0***	*68.5*	*78.5*	***10.0***	*47.5*	*55.5*	***8.0***
75°	*35.0*	*42.5*	***7.5***	*52.5*	*64.0*	***11.5***	*48.5*	*53.5*	***5.0***

Table 2: Mean Values of Tear Length Measurement (mm)

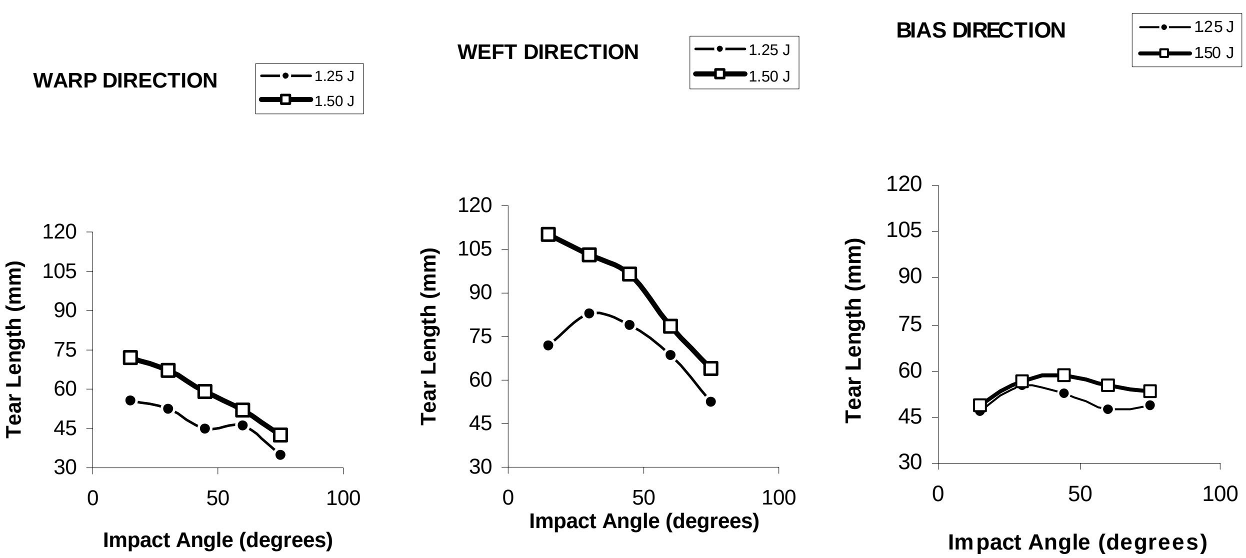

Figure 8. The Effect of Impact Angle And Carriage Weight on the Tear Length

4. DISCUSSION

The statistical method of “Two-way classification with replications” [7] was adopted for the assessment of the results that include the tests of significance.

For all the specimens cut along the warp, weft and bias directions, it can be seen from Table 2 that the impact angle affected significantly the tear length (tear propagation).

In fabrics cut along the warp direction, with increase of the impact angle, a reduction in the tear length was observed. Thus the smaller the impact angle the longer the tear. Furthermore, the significance of the carriage weight on the tear length can be statistically proved. An increase in tear length occurred as the weight of the carriage became heavier with the same manner as previously, i.e., the smaller the impact angle the longer the tear. On the other hand the interaction between impact angle and carriage weight was found no significant.

The significance of the carriage weight on the tear length was also proved. An increase in tear length occurred as the weight of the carriage became heavier. The tear length had an upward trend up to the impact angle of 45°, followed by a downward trend. From the statistical analysis it was found that the interaction between the impact angle and the carriage weight was significant at the level of 5% significance. Using the Least Significant Difference it was found that only in the cases of the impact angles of 45°, 60°, and 75°, the tear length was significantly longer due to the increase of the carriage weight. In particular, the greatest effect was in the case of the impact angle 60°.

5. CONCLUSIONS

In the present paper, the developed COMPUTE device, used for testing the combined puncture and tear propagation of fabrics, was presented in detail.

As the fabric samples cut along the weft direction were concerned, within the first increment of the impact angle, an increase in the tear length was observed. In the next impact angle increments, the graph of the length readings followed the trend of the graph of the heavier carriage. From the statistical analyse, it was found that the interaction between the two parameters was significant at the level of 5% significance. Using the Least Significant Difference, it was found that in any increase of the impact angle, the tear length was longer due to the increase of the carriage weight, but the effect was the greatest particularly in the case of the lowest (15°) impact angle.

For the fabrics cut in a bias direction, in the case of light carriage weight within the first increment of the impact angle, an increase in the tear length was observed. In the next increments of the impact angle, the graph of the length readings followed a diminution trend.

Due to the fact that the method and the device is still in the primary stage of development, an effort was made to understand mainly the parameters of the apparatus affecting the tear propagation of woven fabrics.

The effect of two device parameters, the impact angle and the puncture tool carriage weight, on the length of the tearing was investigated. It could be statistically concluded that the longer tear length occurred when the weight of the puncture tool carriage became heavier and the impact angle was small.

In the near future various fabric parameters will be investigated regarding their effect in the tearing propagation that occurs using the COMPUTE device.

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AUTHOR
Dr. Anthony Primentas
Department of Textile Engineering
Technological Education Institute of Piraeus
250, Thivon & P. Ralli, 122 44 Athens, Greece
aprim@teipir.gr