TEARING BEHAVIOUR OF FABRIC USING VARIOUS TESTING

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Abstract: For a textile product, its serviceability is often likely determinates by the physical performance. Among various kinds of physical behavior, tearing and tensile are two main domains of interest of research. However, only rupture caused by tearing is much more closely related to real life usage. Previous researches and studies all showed that tearing of textile is a complicated phenomenon. In this paper, ISO standards 13937 part 1 to 4 was used for determining of tear force of fabric samples. The Elmendorf, Trouser, Wing and Tongue tear were used for testing chosen fabrics. The results of each test were compared and it was found that no abrupt variation of results of the same fabric obtained from each type of the test can be seen.

1. Introduction

Textile materials fail in service for a number of reasons, depending largely upon the type of use to which they are put [1]. Among various kinds of physical performance, tear resistance and tensile properties are two important determinants. It is well known that a tear frequently terminates the service life of a garment or textile item. Either because the repair cannot be made economically or the original appearance of the garment cannot be restored. Considerable importance is to be associated with the tearing strength, or resistance to tearing rather than tensile properties, of fabrics whose service life exposes them to this kind of damage, as a fabric has s much greater tendency being torn and it is much more related to real life usage of the article.

Most clothing and textile products fall into these categories that are readily prone to tear [2]. In addition, the quality control of textile has become a vital importance for both consumers and manufacturers. And there is an increase in the proportion of knowledgeable consumers often requires better performance and even longer product life [3]. It implied that, tearing is not merely a physical test for woven fabric. Follow the line of reasoning, a common type of failure in textile especially for woven fabric is the tendency to tear. The general concept is that the sequential breakage of yarns or groups of yarns along a line of the direction being torn through a fabric. The tearing strength may be used to give a reasonably direct assessment of serviceability, and a textile fabric with low tearing strength is generally regarded as inferior product.

2. Experimental

2.1. Material

Nine commercial woven fabrics were tested. They were of different structural parameters and their detailed specifications were shown in Table 1. All fabrics were cut and prepared according to BS EN ISO 139 – 2005 (Standard atmospheres for conditioning and testing). The standard defined the characteristics and use of a standard atmosphere for conditioning, for determining the physical and mechanical properties of textiles and a standard alternative atmosphere that may be if agreed between parties. The standard atmosphere was 20.0 ± 2.0ºC and a relative humidity of 65 ± 4.0%.

Table 1: *Specification of samples*

Fabric Code	Thickness (mm)	Weight (g)	Fabric sett (yarns/inch) (warp/weft)	Types
A	0.364	1.4338	65/51	Four-Point Star
B	0.320	1.1868	269/127	Taffeta
C	0.470	1.6549	112/78	Jacquard
D	0.340	1.3711	67/54	Twill
E	0.170	1.0032	142/86	Coated
F	0.820	1.6539	65/48	Special
G	0.260	1.2481	85/70	Plain
H	0.360	1.3739	70/56	Twill
I	0.360	1.2533	90/78	Plain

2.2. Tearing resistance test

The fabric samples were tested based on BS EN ISO standards 13937-2000 which consists four tests: (i) Test 1: Determination of tear force using ballistic pendulum method (Elmendorf); (ii) Test 2: Determination of tear force of trouser-shaped test specimens (Single tear method); (iii) Test 3: Determination of tear force of wing-shaped test specimens (Single tear method) and (iv) Test 4: Determination of tear force of tongue-shaped test specimens (Double tear method)

3. Results and Discussion

3.1. Overview of Four types of Test (Elmendorf, Trouser, Wing and Tongue Tear)

After tested all the nine samples, there are two groups of fabric in terms of tear strength can be observed. For Fabric C and F are regarded as group of high tear resistance. The remaining Fabric A, B, D, E, G, H and I are the group of low tear resistance. Similar results on both warp and weft sides of fabric samples as shown in Figure 1. Therefore, we used Fabrics A, C and F as illustrating samples for discussing the tearing behaviour under different tests.

3.2. Tearing behaviour of fabric with low tear resistance (e.g. Fabric A)

For Fabric A, Elmendorf tear provided the highest results then the other three methods which are similar. There is a greater variation of the results of Trouser tear; the least variation is from Elmendorf test as shown in Figure 2. The results of the Elmendorf tear should be lower than the other three tests. The falling pendulum tears the fabric in the fastest way so yarns within the fabric will have little time to slide and prone to tear readily. So, the results will be lower for most of the cases. The fabric sett of Fabric A is not high and the yarn strength is high, so it is not so easy to break a yarn in this fabric. When tear Fabric A with the Elmatear, some of the specimen were not completely torn due to puckering effect (Figure 3). Progressively increase in resistance to withdrawal of yarns may result from puckering of the fabric along the line of yarn movement [4]. Such a resistance appears in some specimens lead to the rupture of the partially withdrawn yarn (being pushed out by the pendulum, while in other cases sudden partial or complete release of the yam occurs before the point of rupture is reached. As a result of the measurement, the kinetic energy needed for the sample tear test along the initially cut distance is given. It is determined by the measurement of work done during the sample tear test on the tearing distance, the effect of yarn withdrawal is generally increasing force recorded by the testing machine, since the forces involved in the withdrawal (frictional force) are superposed upon those arising from the proper tearing situation. The length of record affected by withdrawal is frequently uncertain, since the magnitude of the forces involved depends upon the sequence of events attending the movement of the yarn. Observation of the specimen during tearing or inspection later will usually reveal whether or not yarns have been withdrawn rather than ruptured. Where yarn withdrawal is happened on the specimen, that particular specimen would be discarded. The experimental evidence suggests that more than one mechanism may contribute to the variations in tearing force resulting from yarn withdrawal.

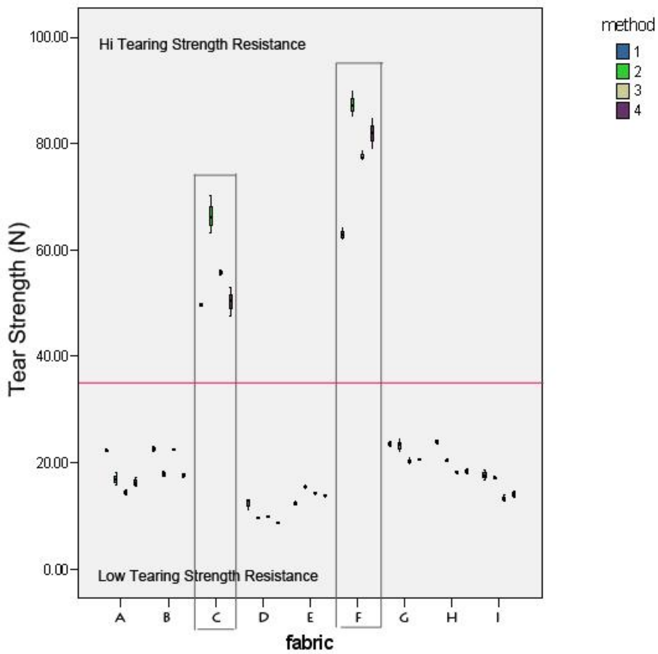

Figure 1: *An overview of the results of all samples on warp side*

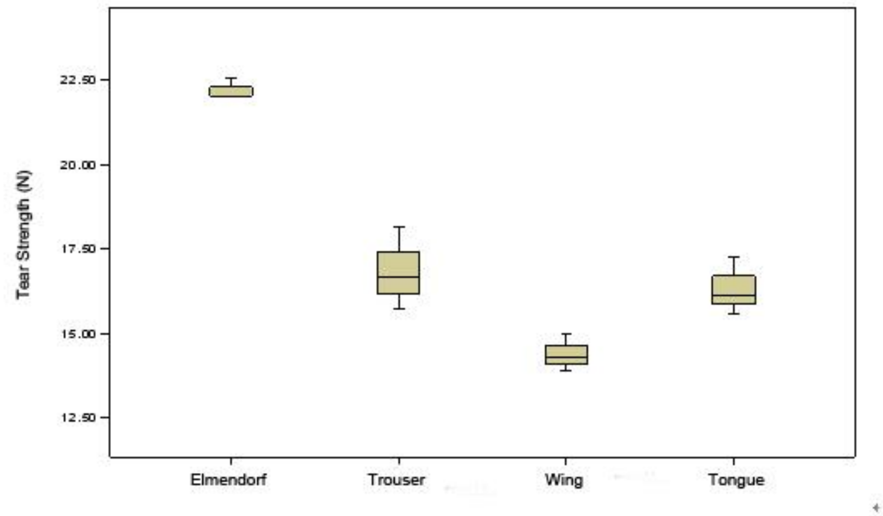

Figure 2: *Tearing strength of Fabric A tested with the four methods*

Figure 3: *Puckering of specimen*

3.3. Tearing behaviour of fabric with high tear resistance (e.g. Fabric C)

Fabric C is a jacquard fabric, the density is high of the two principle directions. Although the yarn strength is not so high, even lower than yarns of Fabric A, Fabric C has a higher resistance than A, nearly 50% higher as shown in Figure 4.

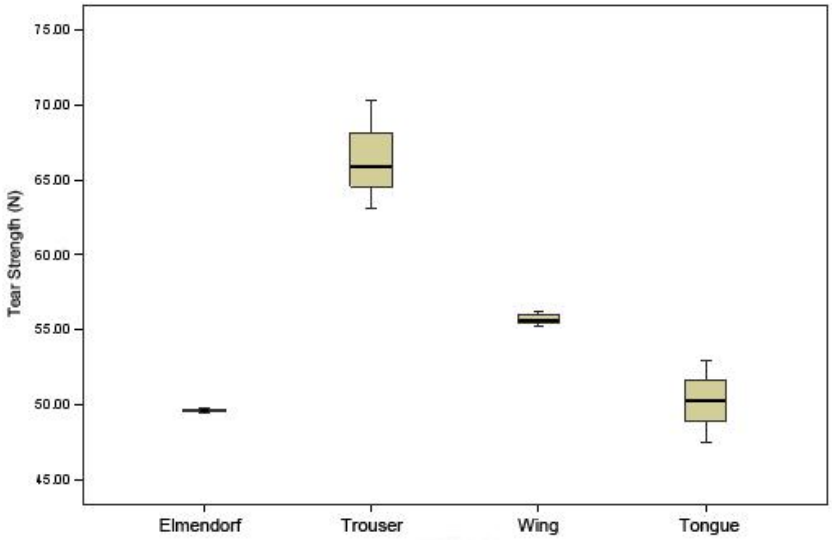

Figure 4: *Tearing strength of Fabric C warp tested with four methods*

The jacquard pattern is made by complex arrangement of warp and weft yarn. When cutting out specimen of a jacquard fabric, it is very likely to have each specimen different from the other of the fabric structure. In addition, when tearing jacquard fabric, because of the yarns were arranged differently from a plain or a twill fabric, it is difficult for a pendulum to break all the yarns at the same time. Furthermore, complex constructions also facilitate aggregation and sliding of yarns. It is very often for jacquard fabric to yield higher resistance results than the plain or twill fabrics. The results provided from Elmendorf are lower than the other three parts of the tests. So, it complies with the theoretical observation.

On the other hand, the greatest results variation is obtained from Trouser tear. The logic is that, trouser tear is a single rip test and the tearing direction and the clamping of samples on the machine is the same (very different of wing tear), it is easy for yarns withdrawal at the edge of the samples and complex construction structures also explain why the variance of Fabric C is high.

3.4. Tearing behaviour of fabric with high tear resistance (e.g. Fabric F)

Fabric F is a slack, bulky and with a special construction structure. The major reason to explain such a high resistance value to tear is its fabric construction. Yarns itself are inherently strong, they are rather free to slide and thus being readily conjugating with each other. Conjugated yarns often required much higher force to break them at once. Results of Elmendorf tear are lower than the other three parts of test for Fabric F (high tear strength fabric). It is reasonable to conclude when tear high tear resistance fabric (C and F) by Elmendorf, the results would give lower results which comply with as shown in Figure 5.

When investigate Fabric A, C and F again, another conclusion can be drawn is that the variance of Wing tear is lower. It is very much closely related to the direction of tear and the direction of clamping specimen on the machine. For Elmendorf, Trouser as well as Tongue tear, the direction of tear and clamping of specimen were parallel, whereas for Wing tear, the tear direction and the direction of clamping is projecting as perpendicular. The experimental procedure of the wing method, suffer least from complications arising from the tearing behavior of certain fabrics. This distinctive feature of Wing tear can hold all the yarns in position much better; it is difficult for yarns to slide and became conjugated at the edge of the specimen, thus less chances for a specimen not being completely torn than the other method.

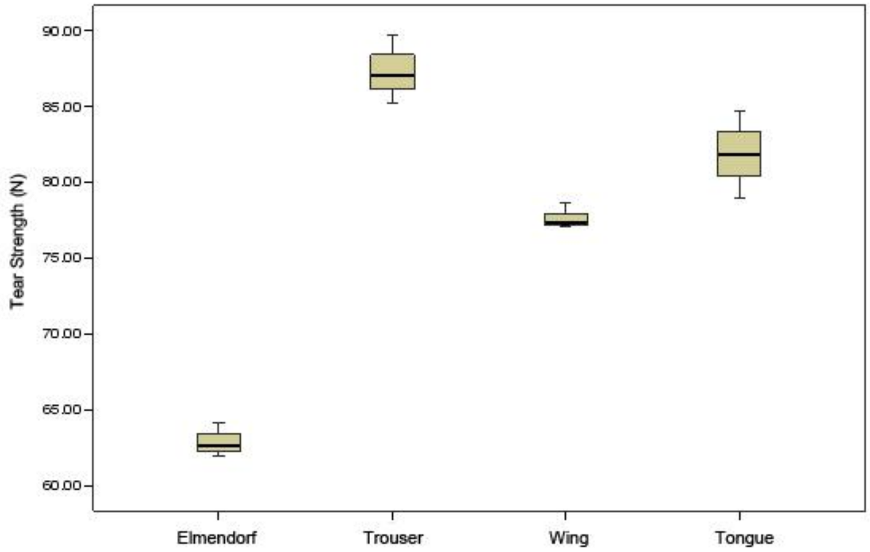

Figure 5: *Tearing strength of Fabric F tested with fours methods*

4. Conclusion

With refer to the sett of fabrics, the warp density is always higher than the weft side. The greater the difference in warp and weft yarn density, the greater the difference in tearing resistance. Fabric C and Fabric F's results were higher than the other. Fabric C was a heavy weight jacquard fabric. Each specimen is believed to be varied from each other, due to the versatile and complex construction of the fabric to produce the pattern. So, each testing sample of Fabric C is different. The general feature of the results of Fabric C is high in tear resistance. The ever changing position of warp and weft yarn implies that both the warp and weft yarn are resisting the falling pendulum at the same time. For Fabric A, a low mobility fabric with very high sett in both direction, especially in the warp side (269 yarns/ inch). When tearing the fabric, the transfer of load from yarns near the edge can lead to high stress concentrations. A similar case described by Hager [5]. For Fabric F (bulky, slack with high mobility and low extendibility of yarn) the tear mechanism of it is similar with the situation depicted by Hamkins and Backer [6]. The observation was that warp yarn would come together along two sides of the slit then the load built up in the transverse yarns was attributed to the frictional grip of the longitudinal yarns and the extension of the transverse yarn were at the very low extend (3.57% and 4.36% for warp and weft yarns). Despite the yarns were not so extend in nature, they could find their way out to encounter the fallen pendulum. As the fabric is so slack, when testing across warp direction, those weft yarn was being "push out" in the del area by the pendulum (edges of cut specimen is free of anything). Furthermore, the filling yarn can also move together at the bottom of the del area as there are lots of space for them to slide and escape from the external force. The filling yarn being "pushed out" from the warp yarn, it is actually generating friction with the warp yarn. Meanwhile, the del area is occupied by all the filling yarn sliding from above and it can hold no more, tearing of the transverse yarns is started at that moment. So, the tearing strength recorded for both side are quite high due to the fact that yarns are free to slide and have time to adjust their position.

In loosely constructions and those with fewer interlacing, where the yarns can easily move and bunch together, there is a higher resistance to the applied force because several yarns must be broken simultaneously. Consequently, Fabric F has a higher tearing strength. For instance, in high-mobility fabrics, slippage could greatly change the geometry, and hence the tear strength and even the direction of tear are especially important for analyzing tongue tear. In conclusion of the fabric process high mobility of yarn, slippage of yarns could greatly changed the geometry, and hence the tear strength, and even the direction of tear.

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References

[1] Krook, C.M.; Fox, K.R.: Study of the tongue tear test, *Textile Research Journal*, **15** (1945) pp. 389-396.

[2] Turl, L.H.: The measurement of tearing strength of textile fabrics, *Textile Research Journal* **26** (1956) pp. 169-176.

[3] Primentas, A.: Puncture and tear of woven fabrics, *Journal of Textile and Apparel, Technology and Management*, **1** (2001) 4, pp 1-8.

[4] Turl, L.H.: A comparison of three methods (single and double rip) for the determination of tearing of fabrics, *Textile Research Journal*, 28 (1958) pp. 839-848.

[5] Hager, O. B.; Galiardi, D. D.; Walker, H. B.: Analysis of tear strength, *Textile Research Journal*, **17** (1947) pp. 376–381

[6] Hamkins, C. P.; Backer, S.: On the mechanisms of tearing in woven fabrics, *Textile Research*, **50** (1980) pp. 323–327.