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A Comparative Analysis of Tear Strength Methods

Abstract
Fabric utility parameters most often depend on its mechanical properties. The most important strength parameters include unidirectional tensile strength, tear strength and elasticity properties. In this work we describe in detail the problem of tear strength, appropriate measurement methods and the correlation relationships between the results obtained by different tear methods. The measurements of tear strength were carried out for a chosen group of protective textiles. In addition, the unidirectional tensile strength was measured for the group of textiles mentioned above, and the correlation coefficients between the tensile strength and tear strength were calculated by different methods.

Key words: *tear force, tearing strength, testing methods, static tearing, dynamic tearing.*

Introduction

The utility functions which fabrics should fulfil first of all depend on their destination. Woven fabrics have a very wide range of applications, starting from underwear and everyday clothing, through protective and work clothing, decorative and furniture fabrics, up to technical textiles. Such a wide range of application means that during their lifetime fabrics undergo actions from different forces and strains depending on their destination and working conditions [1].

They can be stretched in one direction (for example, safety and transportation belts) or in many directions (for example, furniture fabrics), torn (for example, elements of sleeves and trousers) or compressed (for example, rigid interlining). In most of the mentioned cases fabrics are used at least a few times, and sometimes the number of work cycles can total many thousands of repetitions. In each work cycle, the total deformations are significant, and users expect that, after removing the forces, the fabric will return to its primary state [1].

The mechanical properties which most often decide their application onto a given clothing fabric include unidirectional stretching, tear and elastic properties. The significance which the above-mentioned properties have for the utility of each fabric is obvious, but it is worth mentioning that their role increases significantly, if we consider the criteria concerning the individual means of protection.

With Poland's adaptation to EC requirements, the law standardisation and normative acts (EC directive 89/686/EWG) concerning individual protection include criteria which had to be fulfilled by protective and work clothing produced in Poland. These requirements concern the uniforms of safety guard units. A danger to health and human life arises in many work situations in industry, such as welding, oil refinery work, and in the gas industry.

Uniforms and protective clothing, depending on their given destination, must fulfil many diverse specific requirements set down in special standards, which concern high mechanical strength, especially tear and abrasion resistance. To assess tear strength in the application areas mentioned, both static and dynamic methods are used. Tear strength is a very important factor for the fabrics used on tents, tarpaulins, backpacks and for recreational purposes such as deckchairs, garden umbrellas and so on. A dynamic tear method also has an application for clothing fabrics, such as cotton fabrics destined for jeans.

In this paper, we describe in details the resistance to the action of static and dynamic tear force, the measurement methods and correlation relationships between the results obtained by different tear methods. Additionally, for the group of protective fabrics described, the tensile strength was assessed; we also present a trial for finding the correlation relationships between the tensile maximum strength (more precisely, force) and the tear strength obtained by different measurement methods.

Methodology

The tear resistance of fabrics is a property which determines the material strength of an action of static force (a static tear test), kinetic force (a dynamic tear test) and tear test on a nail. The different methods of tear test procedure are reflected in different standards, which are characterised by different methods of sample preparation, their shape and size, the way of clamping and the length of torn fabric distance, as well as the way of reading and calculating the tear force [2].

Below, we describe five static tear test methods and one dynamic method. All the methods (apart from method No. 1, also concerning the knitted fabrics, and method No. 5 for fabrics coated by gum and polymers) have been used for woven fabrics. They are not commonly applied for knitted and elastic fabrics. They are not appropriate for fabrics of high anisotropy or loose structure, because in these fabrics tearing most often occurs in a direction askew to the stretching direction.

We also took into consideration method No. 5 in our measurements, which although it concerns coated fabrics can also find application for testing the fire guard clothing.

The methods presented follow the following standards:

- **No. 1** - PN-P-04640:1976 "Fabric measurement methods. Woven and knitted fabrics. Determination of tear strength"
- **No. 2** - PN-EN ISO 13937-2:2002 "Textiles - Tear properties of fabrics - Part 2: Determination of tear force of trouser – shaped test specimens (single tear method)" (ISO 13937-2: 2000)
- **No. 3** - PN-EN ISO 13937-3:2002 "Textiles – Tear properties of fabrics - Part 3: Determination of tear force of wing-shaped test specimens (single tear method)" (ISO 13937-3:2000)
- **No. 4** - PN - EN ISO 13937-4:2002 "Textiles. Tear properties of fabrics - Part 4: Determination of tear force of

lounge - shaped test specimens (double tear test)” (ISO 13937-4:2000).

- **No. 5** - PN-P-04966:1993/A21:2002 “Rubber or plastics coated fabrics. Determination of tear force”
- **No. 6** - PN-EN ISO 13937:2002 “Textiles. Tear properties of fabrics - Part 1. Determination of tear force using ballistic pendulum method” (Elmendorf)” (ISO 13937-1:2000).

The above numbers are used for figure, graph and table description in the text.

Single tear methods

Static methods (No. 1-5) differ from each other in sample preparation and clamping, tearing direction in relation to the acting force, distance between jaws, and so on. The method of sample preparation is shown in Figure 1, but the method of clamping is shown in Figure 2.

Method No. 1 (according to PN-P-04640:1976) in December 2002 was replaced by PN-EN ISO 13937-2:2002. Additionally, No. 3 and No. 4 (decision no 57/2002 of the Polish Standardisation Committee from 2002.12.23) were introduced as standardised methods. A description of the static tear methods is given in Table 1. In all the methods, the sample is torn at constant speed is maintained until the end of the measurement distance.

Static tear methods

The differences in calculation of results, according to PN-P-04640:1976, according to the standard PN-EN ISO 13937:2002 Part 2, 3 and 4 and PN-P-04966:1993/AZ1:2002, should also be pointed out. The method of dividing the graph into intervals and the readings of force values for the above methods are shown in Figure 3.

Determination of tear forces for the methods so far applied (Figure 3a) relies on the graph’s division into 10 equal intervals along the tear (measurement) distance in such a way that the beginning of the first interval corresponds to the first peak on the graph. Next, the maximum tear force corresponding to the highest peak is read at each interval. As a result, the mean tear force for both directions (longitudinal and reverse) and the maximum tear force (mean from the highest peaks for n samples) for longitudinal and reverse directions are given.

In order to determine a tear force for the methods described in the standard PN-EN ISO 13937:2002 Part 2, 3 and 4 (Figure 3b), the graph should be divided into four equal parts starting from the first and finishing on the last peak. The first part of the graph is not included in calculation of the mean value. Of the remaining three parts, the two highest and two lowest values are chosen. As a result, an arithmetic mean tear force for longitudinal and reverse directions from the chosen peaks is given. Additionally, the maximum tear force for longitudinal and reverse directions as a mean from maximum peaks is given. The standard PN-EN ISO 13937:2002 Part 2, 3 and 4 admits two ways of calculating results, manually and by computer, which cannot give identical results.

Determining tear forces for the method according to PN-P-04966:1993/AZ1:2002 (Figure 3c) relies on determining the median from the five biggest tear forces for a given sample, for the middle part of graph, which consists 50% of the whole tear distance. Median values in both directions are given as a result.

Dynamic tear test

The main element of the device for dynamic tear strength is a ballistic pendulum, by means of which force

***Table 1**. Description of static tear methods.*

Method No.	Standard	Single or double tearing	Tearing direction: ⊥or ‖ to the acting force	Tearing distance, mm	Measurement rate, mm/min	Distance between jaws, mm	Shape of the sample	A way of clamping the sample
1	PN-P-04640:1976	single	⊥	40 ± 1	100	50	Fig. 1a	Fig. 2a
2	PN-EN ISO 13937-3:2002	single	‖	75 ± 1	100	100	Fig. 1b	Fig. 2b
3	PN-EN ISO 13937-3:2002	single	⊥	75 ± 1	100	100	Fig. 1c	Fig. 2c
4	PN-EN ISO 13937-4:2002	double	‖	75 ± 1	100	100	Fig. 1d	Fig. 2d
5	PN-P-04966:1993/AZ1:2002	single	‖	145 ± 1	100	70	Fig. 1e	Fig. 2e

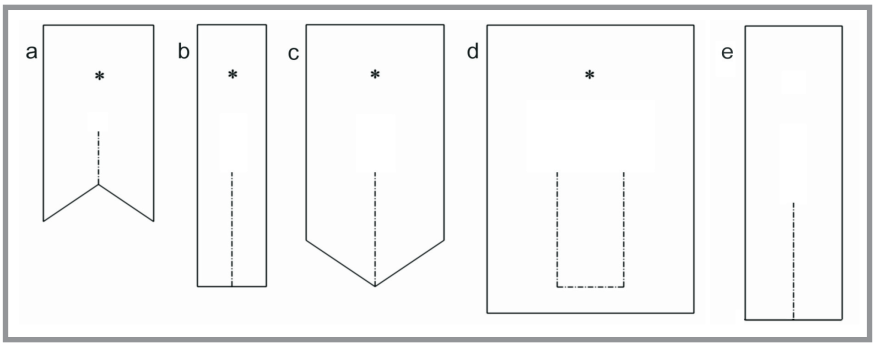

***Figure 1.** Shape of samples according to: a - PN-P-04640:1976, b - PN-EN ISO 13937-2:2002, c - PN-EN ISO 13937-3:2002, d - PN-EN ISO 13937-4:2002, e - PN-P-04966:1993/AZ1:2002.*

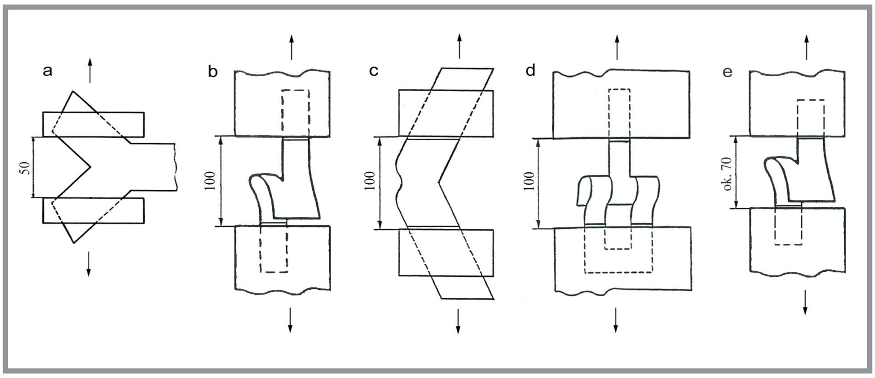

***Figure 2**. Method of clamping the samples according to: a - PN-P-04640:1976, b - PN-EN ISO 13937-2:2002, c - PN-EN ISO 13937-3:2002, d - PN-EN ISO 13937-4:2002, e - PN-P-04966:1993/AZ1:2002.*

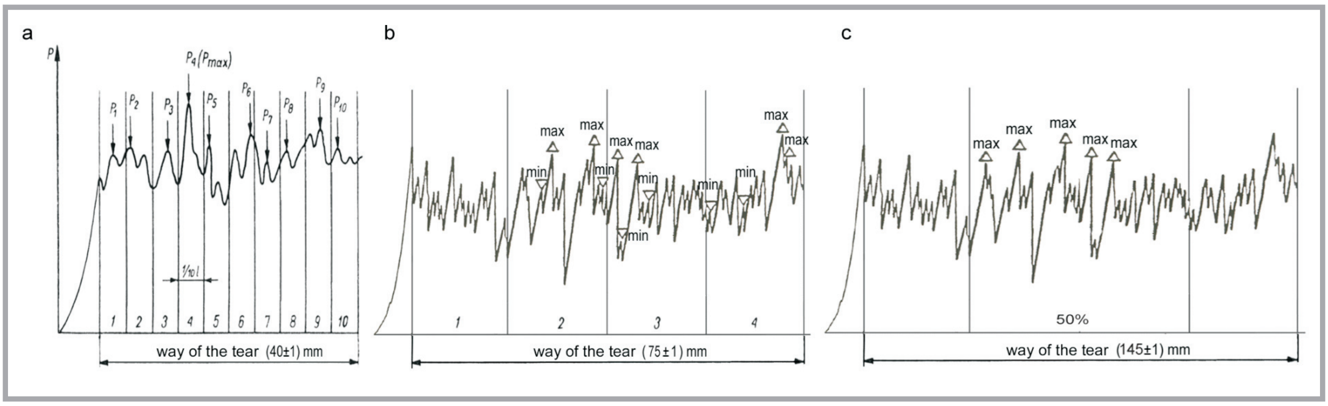

Figure 3. *The way of reading tear forces according to: a - PN-P-04640:1976, b - PN-EN ISO 13937-2:2002, Part 2, 3 and 4, c - PN-P-04966:1993/AZ1:2002.*

is suddenly applied to the appropriately prepared sample; the sample is then mounted between two jaws, one fixed and the second, movable one mounted to the device's body. The movable jaw is connected to a pendulum, which falls down due to the gravimetric force, and the whole sample is torn by the displacement of the immobile jaw. In Figure 4, the Elmatear model 455 for the dynamic tear test is presented.

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 method of sample preparation and its clamping in the jaws is shown in Figure 5. For clothing fabrics, the sample cut distance is 20±0.5 mm, and the tear distance is 43±0.5 mm. In the upper part of the sample, there is a notch which is used to avoid shredding the thread ends.

The advantage of the dynamic tear test is the option of quickly obtaining the results of the tear test (from readings directly on the device). In the case of the static methods, this is connected with reading the maximum and minimum values from the graph, which in the case of a lack of electronic devices is very time-consuming.

Comparative Measurements

The hitherto used method according to PN-P-04640:1976 was replaced by PN-EN ISO 13937-2:2002, and furthermore part 3 and 4 of the above methods were introduced as standard methods. For these reasons, and also because a dynamic tear method according to PN-EN ISO 13937-1:2002 and the method according to PN-P-04966:1993/AZ1:2002 have not been used so far for clothing textiles (not coated), there is a need to carry out comparative measurements. On one hand, they allow the obtained results to be interpreted for methods not as yet applied, and on the other hand they answer the question of which relationships exist between the obtained results of tear strength methods [3,4].

Additionally, unidirectional strength measurements were performed according to PN EN ISO 13934-1:2002 "Textiles. Tensile properties of textiles. Part 1: Determination of maximum force and elongation at maximum force using the strip method" in order to determine the correlation between the maximum force results and the static or dynamic tear force. The comparative measurements were done in the Laboratory of Physical-Mechanical Properties in the Institute of Textile Material Engineering in Łódź.

The Instron tensile tester was used for the measurements. It fulfils all the standard requirements concerning the static tear test and unidirectional tensile strength. For dynamic measurements, we used the Elmatear device from the firm J.H. Heal which fulfils the requirements of standards concerning the dynamic tear strength. The measurements were carried out in the normal climate on the samples conditioned according to PN-EN 20139:1993. We measured the samples of five fabrics designed for the protective clothing. The technical and technological fabric parameters are presented in Table 2. For the fabrics chosen for measurement, the tear test was performed by five static methods and one dynamic method; additionally, the unidirectional tensile strength was measured. For each direction (warp-weft) we used 6 specimens.

As a result, we calculated the mean value (ā) or median of tear forces in [N], the mean value (ā) of maximum force in [N] and strain in [%] at the maximum force and values of random error ($U_{\bar{a}}$) at the significance test level of α=0.05. The results of tear strength obtained, depending on the method used, are presented in Table 3 and in Figure 6; the tensile strength results are presented in Table 4 and in Figure 7.

Figure 4. *Elmatear device.*

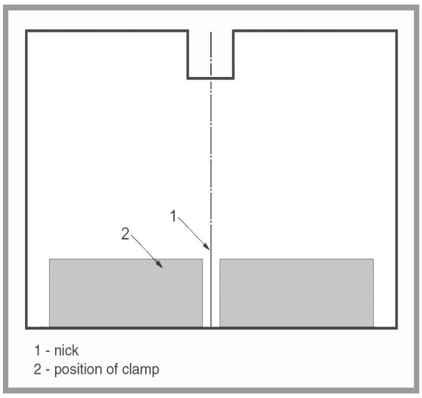

Figure 5. *A method of sample preparation and of clamping in the Elmatear according to PN-EN ISO 13937-1:2002.*

Discussion of Results

Kendall's coefficient of agreement and correlation coefficient

Analysing the values of the tear strength results obtained by the six different methods, we should note that the results of the mean tear force (or median) for six methods are at different levels. Therefore, when starting the measurements, we should choose the appropriate measurement method by taking into account the fabric's destination, the kind of tear performance which can occur in the workplace, and also the parameters and criteria which are in the form of normative documents for many fabrics.

In order to find the relationships between the results of mean tear forces (or median in method No. 5) for the six described methods, we calculated two Kendall's agreement coefficients for five static tear methods and for all six methods (static and dynamic taken together). We wanted to check whether the tear results obtained by different methods are coherent. The ranking of 1 means the lowest mean value (or median) of tear strength, and the ranking of 10 is the highest [5,6].

We obtained the following values of Kendall's agreement coefficients:

- for five static tear methods W_1=0.868, and
- for six tear methods (static and dynamic) W_2=0.869.

Considering that the value of the agreement coefficient can be changed within intervals (0;1), and that values close to +1 mean a high degree of agreement, it was stated that the values obtained confirmed quite a high degree of agreement of tear strength results. In addition, the linear correlation coefficients were calculated in order to confirm the relationships between particular tear methods. Below are presented (Figure 6) the most interesting figures from the methods where the results obtained represent the strongest and weakest correlation between them. All the correlation coefficients are set in Table 5.

The border value of the correlation coefficient at a random degree n-2=8, and the significance level α=0.05, above which the correlation exists, is 0.632. According to this, there is no linear correlation between methods 3 and 5 [7].

The high values of correlation coefficients which we obtained, above 0.8 (except in 3 cases) confirmed a strong linear

Table 2. The set of technical-technological parameters of fabrics.

Characteristic		Fabric A	Fabric B	Fabric C	Fabric D	Fabric E
Raw material		100% Cotton	100% Cotton	50% Poliester; 50% Cotton	90% Cotton 10% Poliester	100% Cotton
Weave		twill 3…/…1	twill 2…/…1	twill 3…/…1	twill 2…/…1	twill 2…/…1
Mass per unit area, g/m²		281 ± 5	247 ± 5	247 ± 5	230 ± 5	244 ± 5
Thread linear density, tex	warp	20 × 2	20 × 2	15 × 2	12 × 2	20 × 2
	weft	50	50	40	20	50
Number of thread per 10 cm	warp	342 ± 7	340 ± 7	490 ± 8	589 ± 8	342 ± 7
	weft	196 ± 6	192 ± 6	235 ± 7	321 ± 7	200 ± 6

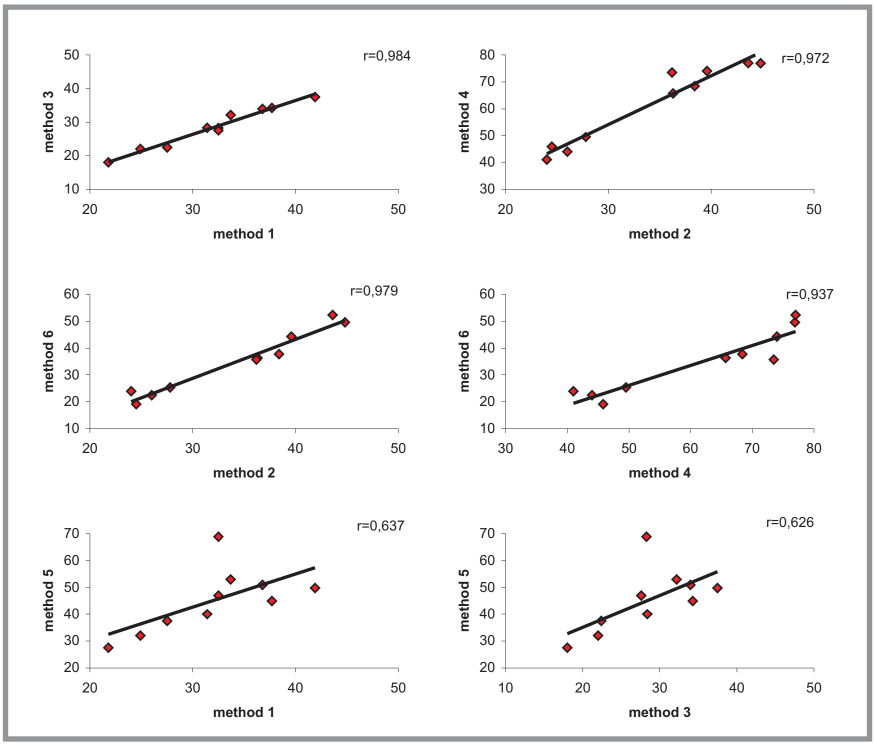

Figure 6. *The most interesting correlation relationships between six tear methods.*

Table 3. *Tear strength results;* $\bar{a}$ *- mean value of the tear strength,* $U_{\bar{a}}$ *- value of random error.*

Fabric	PN-P-04640:1976				PN-EN ISO 13937-2: 2002				PN-EN ISO 13937-3:2002				PN-EN ISO 13937-4:2002				PN-P-04966: 1993/AZ1 :2002		PN-EN ISO 13937-1:2002			
	Method 1				Method 2				Method 3				Method 4				Method 5		Method 6			
	Static																		Dynamic			
	warp		weft		warp		weft		warp		weft		warp		weft		warp	weft	Warp		weft	
	$\bar{a}$	$U_{\bar{a}}$	$\bar{a}$	$U_{\bar{a}}$	$\bar{a}$	$U_{\bar{a}}$	$\bar{a}$	$U_{\bar{a}}$	$\bar{a}$	$U_{\bar{a}}$	$\bar{a}$	$U_{\bar{a}}$	$\bar{a}$	$U_{\bar{a}}$	$\bar{a}$	$U_{\bar{a}}$	median	median	$\bar{a}$	$U_{\bar{a}}$	$\bar{a}$	$U_{\bar{a}}$
A	21.8	0.5	24.9	1.3	24.0	0.6	26.0	1.9	18.0	0.5	22.0	0.6	41.0	1.7	44.0	2.7	27.5	32.0	23.9	1.4	22.4	0.5
B	32.5	0.5	36.8	2.2	44.8	3.5	39.6	0.6	28.3	1.3	34.0	1.3	76.9	5.5	74.0	2.4	68.8	51.0	49.6	5.1	44.3	3.7
C	41.9	3.8	37.7	1.4	43.6	4.1	38.4	1.1	37.5	2.9	34.3	2.4	77.0	1.0	68.4	1.6	49.8	45.0	52.3	1.7	37.8	0.7
D	31.4	0.8	27.5	3.9	27.8	1.2	24.5	1.2	28.4	1.7	22.4	1.4	49.5	0.7	45.8	3.6	40.0	37.5	25.3	1.2	19.1	0.9
E	32.5	1.8	33.7	0.9	36.3	0.8	36.2	1.0	27.6	0.7	32.2	0.8	65.7	2.0	73.5	1.8	47.0	53.0	36.4	2.2	35.8	2.6

Table 4. *Results of tensile strength test;* $\bar{a}$ *- mean value,* $U_{\bar{a}}$ *- value of random error of the value* $\bar{a}$.

Fabric	Maximum force, N				Strain at the maximum force, %			
	warp		weft		warp		weft	
	$\bar{a}$	$U_{\bar{a}}$	$\bar{a}$	$U_{\bar{a}}$	$\bar{a}$	$U_{\bar{a}}$	$\bar{a}$	$U_{\bar{a}}$
A	940	80	590	60	8.5	0.5	17.5	1.0
B	1100	100	630	40	10.5	0.5	19.5	0.5
C	1200	100	650	10	24.5	2.5	14.0	1.0
D	1600	100	870	60	19.0	15.5	15.5	0.5
E	1200	100	840	10	12.5	0.5	23.0	2.5

Table 5. *The correlation coefficients between results of different tear methods.*

Methods	Correlation coefficient r	Methods	Correlation coefficient r	Methods	Correlation coefficient r
1 and 2	0.839	2 and 3	0.818	3 and 5	0.626
1 and 3	0.984	2 and 4	0.972	3 and 6	0.788
1 and 4	0.861	2 and 5	0.883	4 and 5	0.884
1 and 5	0.637	2 and 6	0.979	4 and 6	0.937
1 and 6	0.814	3 and 4	0.861	5 and 6	0.843

correlation relationship between the tear methods. It is worth noting some rules:

- The strongest linear correlation coefficient (above 0.9) is for methods No. 1 and No. 3; No. 2 and No. 4; No. 2 and No. 6; No. 4 and No. 6. All these methods have the same direction of tear force application in relation to the tearing direction. For methods No. 1 and No. 3, the tear test is carried out in the direction perpendicular to the direction of force application, and in methods No. 2 and No. 4 the tearing is carried out in the direction parallel to the force application. An interesting situation arises in methods No. 2 and No. 6, as well as No. 4 and No. 6. Method No. 6 concerns the dynamic tear test, so its procedure differs from the static tear tests described in methods No. 2 and No. 4. Nevertheless, making the same assumptions, we can see certain similarities:
  - the method of sample mounting; the clamping line in both methods is parallel to the torn sample threads,
  - the action of the tear force; in the static method a successive force increase causes the breaking of threads in the tearing direction, and in the dynamic method there is a sudden force action on the similarly mounted threads, so the torn threads are broken simultaneously.

Taking the above into account, it can be assumed that in the case of methods No. 2 and No. 6, as well as No. 4 and No. 6 the tearing is carried out in the direction parallel to the direction of force application. This is confirmed by the high values of the correlation coefficients: 0.979 and 0.937. In the case of the method pairs No. 1 and No. 3, No. 2 and No. 4, No. 2 and No. 6, No. 4 and No. 6, a high value of linear correlation coefficient is observed for data in both measurement directions (warp and weft), as well as for each direction separately.

- The weakest linear correlation is between methods No. 1 and No. 5 and No 3 and No. 5. This is caused by two factors:
  - the directions of force application are different. In methods No. 1 and No. 3 these are perpendicular, and in method No. 5 they are parallel to the force application.
  - different method of calculating results. In methods No. 1 and No. 3, there is a division of the whole graph into intervals. In method No. 1 we have 10 intervals, and as a result the arithmetic mean value from 10 maximum peaks of each interval is taken, whereas in method No. 3 we have a division into 4 intervals. As a result, the arithmetic mean value from two maximum and two minimum peaks for 3 intervals (the first is rejected) is taken (12 peaks in total). In method No. 5 we determine 5 maximum peaks for 50% of the middle part of the graph, and as a result, the median from these 5 maximum values is given.

Comparison of percent values

In order to find the practical plane of comparison for values obtained by the six methods of tear force measurement (which could be useful for the rapid laboratory interpretation of the results obtained), the results obtained by method PN-P-04640:1976 (method No. 1) were assumed as 100%. The results obtained by the other methods were presented in relation to the recommended (base) result (Figure 7).

Method No. 1 was chosen as a base because it was withdrawn and replaced (by the Polish Standardisation Committee) by method No. 2 (PN-EN ISO 13937-2: 2002), but the majority of the tear resistance parameters concerning fabrics for different destinations were determined by method No. 1. In fact, while testing the samples according to the new standards, it is necessary to properly interpret the results obtained in relation to the parameter value.

It is difficult to unequivocally interpret the values obtained in percent; nevertheless, it is worth noting some rules of relationships:

- The results for fabrics A, B, C and E obtained by method No. 2 are at the level of about 107% of the base result (104 to 112%). The exception is a tear force in a warp direction for fabric B, which achieves 138% of the base result. Nevertheless, looking at the tear results for warp in the case of fabric B, it is worth noting that in methods No. 4, No. 5 and No. 6 this fabric obtained the highest percentage values. This may confirm the high tear strength of warp thread in fabric B. In addition, it was observed for fabric B that in the cases of methods No. 1 and No. 3 the mean tear force for a warp is lower than the mean tear force of the weft, and for the results obtained by methods No. 2, No. 4, No. 5 and No. 6 for the same fabric, the mean force (or the median in the case of method No. 5) is higher than the mean tear force for the warp. Similar differences were observed for fabric E. For methods No. 1, No. 3, No. 4 and No. 5, the results we obtained for weft tear forces were higher than analogous for warp tear forces; whereas for methods No. 2 and No. 6, we achieved the better results for the warp. Nevertheless, in the case of fabric E it can be noted that the results obtained for warp and weft are on the similar level. Taking into account the upper value of the confidence limit for warp in methods No. 2 and No. 6 the tear strength values obtained confirm the higher weft tear strength for fabric E.
- The results obtained by method No. 3 are on the same level, i.e., ca. 90%

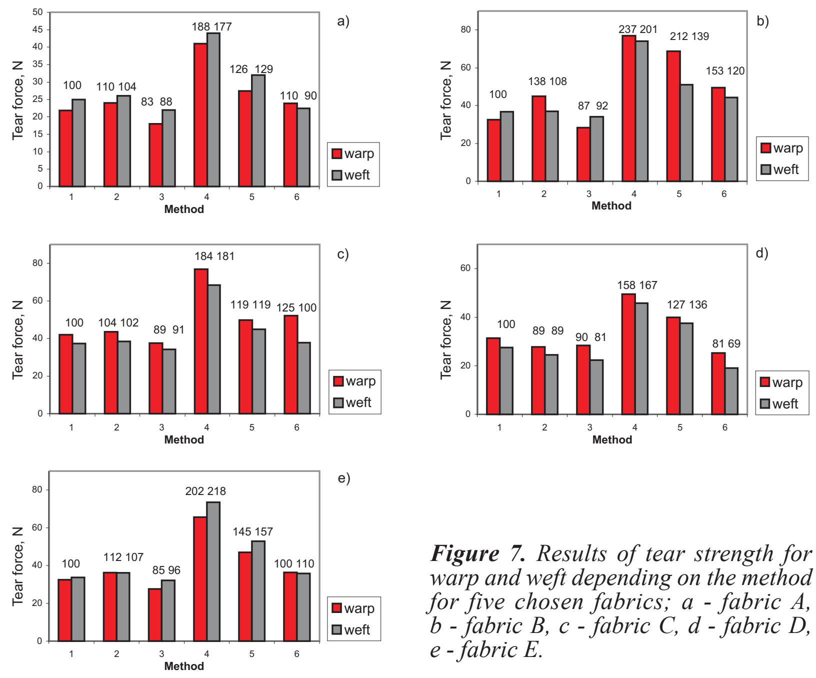

Figure 7. *Results of tear strength for warp and weft depending on the method for five chosen fabrics; a - fabric A, b - fabric B, c - fabric C, d - fabric D, e - fabric E.*

(from 83 to 96%) of the base result for all the fabrics measured. Taking into account the strong linear correlation which exists between methods No. 1 and No. 3 (r=0.984), it can be suggested that method No. 3 could substitute for method No. 1.

- The results for fabrics A, B, C and E obtained by method N. 4 are at a level two times higher (177% to 237%) than those obtained by method No. 1. For fabric D, the results are at a level ca. 160% of the base result; nevertheless, this fabric was characterised by lower yarn linear densities.
- Most difficult is the interpretation of results obtained by methods No. 5 and No. 6. There are big deviations in percentage results in relation to the base result. For method No. 5, values from 119 to 212% were noted. Similarly, for the method No. 6, results were ranged from 69% (fabric 4) to 153%.

To sum up, it should be pointed out that this form of result interpretation could in practice be useful, because by making measurements with the chosen method we could obtain an approximate information on which level a result obtained by a different method would be. Nevertheless, upon analysing the results for five fabrics we can not state unequivocally whether such an interpretation would be useful for a bigger sample population, nor whether any kind of 'anomaly' (e.g. for the same fabric, the result for the warp direction can be once higher and once lower than for the weft direction) is due to the yarn strength uniformity, or whether it is a regularity, which can occur for some fabrics of given technological parameters.

Table 6. *The values of linear correlation between tear forces and tensile strength.*

Tear strength methods	Correlation coefficient r
1	0.107
2	0.041
3	0.054
4	0.007
5	0.138
6	0.078

Comparison with the tensile strength results

In order to establish the relationships between the particular tear methods and tensile strength, the linear correlation coefficients were calculated. The results obtained are presented in Table 6. The very low values of correlation coefficients (0.007 to 0.138) which were obtained confirmed that there was no correlation between these measurements.

Conclusions

On the basis of the results obtained, the following conclusions were drawn:

- Considering the rank coefficient of agreement, a coherency was shown between all the static tear test methods (W_1=0.868), as well as between static methods and the dynamic method (W_2=0.869).
- The following points were proved:
  - there is a high value of linear correlation relationship for methods of the same direction of force application in relation to the tearing direction (r=0.9),
  - a good correlation for the rest of the methods (r= 0.626-0.884).
- There are some similarities between static tear methods, in which the direction of force application is parallel to the tearing direction, and a dynamic tear method, as is confirmed by the high value of correlation coefficients between these methods (r=0.9)
- A lack of linear correlation relationship between the static or dynamic tear strength and the tensile strength was demonstrated.

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