Comparison of Dynamic and Static Tearing Resistance of Different Commercial Papers

Celil Atik[1*], Merve Engin[2]

[1] Istanbul University, Faculty of Forestry, Bahceköy 34473 Istanbul
[2] Istanbul University, Institute of Science, Istanbul

[*] Phone +90 212 226 11 00, E-mail: atikc@istanbul.edu.tr

Abstract

This study was carried out to determine comparability of tearing resistance measured by dynamic and static testing devices. Tearing indices of double tear samples from different commercial paper grades were determined dynamically by using pendulum type Marx-Maller Elmendorf device and statically by using Zwick/Roell universal tensile testing device. Tear resistance values for dynamic and static tests were compared and good correlation was observed (R^2-0.96 and 0.99 for MD and CD respectively). Tear index ratios (cross direction / machine direction) of the two methods was found to be relatively close for all paper grades. Force required for initiation of static tearing at machine direction was bigger than at cross direction and variate from 1 to 7 N for different paper grades.

Keywords: Tearing, tear test, tearing resistance, tearing index, elmendorf, tearing with tensile tester

Farklı Ticari Kâğıtların Statik ve Dinamik Yırtılma Dirençlerinin Karşılaştırılması

Özet

Bu çalışma dinamik ve static test cihazlarının yırtılma direnci sonuçlarının karşılaştırılabilirliğini belirlemek için yapılmıştır. Farklı ticari kâğıt cinslerinin çift yırtılmalı örneklerde dirençler dinamik olarak sarkaç tipli Marx-Maller Elmendorf cihazı ile static olarak Zwick/Roell üniversal çekme testi cihazı ile belirlenmiştir. Dinamik ve static test cihazları ile elde edilen sonuçlar karşılaştırılmış ve aralarında iyi bir korelâsyon olduğu belirlenmiştir (R^2 - 0,96 MD ve R^2 - 0,99 ED). Yırtılma indisi oranları (enine doğrultu / boyuna doğrultu) birbirine nispeten yakın bulunmuştur. Boyuna doğrultuda yırtılmayı başlatmak için gerekli olan kuvvet enine doğrultuya kıyasla daha yüksek olmuştur ve farklı kağıt türleri için 1 ila 7 N arasında değişim göstermektedir.

Anahtar Kelimeler: Yırtılma, yırtılma testi, yırtılma direnci, yırtılma indisi, elmendorf, çekme test cihazı ile yırtma

Received: 30.12.2009; accepted: 29.01.2010

1. Introduction

Since different paper grades produced from different furnishes are heavily used daily and most papers are performed in two different manners: in-plane and out-of-plane. The common tearing test is an out-of-plane tearing test performed by Elmendorf type dynamic tearing test device, where the retardation of a swinging pendulum is taken as a measure of total energy consumed during tearing of paper (Lyne et al., 1972). The new generation tensile testing devices are able to measure energy absorption during destruction of test specimens with tensile forces, accordingly static tearing resistance of paper (tearing with a constant rate of elongation) can be determined with tensile testing devices. Therefore, correlation between dynamic and static tearing test results has become research subject for paper and textile scientists (Witkowska and Frydrych, 2004). Yamauchi and Tanaka (2002) have found that the increase of Elmendorf tear index and are exposed to tearing stresses during converting and end use at different utilization areas, the tearing resistance has become one of the significant mechanical paper properties. Tear tests of most tensile tear index changes in similar manners for both hardwood and softwood pulps. Good correlation between Brecht-Imset and Elmendorf tear strengths of single ply specimens was obtained by Serth and Blinco (1990).

The aim of this study was to compare of tearing resistance values obtained by dynamic (pendulum) and static (tensile) testing devices for double tear samples of different commercial paper grades.

2. Materials and Methods

Thirteen different samples from five different grades (offset, news, office, coated, cardboard) were used for testing.

Tests were performed at standard test conditions relative humidity of 50 % and temperature of 23 °C (ISO 187).

Tensile testing devices are constructed to measure the force acting coaxial with the axis of loadcell. An incorrect position or inclined tearing pattern of the paper sample may cause forces acting perpendicular to the loadcell axis. To prevent this, the samples were prepared for double tear testing for both dynamic and static testing devices. The Marx-Maller type pendulum Elmendorf tearing device was used for dynamic tearing tests and the Zwick/Roell universal testing device with 100 N loadcell was used for static tearing tests. The tensile tearing test condition was 600 mm/min constant speed of elongation.

The samples with 100 by 62 mm dimension were prepared for testing and slitted to have two equal lengths of 44 mm to be torn, according to Figure 1A and Figure 1B for dynamic and static devices, respectively. According to manual instructions of Marx-Maller Elmendorf device two sheets were torn simultaneously in order to obtain suggested reading range, except boards C2, CB1 and CB2 where the single sheet was torn. Lyne et al. (1972) has found that tearing energy has linear dependence to number of sheet test specimens torn together, therefore a single sheet was used for testing at the tensile testing device.

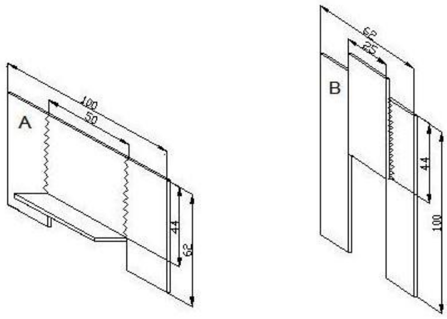

Figure 1. The sample cut for A) Elmendorf and B) tensile testing device

Şekil 1. Örnek kesme şekli A) Elmendorf için B) çekme testi cihazı için

3. Results and Discussion

Test results showed that tearing index values obtained by dynamic device is greater than values obtained by static device (Table 1). The main difference between two devices was test speed, where the tearing speed of paper at the Elmendorf device was higher than speed of the tensile device. The difference of speed caused a higher tearing resistance at higher test speeds. That situation was similar to the tensile test where different speed can be applied, test results obtained by ISO 1924-3 test method that have high speed was greater than results obtained by ISO 1924-2 test method for the same specimens.

Table 1. Properties and tearing index values of paper grades
Tablo 1. Kâğıt cinslerinin özelikleri ve yırtılma indisi değerleri

Paper grades	Basis weight (g/m²)	Calliper (µm)	Tearing index (mN.m²/g)			
			Elmendorf		Tensile	
			MD	CD	MD	CD
Office O1	87.31	110	5.14	5.95	4.95	5.54
Office O2	123.15	135	6.11	6.31	5.66	5.97
Office O3	79.77	90	6.89	7.12	6.21	6.68
Coated C1	119.05	85	4.00	4.74	3.99	4.71
Coated C2	251.25	220	4.32	5.77	4.20	5.47
Mechanical M1	59.11	100	4.20	5.09	3.74	4.81
Mechanical M2	61.86	85	7.62	8.80	7.58	8.62
Offset Printing OP1	79.50	95	5.77	6.22	5.35	5.87
Offset Printing OP2	77.16	95	5.47	6.29	5.46	6.07
Offset Printing OP3	70.79	85	7.06	7.76	6.50	7.58
Offset Printing OP4	90.49	104	6.09	6.49	5.99	6.20
Cardboard CB1	219.84	275	5.70	7.30	5.64	7.27
Cardboard CB2	184.78	270	7.48	8.27	7.28	8.14

MD: Machine Direction, CD: Cross Direction

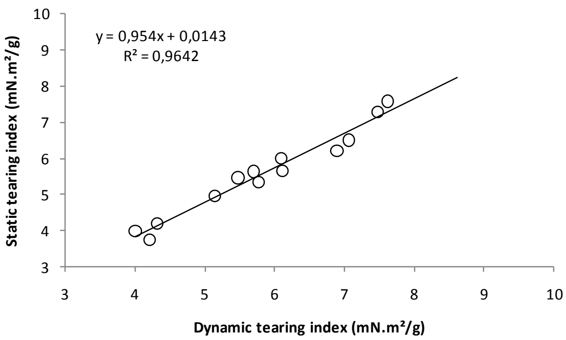

Figure 2. Dynamic versus static tear indices of MD samples
Şekil 2. MD yönünde dinamik yırtılma indisine karşılık gelen statik yırtılma dirençleri

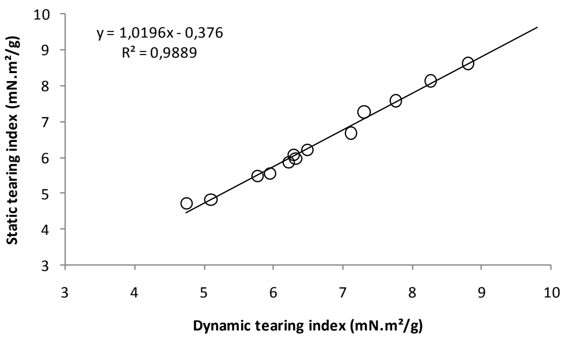

Figure 3. Dynamic versus static tear indices of CD samples
Şekil 3. ED yönünde dinamik yırtılma indisine karşılık gelen statik yırtılma dirençleri

Figure 2 and Figure 3 showed that there was good straight correlation between dynamic and static tearing resistance of papers in both machine direction (MD) and cross direction (CD).

The paper grades used in this study has unequal furnish, basis weight, fibre orientation and additive content. Therefore they had varying CD/MD tearing index ratios (Figure 4), in the meantime the ratios obtained by the dynamic and the static testing device were relatively close to each other.

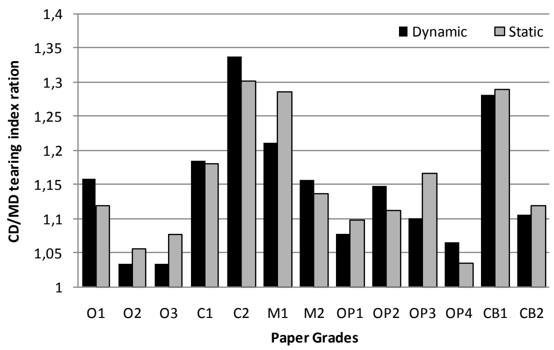

Figure 4. CD/MD ratios of tearing resistance
Şekil 4. Yırtılma direncinin ED/MD oranları

Different paper grades had different tearing curves (Figures 5, 6, 7, 8 and 9). In general the average force to initiate the tearing of paper in MD was greater than that in CD, and the difference increased with the basis weight of the paper sample

(Figure 10). Meanwhile, the average force to continue a started tear in CD was greater than in MD. The tearing curves of all paper grades had a peak at the beginning (the force to initiate the tearing) sharp drop and nearly levelled or very steady rise trough tearing (rest of the straining) and decline steeply at the end. The rise during the progression of the tear can be explained by observed increase of delamination where the energy consumption increase (Lyne et al., 1972), and pull-out of shortened fibre at the end of straining decrease overall energy consumption.

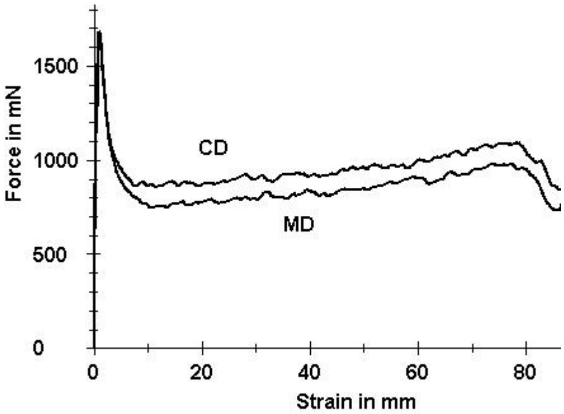

Figure 5. Typical mean load curves during the static tearing (office paper – O1)
Şekil 5. Statik yırtılma sırasında tipik ortalama yük eğirisi (ofis kâğıdı – O1)

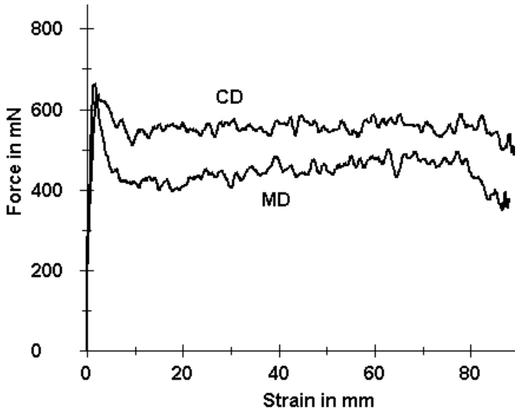

Figure 6. Typical mean load curves during the tearing (mechanical pulp – M1)
Şekil 6. Statik yırtılma sırasında tipik ortalama yük eğirisi (mekanik hamur kâğıdı – M1)

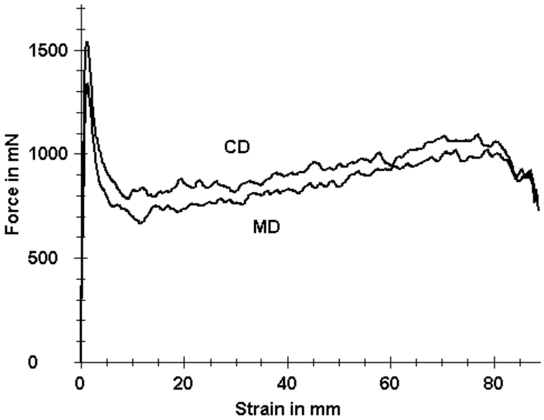

Figure 7. Typical mean load curves during the tearing (offset printing paper – OP1)
Şekil 7. Statik yırtılma sırasında tipik ortalama yük eğirisi (ofset baskı kâğıdı – OP1)

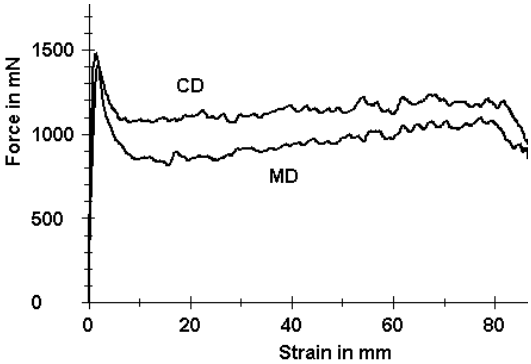

Figure 8. Typical mean load curves during the tearing (coated paper – C1)
Şekil 8. Statik yırtılma sırasında tipik ortalama yük eğirisi (Kuşe kâğıt – C1)

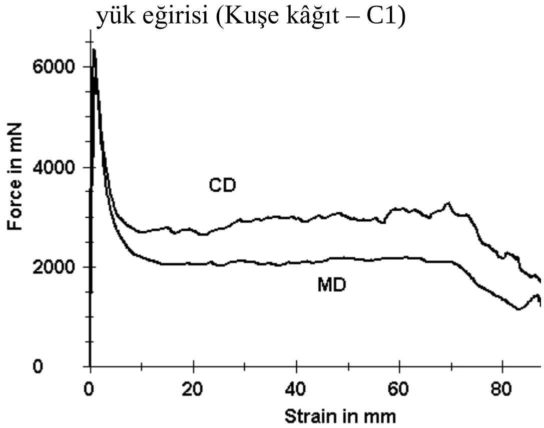

Figure 9. Typical mean load curves during the tearing (coated board – C2)
Şekil 9. Statik yırtılma sırasında tipik ortalama yük eğirisi (kuşe karton – C2)

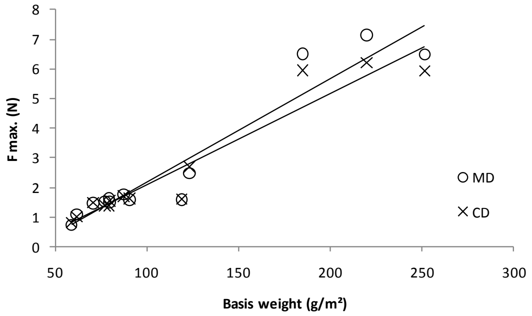

Figure 10. The maximum force for initiation of static tearing according to the basis weight of samples

Şekil 10. Kâğıt gramajına göre statik yırtılmanın başlaması için gereken maksimum kuvvet

4. Conclusion

Tearing strength values obtained by the static testing device were well correlated with the values obtained by the dynamic tearing device, and the dynamic test results are slightly higher than the static test results.

Dynamic and static CD/MD tearing index ratios were also relatively similar for the same paper samples.

Force to initiate the static tearing of paper in MD was higher than that in CD, and the difference increased with the basis weight of paper samples.

Tearing resistance of paper can be determined with reliance with tensile testing devices for scientific and quality control monitoring purposes.

References

Lyne, M.B., M. Jackson and A.E. Ranger, 1972. The in-plane, Elmendorf, and edge tear strength properties of mixed furnish papers. *Tappi Journal.* 55 (6): 924-932.

Seth, R.S. and K.M. Blinco, 1990. Comparison of Brecht-Imset and Elmendorf tear strengths. *Tappi Journal.* 73 (1): 139-142.

Witkowska, B. and I. Frydrych, 2004. A Comparative analysis of tear strength methods. *Fibres and Textiles in Eastern Europe*. 12 (2): 42-47.

Yamauchi, T. and A. Tanaka, 2002. Tearing test for paper using a tensile tester. *Journal of Wood Science.* 48 (6): 532-535.