(REFEREED RESEARCH)

# INVESTIGATION OF ABRASION RESISTANCE AND BURSTING STRENGTH OF WARP KNITTED RASCHEL FABRICS

# ÇÖZGÜLÜ ÖRME RAŞEL KUMAŞLARIN AŞINMA DAYANIMI VE PATLAMA MUKAVEMETİNİN İNCELENMESİ

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**ABSTRACT**

There are growing demands on the warp knitted lace look raschel fabrics in recent years. We can see this fabric as net curtains or outerwears. To the best of our knowledge, there is no published experimental study which focuses on the investigation of the abrasion resistance and bursting strength of warp knitted raschel fabrics for a net curtain or outwears. In this study, the method for testing abrasion resistance of lace look warp knitted raschel fabrics for a net curtain or outwear was created. For this purpose abrasion and reverse abrasion tests were performed with Martindale abrasion tester. Influences of abradant fabric, the lining fabric and the pattern position on abrasion resistance results were examined. To compare the effects of measurement techniques, bursting strength of the warp knitted raschel fabric samples were measured with ball burst mechanism, hydraulic and pneumatic type diaphragm bursting testers. According to the variance analysis results, the effect of the bursting strength test method is highly significant. Lowest bursting strength results are obtained in the wet state. As the measured test area increases, the bursting strength decreases.

**Keywords:** Warp Knitting, Raschel Fabric, Net Curtain, Abrasion Resistance, Martindale Abrasion Tester, Reverse Abrasion Method, Bursting Strength.

**ÖZET**

Son yıllarda dantel görünümlü çözgülü örme raşel kumaşlara talep artmaktadır. Bu kumaşların tül perde yada dış giysi üretiminde kullanıldığını görmekteyiz. Bildiğimiz kadarıyla literatürde, tül perde yada dış giysi üretiminde kullanılabilecek olan çözgülü örme raşel kumaşların aşınma dayanımı ve patlama mukavemeti ile ilgili deneysel çalışma bulunmamaktadır. Bu çalışmada tül perde, iç çamaşırı ya da giysi üretiminde kullanılan raşel tipi çözgülü örme kumaşların aşınma dayanımlarının test edilmesi için metot oluşturulması amaçlanmıştır. Bu amaçla Martindale cihazında standart ve ters aşınma deneyleri gerçekleştirilmiştir. Aşındırıcı malzeme değişimi, deney numunesi altına farklı yapıda destek kumaşı yerleştirme, kumaş numunesinin aşınma alanına farklı yerleşiminin aşınma dayanımına etkisi incelenmiştir. Ölçüm tekniklerinin etkilerini karşılaştırabilmek için çözgülü örme raschel kumaş numunelerinin patlama mukavemetleri bilyalı patlatma mekanizması, hidrolik ve pnömatik patlama mukavemeti test cihazları ile ölçülmüştür. Varyans analiz sonuçlarına göre, patlama mukavemeti test metodu istatistiksel olarak önemli etki yapmaktadır. Kumaşların yaş durumda ölçülen patlama mukavemetleri daha düşüktür. Test alanı arttıkça patlama mukavemeti değerleri azalmaktadır.

**Anahtar Kelimeler:** Çözgülü Örme, Raşel Kumaş, Tül Perde, Aşınma Mukavemeti, Martindale Aşınma Cihazı, Ters Aşınma Metodu, Patlama Mukavemeti

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## 1. INTRODUCTION

In a jacquard raschel machine, ground guide bars are used to generate a ground net while the jacquard bar covers the openings to create a motif(1). Jacquard raschel machine with fall plate is used to produce net curtains and outwear with detailed, 3D jacquard patterns(2). Especially the three and four needle patterning technology increased the lapping and patterning possibilities. These fabrics can be now produced with an even wider range of the special effects. They feature fine-mesh net areas, seemingly completely open structures, almost three-dimensional relief effects, and dense surface effects in a varied interplay with each other, and are produced not with long floats but by a combination of jacquard structures and pillar stitch constructions(3).

There are growing demands on the warp knitted lace look raschel fabrics in recent years. Jacquard warp knitted raschel fabric's most popular end usages are net curtains and garment production. We can see this fabric as net curtains, in blouses, footwears, under wears, shawls, etc. Fashion designers used lace look jacquard raschel fabrics as sleeve, neck, collar or chest part of the garment.

If asked many people would equate the ability of fabric to "wear well" with its abrasion resistance (4). Abrasion is defined as the wearing away of any part of the fabric by rubbing against another surface. Fabrics are subjected to abrasion during their lifetimes, and this may result in wear, deterioration, damage and the loss of performance (5). The main factors that reduce the service life of the garment are heavily dependent on its end use. However, especially certain parts of apparel such as a collar, cuffs, and pockets are subjected to serious wear in use. Abrasion is a serious problem for home textiles like as carpets and upholstery fabrics, socks and technical textiles as well (6). The durability of knitted underwear is commonly characterized by bursting strength and abrasion resistance (7).

A fabric's resistance to abrasion is affected by many factors, such as fiber type, the inherent mechanical properties of the fibers, the dimensions of the fibers, the structure of the yarns, the construction and thickness of the fabrics, and the type and amount of finishing material(5).

In the literature, there are many studies on influences of fabric production parameters on the abrasion resistance. However, these studies mostly performed for woven[8-10], flat[11-13] or circular[14-19] knitted fabrics. Değirmenci investigated the effects of pile yarn count, silicone resin and tuft density on the abrasion resistance of warp knitted carpets(20). Jeon et. al. investigated the abrasion behavior of three kinds of warp knitted fabrics, which are normally used for the upper sole of footwear (21). Chen et. al. investigated the comfort and abrasion properties of differential shrinkage polyester warp knitted fabrics(22).

The fabric should have sufficient strength against forces acting upon it during dyeing, finishing and use(23). Tensile strength tests are used for woven fabrics where there are definite warp and weft directions in which the strength can be measured. Knitted materials, lace and nonwovens do not have such distinct directions where the strength is at maximum. Bursting strength is an alternative method of measuring strength in which the material is stressed in all directions at the same time(4).

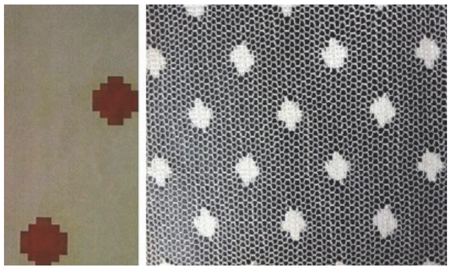
The effects of various yarn type or knit structures on the bursting strength of weft knitted fabrics have analyzed by many researchers[11-18, 23-26]. In these research bursting strength of knitted fabrics measured with hydraulic diaphragm bursting tester, pneumatic diaphragm bursting tester or ball burst mechanism.

To the best of our knowledge, there is no published experimental study which focuses on the investigation of the abrasion resistance and bursting strength of warp knitted lace look raschel fabrics. In this study, abrasion resistance measurement techniques of warp knitted lace look raschel fabrics were investigated. To compare the effects of measurement techniques, bursting strength of the warp knitted raschel fabric samples were measured with three different bursting strength test apparatus.

## 2. MATERIALS AND METHOD

### 2.1. Material

Experimental samples were knitted on E18 gauge electronic jacquard warp knitting machine. Eight different fabric samples were knitted with the same structure (Figure 1). All fabric types were knitted with 100% polyester yarn with a count of 167dtex 274f as a ground yarn. 100% polyester yarn with a count of 167 dtex 274f or 222 dtex 328f were used as a pattern yarn. To see the effects of the tightness; two different courses per cm values were chosen.



**(a)** **(b)**

**Figure 1.** (a) Knitting structure (b) photograph of the raschel fabric samples

Lace look raschel warp knitted fabrics can be used as a home textile (curtain, table cloth, etc) or clothing (outerwear, underwear). Raschel warp knitted fabrics which used in clothing should have a softer hand than net curtain fabrics. Because of this, two different finishing routine was chosen after washing, blank dyeing and drying in stenter: soft finishing and stiff finishing. All the fabrics were processed under industrial conditions. Fabric codes and properties of fabric samples were given in Table 1.

### 2.2. Methods

Dry-relaxation was made by laying the samples on a smooth and flat surface in standard atmospheric conditions (20±2°C and 65±4% relative humidity) for a week(29). The following properties of the fabrics were measured by relevant standards: Courses and wales per cm, EN 1049-2; weight (g/m$^2$), EN 12127; thickness (mm), EN ISO 5084.

#### 2.2.1. Abrasion resistance measurements

The abrasion resistance of the fabrics was determined by using Nu-Martindale Abrasion tester according to EN ISO 12947-2:2001 and EN 530 test methods. To compare the effects of loading peace, 9 kPa and 12 kPa forces were applied to the top of the specimen to hold it against the abradant. For assessment, the specimen is examined at 1000 cycles intervals to see whether hole occurs, or appearance has changed.

Because of the net structure of the raschel fabrics, during the abrasion test, the fabric could be press the foam and foam could be deformed. For this reason, %100 polyester, 32 wefts/cm, 50 warps/cm, 80 g/m$^2$ plain woven curtain fabric was mounted over a foam as a lining. To compare the effects of the lining fabric type, the standard abradant fabric was mounted over a foam as a lining too. To compare effects of pattern position on abrasion resistance results, the test specimen was mounted on a foam and lining two different type: Pattern was mounted randomly, or pattern was centered to the holder.

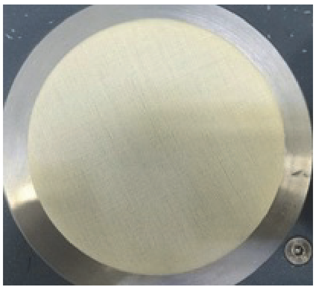
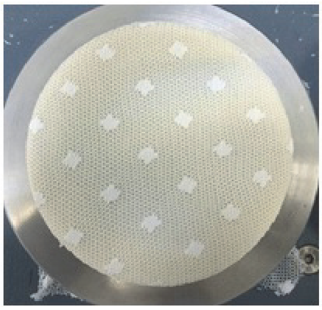
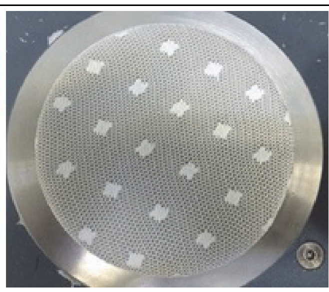
In daily usage, there is friction between arms and body of the clothing made with raschel warp knitted fabrics. Because of this, test samples were attached to the both holders.

Abrasion resistance test conditions which conducted in this study were given schematically in Table 2.

**Table 1.** Fabric codes and properties of raschel fabric samples (27,28)

| Fabric Code | Type of Finishing | Adjusted Courses/cm | Yarn Count | | Courses/cm | Wales/cm | Weight (g/m²) | Thickness (mm) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Pattern (dtex) | Ground (dtex) | | | | Pattern | Ground |
| 1S | stiff | 17,88 | 167 | 167 | 15,3 | 15,2 | 63,74±0,77 | 0,57±0,01 | 0,77±0,03 |
| 2S | stiff | 17,88 | 222 | 167 | 12,8 | 14,2 | 57,54±0,85 | 0,39±0,00 | 0,60±0,02 |
| 3S | stiff | 12,04 | 167 | 167 | 9,2 | 13,2 | 44,50±0,48 | 0,42±0,00 | 0,52±0,01 |
| 4S | stiff | 12,04 | 222 | 167 | 9,2 | 12,5 | 45,26±0,49 | 0,41±0,02 | 0,57±0,02 |
| 1Y | soft | 17,88 | 167 | 167 | 14,7 | 14,3 | 68,02±0,49 | 0,53±0,02 | 0,7±0,02 |
| 2Y | soft | 17,88 | 222 | 167 | 15 | 13,8 | 73,90±1,23 | 0,49±0,02 | 0,81±0,03 |
| 3Y | soft | 12,04 | 167 | 167 | 10,7 | 11,8 | 54,22±0,22 | 0,58±0,03 | 0,77±0,01 |
| 4Y | soft | 12,04 | 222 | 167 | 11,3 | 12,3 | 57,92±1,73 | 0,56±0,02 | 0,87±0,03 |

**Table 2.** Abrasion resistance test conditions

| Test Method<br>Test Standard | Top Holder | Bottom Holder | Experimental Parameters |
|---|---|---|---|
| **Abrasion Test (EN 12947-2)** | <br>Sample+ Woven Lining Fabric+Foam | <br>Standart Abradant Fabric+Felt | Loading Pieces:<br>9 - 12 kPa<br>*The pattern was mounted randomly* |
| **Abrasion Test (EN 12947-2)** | <br>Sample+ Standart Abradant Fabric +Foam | <br>Sample+ Standart Abradant Fabric +Felt | Loading Pieces:<br>9 kPa<br>*The pattern was centered* |
| **Reverse Abrasion Test (EN 530)** | <br>Standart Abradant Fabric+Foam | <br>Sample+Woven Lining Fabric +Felt | Loading Pieces:<br>9 - 12 Kpa<br>*The pattern was mounted randomly* |

#### 2.2.2. Bursting strength measurements

Bursting strength of the manufactured knitted fabrics was measured by hydraulic diaphragm bursting tester, pneumatic diaphragm bursting tester and ball burst mechanism.

**Hydraulic diaphragm bursting test:** Bursting strength of the fabrics were measured in accordance with the TS 393 EN ISO 13938-1:2002 standard. SDL Atlas M229 Auto burst bursting strength tester was used. According to TS 393 EN ISO 13938-1:2002 standard, 7,3 $cm^2$, 10 $cm^2$, 50 $cm^2$ or 100 $cm^2$ test areas may be used. To compare the effects of the test area, bursting strength of fabrics measured with 7,3 $cm^2$ and 10 $cm^2$ test areas.

Bursting strength of the fabrics was tested in the wet and dry state. To prepare wet samples, fabrics were placed in the 20±2°C distilled water for an hour. Test specimens were removed and gently squeezed to removed excess water (30).

**Pneumatic diaphragm bursting test:** Bursting strength of the fabrics were measured in accordance with the TS 393 EN ISO 13938-2:2003 standard. SDL Atlas M229P Pnuburst bursting strength tester was used. To compare the results of the hydraulic bursting tester, bursting strength of fabrics measured with 7,3 $cm^2$ test areas.

**Ball Burst Test:** Bursting strength of the fabrics were measured in accordance with the ASTM D6797-07 standard. 4301 model Instron tensile tester was used. A specimen of the fabric was securely clamped to the Instron without tension to the ball burst attachment. A force was exerted against the specimen by a polished, hardened steel ball until rupture occurs.

The results were analyzed statistically by using SPSS software. Analysis of variance (ANOVA) was performed to determine whether the factors differed significantly from each other. The results were evaluated at 5% significance level. The means were compared by SNK (Student Newman Keuls) test for rejected hypothesis. The treatment levels were marked in accordance with the mean values, and any levels marked by the same letter showed that they were not significantly different.

## 3.RESULTS AND DISCUSSIONS

### 3.1. Abrasion resistance test results

Abrasion test results were given in Table 3. In this table, greater numbers of cycles (rubs) correspond to better abrasion resistance.

**<u>Influence of lining fabric under the specimen:</u>** In Martindale abrasion tests, for specimens having a mass/unit area of fewer than 500 grams per square meter, you should place a disk of polyurethane foam between the specimen and a metal face. Because of the net structure of the raschel fabrics, during the abrasion test, raschel fabric could make pressure to the foam. The foam could be deformed, and particles from the deformed foam could affect the abrasion test results. To prevent this effect, a lining fabric was mounted over the foam in this study. We have used woven curtain fabric or woven wool fabric which are used as standard abradant as a lining (Figure 2). The results of the variance analysis reveal that the effect of lining fabric is not significant. (Significance value 0,756>0,05) Using lining fabric caused to measure abrasion resistance of the lace look raschel fabric objectively. Using standard abrasive wool fabric lining is advisable to make the test method standard.

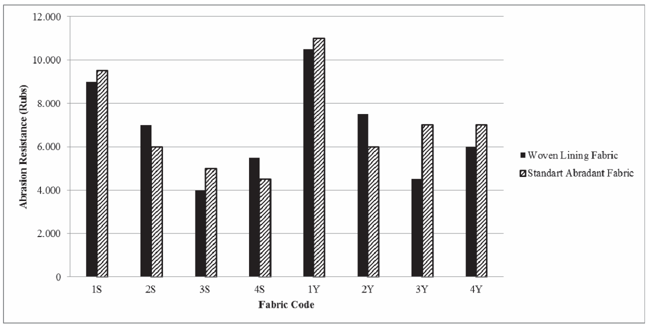



**Figure 2.** Influence of the lining fabric placed under the specimen on abrasion resistance values

**Table 3.** Abrasion resistance test results (Rubs until a hole occurs)

| **Test Method:** | Abrasion (EN 12947-2) | | | | | Reverse Abrasion (EN 530) | |
|---|---|---|---|---|---|---|---|
| **Abradant Fabric** | Standart Abradant Fabric | | | | Raschel Fabric | Standart Abradant Fabric | |
| **Pattern Position** | Random | | Pattern Centered | | | Random | |
| **Lining Fabric** | Woven Lining Fabric | | | Standart Abradant Fabric | | Woven Lining Fabric | |
| **Loading Pieces** | 9 kPa | 12 kPa | 9 kPa | 9 kPa | 9 kPa | 9 kPa | 12 kPa |
| **Fabric Code** | | | | | | | |
| **1S** | 7.000 | 5.000 | 9.000 | 9.500 | 19.000 | 50.000 | 29.000 |
| **2S** | 3.000 | 2.000 | 7.000 | 6.000 | 8.500 | 45.000 | 28.000 |
| **3S** | 3.000 | 2.000 | 4.000 | 5.000 | 9.000 | 23.000 | 12.000 |
| **4S** | 3.000 | 2.000 | 5.500 | 4.500 | 8.000 | 24.000 | 17.000 |
| **1Y** | 13.000 | 7.000 | 10.500 | 11.000 | 17.500 | 50.000 | 38.000 |
| **2Y** | 9.000 | 4.000 | 7.500 | 6.000 | 12.000 | 48.000 | 35.000 |
| **3Y** | 7.000 | 4.000 | 4.500 | 7.000 | 9.000 | 35.000 | 24.000 |
| **4Y** | 10.000 | 6.000 | 6.000 | 7.000 | 13.500 | 80.000 | 36.000 |

**Influence of reverse abrasion method:** According to EN ISO 12947-2:2001 standard, 140 mm diameter woven worsted wool abradant fabric were attached to bottom holder while 38mm diameter test specimen were attached to the top holder. On the other hand, jacquard warp knitted raschel fabrics could have a large pattern. In this case, a 38 mm diameter holder could not be useful for the assessment of appearance change. According to EN 530 standard, these roles are reversed, and the specimen is placed on the 140mm diameter abradant table. In this study, we called "reverse abrasion method" for this method. As may be seen from the figure 3, the bigger abrasion cycles were experienced from the reverse abrasion method. However, in the reverse abrasion method, because of the lace look raschel fabrics flexible structure, during the Lissa Ja ous movement, test fabric could be deformed as can be seen from figure 4.

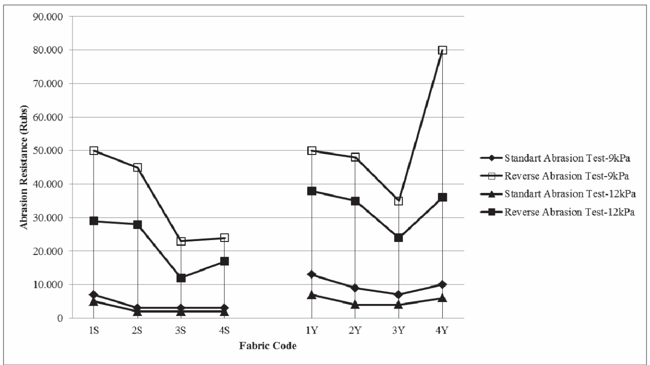



**Figure 3.** Abrasion resistance and reverse abrasion test results of the fabrics

In order to compare the effects of loading peace, 9 kPa and 12 kPa forces were applied to the top of the specimen to hold it against the abradant. According to test results, for both abrasion and reverse abrasion test methods, as the loading peace were increased, the smaller rubs were taken until a hole occurs as can be seen from figure 3.

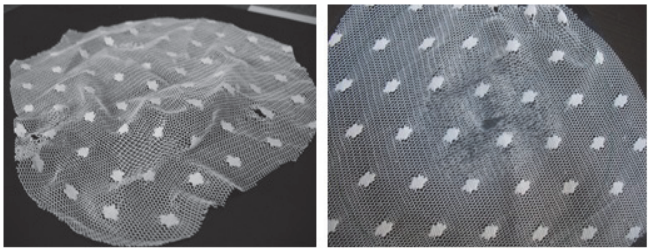


**Figure 4.** Fabric deformations after the reverse abrasion test

**Influence of pattern position on abrasion resistance results**

Jacquard warp knitted raschel fabrics could have a smaller pattern like our samples. In this case, it is possible to mount the test fabric to the holder as pattern position of the sample centered or randomly. To examine the influence of pattern position on abrasion resistance results, in this study 3S and 3Y fabrics were tested as pattern position of the sample centered or randomly in the holder. As may be seen from the figure 5, abrasion resistance test results of fabrics are not affected by pattern position in the holder.

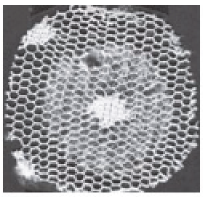
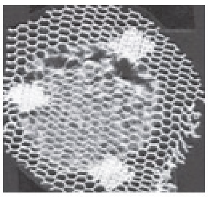
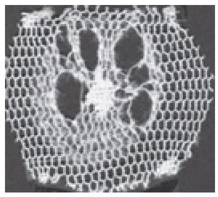
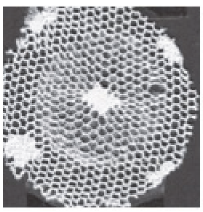
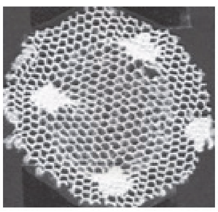
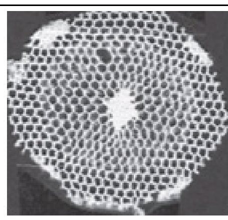
| Fabric Code | Pattern Position of the Sample: Centered Technical Face of the Fabric Sample Downwards | Pattern Position of the Sample: Random Technical Face of the Fabric Sample Downwards | Pattern Position of the Sample: Centered Technical Back of the Fabric Sample Downwards |
|---|---|---|---|
| 3S-Stiff Finish |  *4000-5.000 rubs* |  *5000-6.000 rubs* |  *4.000-5.000 rubs* |
| 3Y-Soft Finish |  *5000-6.000 rubs* |  *4000-5.000 rubs* |  *4.000-5.000 rubs* |

**Figure 5.** Abrasion resistance test results for different pattern positions

In abrasion resistance tests, mounting the test fabric to the holder is another important subject. You should assemble the holder by placing the test specimen with the technical face down into the ring. To compare test results for technical face and technical back side of the raschel fabrics, 3S and 3Y fabrics were tested. The technical face of the fabric is more rugged than the technical back of the fabric. As may be seen from the photographs in figure 5, for the stiff finished fabric (fabric code 3S), the technical back of the fabric sample is less resistant to abrasion than the technical face of the fabric. More holes on the technical back face of the fabric after 4000 rubs occurred. On the technical face of the soft finished fabrics, after 5000 rubs a hole occurred. On the technical back of the soft finished fabrics, after 4000 rubs a hole occurred. Because of the production technique, pattern section of the raschel fabric is thicker than the ground section. At the end of the abrasion test, there are not any broken threads or holes in the pattern section. Contrary to expectations, abrasion of the ground part worse than the pattern part of the raschel fabrics.

**Influence of abradant fabric type on abrasion resistance results**

The resistance of textile materials to abrasion as measured on a testing machine in the laboratory is only one of several factors contributing to wear performance or durability as experienced in the actual use of the material. While "abrasion resistance" and "durability" are frequently related, the relationship between them varies with different end uses, and different factors may be necessary for any calculation when trying to predict durability based on findings obtained from specific abrasion tests. Abrasion resistance is measured by subjecting the specimen to rubbing with a standard abrasive fabric.

To simulate abrasion occur between arm and body during wearing, in this study, raschel warp knitted fabric test samples were attached to the bottom holders as an abradant. In this case, we measured abrasion resistance for raschel fabric against itself. Results were given in Figure 6. The results of the variance analysis reveal that the effect of abradant fabric type is highly significant. (Significance value 0,000<0,05).

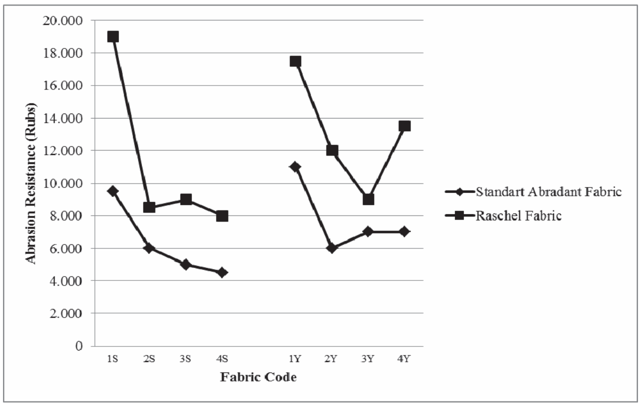



**Figure 6.** Influence of abradant fabric type on abrasion resistance test results

Abrasion resistance results of the tests which net curtain fabric was used, give bigger abrasion resistance values. On the other hand, there will be big holes on the test fabrics when the net curtain was used as an abradant.

### 3.2. Bursting strength test results

According to ASTM D3691-02, lace and knit fabrics intended for household curtain and drapery should meet 138 kPa bursting strength. This standard recommends diaphragm bursting tester or ball burst mechanism. According to TS 11680, lace and knit fabrics intended for household curtain should meet 140 kPa bursting strength. This standard recommends hydraulic type diaphragm bursting tester for the tests.

**Hydraulic type bursting strength test results**

Bursting strength values of the fabrics which measured with a hydraulic tester at 7,3 $cm^2$ and 10 $cm^2$ test area were given in Figure 7. The results of the variance analysis for the hydraulic bursting strength values reveal that the effect of the test fabric condition (wet or dry state) is highly significant. (Significance value 0,001<0,05).

Lowest bursting strength results are obtained in the wet state. According to the variance analysis results, the effect of the test area is highly significant. (Significance value 0,000<0,05). As the test area increases, the bursting strength decreases (Table 4).

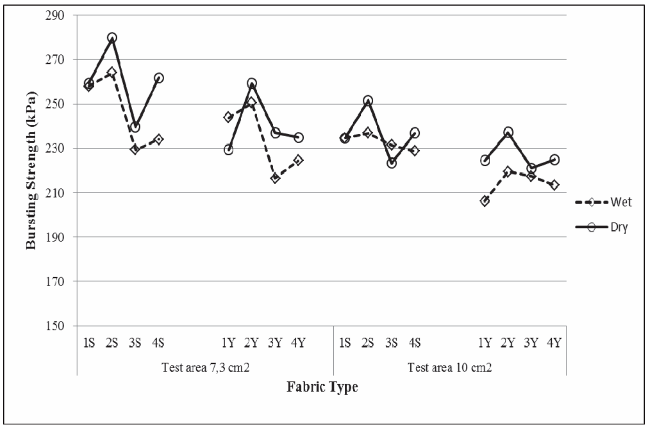



**Figure 7.** Bursting strength values of the fabrics (Hydraulic test)

**Influence of measurement technique on bursting strength results**

According to TS 393 EN ISO 13938-1:2002 standard, no significant difference in the bursting strength results achieved using hydraulic and pneumatic bursting testers for pressures up to 800 kPa. In our study, contrary to TS 393 EN ISO 13938-1:2002, the results of the variance analysis for the bursting strength values reveal that the effect of the test method is highly significant. (Significance value 0,000<0,05). The SNK test results reveal that the lowest bursting strength results were obtained from ball burst mechanism (Table 4). Highest bursting strength results were obtained from pneumatic bursting strength tester (Figure 8).

**Table 4.** SNK test results for bursting strength measurements

| Fabric Sample | Hydraulic Bursting Strength |
|---|---|
| 1A | 246,545c |
| 2A | 258,035d |
| 3A | 230,905ab |
| 4A | 240,340bc |
| 1B | 225,935a |
| 2B | 241,535bc |
| 3B | 222,930a |
| 4B | 224,295a |
| **Test Area** | |
| 7,30cm$^2$ | 245,064b |
| 10,00cm$^2$ | 227,566a |
| **Fabric State** | |
| Wet | 231,7538a |
| Dry | 240,8763b |

| Fabric Sample | Bursting Strength |
|---|---|
| 1A | 187,231b |
| 2A | 188,584b |
| 3A | 162,789a |
| 4A | 176,319b |
| 1B | 180,309b |
| 2B | 179,560b |
| 3B | 160,176a |
| 4B | 165,292a |
| **Test Method** | |
| Ballburst | 90,8823a |
| Hydraulic | 250,0875b |
| Pneumatic | 268,2775c |
| | |
| | |

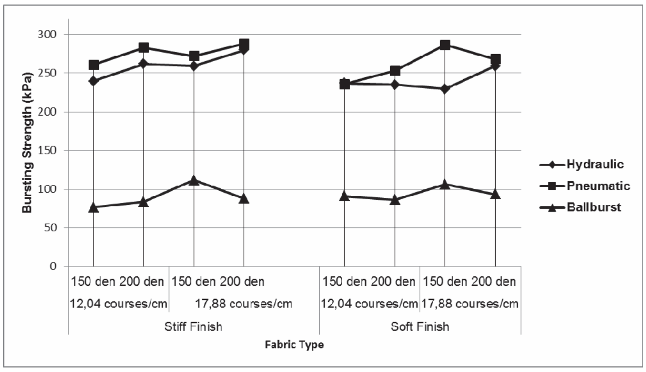



**Figure 8.** Bursting strength values of the fabrics

### 3.3. Influence of fabric parameters on abrasion resistance and bursting strength results:

Abrasion resistance of fabrics is not affected by pattern yarn count, tightness and finishing procedure statistically. On the other hand, according to SNK results, as may be seen from the table 5, bursting strength measurement technic influences the bursting strength results. For example, according to ball burst test, bursting strength of fabrics is not affected by finishing procedure statistically. On the other hand, according to hydraulic and pneumatic test results, bursting strength of fabrics is affected by finishing procedure statistically. The tighter fabrics have the highest bursting strength values. Soft finished fabrics show higher abrasion resistance values than stiffer finished fabrics.

## CONCLUSIONS

There are growing demands on the warp knitted raschel fabrics in recent years. We can see this fabric as net curtains, in blouses, footwears, under wears, shawls, etc. Abrasion is one of the most important reasons that make the textile products unusable. Martindale abrasion tester is most accepted tester although it may be the most complex(31). Abrasion resistance test results affected by the test conditions. In this paper, factors affecting the measurement of abrasion resistance of warp knitted raschel fabrics was investigated in detail.

Using lining fabric enable to measure abrasion resistance of the net curtain fabric objectively. Using standard abrasive wool fabric lining is advisable to make the test method standard.

-The bigger abrasion resistance values were experienced from the reverse abrasion method than abrasion method

-In the reverse abrasion method, because of the net curtain fabrics flexible structure, during the Lissa Ja ous movement, test fabric could be deformed

-pattern sections of the raschel fabrics show more abrasion resistance than ground sections

-the tighter fabrics have the highest abrasion resistance values.

-The finishing process affects the abrasion resistance of the fabrics. Fabrics with soft finish show higher abrasion resistance values than stiffer finished fabrics.

In order to compare the effects of measurement techniques, bursting strength of the warp knitted raschel fabric samples were measured with three different bursting strength test apparatus. According to the variance analysis results, the effect of the test method is highly significant. The SNK test results reveal that the lowest bursting strength results were obtained from ball burst mechanism. Lowest bursting strength results are obtained in the wet state. According to the variance analysis results, the effect of the test area is highly significant for the hydraulic bursting strength test. As the measured test area increases, the bursting strength decreases.

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**Table 5.** SNK test results for abrasion resistance and bursting strength measurements

| | Bursting Strength | | | | | | Abrasion Resistance | |
|---|---|---|---|---|---|---|---|---|
| | Hydraulic | | | | Pneumatic | Ball Burst | Raschel Fabric to Standart Abradant | Raschel Fabric to Raschel Fabric |
| | 7,3 $cm^2$ Dry Samples | 7,3 $cm^2$ Wet Samples | 10 $cm^2$ Dry Samples | 10 $cm^2$ Wet Samples | 7,3 $cm^2$ Dry Samples | Dry Samples | | |
| **Finishing** | | | | | | | | |
| Stiff | 260,08(b) | 246,32(b) | 236,53(b) | 232,91(b) | 275,88(b) | 90,02(a) | 7750(a) | 13000(a) |
| Soft | 240,10(a) | 233,77(a) | 226,81(a) | 214,03(a) | 260,68(a) | 94,34(a) | 6250(a) | 11125(a) |
| **Tightness (courses/cm)** | | | | | | | | |
| 12,04 | 243,31(a) | 226,06(a) | 226,47(a) | 222,65(a) | 258,06(a) | 84,49(a) | 5875(a) | 10500(a) |
| 17,88 | 256,87(b) | 254,03(b) | 236,87(b) | 224,29(a) | 278,50(b) | 99,86(b) | 8125(a) | 13625(a) |
| **Pattern yarn count (dtex)** | | | | | | | | |
| 167 | 241,29(a) | 236,89(a) | 225,74(a) | 222,39(a) | 263,65(a) | 96,41(b) | 7125(a) | 11375(a) |
| 222 | 258,88(b) | 243,19(a) | 237,59(b) | 224,54(a) | 272,91(a) | 87,94(a) | 6875(a) | 12750(a) |

## REFERENCES


1. Raz, S., 2016, “Warp Knitting Production”, Melliand Textilberichte Gmbh, Heidelberg, Deutschland, pp: 548
2. http://www.karlmayer.com/en/products/warp-knitting-machines/lace-machines/jacquard-curtain/(Accessed:23.12.2016)
3. http://www.knittingindustry.com/net-curtains-make-bright-comeback (Accessed:23.12.2016)
4. Saville, B.P., 1999, “Serviceability”, Physical Testing of Textiles, Woodhead Publishing, New York, pp: 184-205
5. Hu, J, 2008, “Fabric Testing”, Woodhead Publishing Limited. Cambridge, England, pp: 108-112
6. Özdil N., Kayseri Ö. and Mengüç S., 2012, “Analysis of Abrasion Characteristics in Textiles Abrasion Resistance of Materials”, Dr. Marchin Adamlak (Ed.), ISBN 978-953-51-0300-4, Intech, Rijeka, Croatia, pp:119-142
7. Au, K.F.,2011, “Women’s Apparel: Knitted Underwear”, Advances in Knitting Technology, Woodhead Publishing, Cambridge, England, pp: 38-39
8. Yang C., Zhou W., Lickfield G.C. and Parachura K., 2003, “Cellulase Treatment of Durable Press Finished Cotton Fabric: Effects on Fabric Strength, Abrasion Resistance and Handle”, Textile Research Journal, Vol: 73(12), pp: 1057-1062
9. Vasumathi, B.V., Somashekar T.H., Chilakwad S.L., and Shrikanth G., 2004, “Studies on Abrasion Resistance of Silk Fabrics”, Indian Journal of Fibre&Textile Research, Vol 29, March pp:69-73
10. Babaarslan O., Balcı H. and Güler Ö., 2007, “Elastan İlavesinin Poliester/Viskon Karışımlı Dokuma Kumaş Özellikleri Üzerindeki Etkisi”, Tekstil ve Konfeksiyon Dergisi, Vol:2, pp:110-114
11. Kavuşturan, Y. and Tekoğlu O., 2007, “Şenil ve Makarna İpliklerden Üretilen Düz Örme Kumaşların Aşınma, Patlama ve Eğilme Özellikleri”, Uludağ Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi, Vol:2, pp:109-122
12. Emirhanova, N. and Kavuşturan, Y., 2008, “Effects of Knit Structure On The Dimensional And Physical Properties Of Winter Outerwear Knitted Fabrics” Fibers & Textiles in Eastern Europe, 67, pp: 69-74 67
13. Nergis, B. and Candan, C., 2003, “Properties of Plain Knitted Fabrics From Chenille Yarns”, Textile Research Journal, Vol: 73(12), pp: 1052-1056
14. Ünal, S. and Ömeroğlu S., 2013, “Farklı Sitemlerle Direkt Olarak Elde Edilmiş Çift Katlı İplik Özelliklerinin Örme Kumaş Özelliklerine Etkileri” Tekstil ve Mühendis, Vol:20:91, pp: 9-15
15. Sharma, A. and Pant, S. , 2013, “Studies on Camel Hair-Merino Wool Blended Knitted Fabrics., Indian Journal of Fibre&Textile Research, Vol 38, September, pp:317-319.
16. Rameshkumar, C., Anandkumar P., Senthilnathan, P., Jeevitha R. and Anbumani N. 2008, Comparative Studies on Ring, Rotor and Vortex Yarn Knitted Fabrics”, AUTEX Research Journal, Vol 8, No 4 pp:100-105
17. Chinta, S.K., Landage S.M. and Vera K., 2012, “Effect of Biopolishing Treatment on Various Spun Yarn Knitted Fabrics”, Global Journal of Bio-Science & Biotechnology, vol.1(2), pp:287-295
18. Özcan, G. and Candan C., 2005, “Properties of Three Thread Fleece Fabrics”, Textile Research Journal, Vol:75(2), pp: 129-133
19. Uçar N. and Karakaş H.C., 2005, “Effect of Lyocell Blend Yarn And Pile Type On The Properties Of Pile Loop Knit Fabrics,” Textile Research Journal, Vol: 75(4), pp: 352-356
20. Değirmenci Z., 2016, “An investigation on the availability of face to face warp knitted pile fabrics as a durable carpet,” Tekstil ve Konfeksiyon Dergisi, Vol:26, pp: 31-39
21. Jeon H.Y., Jeong, W.Y., Park, J.W. and Kook Ann S., 2003, “The Mechanical Properties and Abrasion Behavior of Warp Knitted Fabrics for Footwear”, Fibers and Polymers, Vol:4, 4, pp:151-155.
22. Chen, Q., Miao, X., Mao, H. Ma, P and Jiang G., 2016, “The Comfort Properties of Two Differential-Shrinkage Polyester Warp Knitted Fabrics”, AUTEX Research Journal, Vol 16, No 2, pp:90-99
23. Ertuğrul S. and Uçar N., 2000, “Predicting Bursting Strength of Cotton Plain Knitted Fabrics Using Intelligent Techniques”, Textile Research Journal, Vol: 70(10), pp: 845-851
24. Jamshaid, H, Mishra, R., and Novak, J. 2015, “End-Use Performance Characterization of Unconventional Knitted Fabrics,” Fibers and Polymers; 16; 11; pp:2477-2490
25. Kan, CW., 2015, “Relationship Between Bursting Strength and Ultraviolet Protection Property Of 100% Cotton-Knitted Fabrics”, Journal of The Textile Institute;2, 106; 9; pp:978-985

26. Ciobanu, A.R., Ciobanu, L., Sârghie, B. and Dumitras, C., 2016, "Comparative Analysis of The Bursting Strength of Knitted Sandwich Fabrics," Fibres and Textiles in Eastern Europe, 24(2), pp:95-101

27. Bönceoğlu F. and Meral F.D., 2013, "Farklı iplik numarası ve sıklık değerlerinin raşel kumaş özelliklerine etkilerinin incelenmesi," Lisans Bitirme Çalışması, Uludağ Üniversitesi, Tekstil Mühendisliği Bölümü, Bursa,

28. Tiritoğlu M., 2016, "Çözgülü örme raşel kumaşların performans özelliklerinin incelenmesi," Uludağ University, Institute of Science, Department of Textile Engineering, Ph.D. Thesis, 141 p

29. Anonymous, 2008, TS EN ISO 139 "Şartlandırma ve deney için standart ortamlar," Turkish Standardization Institute, Ankara

30. Anonymous, 2002, 13938-1 "Kumaşların patlama özellikleri – Bölüm 1: Patlama mukavemetinin ve patlama gerilmesinin tayini için hidrolik metot.", Turkish Standardization Institute, Ankara.

31. Kotb N.A. and Megeid Z.M.A., 2011, "Evaluation of abrasion behavior of knitted fabrics under different paths of Martindale Tester", Journal of American Science, 2011, Vol:7(7), pp:164-189