Uludağ University Journal of The Faculty of Engineering, Vol. 23, No. 3, 2018 RESEARCH

DOI:10.17482/uumfd.445916

EFFECT OF WET LAUNDERING ON STRETCHING AND AIR PERMEABILITY PROPERTIES OF POLYESTER WARP KNITTED FABRICS WITH DIFFERENT FABRIC WEIGHTS

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Received: 19.07.2018 ; revised: 03.10.2018 ; accepted: 08.10.2018

Abstract: Warp knitting technology combines the two properties of dimensional stability and elasticity which are provided from woven and knitted fabrics separately. These fabrics consist of several threads (warp) which are formed as loops via needles and run through the fabric mainly in a vertical direction. These fabrics may be produced on a flat or a circular warp knitting machines. This study aims to investigate the influence of washing cycles (1, 5 and 20) on stretching (%) and air permeability properties of the polyester warp knitted fabrics of different weight. In order to analyze the effect of washing process on stretching ratios (%) and air permeability of the samples; Fyrma fabric extensometer and SDL Atlas M021A model Air Permeability Tester devices were used respectively. Additionally, the changes in fabric weight according to washing cycles of 1, 5 and 20 were also evaluated. According to test results; the stretching properties and air permeability values of the polyester warp knitted fabrics produced in different weights varied according to the laundering cycle which emphasized that caring processes should also be considered during the evaluation of mechanical properties (such as stretching, air permeability properties) of polyester warp knitted fabrics.

Keywords: warp knitting, polyester, stretching properties, air permeability, wet laundering

Farklı Ağırlıklarda Üretilen Poliester Çözgülü Örme Kumaşların Uzama Ve Hava Geçirgenlik Özelliklerine Yıkamanın Etkisi

Öz: Dokuma ve örme kumaşlardan ayrı ayrı sağlanan boyutsal stabilite ve elastikiyet özellikleri çözgülü örme teknolojisinde bir araya getirilmektedir. Bu kumaşlar dikey doğrultuda kumaş boyunca uzanan, iğneler vasıtasıyla ilmekler oluşturabilen çözgü ipliklerinden oluşmaktadır. Çözgülü örme kumaşlar düz ya da dairesel çözgülü örme makinelerinde üretilebilmektedir. Bu çalışma kapsamında yıkama işleminin (1, 5 ve 20 tekrar sayısında) farklı ağırlıklarda üretilen poliester çözgülü örme kumaşların uzama ve hava geçirgenlik özelliklerine etkisini incelenmesi amaçlanmaktadır. Bunun için sırasıyla, Fyrma kumaş ekstensiyometresi ve SDL Atlas M021A model hava geçirgenliği ölçüm cihazları kullanılmıştır. Ayrıca 1, 5 ve 20 yıkama sayısı ile kumaş ağırlıklarındaki değişim değerlendirilmiştir. Yapılan testlere göre farklı ağırlıklarda üretilen poliester çözgülü örme kumaşlar, uzama ve hava geçirgenliği özellikleri bakımından yıkama tekrar sayısına göre değişiklik göstermiştir. Bu sonuç ise poliester çözgülü örme kumaşların mekanik özellikleri değerlendirilirken bakım işlemlerinin de göz önünde bulundurulması gerektiğini vurgulamaktadır.

Anahtar Kelimeler: çözgülü örme, poliester, uzama özellikleri, hava geçirgenliği, yıkama

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1. INTRODUCTION

Knitted textiles are made of stitches where the loops are intersecting one another. A stitch structure can be made of one yarn end (a weft knitted fabric) or it can be made of a sheet of parallel yarn ends (warp knitted fabric). Today warp knitted is defined as a loop forming process in which the yarn is fed into knitting zone, parallel to the fabric selvedge. In warp knitting, fabric is made by forming loops from yarns coming in parallel sheet form which run in the direction of fabric formation (like warp in weaving). Every needle is fed by a separate yarn in warp knitted machines where the yarns are shogged (shifted) between the needles. The new loop formed is drawn through the previous loop formed by the another yarn as the production principle. Number of guide bars in a machine is the same with the number of warp beams. The guides which are fitted on the guide bars are feeded with the yarns of equal number of each warp beam. Although yarns may vary in color and composition; all guides on the guide bar should provide same identical lapping motion with the same warp tension (Ray, 2011). Figure 1 reveals the individual yarn guides set in a solid bar. The front-to-back movements are called swings. The first swing from front to back is followed by a lateral shog: the overlap, which wraps the yarn in the needle hook. The next movement is a swing from back to front followed by the underlap that may be from 0 to 8 needle spaces depending on the fabric structure being knitted (Spencer, 2001). The loop can be closed or open in warp knitting. If the direction of the incoming thread (overlap) is the same as the direction of the outgoing thread (underlap), we call it an open loop. In case of opposite direction, we call it a closed loop. It is also essential to emphasize the preparation of warp beams from where large numbers of yarns in parallel sheet form are supplied. Warp knitting machines are flat and comparatively more complicated than weft knitting machines. Today tricot and Raschel warp knitting machines are the most frequently used ones. A stitch comb and knock-over comb bar in Raschel machines whereas a sinker bar is used in Tricot machines. Double-bar raschel machines are also used for producing three-dimensional textiles including spacer textiles. However, warp knitting have limited elastic properties in longitudinal directions which can only be improved by subsequent finishing. A few of the popular warp knitted structures are locknit, sharkskin, queens'cord, double atlas, velour etc. (Ray, 2011; Spencer, 2001).

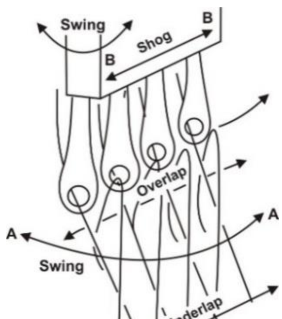


Figure 1:
Lapping movement of guide bar (Spencer, 2001)

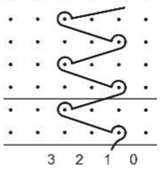
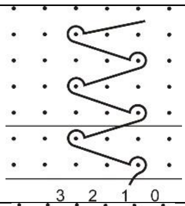
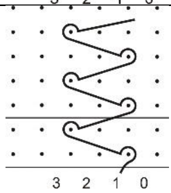
It is important to select suitable materials and structures for warp knitted fabrics for ensuring the required comfort characteristics as well as with the tensile properties. In the commercial warp knitted products, polyester which provides a wide range of applications allows a quick response to the demands of the market. Those products may include upholstery fabrics, sportswear, coating substrates and velours produced with tricot machine and plush fabrics, 3D spacer fabrics, nets and seamless articles produced with raschel machine (www.karlmayer.com/en/products/warp-knitting-machines, 2018). In the early literature, there are some studies related to influences of fabric production parameters on mechanical properties of the warp knitted fabrics. Abrasion resistance of warp knitted carpets were investigated for analysing the effect of pile yarn count, silicone resin and tuft density in Değirmenci's study (2016). Chen et al. evaluated the comfort and abrasion properties of polyester warp knitted fabrics which reveal differential shrinkage (Chen et al., 2016). Lee (2006) investigated the changes of pulling-out length and shrinkage ratio in polyester/spandex power net warp knitted fabrics. The researcher declared that as the treatment temperature increased, extensibility increased proportionally to the sample length. The shrinkage ratio (%) also increased in the wale and course direction so the pulling out length proportionally. Influence of fabric structure on stress relaxation of two bar warp knitted fabrics (reverse locknit, sharkskin, queens'cord) was evaluated in Hashemi et al.'s study (2016). The authors concluded that fabric structure was one of the important factor affecting the stress, stress relaxation percent of the fabric. Some researches related to special warp knitted fabrics for technical textiles applications have also been conducted (Blaga et al., 2013; Wang and Hu, 2014). Peled et al. searched the influence of different textile characteristics of the warp knitted fabrics made from multifilament yarns on tensile properties of textile reinforced cement elements and on the bonding quality between the fabrics and the cement matrix. Loop size, bundle size (number of filaments) and fiber type (high density, polyethylene, polypropylene, AR-glass and aramid) were investigated in order to evaluate the bond strengths with the cement matrix (Peled et al., 2008). Ye et al. (2007) made a study about the application of warp knitted spacer fabrics in car seats as a substitute for polyurethane foam as padding in car seats. The results revealed that relatively to polyurethane foam, warp knitted spacer fabrics indicated better recovery to compression, thermal properties and breathability as well as with the properties of easy recycling and keeping their original thickness for a longer period (Ye et al., 2007). Liu et al. (2012) presented a study of the impact compressive behavior of warp-knitted spacer fabrics which were developed for human body protections. It was declared that all structural parameters significantly affected impact compressive behavior of the warp knitted spacer fabrics in terms of peak contact force, peak transmitted force and energy absorbed at different impact compressive stages. A decrease of peak contact force about 33.16% was provided with the warp-knitted spacer fabrics. Yip and Ng (2008) investigated the physical and mechanical properties of the special "spacer fabrics" which are three dimensional knitting for industrial applications. The characteristics of different spacer fabrics including low-stress mechanical properties, air permeability and thermal conductivity were analyzed in the study. They concluded that tensile, bending and compression properties influenced from the fabric type (warp or weft knitting), spacer yarn used (monofilament or multifilament), spacer yarn configuration. Additionally, air permeability and thermal conductivity of spacer fabrics were found related with the fabric density as well (Yip and Ng, 2008).

Warp knitted fabrics have been studied in aspects for many years, however to the best of our knowledge; Very little research work has been done related to evaluation of washing effect on stretching ratios (%) and air permeability values of the warp knitted fabrics which are produced at different weights. Since the warp knitted textiles include textile products which may require caring processes; it was thought to be useful to consider the warp knitted polyester fabrics' stretching ratios (%) with the washing effect within this study. Additionally, air permeability properties of the samples were also evaluated in order to have some idea about their breathability features

2. MATERIAL METHOD

In order to evaluate the influence of washing process on stretching ratios (%) and air permeability properties of polyester warp knitted fabrics produced in different weights; Warp knitted fabrics were produced on Karl Mayer HKS 3 model Tricot warp knitting machine (Figure 2) by using three guide bars. Polyester yarns with different yarn linear densities were fed to the guide bars according to experimental design indicated in Table 1. After the relaxation process of the warp knitted fabrics, the 50x50 cm samples were exposed to laundering cycles of 1, 5 and 20 at 30° C by using the 5.85 gram 3.94 gram and 1.98 gram standard reference detergent respectively (ISO 6330, 2012). Home drying process was applied for 40 minutes after each washing cycle. Before the measurements, all fabric samples were conditioned for 24 hours in standard atmospheric conditions (at a temperature of 20 ± 2 °C and relative humidity of 65 ± 2%).

Table 1. Experimental design of the study

Fabric Appearance	stitch type: 2 x 1 open lap (tuch)	Fabric Code	Fabric weight (g/m^2)	*wpc	*cpc	Number of yarn guide	Yarn count	Yarn Type
		B	174	8	8	2 Guide Bar	75 Denier /36 fil	Polyester
						1Guide Bar	75 Denier/34 fil	Polyester
		W1	128	8	6	2 Guide Bar	75 Denier /30 fil	Polyester
						1 Guide Bar	75 Denier/36 fil	Polyester
		W2	108	10	10	2 Guide Bar	50 Denier /24 fil	Polyester
						1Guide Bar	75 Denier/36 fil	Polyester

wpc: wale per cm *cpc: course per cm

Figure 2:
Karl Mayer HKS 3 warp knitting machine

The extensibility of the warp knitted fabrics was tested in both wale and course direction, using a Fryma Fabric Extensometer under a 30 N tensile force which is considered to be in the range of the regular strain (Figure 3). Fyrma fabric extensometer is a stretch testing instrument for determining the stretching ratio (%), permanent stretching ratio (%) and elastic recovery properties according to test standard of BS 14704 (BS 14704, 2005). The specimens were prepared so that they would be (85±1.0) mm in longitudinal and (75±1.0) mm wide wise. Stretching tests were evaluated for the non-washed warp knitted fabrics, for the warp knitted fabrics applied to 1 washing cycle, for the warp knitted fabrics applied to 5 washing cycles and for the warp knitted fabrics applied to 20 washing cycles.

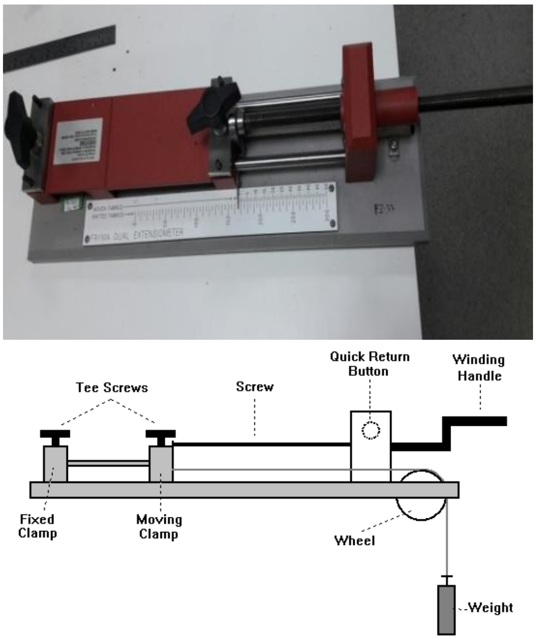


Figure 3:
FRYMA Fabric Extensometer Device (SDL Atlas)

Stretching ratio (%) is described as the ratio of extension of the test specimen to its initial length expressed as a percentage (%). In the Fryma fabric extensometer device, the test specimens (85x75 mm) were subjected to 5 cycling between gauge length and the required force of 3kg by using cross-head in motion. The stretching ratios (%) were recorded after ten seconds according to equation 1.

$$S=\frac{E-L}{L} \quad (1)$$

where E: is the extension (mm) at maximum force on the 5th cycle

L: is the initial length (mm)

For the permanent stretching calculation; the specimens were marked 5 mm inside the short edge of the fabric and a 3 kg of load was applied for 2 hours. At the end of 2 hours, the fabrics were exposed to relaxation for one minute and the permanent stretching was calculated. For the warp knitted fabrics, the permanent stretching percentage shouldn't be more than 3 %; For obtaining the elastic recovery ratios (%), the fabrics exposed to permanent stretching test were released for 30 minutes and the shortening distance of marked points were calculated.

Warp knitted polyester fabrics were also measured for their air permeability (mm/s) by using SDL Atlas Digital Air Permeability Tester Model M 021A which was provided from textile laboratory of Textile Engineering Department in Uludağ University. The air permeability values of the fabrics were measured in a 20 cm^2 test area at 100 Pa air pressure according to EN ISO 9237:1997 standard. Five different areas from the front of each fabric were measured for the air permeability test. The air permeability (mm/s) was determined as follows (EN ISO 9237, 1995):

$$R=\left(\frac{\bar{q}_v}{A}\right).167 \quad (2)$$

where: $\overline{q}_v$: an arithmetical average of the debit of air flow ,dm^3/min; A: Test area, cm^2; and 167: coefficient of conversation from dm^3/min to cm^3/s and then from cm/s to mm/s. Results were expressed as "mm/s"

3. RESULTS&DISCUSSION

3.1. Fabric Weight (g/m^2)

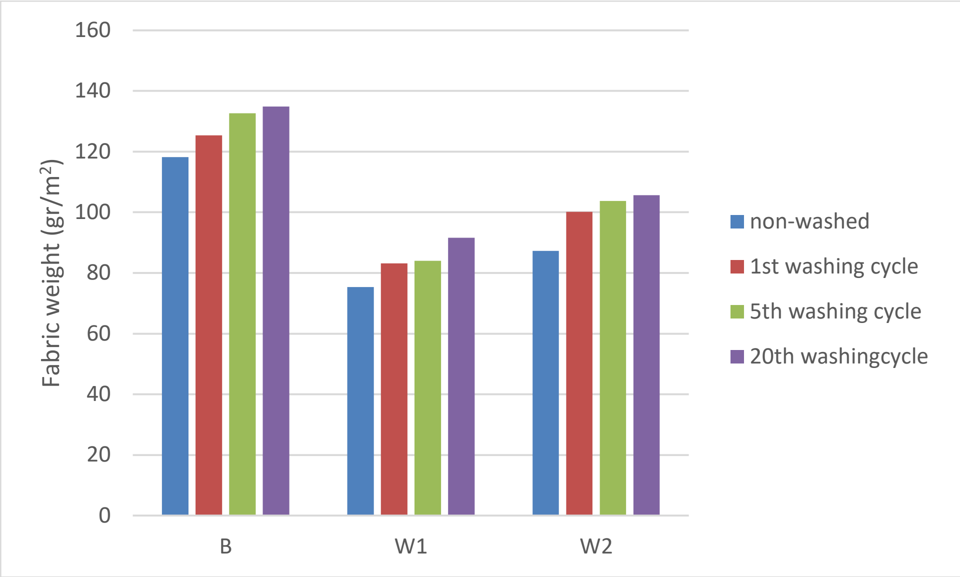


Figure 4:
Weight of the warp knitted fabrics (g/m^2) versus washing cycles

Figure 4 reveals the change in knitted fabrics' weight regarding to washing cycles. As it is expected, B", "W1" and "W2" knitted fabrics revealed an increasing trend for the fabric weights with the washing cycle without depending on their structural parameters. "B" coded knitted fabrics revealed the highest fabric weights (g/m^2) where "W2" and "W1" coded knitted fabrics followed it mannerly.

3.2. Stretching Ratios (%)

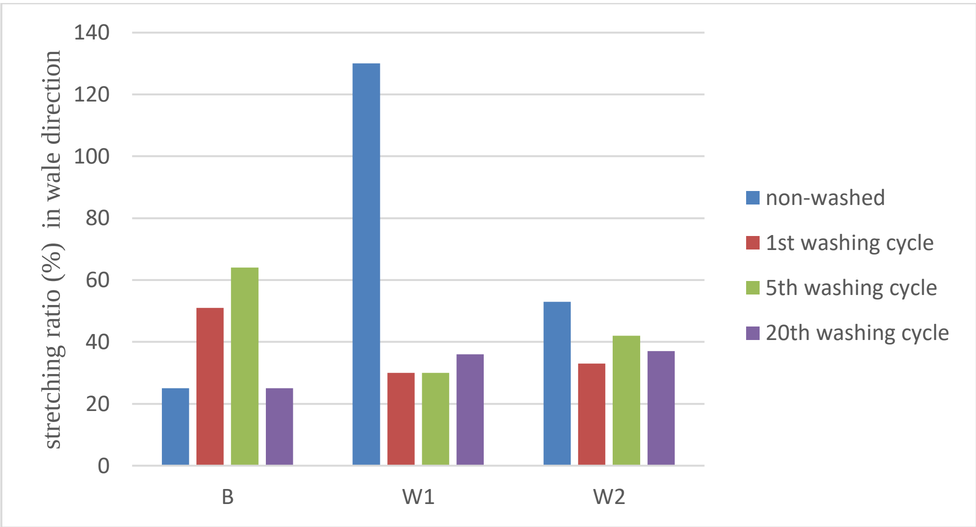


Figure 5:
Stretching ratio (%) in wale direction (after 10 seconds)

Figure 5 indicates the stretching ratio (%) in wale direction (after 10 seconds). Considering the "B" samples which have the highest fabric weight (g/m^2), maximum value was obtained in the samples treated to 5 washing cycle as 64 % whereas the lowest values were found among the non-washed and the samples treated to 20 washing cycle as the same value of 25 % among the "B" coded fabrics. The non-washed samples revealed a prominent high stretching ratio (%) as "130" comparing to others whereas the samples treated to 1st washing cycle and treated to 5 washing cycle revealed the lowest values among the "W1" samples of medium weight. When it comes to "W2" coded fabrics of the lowest weight (g/m^2), maximum stretching ratio (%) was obtained from non-washed warp knitting fabrics as 53 % whereas the samples treated to 1st washing cycle indicated the lowest value as 33 %.

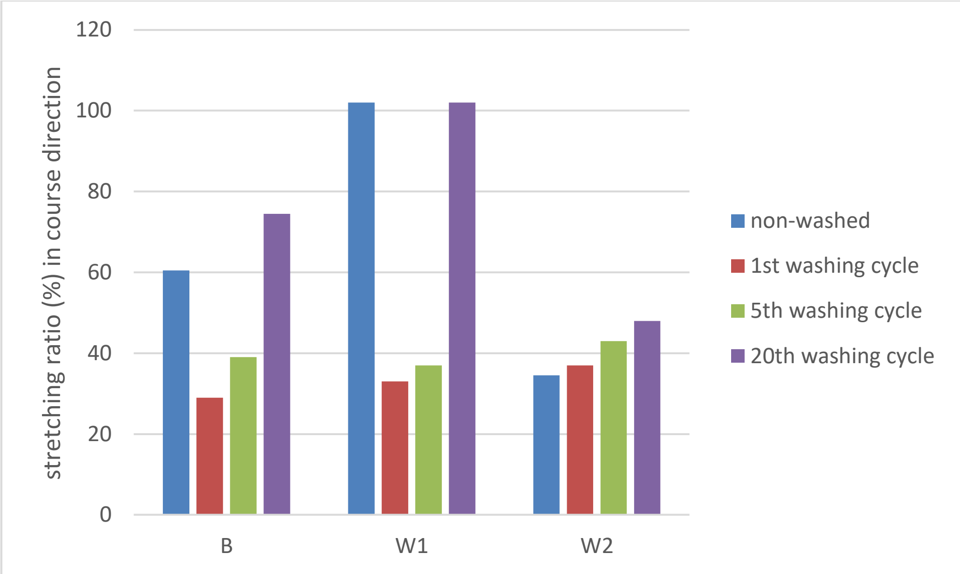


Figure 6:
Stretching ratio (%) in course direction (after 10 seconds)

Stretching ratio (%) in course direction (after 10 seconds) is indicated in figure 6. Among the "B" coded fabrics with highest fabric weight (g/m^2); maximum stretching ratio (%) was obtained from 20th washing cycle as 74.5 % whereas minimum stretching ratio % was found in the samples treated to 1st washing cycle as 29 %. The samples treated to 5th washing cycle and non-washed samples follow it from lowest to highest. Considering "W1" coded warp knitted fabrics of medium weight (g/m^2); Non-washed and samples treated to 20 washing cycle revealed the same stretching ratio (%) in course direction as a maximum value whereas the samples treated to "1st" washing cycle indicated the lowest value as 33%. When it comes to "W2" coded fabrics of the lowest weight, the highest stretching ratio (%) in course direction was obtained from samples to treated 20 washing cycle as 48 % whereas the lowest value (%) was found among the non-washed samples as 34.5 %.

According to Figure 7; the highest permanent stretching ratios in wale direction was found in the 5th washing cycle among all "B, W1 and W2" coded fabric groups. Considering the "B" coded knitted samples of the highest fabric weight; Maximum permanent stretching (%) was obtained from the samples treated to 5th washing cycle whereas the lowest stretching ratio (%) was found among the fabric groups of non-washed and subjected to 1st washing cycle as 1.29 %. Considering "W1" fabric groups of medium weight; the non-washed, treated to 1st washing cycle and treated to 20th washing cycle fabric samples all revealed the same permanent stretching ratio (%) as 1.29. When it comes to "W2" coded fabric groups of lowest fabric weight; Non-washed, subjected to 20 washing cycle and subjected to 1st washing cycle samples followed the highest permanent stretching (%) indicating fabric groups (treated to 5th washing cycle) orderly.

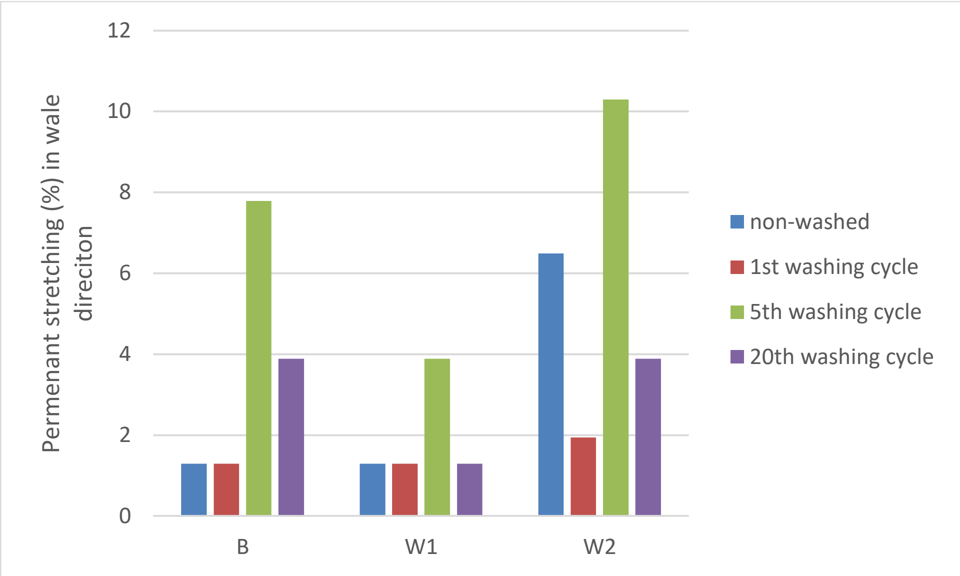


Figure 7:
Permanent stretching (%) in wale direction

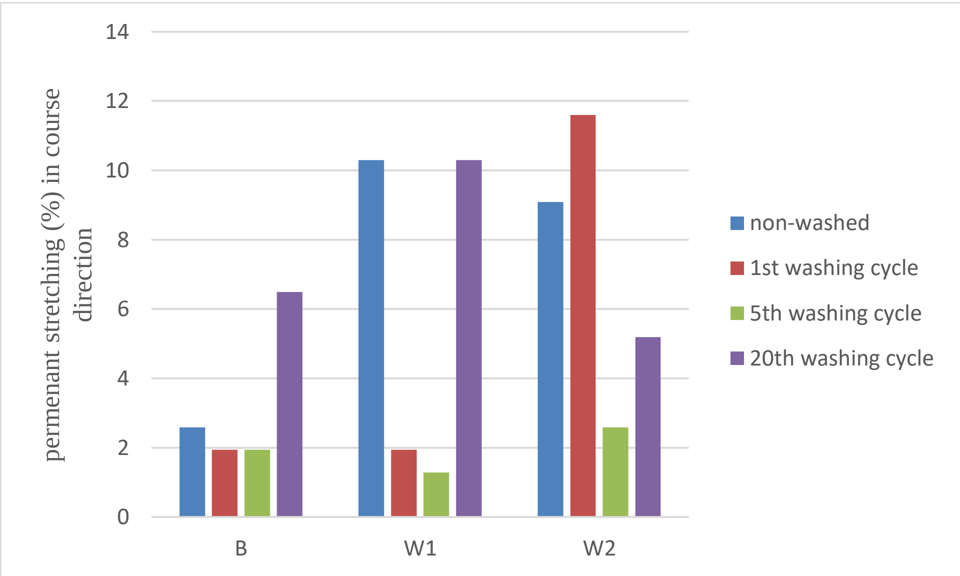


Figure 8:
Permanent stretching (%) in course direction

Figure 8 indicates the permanent stretching ratios (%) in course direction. Considering "B" coded fabrics of maximum fabric weight; the highest values were obtained from the samples subjected to "20" washing cycle as 6.49 % whereas the lowest values were found among the warp knitted samples subjected to "1" and "5" washing cycles as 1.94 %. When it comes to W1 coded samples; the highest permanent stretching ratios (%) were found among the fabric groups of non-washed and which are treated to 20th washing cycle as 10.3 % whereas the lowest value was found among the samples subjected to 5 washing cycle as 1.29 %. Considering "W2" fabric samples of lowest weight; the highest permanent stretching (%) was obtained from the samples subjected to 1st washing cycle whereas the lowest value was found among the samples treated to 5 washing cycle.

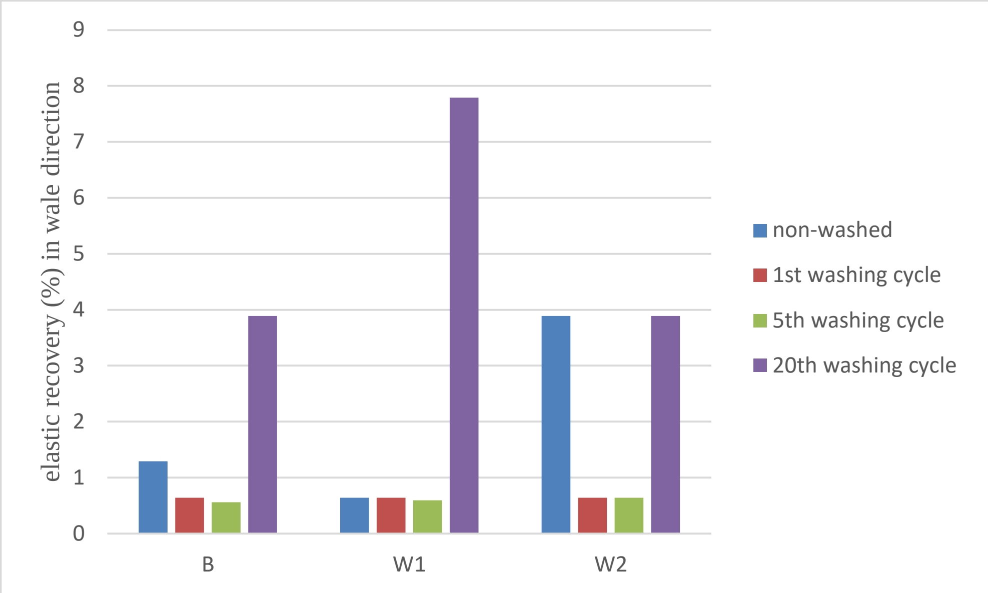


Figure 9:
Elastic recovery (%) in wale direction

According to figure 9, the highest elastic recovery (%) in wale direction was found in the samples treated to 20 washing cycle whereas the lowest value was found in the samples treated to 5 washing cycle among the "B" and "W1" coded fabric groups which have the highest and medium fabric weight (g/m^2) respectively. When it comes to "W2" coded fabric samples of lowest weight; the highest elastic recovery (%) was found in the non-washed and treated to 20 washing cycle samples as 3.89 % again whereas the lowest value belonged to samples treated to 1st and 5 washing cycle as 0.64 %.

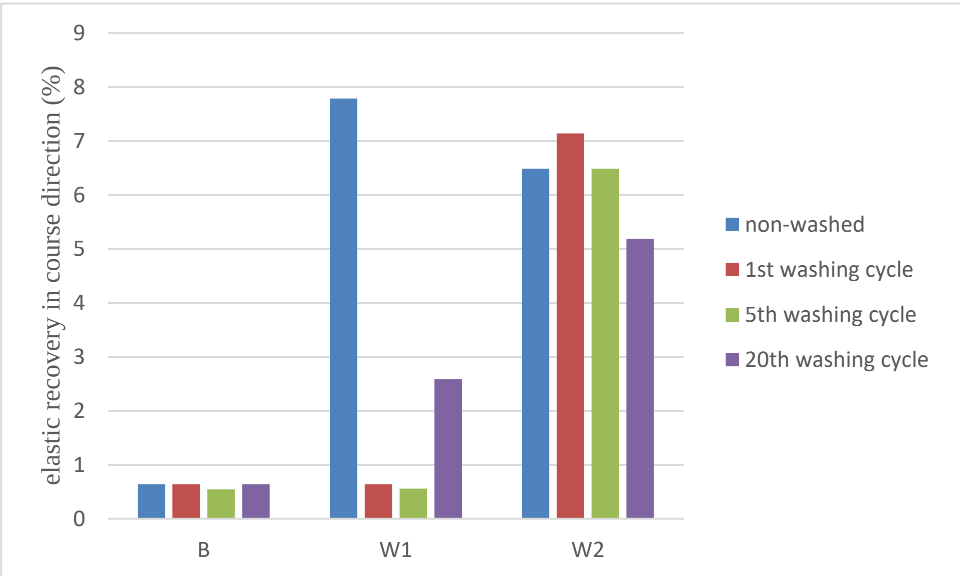


Figure 10:
Elastic recovery (%) in course direction

Figure 10 indicates the elastic recovery (%) of the samples in course direction. As a general trend; “B” coded warp knitted fabrics of highest weight indicated lower values comparing to “W1” and “W2” coded fabrics for all washing cycles. There was not any prominent change in elastic recovery (%) in course direction for the washing cycles among “B” coded knitted fabrics however the samples treated to “5” washing cycle indicated slightly lower values. Considering “W1” coded fabrics of medium weight; non-washed samples revealed the highest ratio as 7.79 % whereas the samples subjected to 5th washing cycle indicated the lowest elastic recovery (%) as 0.56 % in course direction. When it comes to “W2” coded fabric groups of lowest weight; the highest recovery ratio (%) was found in the samples treated to 1st washing cycle as 7.14 %. The non-washed samples and the samples treated to 5 washing cycle indicated the same recovery ratio (%) as 6.49 % whereas the samples treated to 20 washing cycle followed them as 5.49 %.

3.3. Air permeability

Figure 11 indicates the air permeability (mm/s) of the warp knitted fabrics. Non-washed warp knitted samples revealed the highest air permeability (mm/s) values among all fabric groups. Considering “B” coded samples of highest weight; fabric groups treated to 20 washing cycles, fabric groups treated to 5 washing cycle and fabric groups treated to 1 washing cycle followed non-washed samples with maximum air permeability values orderly. When “W1” fabric groups are considered, non-washed samples revealed the highest air permeability (mm/s) values whereas the samples subjected to 1st washing cycle indicated the lowest value. When it comes to “W2” coded samples of lowest weight, the samples treated to 1st washing cycle indicated the minimum air permeability (mm/s) where the non-washed samples revealed the highest air permeability (mm/s) values.

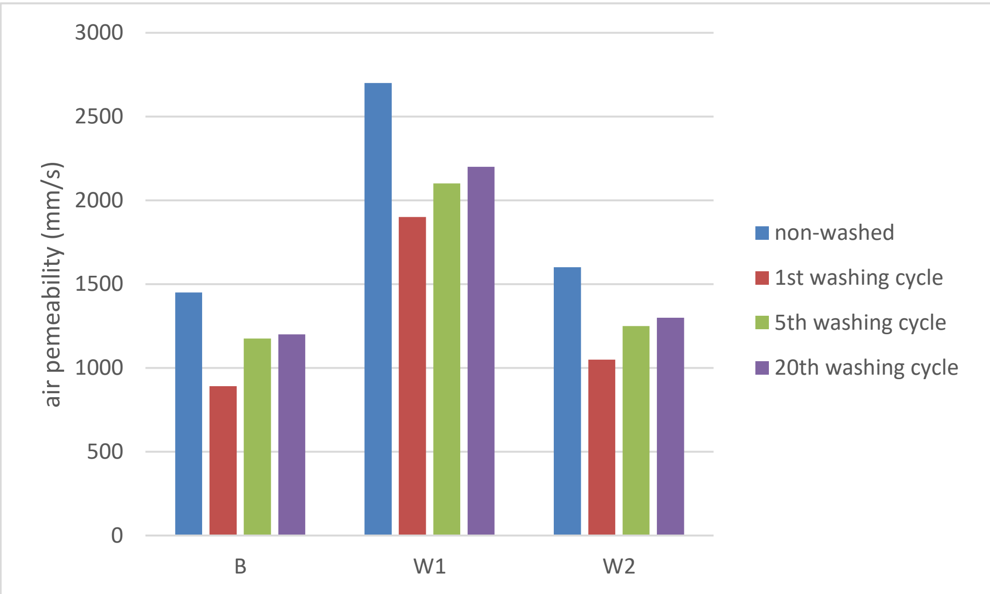


Figure 11:
Air permeability (mm/s)

4. CONCLUSION

According to subjected tests and the evaluations; it should be emphasized that laundering effect should be considered for the warp knitting fabrics' stretching (%) and air permeability values (mm/s). Warp knitted samples' fabric weight (g/m^2) revealed an increasing trend with the washing cycles among "B", "W1" and "W2" coded knitted fabrics. Maximum stretching ratios (%) after 10 seconds in wale direction was found in the non-washed "W1" coded fabrics of medium weight. Samples treated to 20th washing cycle indicated the maximum stretching ratio (%) after 10 seconds in course direction among all fabric groups of different weight. The highest permanent stretching ratios (%) in wale direction was found in the fabric samples treated to 5th washing cycles. However, all fabric groups treated to 5th washing cycles indicated the lowest values for the permanent stretching ratios (%) in course direction. The highest elastic recovery (%) in wale direction was found among the samples treated to 20th washing cycle among "B", "W1" and "W2" knitted fabrics. Non-washed "W1" samples of medium fabric weight (g/m^2) indicated higher elastic recovery (%) in course direction prominently. "B" coded warp knitting samples of highest weight indicated the lowest elastic recovery values (%) when compared with the other fabric groups. Finally, regarding to air permeability; Non-washed warp knitted samples revealed the highest air permeability (mm/s) values among all fabric groups of "B, W1 and W2" whereas the samples treated to 1st washing cycle indicated the lowest values (mm/s)

Disclaimer

Mention of trade names or commercial products in this manuscript is solely for the purpose of providing specific information and does not imply recommendation or endorsement.

Acknowledgement

The authors wish to express their thanks to Emre AKDEMİR ,Ahmet GÜLER and İlker SERİNDAĞ for their contributions to the study.

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