

THE EFFECT OF REPEATED LAUNDERING ON PROPERTIES OF NEEDED AND CALENDERED NONWOVEN CLEANING MATERIALS PRODUCED WITH DIFFERENT PROCESS CONDITIONS

TEKRARLI YIKAMANIN FARKLI ÜRETİM PARAMETRELERİYLE ÜRETİLMİŞ İĞNELENMİŞ VE KALENDERLENMİŞ DOKUSUZ YÜZEY TEMİZLİK BEZLERİNİN ÖZELLİKLERİNE ETKİSİ

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ABSTRACT

The aim of this study is to evaluate the physical and performance properties of needed and thermal bonded nonwoven cleaning materials produced with different conditions after changing washing cycles; 0, 1, 5 and 10 cycles. For this purpose, 5 different nonwoven cleaning materials with different areal weights containing polyester and viscose fibers and produced by either calendering or through air bonding after needling process was selected as material. All the samples were washed with standard washing procedures for 1, 5 and 10 times and tested before and after washing cycles. The variation in areal weight, thickness, bulk density, abrasion resistance, bursting strength and water absorption capacity was analyzed and assessed in detail considering production process difference. The results derived from the study indicated that through air bonded samples had better performance properties after washing cycles compared with calendered counterparts.

Keywords: Nonwoven, cleaning cloth/wipe, repeated washing, abrasion resistance, functional properties

ÖZET

Bu çalışmanın amacı; farklı koşullarda üretilen iğnelenmiş ve ısırl bağlanmış dokusuz yüzev temizlik bezlerinin 0, 1, 5, 10 defa yıkama sonrasındaki fiziksel ve performans özelliklerinin değerlendirilmesidir. Bu amaçla, farklı gramajlarda olan, polyester ve viskon lifi içeren ve iğnelendikten sonra ya sıcak silindirlerle ya da sıcak hava ile ısırl bağlama uygulanmış dokusuz yüzev temizlik bezi materyal olarak seçilmiştir. Bütün numuneler standart yıkama işlemi ile 1, 5 ve 10 defa yıkanıp test edilmiştir. Yıkama sonrasında; gramaj, kalınlık, yoğunluk, aşınma dayanımı, patlama mukavemeti ve su emme kapasitesi özellikleri analiz edilmiş ve üretim işlemlerindeki farklılıklar dikkate alınarak ayrıntılı olarak değerlendirilmiştir. Çalışmadan elde edilen sonuçlar, sıcak hava ile bağlama uygulanmış numunelerin sıcak silindirlerle olan eşleniklerine göre yıkamadan sonra daha iyi performans özelliklerine sahip olduklarını göstermiştir.

Anahtar Kelimeler: Dokusuz yüzev, temizlik bezi, tekrarlı yıkama, aşınma dayanımı, fonksiyonel özellikler

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1. INTRODUCTION

Nonwoven materials have been among the most demanded textile materials in many application areas in recent years due to the easy and lower number of processes in manufacturing line, higher production rates and lower costs compared to the similar woven or knitted products and diverse characteristics and properties. Nonwoven cleaning

materials/wipes are one of the most widely used nonwoven products which constitute 16% of the whole nonwoven market share with dry and wet wipes [1, 2].

These materials are generally constituted from viscose, polyester, polypropylene, cotton fibers and their mixtures by needle punching method followed by thermal bonding process applied either by calendering or through air bonding

[3]. The properties of these products are closely related with the fiber type and fiber characteristics constituting the nonwoven, the structural arrangement of fibers in the web and the bonding constructions which are influenced by the production method and production parameters [3, 4]. The key performance properties of nonwoven cleaning cloths can be considered as abrasion resistance, strength and water absorption properties. Besides, abrasion resistance determines the lifespan of nonwoven cleaning wipes since they are classified as semi-durable products. During their usage, these cleaning materials are exposed to short washing processes conducted with warmer water by hand again and again.

The performance properties of many textile products after repeated washing were evaluated by many studies [5-9] whereas some of the studies handled the effectiveness of finishing processes after repeated laundering [10, 11]. The influence of repeated washing on nonwoven fabric properties were discussed in a few studies [12, 13]. Kwon and Sarmadi [12] investigated the wetting properties of polypropylene spunbond, polyester/pulp hydroentangled and SMS (Spunbond/Meltblown/Spunbond) nonwoven fabrics treated with different flochemicals after repeated laundings. The effect of laundering on hydroentangled cotton nonwoven fabrics were evaluated by Sawhney et. al [13].

The conducted literature survey indicated that there were not enough studies about the effect of laundering on nonwoven fabrics. Therefore; this study handles the effect of repeated washing processes on performance properties of nonwoven cleaning materials produced with different process conditions. For this aim; 5 different nonwoven cleaning cloth produced with different conditions and areal weights were subjected to washing with different numbers of washing cycles; 0, 1, 5 and 10 cycles. The physical properties such as areal weight (g/m^2), thickness (mm), bulk density (g/cm^3) and performance/functional properties named abrasion resistance, bursting strength and water absorption capacity of unwashed and washed samples were measured. Also, the dimensional changes in samples were determined after each washing cycles. The structural and

functional properties of unwashed and washed samples were compared and the influence of production conditions and washing cycles on these properties were explained in detail.

2. MATERIALS AND METHODS

2.1. Materials

Five different nonwoven cleaning cloths constituted by different viscose and polyester mixtures and produced with needle punching process followed by different thermal bonding procedures were used as material in this study. All the samples were opened, carded and cross-lapped before needling processes. The coded names and properties of the samples can be seen in Table 1. C identifies the calendaring whereas T means through air bonding as thermal bonding process. Also the numbers such as 90 shows the target areal weight of the samples during production step [14].

2.2. Methods

The samples were cut into 4 pieces and first piece was kept for unwashed samples. The other 3 samples were marked with benchmarks to determine dimensional change according to AATCC TM -135-2000 test standard [15]. The samples were subjected to washing together following home laundering process by home laundering machine with different numbers of washing cycles; 0, 1, 5 and 10 cycles specified in AATCC TM-135-200 test method. During laundering; $66 \pm 5\text{g}$ Standard Reference Detergent was used and the washing temperature and duration was selected as $40 \pm 3^\circ\text{C}$, 50 minutes, respectively. Although cleaning cloths are generally exposed to hand washing with colder water, harder conditions were selected in this study to reveal the properties of the samples in harder conditions. The dimensional change values of the samples were measured in both machine and cross direction after flat drying.

The areal weights, thickness of the samples were measured following NWSP 130.1 and NWSP 120.1 [16, 17] test standards, sequentially. The bulk density (d_n ; g/cm^3) of the samples were calculated by using areal density (W ; g/cm^2), thickness (t ; mm) as follows [18].

Table 1. Nonwoven samples used in the study [14]

	Fiber Content	Punch. Den. (g/cm^2)	Thermal Process	Areal Weight (g/m^2)	Thickn. (mm)	Bulk Den. (g/cm^3)
S-C90	%65 V (1.5d X 51mm) %25 P (1.5d X 51mm) %10 BP (4d X 51mm)	200	Calendered at 200°C	95.83 (4.34)	1.173 (10.48)	0.0817
S-C120	%80 V (1.5d X 51mm) %10 P (1.5d X 51mm) %10 BP (4d X 51mm)	200	Calendered at 200°C	129.04 (6.89)	1.377 (4.41)	0.0937
S-C140	%80 V (1.5d X 51mm) %10 P (1.5d X 51mm) %10 BP (4d X 51mm)	200	Calendered at 200°C	148.73 (5.06)	1.529 (3.75)	0.0973
S-T90	%88 V (1.5d X 51mm) %12 BP (4d X 51mm)	330	Through air bonded at 185°C and cold calendered	93.20 (7.02)	1.258 (7.81)	0.0745
S-T120	%88 V (1.5d X 51mm) %12 BP (4d X 51mm)	330	Through air bonded at 185°C and cold calendered	122.00 (5.17)	1.481 (4.87)	0.0823

V: Viscose, P: Recycled Polyester; BP: sheath/core Bi-component polyester melting point of 110°C
The values in parenthesis shows the CV(%) values

$$d_n = \frac{W}{1000 * t} \quad (1)$$

The abrasion resistances of the samples were conducted on James H. Heal Martindale abrasion tester following NWSP 20.5 [19] test standard and using woolen fabric as an abradant. The abrading cycles that create a hole in the fabric was reported to determine abrasion resistance of the nonwoven samples. The bursting strength test of nonwovens was performed by using the pneumatic method on James H. Heal Truburst tester using NWSP 030.1 [20] test standard with a test area of 7.3 cm². The water absorption capacity tests of nonwovens were conducted using standard of NWSP 10.1 [21]. The initial dry weight (M_d) of 10cm x10cm size samples cut from different parts of each fabric was measured. Each specimen was firstly immersed in distilled water for 60 seconds, secondly hung in free air vertically for 120 seconds to drain excess water. Finally, wet samples were reweighted to determine wet weight of the samples (M_w). Water absorbency capacity (WAC, g/g) of the samples were calculated as

$$WAC = \frac{(M_w - M_d)}{M_d} \quad (2)$$

3. RESULTS AND DISCUSSION

Dimensional Change, Areal Weight, Thickness and Bulk Density

The dimensional change before and after washing cycles were shown in Table 2. As seen from the table, the dimensions of all the samples decreased after all washing

cycles and the decrease in dimensions increased with increasing washing cycles, as expected. The decrease of dimension in cross direction was higher than that of machine direction for calendered samples and vice versa for through air bonded samples due to the difference in orientation way of the fibers in the samples. Generally, higher dimension decrease was obtained for through air bonded nonwoven samples. This was attributed to the closer bonding structure in thickness way provided by calendering process where pressure was applied to the samples to constitute bonding bridges in this way. Because of the higher heat transfer applied by contact of calenders, stronger and larger thermal bonds could be constituted between the fibers which result in smaller dimensional change after washing cycles. In addition, the through air bonded samples include more hydrophilic fiber (viscose) so; these samples may be highly affected by washing processes. The images of the chosen calendered and through air bonded samples after 10 washing cycles presented in Figure 1, also supports the dimensional change difference between these samples [14].

The areal weight, thickness test results and calculated bulk density results before and after washing cycles were illustrated in Figure 2, 3 and 4, respectively. The areal weights and thicknesses of the samples increased with washing cycles due to the shrinkage comprised after washing processes. Therefore, the bulk densities of the samples generally increased. The increase in areal weight and thickness was generally higher for through air bonded samples compared to calendered identical areal weighted samples because of higher dimensional decrease observed in through air bonded samples. In spite of the different fiber content of sample S-C90, the properties such as areal weight, thickness and bulk density show similar trend with other samples.

Table 2. Dimensional change results of the samples [14]

W. Cycles	S-C90		S-C120		S-C140		S-T90		S-T120	
	MD	CD	MD	CD	MD	CD	MD	CD	MD	CD
1	-1.78 (2.2)	-1.89 (1.7)	-2.56 (3.0)	-3.22 (0.8)	-3.22 (0.5)	-2.67 (2.3)	-3.44 (3.3)	-3.11 (3.8)	-7.33 (2.5)	-4.22 (3.2)
5	-2.33 (3.4)	-6.22 (2.8)	-3.22 (1.6)	-4.78 (2.1)	-3.56 (1.5)	-4.56 (1.6)	-8.55 (2.8)	-5.88 (3.1)	-13.88 (2.7)	-7.11 (2.2)
10	-3.78 (1.8)	-7.22 (0.9)	-4.67 (1.7)	-6.00 (1.4)	-4.67 (1.2)	-5.11 (1.1)	-12.00 (2.4)	-8.55 (1.9)	-14.56 (3.9)	-8.11 (3.3)

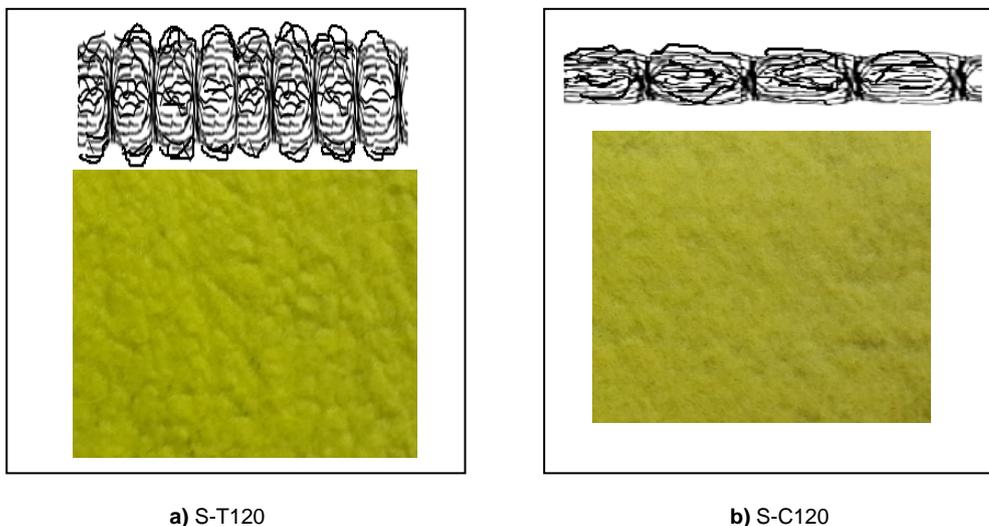


Figure 1. Image of the chosen samples after 10 cycle washing

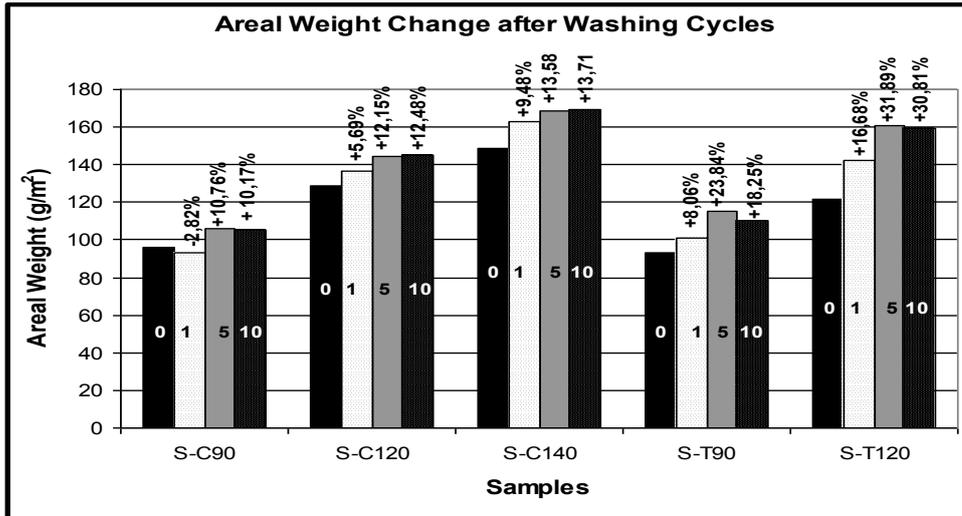


Figure 2. Areal weight change results of the samples (The numbers on the top of the columns in the graphs refer to the percentage change compared to the unwashed samples.)

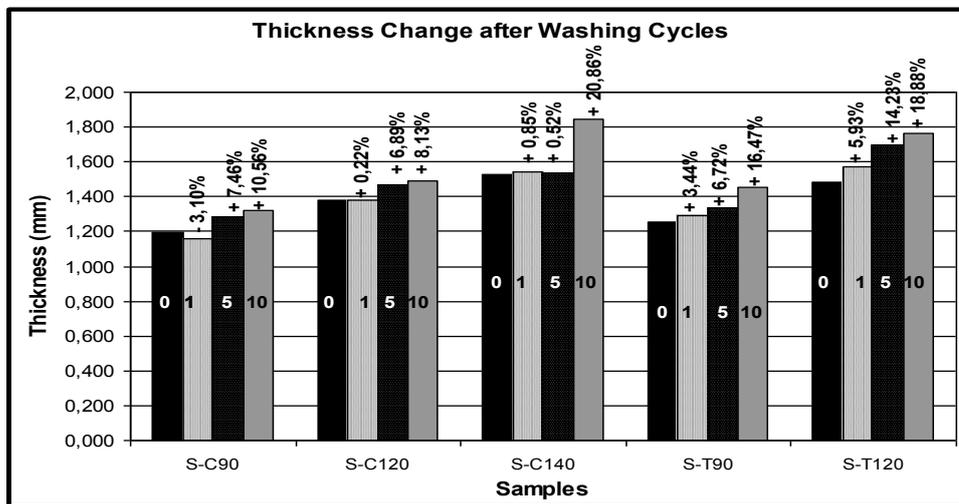


Figure 3. Thickness change results of the samples (The numbers on the top of the columns in the graphs refer to the percentage change compared to the unwashed samples.)

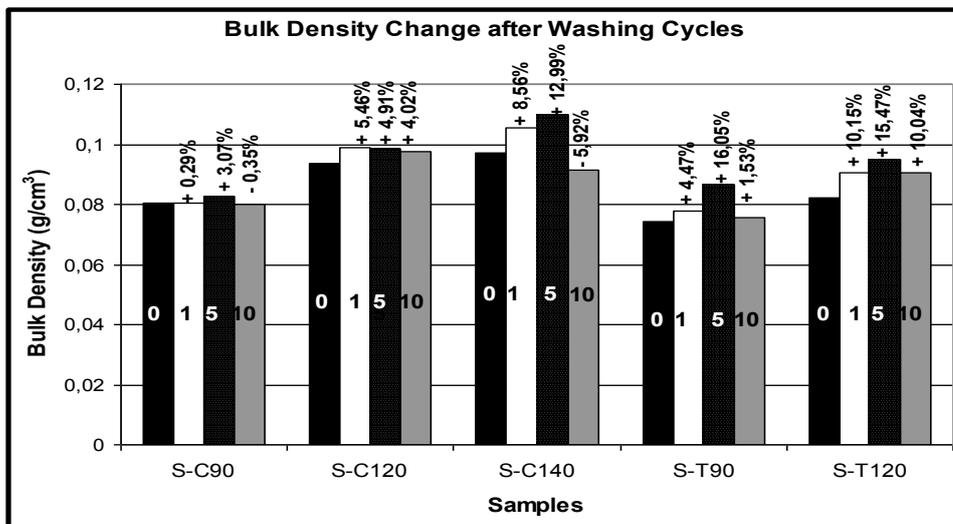


Figure 4. Bulk density change results of the samples (The numbers on the top of the columns in the graphs refer to the percentage change compared to the unwashed samples.)

Abrasion Resistance

The key factor which determines the using life of nonwoven cleaning material can be stated as abrasion resistance. The abrasion resistances of the samples before and after washing cycles and the percentage change in abrasion resistance compared to unwashed samples were illustrated in Figure 5. According to the figure, the abrasion resistances of the unwashed calendered samples were higher than that of unwashed through air bonded nonwovens, if the abrasion resistances of the same areal weighted samples investigated. This trend is valid for S-C90 sample although it has higher amount of polyester in the blend. The punching density of the through air bonded nonwovens are higher compared to the calendered samples. Increased punching density provided better interlocking of the fibers and fabrics resisted to abrading action. On the other hand, by increasing the punching density the number of fibers migrated from un-bonded region of the web towards to interior of fabric increased. Since the mass per unit area was same for two groups of the samples, higher punching density also caused the number of fibers in un-bonded region to decrease and un-bonded regions got weaker for abrasion action [22]. Besides, increasing punching density causes thinner samples and higher number of needle holes in the sample and it could be easier to abrade this type of samples.

The abrasion resistance of all the samples decreased with increasing washing cycles except 1 washing cycle of 140g/m² calendered sample, 1 and 5 washing cycle of 120g/m² through air bonded samples, despite of different fiber content of sample S-C90. The repeated washing processes result in shrinkage in the samples and the holes constituted by needles and un-bonded regions increases in a constant area. Thus, the abrasion force affects more

weaker area and abrasion resistance decreases. Also, the washing process may damage the fibers.

Although unwashed calendered samples possess higher abrasion resistance, the abrasion resistance of washed through air bonded samples were higher than that of washed calendered samples for identical areal weights. As the increase in thickness of the through air bonded fabrics were slightly higher than thicknesses of through air bonded ones after washing cycles, the abrasion of the through air bonded samples were higher after washing cycles. During abrasion test, abrasion force first affects the fibers and bonds on the surface and then fibers and bonds in other layers in thickness direction. Since the abrasion cycle which causes a hole in the sample is determined during the test, the higher thickness resulted in higher abrasion resistance [14].

Bursting Strength

The bursting strengths of the samples before and after washing processes were presented in Figure 6 by including the variations. As expected, the bursting strength of through air bonded samples were higher compared to calendered counterparts owing to higher needling density, in spite of higher polyester fiber content of calendered samples. Although sample S-C90 has higher proportion of polyester fiber, the higher needling density in S-T90 sample lead to higher bursting strength than S-C90 sample. The bursting strength of all the samples increased after washing processes and the increase in bursting strength also raised by increasing washing cycles. The higher increment in bursting strength with higher number of washing cycles can be ascribed to higher shrinkage compromised by higher washing cycles which result in higher bonding points in constant area. Thus, the number of bonds which resist to bursting force increases and accordingly, bursting strength increases.

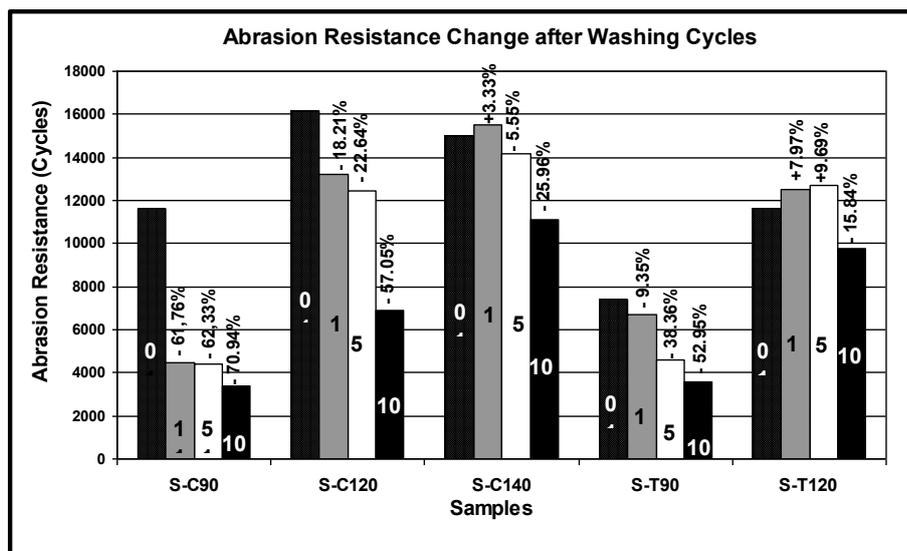


Figure 5. Abrasion resistance change results of the samples [14] (The numbers on the top of the columns in the graphs refer to the percentage change compared to the unwashed samples.)

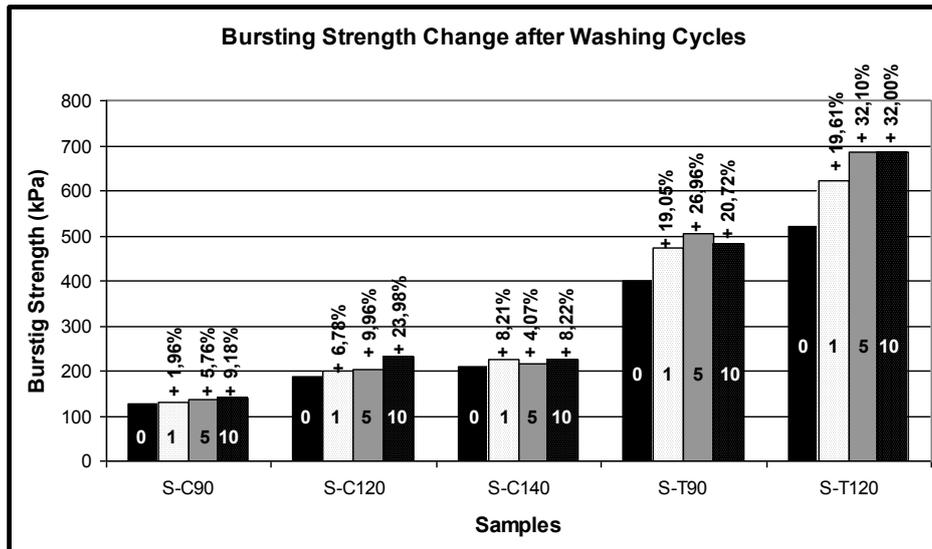


Figure 6. Bursting strength change results of the samples (The numbers on the top of the columns in the graphs refer to the percentage change compared to the unwashed samples.)

Besides, the increment in bursting strength of through air bonded samples was higher than that of calendered samples of identical areal weights. The reason of this can be considered as higher shrinkage occurred for through air bonded samples which lead to higher bonding points in constant area that resist to bursting force during test.

Water Absorption Capacity

Water absorbency is one of the important properties which affect the performance of nonwovens used for cleaning materials. Figure 7 shows the water absorption capacity properties of unwashed and washed samples including water absorption variations compared to unwashed samples. The water absorption capacities of calendered samples were lower than that of through air bonded ones due to the lower thickness of calendered samples constructed with calendaring process and due to the lower hydrophilic fiber (viscose) content. The bulk density and

fiber content are the critical factors which configure the water absorbency properties. Higher bulk density was obtained for unwashed calendered samples compared to unwashed through air bonded samples (Figure 4) with the effect of lower thickness for similar areal weights. As the bulk density increases the fabric structure becomes more compact and consequently lower the water absorption capacity is acquired. The water absorbency capacity of Sample S-T90 is higher than that of S-C90, as S-C90 has lower proportion of hydrophilic fiber (viscose) and higher bulk density.

The water absorption of all samples decreased after all washing cycles because of the dimension decrease after washing. The washing procedure conducted in the present study causes increment in bulk density of the samples depending on the shrinkage amount. The higher bulk density the more compact structure was achieved which leads to a decrease in water absorbency capacity.

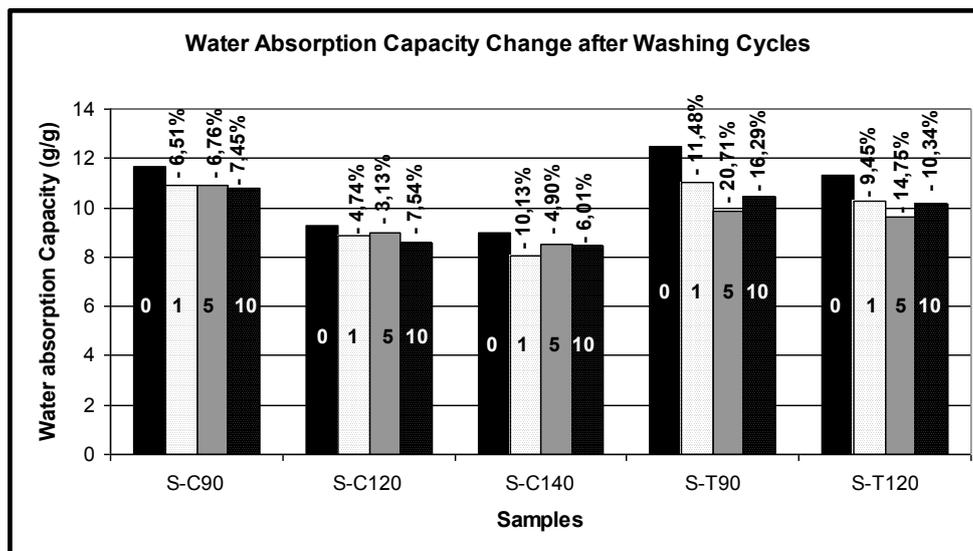


Figure 7. Water absorption capacity change results of the samples (The numbers on the top of the columns in the graphs refer to the percentage change compared to the unwashed samples.)

The decrease in water absorption capacity generally higher for through air bonded samples compared to calendered samples for identical areal weights. The dimensional diminution is higher for washed through air bonded samples related with unstable and weaker point bonds constructed by through air bonding. As a result of higher thermal bonding areas and accordingly stronger bonds emerged for calendered samples, the lower shrinkage and lower bulk density increment was observed. Thus, the decrease in water absorption capacity is lower for calendered samples after washing cycles for identical areal weights. Furthermore, despite higher water absorption capacity decrease, the more water absorption capacity values of through air bonded samples were determined after washing processes.

CONCLUSION

As a result of experimental study conducted on the physical and performance properties of needled and thermally bonded nonwoven fabrics produced with different conditions after different numbers of washing cycles; 0, 1, 5 and 10 cycles, the following conclusions can be drawn.

- It was determined that all of the washed samples displayed dimensional shrinkage differing according to the production parameters. The shrinkage amount of all the samples increased with increasing washing cycles and higher shrinkage was detected for through air bonded samples compared with calendered samples of similar areal weights.
- The areal weight, thickness and bulk density of the nonwoven samples generally increased after washing cycles due to the dimensional shrinkage occurred after washing procedures. The areal weight, thickness and bulk density increments were higher for through air bonded samples in comparison with calendered counterparts.

- The abrasion resistance of all samples generally decreased after washing cycles except some samples. The abrasion resistances of through air bonded samples were slightly higher compared to that of calendered samples after washing processes due to the higher thickness.
- The bursting strength of all the samples increased with washing process and increased number of washing cycles because of increased bonding points, which resist to bursting force, due to the shrinkage occurred in the samples. The bursting strength of washed through air bonded samples and increment in bursting strength with the effect of washing cycles were higher because of higher number of needling density and higher shrinkage occurred.
- Although the water absorption capacity of all the samples decreased after washing cycles, the decline was higher for through air bonded samples compared to calendered counterparts due to the higher increment in bulk density caused by higher dimensional decrease. despite higher water absorption capacity decrease, the more water absorption capacity values of through air bonded samples were determined after washing processes.
- Despite of the fiber content difference, the properties of sample S-C90 show similar trend with other samples after washing cycles.
- Considering overall results, the through air bonded samples with high needling density can be advised to the producers and users for their better performance properties than calendered counterparts.

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