INVESTIGATING THE EFFECTS OF WEIGHT VARIATION AND PATTERNING ON STRENGTH OF NONWOVEN PRODUCTS

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Received: 13.06.2018 Accepted: 07.11.2018

ABSTRACT

In this study, the dry and wet strengths of standard/recycled and plain/patterned nonwoven products with weight variation are studied. In the first part of the study, the machine and cross direction strengths of the standard and recycled products of the same unit weight were tested in dry and wet conditions. And the efffect of weight variotion on the strength is investigated. In the second part of the study, the strengths of the plain and patterned products in the machine direction and crosswise direction of the same unit weight were tested in dry and wet state. The effect of patterning on the strength is tried to find out. Study's mathmatical and statistical results show that in terms of sustainability, it has been concluded that viscose/polyester blended recycled nonwoven produc ts can be used instead of standard fabric by increasing the unit weight. Also, patterning does not cause strength loses.

Keywords: Disposable nonwoven, strength, recycle, MD direction, CD direction

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1. INTRODUCTION

As in everything in the world, textile production is also a matter of rapid production and consumption. Factors such as degradation of ecological balance, environmental pollution, chemical use, increased water and energy consumption have made recycling products important. In addition, the increase in the cost of raw materials in the world, along with the increase in production costs, has made recycling products important. It has become very important both in terms of environment and cost to make as little waste as possible at every stage of textile production and to convert the resulting waste into product using again. In this study, too, we focused on the strength values of recycled nonwoven products. The use of recycled polyester fibers is very important in terms of environmental awareness and sustainability. It also contributes in terms of raw material resources. The recycled polyester fibers obtained by mechanical means have high strength and elongation values, while at the same time providing low cost (1-4).

Nonwoven surfaces are a collection of layers separated from each other by natural fibers and / or synthetic fibers or filaments. The nonwoven production process usually consists of three steps: Web forming, Web bonding, Fabric finishing. Nonwoven production begins with the arrangement of fibers in a layer or layer. The fibers may be in the form of packed staple fibers or extruded filaments of molten polymer granules. Four basic methods are used to create a network, and nonwoven surfaces are often referred to by one of these methods: There are three main methods to form web as dry laid, wet laid, polymer laid. The methods differ from each other in productivity and fiber orientation and properties of resulting fiber layers (5).

Webs, other than spunlaid, have little strength in their unbonded form. The web must therefore be consolidated in some way. This is effected by bonding, a vital step in the production of nonwovens. The choice of method is at least as important to ultimate functional properties as the type of fibre in the web. There are three basic types of bonding as chemical, thermal and mechanical. In this study dry laid method was used to form net and hydroentanglement was used to bond fibers. There are two methods of drylaying: as carding and airlaying. Carding is a mechanical process which starts with the opening of bales of fibres which are blended and conveyed to the next stage by air transport. They are then combed into a web by a carding machine, which is a rotating drum or series of drums covered in fine wires or teeth. The precise configuration of cards will depend on the fabric weight and fibre orientation required. The web can be parallel-laid, where most of the fibres are laid in the direction of the web travel, or they can be random-laid. Typical parallel-laid carded webs result in good tensile strength, low elongation and low tear strength in the machine direction and the reverse in the cross direction. Relative speeds and web composition can be varied to produce a wide range of fabrics with different properties. In airlaying, the fibres, which can be very short, are fed into an air stream and from there to a moving belt or perforated drum, where they form a randomly oriented web. Compared with carded webs, airlaid webs have a lower density, a greater softness and an absence of laminar structure. Airlaid webs offer great versatility in terms of the fibres and fibre blends that can be used. Hydroentanglement is mainly applied to carded or wetlaid webs and uses fine, high pressure jets of water to cause the fibres to interlace. Hydroentanglement is sometimes known as spunlacing, as the arrangement of jets can give a wide variety of aesthetically pleasing effects. The water jet pressure used has a direct bearing on the strength of the web, but system design also plays a part [5].

There are various studies investigating the tensile properties of nonwovens (6-12). Ray and Ghosh studied the fibre cross laying as well as fibre orientation angle in cross-laid needle-punched nonwoven fabric and its relationship with tensile properties of fabric. Nine fabric samples were produced by using three types of fibres, namely 100 % polyester, 100 % jute and 50:50 jute-polyester blend with three different numbers of layers (6, 12 and 18). The tensile properties of different cross-laid structures were measured both in machine direction (MD) and cross direction (CD) observed that the number of layers in the web influences the cross laying angle (LA) as well as tensile properties of the fabric. The maximum tenacity was obtained in case of CD and then the tenacity gradually reduced towards the MD(6). Çinçik and Koç, examined the structure and mechanism of the tensile strength of needle-punched nonwoven fabrics. The effect of blend ratio, mass per unit area and needling density on the tensile properties of polyester/viscose blended nonwovens was investigated. In conclusion, the regression model indicated that the tensile strength of the needle-punched nonwovens decreases with the increase of polyester proportion in the mixture and increases with the increase in mass per unit area and punching density (7). Rawal predicted the tensile behavior of nonwoven structures including needle punched and thermal bonded by modifying the micromechanical model based upon the geometrical and mechanical properties (8). Kotari et. al. studied layered composite needle-punched nonwoven fabrics which were prepared using 6 den and 15 den polyester staple and in 50:50 proportion and their air filtration and other associated properties. Processing parameter such as punch density were altered to investigate its effect on filtration efficiency as well as on associated properties like dimensional stability, air permeability, compression-recovery, tensile strength, abrasion resistance and friction. Machine direction breaking load was higher than that of cross direction (9). Bulacu et al. Researched the influence of the main needlepunching process parameters on the tensile strength properties of the extra wide nonwoven geotextiles. The needlepunching process parameters of influence were the needlepunching density and the needle penetration into fibrous web made from recycled polypropylene and polyester fibre mixture (10). Rawal et. al. studied a modified micromechanical model describing the tensile behaviour of thermally bonded nonwovens which was proposed by incorporating the effect of fibre re-orientation during the deformation. The anisotropic behaviour of through-air bonded structures was demonstrated through theoretical stress–strain curves and the relationship between the fibre re-orientation and fabric strain was also analysed. Furthermore, the failure criterion of thermally bonded nonwovens was analysed using pull-out behaviour of fibres in the system. A parametric study revealing the dependencies of various structural and geometrical characteristics of fibres on pull-out behaviour of fibres in thermally bonded nonwovens was also discussed (11). Çinçik et. al. evaluated the physical and performance properties of needled and thermal bonded nonwoven cleaning materials produced under different conditions by varying washing cycles (0, 1, 5, and 10); For this purpose, 5 different untreated cleaning materials with different thickness weights containing polyester and viscose fibers were selected. Performance and strength properties were analyzed (12). In general nonwoven fabrics are, flat, flexible and pored structures that are made by interpassing fibers, filament or filament structures like film as layers. Generally they are subdivided as two categories depends on end use area as disposable and durable. And all around world nonwovens have larger using area in medical and industrial sectors.

Figure 1. patterned, recyle, standard nonwoven samples

The aim of the study is to find out the strength differences of the disposable nonwoven samples which are produced by patterned, recycle and standard nonwoven fabrics.

2. MATERIAL AND METHOD

2.1 Material

This study is formed by two parts: In the first part there are three different unit weights of 35 gsm (gram per square meter), 38 gsm, 40 gsm, and viscose / polyester (20/80%) nonwoven fabrics laid out with dry-lay system and combined with an water jet system. The purpose of this part is to use recycled nonwoven fabrics of the same unit weight to determine the difference of strength between recycled and standard nonwoven fabrics. For this aim nonwoven fabrics with the following weights were produced regularly than the waste of nonwoven fibers were fed to the system again with the same weights and they were called as recycle. As seen actually these products were not used; they only had some faults during production. And by this study we tried to prove that using these waste products as regular ethical or not. And in the second part to determine the difference of strength between standard and patterned nonwoven fabrics. Generally as wet wipe patterned nonwoven fabrics are used to make the product attractive. However in the literature there were not enough research about the patterning effect on the strength of the nonwoven products. Therefore this paper is tried to investigate this effect dependingly unit weights. The properties of the samples used in the first part of study are given in Table 2.1 and the properties of the samples used in the second part of study are given in Table 2.2. respectively. In these table the samples which are produced from standard/recycle raw material and standard/ patterned are coded with the unit weight.

Table 2.1. Physical properties of recycle and standard samples properties

Sample Names	Unit Weight (g/m^2)	Thickness (mm)
Standard35	35	0,45
Recycle35	35	0,40
Standard38	38	0,50
Recycle38	38	0,45
Standard40	40	0,42
Recycle40	40	0,48

Table 2.2. Physical properties patterned and standard (or plain) of samples

Sample Names	Unit Weight (g/m^2)	Thickness (mm)
Standard35	35	0,45
Patterned35	35	0,47
Standard38	38	0,50
Patterned38	38	0,52
Standard40	40	0,42
Patterned40	40	0,45
Standard45	45	0,45
Patterned45	45	0,46
Standard55	55	0,47
Patterned55	55	0,49

2.2 Method

The unit weight and thickness of standard and recycled fabric samples were measured. The thickness of the nonwoven fabrics has been measured by means of the digital thickness meter under the load of 1 kPa on the fabrics for 1 min. The tensile properties of the 13 sample nonwoven fabric in cross, machine and other bias direction have been measured using Zwick-Roell tensile tester in wet and dry conditions. The strength properties of the nonwoven fabrics obtained in different directions have been subjected to Two-way ANOVA analysis by using SPSS 11.0 package programme.

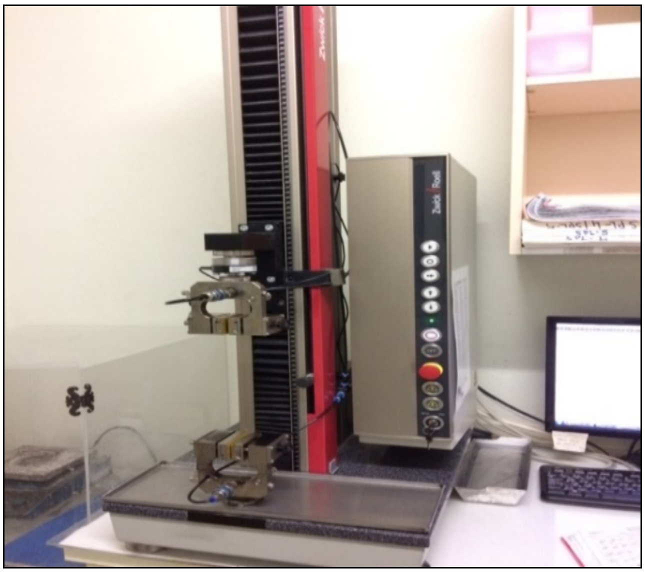

Figure 2.1. Strength tester

3. RESULTS AND DISCUSSION

Part I: Strength variations of standard and recycled fabrics

3.1.Comparison of strength values

The machine and cross direction strength measurements of the standard and recycle fabrics were made separately in dry and wet state both in machine direction (MD) and in cross direction (CD). The results were analyzed by graphs and supported by statistical information.

3.1.1 Dry strength (MD)

The dry tensile strength results in the machine direction of the sample fabrics are shown in Figure 3.1.

Dry strength test results of the samples in CD direction is shown in the Figure 3.2.

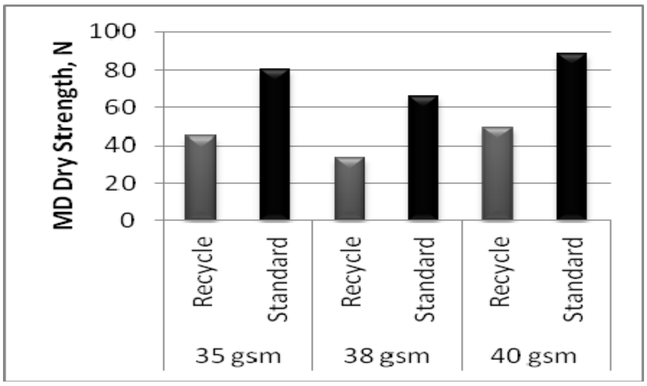

Figure 3.1. Comparison of dry strength results of standard and recycle in MD direction

It has been observed from the Figure 3.1 that as the unit weight increases, the dry MD strength increases as predicted. The results support both recycle and standard fabric. However, when the 38 gsm specimens determined as intermediate gauges are examined, there is a decrease in strength. Since this result is at the same level for both the recycle and the standard, it is concluded that the results are not accidental. The reason for this is thought to be the unit thickness value of the group. But; when the thicknesses of the subject samples are examined, it is seen that the thicknesses of 35 gsm, 38 gsm and 40 gsm are 0.45, 0.50 and 0.42 mm, respectively. Therefore, neither unit weight nor unit thickness is considered to be an effective parameter alone in the strength of nonwoven surfaces produced by spunlace technology. During the production of nonwoven fabric, the behavior of holding the fibers together by changing the jet pressure can also be changed. Since tensile strength essentially separates the fibers from each other due to the strength of the tensile strength, the better the fibers are held together, the higher the strength This is enough to explain the strength results of the samples in this group.

3.1.2 Dry Strength (CD)

Figure 3.2 shows that as the unit weight increases, the dry CD strength increases as predicted. The results support both recycle and standard fabric. The results are similar in terms of unit weight and unit thickness in the MD direction. It is clear that the strength values in the CD direction are considerably lower than those in the MD direction. The reason is that this tulle is produced by parallel laying technique. With this technique, the strength is low because the binding force is low in the transverse direction in production.

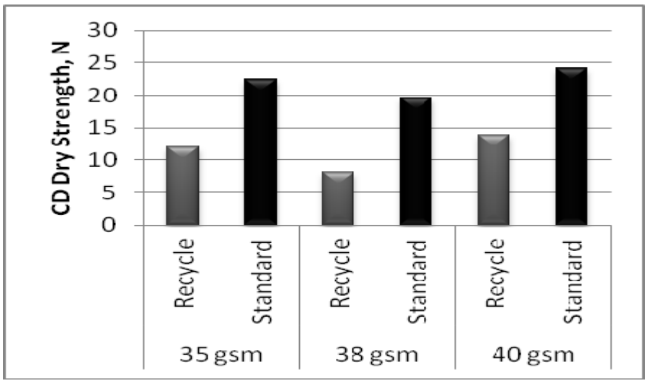

Figure 3.2. Comparison of dry CD strength of standard and recycled products

3.1.3 Wet Strength (MD)

The machine direction wet strength results of the sample fabrics are shown in Figure 3.3.

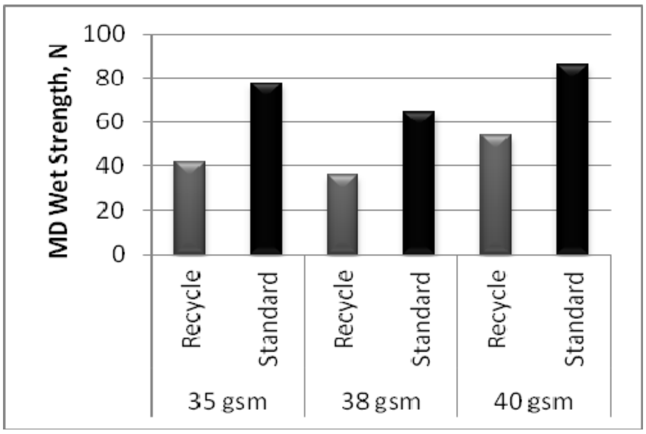

Figure 3.3. Wet MD strength comparison of Standard and Recycled products

Figure 3.3 shows that the strength values of standard products are better. It has also been found that the resistance values of the said group are less than the dry strength values. The reason is that the wet strength of the viscose fiber used as the raw material is lower. This leads to the fact that the selected raw material group is as important as the least selected method when producing these fibers.

3.1.4 Wet Strength (CD)

The wet strength results in the cross direction of the sample fabrics are shown in Figure 3.4.

In figure 3.4. it is seen that the strength of the samples in this group is very low. They appear to be both wet and CD oriented. When considered for the user group, the use of such samples as wet wipes makes such strength testing results important.

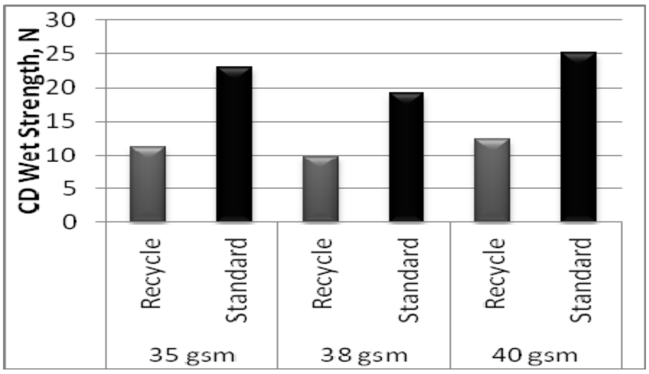

Figure 3.4. Wet CD strength comparison of Standard and Recycled products

<u>Part II: Strength variations of standard and patterned fabrics</u>

3.2. Comparison of strength values

The machine and cross direction strength measurements of the standard and recycle fabrics were made separately in dry and wet state both in machine direction (MD) and in cross direction (CD). The results were analyzed by graphs and supported by statistical information.

3.2.1 Dry strength (MD)

The dry tensile strength results in the machine direction of the sample fabrics are shown in Figure 3.5.

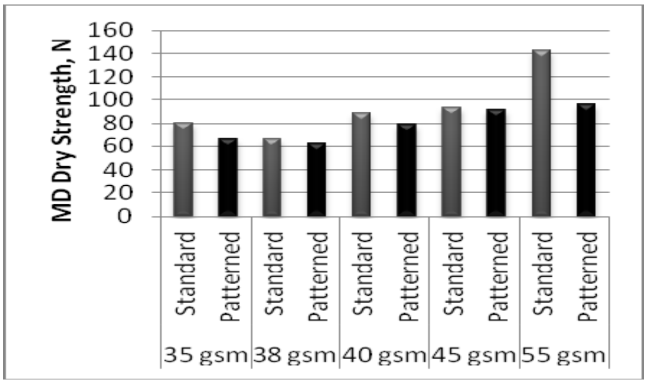

Figure 3.5. Dry MD strength comparison of Standard and Recycled products

According to MD test results, the strength of the standard and patterned specimens increases with increasing unit weight. The reason for this is thought to be the increase in the number of fibers per unit area. When evaluated for the purpose of the work, it is observed that the patterning reduced the strength. The reason for this is thought to be the reduction of the fabric thickness of the applied pressure during patterning.

3.2.1 Dry strength (CD)

From Figure 3.6 it is seen that the strength in the CD direction is considerably lower than the strength in the MD direction. The reason for this is that the MD is oriented in the direction of the MD, which leads to an increase in the mobility and an irregular fiber arrangement in the direction of the CD. However, when the unit weight is increased as in the MD direction in the CD direction, the strengths of both standard and patterned samples are increased. The fiber orientation in the CD direction caused the patterning effect to be invisible due to the layout irregularity.

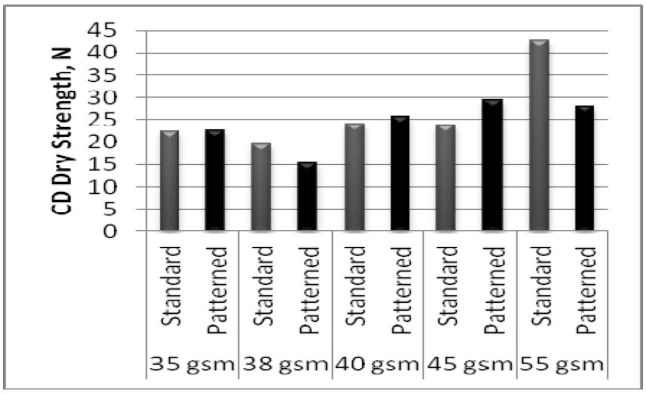

Figure 3.6. Dry CD strength comparison of Standard and Recycled products

3.2.3 Wet strength (MD)

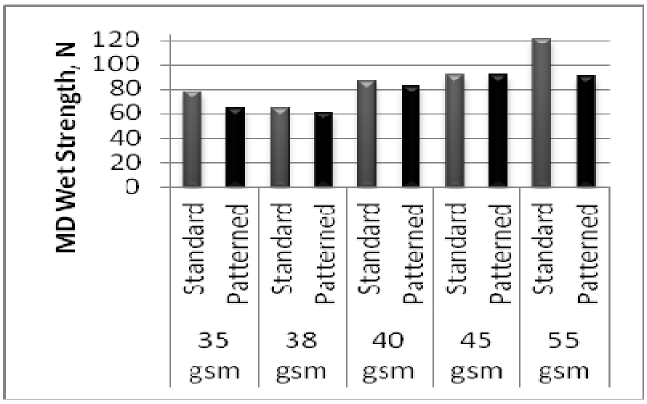

Figure 3.7. Wet MD strength comparison of Standard and Patterned products

When compared to Figures 3.5 and 3.7, it was concluded that wetting did not cause significant loss of strength on the samples. Other results are similar. For this reason it has been decided that the wetting of the samples does not reduce the strength. However, it may not be applied at very high pressure due to the reduced strength of the pattern.

3.2.4 Wet strength (CD)

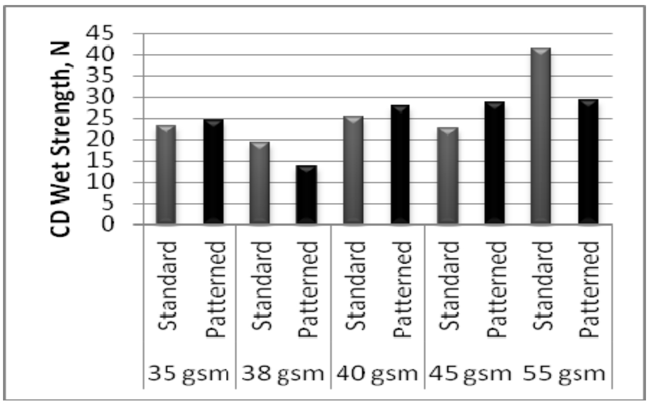

Figure 3.8. Wet CD strength comparison of Standard and Recycled products

Looking at Figure 3.8, the factor causing the strength variation is not clearly visible. Since the cross and random settling of fibers change the number of fibers per unit area, the results are not clearly linked for a significant reason

4. Statistical Analysis

Two-way ANOVA and correlation tests are applied to the results with SPSS 11.0 package program in order to determine whether the data obtained in the study are statistically significant.

Two-way ANOVA analysis was used to determine the effect of two different variables. The tests were performed at a significance level of 0.05. Accordingly, if the test results are less than 0.05, it is decided that the results are significantly different from each other and the effect level is tried to be determined. The results of the analysis are given in Table 4.1.

Given in Table 4.1. According to the two-way ANOVA test results, there is a statistically significant effect of the sample type and the unit weight on the 95% confidence interval of the dry strength measurement results applied to the machine direction and the cross direction of the samples. When the results are analyzed, it is seen that the strength of the specimen in the machine direction is 86% while the unit weight is 60%. When the strengths in the crosswise direction on the same table are examined, it is seen that the strength of the cross direction of the specimen type is 90% while the unit weight is 46%. In this case, it can be said that the effect of the sample type (standard or recycle) is statistically high on the dry strength. This can be attributed to shortening of fiber length of fiber, decrease of fiber strength and low homogeneity. When the wet strength results in the same table are analyzed, it can be said that both the sample type and the unit weight have a statistically significant effect on the 95% confidence interval on the strength. It is determined that 95% of the sample is of the unit weight and 80% of the sample type is the effect of the unit weight. In this case, it can be said that sample type and unit weight are also important factors on both machine and transverse strengths.

Same analysis was done to see the significance of type (standard/patterned) and weight effects on the strength values both machine and cross directions. The results are emphasized on Table 4.2.

According to the two-way ANOVA test results given in Table 4.2., there is a statistically significant effect of the sample type and the unit weight on the 95% confidence interval of the dry strength measurement results applied to the machine direction and the cross direction of the samples. When the results are analyzed, it is seen that the strength of the specimen in the machine direction is 77% while the unit weight is 94%. When the strengths in the crosswise direction on the same table are examined, it is seen that the strength of the cross direction of the specimen type is 86% while the unit weight is 14%. In this case, it can be said that the effect of the sample type (standard or recycle) is statistically high on the dry strength (especially in MD). When the wet strength results in the same table are analyzed, it can be said that both the sample type and the unit weight have a statistically significant effect on the 95% confidence interval on the strength. However the effect of unit weight is guite higher than that of sample type. Finally, it can be said that sample type and unit weight are also important factors on both directions and before and after wetting.

In these two-way ANOVA tests only the sample type and unit weight effects on the strength loss of samples but to see the relation between dry strength and wet strength and their relations on the type and weight with the relation levels corelation analysis were applied for standard/recycle fabrics and standard/patterned fabrics separetely and shown in Table 4.3 and 4.4 respectively.

According to Table 4.3. there is a positive and strong relation between dry strengths both CD and MD with 88 %. It means if the fabric has high strength in MD direction this fabric can have high strength in CD direction. Also there are positive and strong relations between CD dry strength and CD wet strength and so wetting does not cause significant changing on the strength. There are negative and high relations between sample type and strength values both directions and both conditions. Then it means using recycle nonwoven fabrics instead of standard one is quite significant statistically. Since figures show that weight is an effective parameter on the strength this correlation test shows the opposite.

Table 4.1. Two-way ANOVA Table of standard and recycle nonwoven fabrics

		Type (Standard/Recycle)		Weight		Type*Weight	
		Sig.	*P.E.S.	Sig.	*P.E.S.	Sig.	*P.E.S.
DRY	MD-strength	**0,000**	0,866	**0,004**	0,604	0,962	0,006
	CD-strength	**0,000**	0,905	**0,024**	0,464	0,962	0,006
WET	MD-strength	**0,000**	0,958	**0,000**	0,873	0,134	0,285
	CD-strength	**0,000**	0,953	**0,000**	0,814	0,690	0,060

*P.E.S.=Partial Eta Squared

Table 4.2. Two-way ANOVA Table of standard and patterned nonwoven fabrics

		Type (Standard/Pattern)		Weight		Type*Weight	
		Sig.	*P.E.S.	Sig.	*P.E.S.	Sig.	*P.E.S.
DRY	MD-strength	**0,000**	0,773	**0,000**	0,944	0,000	,746
	CD-strength	**0,000**	0,863	**0,014**	0,143	0,000	0.651
WET	MD-strength	**0,000**	0,592	**0,000**	0,892	0,000	0,667
	CD-strength	**0,000**	0,105	**0,000**	0,870	0,000	0,669

*P.E.S.=Partial Eta Squared

Table 4.3. Correlation Analysis for Standard/Recycle Fabrics

Correlations						
	CD Dry Strength	MD Dry Strength	Sample Type	Weight	CD Wet Strength	MD Wet Strength
CD Dry Strength	1	,886**	-,912**	,162	,919**	,924**
MD Dry Strength	,886**	1	-,848**	,152	,956**	,958**
Sample Type	-,912**	-,848**	1	,000	-,888**	-,856**
Weight	,162	,152	,000	1	,218	,204
CD Wet Strength	,919**	,956**	-,888**	,218	1	,967**
MD Wet Strength	,924**	,958**	-,856**	,204	,967**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.4. Correlation Analysis for Standard/Patterned Fabrics

	Correlations					
	Sample Type	Weight	MD Dry Strength	CD Dry Strength	MD Wet Strength	CD Wet Strength
Sample Type	1	,000	-,341*	-,133	-,338*	-,109
Unit Weight	,000	1	,801**	,747**	,719**	,676**
MD Dry Strength	-,341*	,801**	1	,884**	,908**	,841**
CD Dry Strength	-,133	,747**	,884**	1	,810**	,932**
MD Wet Strength	-,338*	,719**	,908**	,810**	1	,780**
CD Wet Strength	-,109	,676**	,841**	,932**	,780**	1

According to Table 4.4 the relation between sample type and strength values are not strong than it means patterning is applicable method in accordance with the strength statistically. Howvever opposite to recycled samples on patterned fabrics there is positive and strong relations between weight variations and strength values. Then it can be said that increasing the unit weight the srength increases. Also there is strong relation between strength values of MD and CD directions both dry and wet conditions.

5. Conclusion

In this study, the strengths of wet wipes, which are very popular in nonwoven products, have been studied. In the first part of the study, the machine and cross direction strengths of the recycled products of the same unit weight standard and faulty production were tested dry and wet conditions. In the second part of the study, the strengths of the standard and recycled products in the machine direction and crosswise direction of the same unit weight were tested in dry and wet state. The results were compared with the graphs and then analyzed statistically by two-way ANOVA and correlation tests. The results are as follows:

- ❖ The increase in weight in standard / recycle fabrics caused an increase in strength. The increase in unit weight means an increase in the number of fibers exposed to tension during the test.
- ❖ The strength of recycle samples is considerably lower than standard fabrics. For this reason, these products with faulty production can not be used in place of standard fabrics.
- ❖ Generally, the strength of the fabrics in the machine direction is higher than the strength in the cross direction. The reason for this is that the crossing is random and the number of fibers per unit area is not homogeneous.
- ❖ Wetting did not cause a significant change in the strength values of the fabrics. Because the raw material of the samples is 20/80% viscose polyester. And becuse of the fact that polyester does not absorb water, water does not change the structural properties of the fabrics produced by polyester. However if the ratio of viscose increases, the strength can decrease because the strength of viscose decreases by the effect of water.

Some similar results were also found in standard / patterned fabrics. These are the lower strength in the cross direction, the strength increments due to unit weight increase and the wet end unchanging strength values. The patterning of the fabric should continue to be applied as it increases the attractiveness while causing statistically no loss of strength.

As a result, in terms of sustainability, it has been concluded that the use of recycle products can be produced in viscose / polyester with patterned form as disposable wet wipes by increasing the unit weight.

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