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Effect of Pile Geometry on Shearing Process of Terry Towels

Direselgn Molla Semanie, Muktar Seid Hussen
Ethiopian Institute of Textile and Fashion Technology (EiTEX), Bahir Dar University, Bahir Dar, Ethiopia.
Email: kirubelmolla05@gmail.com, henok1450@gmail.com

Abstract
Fabric structure has a very significant effect on pile geometry and properties of terry fabric. The effect of fabric structure on GSM was investigated and pile yarn consumption using various fabric constructions were analyzed. This study includes fabric GSM, fabric design, yarn type, weft density, pile height and angle. Effect of these parameters on shearing waste and cutting depth during shearing, and their correlation with each other are discussed. Direct experimental work was conducted on 60 samples of terry fabric designed with three different types of fabric structures. The designs known as Selin, Opal and Hurrum in the first group were used to analyze the effect of pile geometry on shearing. Similarly, 40 samples of terry fabric were used to show the relationship between the pile height and angle in two different types of terry fabric - Paris and Selam - with the same structure in the second group. As a result, the actual shearing waste of terry fabric was found as 3%, 4.07% and 4.1% of the total weight of a towel, and shearing waste from the total weight of pile warp was found as 4.9%, 6.5% and 6.6% depending on the design of Selin, Opal and Hurrum respectively. It was found that an increase in fabric design complexity causes more piles to fall on the surface of the fabric. Hence, it requires a deep cut during shearing process, which actually increases the shearing waste. Increasing the pile height causes an increment in shearing ratio of Paris and Selam from 3.2% to 4.8% respectively and confirms the reduction of pile angle with similar fabric structure due to gravitational weight of the pile. Finally, it is suggested that additional combing process should be used for raising the fallen pile instead of deep cutting during shearing process when the design is more figurative.
Keywords: *Terry Fabric, Pile Geometry, GSM, Shearing Waste.*

I. INTRODUCTION

The terry pile is a class of warp pile structure in which certain warp ends are made to form loops on the surface of the fabric. The loops may be formed on one side only or on both sides of the fabric thus producing single-sided and double-sided structures. High tension is applied to a ground warp and very low tension to a pile warp. In traditional terry weaving, by means of a special device on the weaving machine, two picks are inserted at a variable distance ‘‘the loose pick distance’’ from the fabric fell. The two picks are beaten up short of the true fabric fell and produce a temporary false fell. The loose pick distance is varied according to the desired loop height. On the third pick of the group, full beat-up takes place, the three picks being pushed forward together to the true fell position. During this action, the three picks are capable of sliding between the ground ends, which are kept very taut.

Terry fabrics must be produced at a certain weight per square meter, using mostly 100% cotton yarns as weft-, ground and pile warp yarns. Certain yarn counts, such as Ne20/2, Ne16/1, and warp density are used by factories producing terry fabrics. After the ground and pile warp yarns are prepared and drafted as one ground and one pile warp yarn, the weight per square meter of a terry fabric is adjusted by changing the pile height, or in some cases, the weft density (Karahan, Eren, & Alpay, 2005). The name “terry” comes from the French word “tirer” which means to pull out, referring to the pile loops which were pulled out by hand to make absorbent traditional Turkish toweling. Latin “vellus”, meaning hair, has the derivation “velour”, which is toweling with cut loops. In research conducted on terry weaving by the Manchester Textile Institute, it was concluded that original terry weaving was likely the result of defective weaving (Schools, 2011). The research indicates that this development occurred in Turkey, probably in Bursa City, one of the major traditional textile centers in Turkey. Terry weaving construction is considered a later development in the evolution of woven fabrics [6]. Terry toweling is still known as "Turk Fabric", "Turkish Toweling" or "Turkish Terry"(Yilmaz & Powell, 2005).

A woven towel consists of five parts. These are the pile area, fringes, beginning and end part, selvedge, and border. Every towel does not have to contain all of these parts. The pile area is considered the toweling part of the towel. Fringes are tied or an untied tasseled part of ground warps and pile warps, which are left unwoven at the beginning and the end edges of the towel. The beginning and end sections are the tightly woven areas of a towel, which come before or after the pile fabric part and prevent this pile area from unraveling. They are woven without pile loops, in a flat weave construction. The selvedge contains fewer number of warp ends than the pile area; for example, 90 comparing to 4000 total warp ends, woven without pile as a flat weave and has the purpose to reinforce the towel sides (Yilmaz & Powell, 2005).

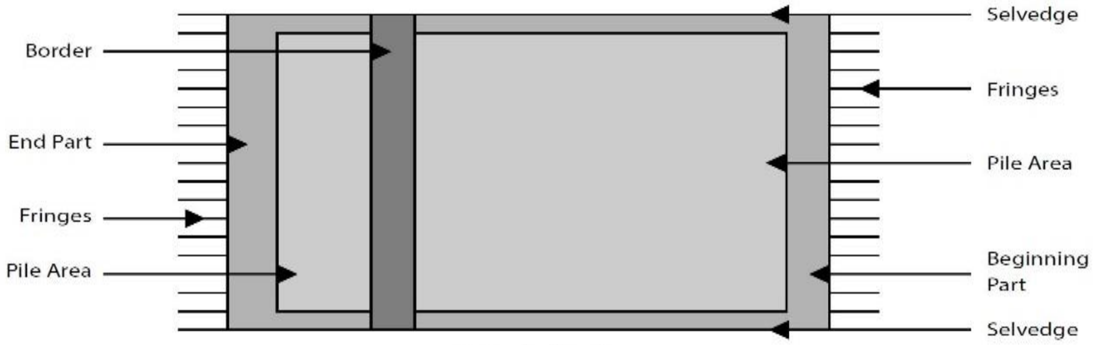

Fig 1. Part of towel

The classification of towels can be made according to weight, production, pile presence on fabric surfaces, pile formation, pile structure, and finishing. These classifications are shown below. In velour towels, pile loops on one side of the fabric are sheared in order to give a smooth cut velvet appearance. Uncut loops give the best absorbency, whereas velour gives a luxurious velvety hand. A towel with appliqués is embellished with additional pieces of decorative fabric in a motif, which is stitched onto the towel. Two-pick terry towels which were woven for bathrobe end-use have lost their importance today due to instability of the loops. Five or more pick terry towels are rarely produced because they need to be beaten for each pile twice. Now, the most prevalent towels are three and four-pick terry towels (Journal & Engineering, n.d.). As one-sided pile toweling has low water absorbing capacity, it is only used for special purposes such as a limited number of bathrobes. Furthermore, weaving one sided pile terry with few or no defects is difficult. In two-sided pile terry, both sides are covered with pile, whereas all the irregularities are visible in one-sided terry fabric as one side is bare, without pile (Siegmund, Kaehm, & Handtke, 2016). Towels are divided into groups according to end use and size as bath towels, hand towels, face towels, fingertip towels, kitchen towels and washcloths (Yilmaz & Powell, 2005).

1.1. Shearing process

It is quite common practice to shear the terry loops after manufacture in order to create a cut-pile effect. Many hand towels are sold with one face showing the traditional terry loop, whilst the other side is shorn to give the velour effect (Yilmaz & Powell, 2005).

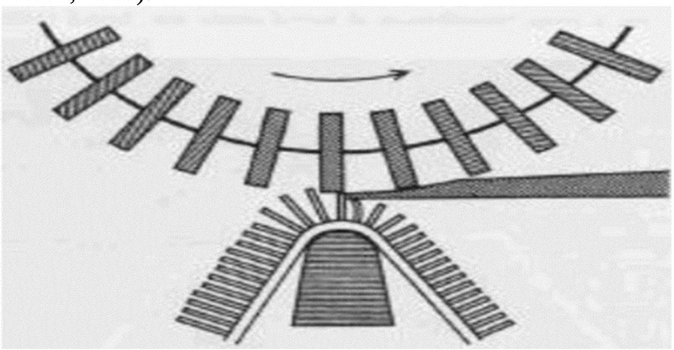

Fig 2. Shearing process (Yilmaz & Powell, 2005)

Shearing is applied to the pile fabric, by passing it over a cylinder with blades like a giant cylindrical lawnmower. The velour fabric is then brushed with bristles set in a cylinder to remove cut bits of fiber. Brushing leaves the surface fiber lying in one direction, so care must be taken to have all the fabrics in the same batch laid out in the same direction, or light will reflect off various pieces differently. In Figure 2, a simplified diagram of the shearing process is given. The pile fabric is guided across the shearing table and is sheared between the shearing blades mounted on a cylinder and a fixed blade (Yilmaz & Powell, 2005).

II. METHODOLOGY

2.1. Materials

Yarns: 100% cotton carded ring spun yarn of 16 Ne and viscose rayon of 20/2 Ne was used for ground weft yarn. And, 20/2 Ne carded ring spun yarn with 470 tpm of twist and 20/2 Ne carded ring spun yarn with 230 tpm of twist for ground and pile warp respectively were used in this study.

Fabrics: Three-pick terry woven fabrics of *Selin*, *Opal*, *Hurrum*, *Slam* and *Paris* design with three different weft densities were used in this study.

Equipment: Digital ground balance, magnifying or pick glass, circular GSM cutter, ruler, scissors, protractor, shearing and combing machine were used in this study.

2.2. Methods

The measurements and measurement methods applied to the terry fabric samples are explained below.

Measurement of weight per square meter of the fabrics

Weight before and after shearing for each of the 20 terry fabric constructions were measured and the weight per square meter values were calculated. In the measurements, a digital balance with a precision of 1/100 gram was used.

Measurement of shearing waste of velour type terry fabrics

All velour type terry fabrics have been used in this study. It is important to determine the pile waste ratio to correctly calculate pile height after shearing. To determine the pile waste ratio, the terry fabrics (whose weight per square meter was determined in advance) were passed through the shearing machine at the same speed. Next, the weight per square meter of the velour type of the terry fabrics was measured. By comparing the pre and post-cutting weight per square meter values, the shearing waste ratio was calculated.

Measurement of angle of pile inclination of terry fabrics

The pile inclines to the opposite side of the fell of the cloth (Nishimatsu & Sawaki, 1984). Since it is difficult to know without any resolution, I used a pick glass and protractor to measure its inclination. The angle of pile inclination was measured by taking two trials from each of 60 towels and an average was calculated. All terry fabrics, which were taken as a sample, have similar yarn properties except some of the differences in actual weaving that were given according to their design. Sample fabrics were selected randomly by their own design complexity and their design becomes complex when we go from *Selin* to *Hurrum*.

III. RESULT AND DISCUSSION

3.1. Result

The terry fabrics are sometimes used with the piles shown on one side, i.e. velour-type terry fabric. In this case, it is important to keep shearing waste at a minimum to reduce the terry fabric production costs. It is also important to know the shearing waste ratio in order to obtain the correct finished terry fabric weight per square meter, and to correctly calculate the amount of pile warp yarn required for a certain terry fabric. The face of terry fabrics produced for the purpose of this study was shorn to determine the shearing waste ratio for different terry fabric constructions. The shearing height in the machine was adjusted depending on different pile heights until satisfactory shearing quality was obtained.

The following table shows samples of two groups of different terry towel fabrics to study different parameters. The first group of sample fabrics (namely *Selin*, *Opal* and *Hurrum*) was designed to check the effect of fabric structure on pile angle and shearing waste. Thus, twenty samples from each of the three fabrics were taken and 60 individually dimensioned towels were included in this study. The last two towels (namely *Selam* and *Paris*) were taken to prove the relationship between pile height, pile inclination and shearing waste as well. Similarly, twenty samples from each of the fabrics were taken and the average results are displayed in Table 1.

Table 1: EPC, PPC and Pile Height

Design	Size (cm)	Number of Towels	EPC	PPC			Pile Height (mm)	Level of Design
				Body	Boarder	Selvedge		
First Group								
Selin	50*90	20	24	15	43	23	6.5	Flat
Opal	70*140	20	24	15	51	19	5	Medium
Hurrum	90*150	20	24	17	39	25	5.5	Figured
Second Group								
Paris	70*140	10	24	15	37	22	5	Flat
Selam	50*90	10	24	17	48	19	9	Flat

The average result of all terry towel samples for three different fabric designs were passed through shearing and polishing process in order to open the closed terry pile. The initial and final data of towels are presented in Table 2.

Table 2: Towel weight before and after shearing

Design	Average Pile Angle (^{0})	Expected GSM (g/m^2)	Before Shearing			After Shearing			Waste
			GSM (g/m^2)	Total Weight (kg)	Piece Weight (g)	GSM (g/m^2)	Total Weight (kg)	Piece Weight (g)	GSM (g/m2)
First Group									
Hurrum	48	470	550	15.2	760	540	14.6	730	70
Opal	51	430	500	9.7	485	470	9.3	466	40
Selin	58	510	600	5.5	274	590	5.3	266	80
Second Group									
Paris	65	450	540	5.3	530	600	5.13	513	150
Selam	46	500	523	2.7	270	571	2.57	257	71

The shearing height in the machine was adjusted depending on different pile heights until satisfactory shearing quality was obtained and satisfactory shearing depth for pile height from 4.5 to 9 mm is taken as 3.7 mm (Karahan et al., 2005). According to this, the difference between standard and actual weight loss during shearing process is presented in Table 3.

Table 3: Actual shearing waste ratio compared with its standard

Design	Cutting Depth	Stand -ard Loss	Piece Weight (g)		Actual Loss Per Piece (g)	Difference Per Piece (g)	Total Unwanted Waste (g)	Total Shearing Waste (g)
			One	Two				
First Group								
Hurrum	3.7	25.9	760	730	30	4.1	82	600
Opal	3.7	16.6	485	466	19	2.4	48	380
Selin	3.7	8.14	274	266	8	-0.14	-2.8	160
Second Group								
Paris	3.7	16.65	530	513	17	0.35	3.5	170
Selam	3.7	8.14	270	257	13	4.86	48.6	130

Many researchers investigated the ratio of ground warp, weft and pile warp coverage as the total weight percentage depends on the fabric design, density, count, pile height and other related parameters. In the constraint of terry towels, pile warp/ground warp/ground weft has a cover of the total weight of towels 70%/15%/15%, 65%/15%/20%, and 60%/22%/18% (Karahan et al., 2005) respectively. According to these ratios, the percentage of shearing waste was calculated relative to their total piece weight of towels.

Table 4: Relative percentage of shearing waste

Design	Piece Weight (g)	Weight of Pile Warp (g)	Percentage of Shearing Waste from the Total Weight	Percentage of Shearing Waste from Pile Ratio
First Group				
Hurrum	760	456	4.1%	6.6%
Opal	485	291	4.07%	6.5%
Selin	274	164.4	3%	4.9%
Second Group				
Paris	530	318	3.2%	5.3%
Selam	270	162	4.8%	8.0%

3.2. Discussion

a) Effect of Fabric Structure and Yarn Type

The shearing waste ratios are presented in Table 4 as a percentage for single piece and the shearing waste ratio is 3%, 4.07% and 4.1% as the design changed from *Selin*, *Opal* and *Hurrum* respectively in the first group. When the level of design complexity of the towel is high, the amount of yarn removed from the pile will be undetermined. However, it is expected to increase the amount of shearing waste with increasing design complexity as mentioned earlier. The reason behind this is that most of the piles are viewed on the opposite side of the fabric to have the correct structure, but it causes the rest of the piles to fall on the towel surface. During the struggle to find fallen piles in the cutting operation, the cutting knife should be adjusted deeper so that unexpected waste is recorded. When the shearing waste ratios are analyzed, logical relation is found between the shearing waste and pile geometry. Generally, the design complexity increases the amount of shearing waste. And, a close examination of data in Table 4 shows that the amount of waste changes linearly with pile geometry due to their difference in fabric designs.

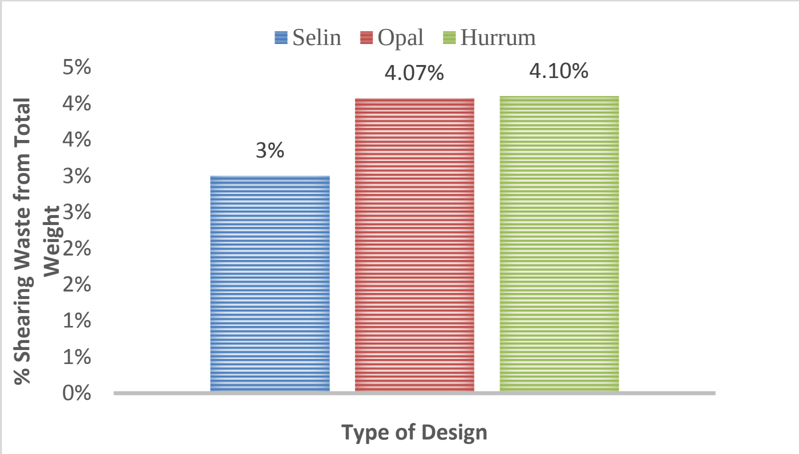

Fig 3. Effect of fabric structure on shearing waste

Yarn type also has the most significant effect on geometry of terry fabric. Loops produced from double yarn show more stability and do not fall on the fabric surface having more free space as compared to that produced from single yarn (Singh & Behera, 2015). The reason behind this is that the double ply yarn has twist balance and less chance of snarling or twisting of the loop. Thus, the double ply yarn shearing waste is higher than the single yarn that is used to construct the terry fabric with the same pile height and cutting depth.

b) Effect of Pile Height and Weft Density

Apart from these, there is another factor that affects the angle of inclination of terry piles called pile height. And, it is a determinant factor that should be considered during the shearing process of terry towels. When the length of the pile increases, the total piece weight of the pile increases and tends to fall on the towel surface due to its gravitational weight. On the contrary, increasing the pile height tends to reduce the bending rigidity of the pile due to its linearly proportional relationship between length and mass. As shown in Table 1, the height of the pile for *Selam* is greater than that of *Paris*. Consequently, pile height increment causes the shearing ratio to increase from 3.2% to 4.8% respectively for the second group. Thereby, the extent adversely affects the shearing quality and waste.

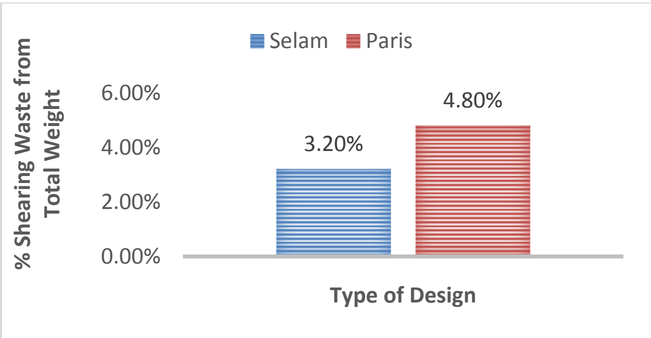

Fig 4. Effect of pile height on shearing waste

An increase in warp and/or weft density increases the weight per square meter due to an increase in the amount of ground warp and/or weft yarn in a square meter, on one hand. On the other hand, it increases the total pile length due to the increase in the number of pile in a square meter (Karahan et al., 2005). It shows that when the number of piles per square meter of the fabric is increased, piles can stand as vertical and their angle of inclination will be higher. Hence, it helps to satisfy the customer requirement easily with minimum waste because it has its own effects on the amount of shearing waste and quality.

c) Effect of GSM and Pile Yarn Consumption

The weight of pile warp in the terry fabric construction is presented in Table 4. It is obvious that the pile warp yarns constitute the largest portion of terry fabric weight. Hence, 4.9%, 6.5% and 6.6% of the total pile warp yarn ratio of *Selin*, *Opal* and *Hurrum* were removed during shearing process respectively. The final GSM requirement is added to produce the given towel and the deviation leads to the wrong cost as well as wrong amount of yarn consumption. However, the remaining weight of the towel is delivered to the customer without their desire. Thereby, an expected and actual GSM shows that the effect of fabric structure on GSM is taken as a reference for their significant loss of yarns.

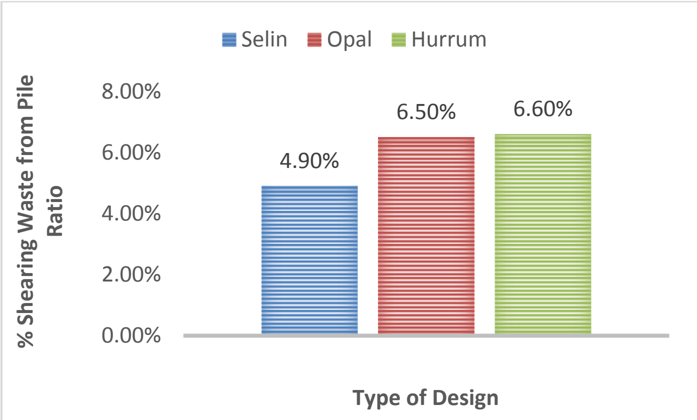

Fig 5. Effect of GSM on shearing waste

IV. CONCLUSION

It is important for the piles to be as vertical as possible during shearing. When terry fabric design is more figurative, it needs a deep cut because most piles fall on the surface of the towel. Since there is no neighboring pile which helps them to stand as vertical, that additional combing process is required. The number of piles per square meter of the fabric can help to increase the angle of inclination and stands the pile as vertical as possible. At very low pile heights, it is expected that the shearing waste ratio increases because the shearing waste constitutes a larger portion of the total pile weight of a terry fabric, compared to terry fabrics with higher piles (Karahan et al., 2005). And, the double ply yarn shearing waste is higher than that of single yarn due to its twist balance. Generally, complexity of fabric structure is the most significant factor that should be considered during shearing process and also in towel manufacturing.

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