

A study of Terry woven fabrics' dimensional stability and areal density during wet processing

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Abstract: Experimental work on three fabrics, made from 100% cotton, with different pile ratios and yarn densities was conducted during wet processing. Areal density, dimensional stability, yarn crimp and yarn densities were investigated at three different stages of wet processing namely greige state, bleached state and dyed state. Results showed an increase in dimensional contractions as pile ratio was increased. Fabric dimensions were measured after each processing stage, and the widthwise contractions were between 2.4% and 7.9% for all the fabrics whereas the lengthwise contractions were between 9.7% and 14.6%. Areal density was determined using two methods thus by manual measurement and also by calculation. The measure and calculated result both showed that the areal density for each fabric increased during all stages of wet processing. Generally, warp crimp was higher than weft crimp for all the three fabrics, at all three stages of fabric ion. Weft crimp was between 2% and 7% whereas warp crimp was between 6% and 14%. The measured and calculated results were compared and analyzed using regression analysis methods, and it was found that there was a correlation between the measured and the calculated results. It was concluded that wet processes have a significant effect on dimensional stability and areal density. Also, it was concluded that the effect of wet processing is dependent on the fabric construction parameters which include the pile ratio and yarn density.

Keywords: terry woven fabrics, areal density, dimensional stability, wet processing

1. INTRODUCTION

Terry fabrics are used in various fields such as bath towels because of their water absorption properties. Terry fabrics are pole fabrics that can be woven or knitted. Terry fabrics should conform to specific areal density (weight per square meter) so as to fulfil their design purpose (Frontczak-Wasiak et al., 2002; Karahan & Eren, 2006). Fabric areal density is dependent on physical properties and is affected by wet processing. Dimensional stability of the fabric is a

measure of the extent to which a fabric keeps its original dimensions subsequent to its manufacture. It is possible for the dimensions of the fabric to increase but any change is more likely to a decrease or shrinkage. Wet processing causes lengthwise and width contractions, hence a change in areal density and fabric sett (Zervent & KoC, 2006). The width and lengthwise and widthwise contractions differ due to different tensions and yarn crimps suffered in both warp and weft yarns. Some

terry fabric manufactures, such as Merlin Zimbabwe Limited, make assumptions that 100% cotton fabrics have 5%-dimensional shrinkage despite differences in the fabrics structure and pile ratio. Since shrinkage affects areal density. It is therefore important to determine the exact shrinkage values. Much of the planning that is carried out in the industry is based on calculations hence there is a need to have a calculation system that is reliable and accurate. Areal density changes strongly depend on pile ratio, warp and weft densities (Zervent, & Koc, 2006; Hsieh, et al., 1996). It is also important to establish between tarr densities and pile ratio so as to attain an optimum in areal density values. The relationship can be established through close monitoring of the changes in the fabric properties during wet processing. Ignorance of the actual fabric changes lead to assumptions that will result in wrong cost, wrong yarn requirement calculations and wrong fabric areal density which will result in inaccurate costing of fabrics, wrong yarn requirement calculations and wrong fabric areal density. The wrong yarn requirements calculations can cause interruptions in fabric manufacture because of shortages of required yarn or overstocking due to an excess amount of yarn in the storeroom because of inaccurate calculations.

Wet processing in a typical cotton fabric manufacturing facility, will involve processes such as desizing, scouring, dyeing, bleaching and applications finishes such as softeners. During wet processing of fabrics, fabrics are agitated to achieve penetration of the fabric by the solution be it

dyeing, bleaching or any other wet process. This agitating results in mechanical forces being applied to the fabric, and combined with other chemical actions from substances such as alkali and acid, may affect the fabric shrinkage and stability of the fabric. Mechanical forces on the yarns lead to stressing of the yarn hence there will be shrinkages in the fabric structures. During processes such as scouring, the structure of the cotton fibers is affected since the opens up pore by removing material from the surface of the fibers resulting in improved wetting. This improved wetting according to Thompson et al . leads to the shrinkage of the fabric.

The fabrics were processed in rope form in Winch dyeing machines. Fabrics were subjected to wet

Moisture diffuses into polar polymers such as cotton, nylon and wool. Water and water vapor are highly polar materials hence they are absorbed in natural fibers like cotton. When water is absorbed into a fiber a number of phenomena occur. New, strong secondary bonds may result and facilitate the liberation of heat. Water is absorbed and diffuses to the center of the fiber. When water is absorbed into the fiber, physical properties of the fibers change. The absorption of water into the fiber causes swelling of the fiber polymer. The swelling continues and stops when the fiber is saturated completely with the equilibrium amount of water. Moisture absorption is known to be proportional to moisture uptake. An increase in the amount of moisture taken up will result in an increase in the dimensions of any fabrics. Properties

such as stiffness, size, and permeability will be affected by the uptake of moisture.

In relation to hydrophilic terry fabrics, especially those made from cotton, the pile ratio decreases the sinking in time, which is interpreted as the increasing the hydrophilic degree. This increased hydrophilic degree is due to the increased surface area that is exposed to water. The loop structure of the terry fabrics means that there are areas of the yarn that are easy to reach for the water drops. The presence of the looping structure also means that the base structure is has bigger pores where the foot of the loop meshes with the yarn from the base yarn.

2. MATERIAL AND METHODS

2.1. Materials

Fabrics were made using the three-pick pile formation principle. Yarns for the manufacture of the towels were 100% cotton yarns. Pile yarns had a linear density of 42 Tex, weft yarns were also 42Tex while the warp yarns were 50Tex. All the yarns were manufactured using the Open-End spinning Machine.

2.2. Weaving

The terry fabrics were woven on a 250cm wide Sulzer Ruti G6100 terry weaving machine utilizing the Dobby selection system. Humidity in the weaving room was kept at 65% while the temperature was kept at 24°C.

2.3. Wet processing

The fabrics were processed in rope form in Winch dyeing machines. Fabrics were

subjected to wet processes namely scouring, bleaching and dyeing. During scouring all the terry fabrics were treated with caustic soda (alkaline) at 90°C for about 45 minutes. The fabrics to be dyed (fabric Band fabric A) were taken for pre-bleaching to remove the natural dyes and impurities. Pre-bleaching was carried out 90°C for an hour after which the fabrics were bleached dyed at 80°C for an hour.

2.4. Testing

2.4.1. Areal density

Samples of 100cm² were prepared for each of the types of fabrics under laboratory conditions. The areal density of each was measured using an electronic scale. The samples for different terry fabrics were taken from greige state, pre-bleached and dyed states for fabric A and fabric B while fabric C samples were taken from greige and fully bleached states.

2.4.2. Warp density

A pick glass was used to measure the number of picks per centimeter and number of ends per centimeter. The instrument has a 9cm² observation area and a magnifying glass that enables the counting of picks and ends.

2.4.3. Pile length

The ratio in a terry fabric affects the weight per square meter (areal density) and the weft ground warp ratios. For such a sample the pile warp yarn was measured, thus the pile length was measured using a ruler.

2.4.4. Dimensional stability

From the woven terry fabrics units were measured both lengthwise and widthwise in the greige state. The fabrics were taken for wet processing in the dye house. The dimensions for the fabric B and fabric A were then measured in pre-bleached and dyed states while the dimensions for the fabric C were measured in the fully bleached state. The lengthwise and the widthwise dimensional changes were then calculated.

2.4.5. Crimp

Warp and weft yarns were drawn out in from the greige, bleached and dyed terry fabric samples. The crimp was found by measuring the length of the drawn yarn at its relaxed state and straightened states. Respectively. The difference between the two lengths was divided by 100 to get the crimp percentage. Crimp was calculated using equation 1

$$\text{crimp} = \frac{l - S}{S} \times 100 \quad (1)$$

Where

S is the relaxed state and

l is the straightened length

2.4.6. Areal density of terry fabrics

There are three yarn systems in terry fabrics in a terry fabric namely weft, ground and pile yarn. The terry fabric areal density (W), was formulated by taking into account of the weight of each of the yarn systems,

and by using equations 2, 3 and 4, leading to the derivation of equation 5.

$$W_1 = \frac{n_1 \times 100 \left(1 + \frac{C_1}{100}\right) \times Tex_1}{1000} \quad (2)$$

Where

W_1 is the weight, in grams, of weft yarn in a square meter of terry fabric

n_1 is the weft density in picks per centimeter

C_1 is the weft yarn crimp in percentage

Tex_1 is the weft yarn count in Tex

$$W_2 = \frac{n_2 \times 100 \left(1 + \frac{C_2}{100}\right) \times Tex_2}{1000} \quad (3)$$

Where

W_2 is the weight, in grams, of warp yarn in a square meter of terry fabric

n_2 is the warp density in ends per centimeter

C_2 is the warp yarn crimp in percentage

Tex_2 is the warp yarn count in Tex

$$W_3 = \frac{(n_3/3)100 \times n_2 100 \times h \times Tex_3}{1000 \times 1000} \quad (4)$$

Where

W_3 is the weight, in grams, of pile warp yarn in a square meter of terry fabric

h is the pile length in mm

Tex_3 is the weft yarn count in Tex

$$W = W_1 + W_2 + W_3 \quad (5)$$

Where

W_1 is the weight in grams per square meter of the weft yarn

W_2 is the weight in grams per square meter of the warp yarn

W_3 is the weight in grams per square meter of the pile yarn

2.5. Regression analysis

Regression analysis was used to compare the measured values against the measured values.

3. RESULTS AND DISCUSSIONS

3.1. Fabric dimensions

The results in Table 1 show that the widthwise and lengthwise contractions vary between 2.4%

and 6% depending on the fabrics. Fabric A and fabric B fabrics, generally, had higher lengthwise contractions than widthwise contractions while fabric C had fabric C had lower lengthwise contractions than widthwise contractions. Fabric A being the fabric with the lowest pile ratio had the lowest width and lengthwise contraction of 4.8% and 13.0% respectively.

Fabric B which had a higher pile ratio than fabric A had its width and lengthwise contractions being 7.9% and 14.6% respectively. These two fabrics underwent the same wet processing stages and had different stages, and had different physical changes. From the results obtained (Table 1), it is clear that as pile ratio increased so did the dimensional contractions. Fabrics with higher pile ratio, in this case Fabric B, absorb more water and have higher dimensional contractions due to fiber swelling and yarn shrinkages. From Table 2 it is clear that fabric A and fabric B have almost the same yarn crimp but Table 1 shows that they have different dimensional changes.

Table 1 Fabric contractions during and after wet processing

Fabric	Pile length (mm)	Contractions during and after wet processing (%)			
		Bleached state		Dyed state	
		Width	Length	Width	Length
A	8.0	2.4	9.7	4.8	13.0
B	8.5	2.8	11.7	7.9	14.6
C	9.0	5.8	4.2	-	-

This shows that the pile ratio has a significant effect on dimensional changes. From all the fabrics the shrinkages in width and lengthwise directions increase at each stage of wet processing. For example, fabric A had its widthwise shrinkages increasing from 2.4% to 4.8% and

lengthwise shrinkages increasing from 9.7% to 13%. In the case of fabric C the widthwise shrinkages are 5.8% and 4.2% respectively. The shrinkages of fabric C are less than those of fabric A and fabric B because fabric C did not go through the dyeing stage. When terry fabrics get wet the

internal stress in the yarn is removed and the volume of cotton yarns increases because of the swelling of cotton fibers. As a result the yarns have to follow a longer path around each other and this causes contractions in the lengthwise and widthwise directions when there is sufficient space between the yarns, the changes in the yarn volume are fully reflected to the width and lengthwise contractions. As the fabric becomes denser the space between the yarns decreases and after some contractions the yarns rest on each other and prevent further contraction.

3.2. Yarn crimp and yarn density

From Table 2 warp crimp is between 6% and 12% whereas weft crimp is between 2%

and 8%. Generally, warp crimp is higher than the weft crimp. This is because of different tensions applied to warp and weft during weaving. All the fabrics have the same pattern of increases in the crimps during stages in wet processing.

From the obtained results in Table 2, it shows that fabric C has the highest warp crimp changes, meaning that it has the highest width contractions as witnessed from Table 2. The results also show that the yarn crimp changes increase with the pile ration. Weft crimp and warp crimp increase during wet processing due to swelling and water uptake.

Table 2 Fabric yarn crimp during and after wet processing

State	Yarn crimp (%)					
	Fabric A		Fabric B		Fabric C	
	Warp	Weft	Warp	Weft	Warp	Weft
Greige	10	2	8	2	6	2
Bleached	11	5	9	6	10	4
Dyed	12	8	11	8	-	-

Fibres are subjected to swelling when they absorb water. Fibre swelling then leads to increase in yarn diameter. Warp yarn then takes a longer path around the swollen weft yarn resulting in more crimp in warp yarn than weft yarn. The swelling of fibres also causes the yarns to move closer to each other as they absorb water during wet processing. From Table 3, it can be seen that both warp and weft density increase during wet processing as a result of crimp. Thus, all the fabrics have both warp and

weft moving closer to each other during stages of wet processing.

Table 3 Fabric yarn densities during and after wet processing

State	Yarn density					
	Fabric A		Fabric B		Fabric C Picks/cm	
	Ends/cm	Picks/cm	Ends/cm	Picks/cm	Ends/cm	
Greige	9.3	11.7	10	11.7	13.7	11.3
Bleached	10.7	12.3	11.7	12.7	14.3	12
Dyed	10.3	12.0	11.3	12.3	-	-

3.3. Areal density

The measured areal density of each fabric increases during wet processing because of an increase in both warp and weft density which increase in weight due to swelling on absorbing water. Fabric A recorded the lowest areal density in all wet processing stages while fabric C has the highest areal density. The difference in areal density is due to differences in pile ratio of the fabrics,

thus fabric C has the highest areal density because of its higher pile ratio than other fabrics. Fabric C had a high change in areal density despite undergoing fewer stages in wet processing. Fabric A had less areal density changes though it had many stages in wet processing. The results in Table 4 show that as the pile ratio increase, the greater the change in areal density. The pattern in the measured areal is also seen in calculated results in Table 5.

Table 4 Fabric measured areal densities during and after wet processing

State	Measured weight (g/m ²)		
	Fabric A	Fabric B	Fabric C
Greige	248.5	251.9	324.5
Bleached	261.1	294.1	375.4
Dyed	271.1	313	-

Table 5 shows that all fabrics have the pile yarn with the highest calculated density as compared with the warp and weft yarn. This is because of the loops that are formed by the pile on the terry fabric. On the other hand, the weft yarn records the lowest density in all fabrics. Table 2 and 3 show that the weft has the lowest crimp and density (picks/cm) which explain the reason why the weft has the lowest density or weight in Table 5. Fabric A and fabric B have almost similar warp and weft weight but different areal density, the reason being that fabric A has lower pile ratio than fabric B.

As expected, the increase in weft density, warp density and pile ratio increase the areal density. The increase in the pile ration causes the areal density to increase because of an increase in the total pile warp length in a square meter of the fabric.

Table 5 Fabric calculated areal densities during and after wet processing

State	Yarn type	Calculated weight (g/m ²)		
		Fabric A	Fabric B	Fabric C
Greige	Warp	64.34	63.18	59.89
	Weft	39.84	42.84	58.69
	Pile	137.11	147.42	205.88
	Areal density	241.3	253.44	324.46
Bleached	Warp	66.6	67.04	66
	Weft	45.42	50.3	62.46
	Pile	147.08	175.12	228.22
	Areal density	259.1	292.46	356.68
Dyed	Warp	68.88	70.49	-
	Weft	48.54	53.07	-
	Pile	156.62	187.23	-
	Areal density	274.04	310.79	-

An increase in the warp density and weft density increase the areal density due to an increase in the amount of ground warp and weft yarn in a square meter. Generally, width and lengthwise contractions cause and increase in areal density. When fibres absorb water or moisture they increase in diameter and density hence the weight of the fibre. After absorption of water swelling results and yarn move close together becoming more packed on the structure of the fabric hence the increased yarn density the areal density of the fabric will therefore increase due to the closeness of the yarns.

3.4. Regression

In Figure 1, the correlation coefficient (R^2) between the measured and the calculated values was found to be 0.9912. The correlation proves that the measured and calculated areal density results have no significant difference. This shows that there is a strong relationship between the measured and the calculated values. The results also show that the calculation approach can be used to determine the areal density of terry fabrics.

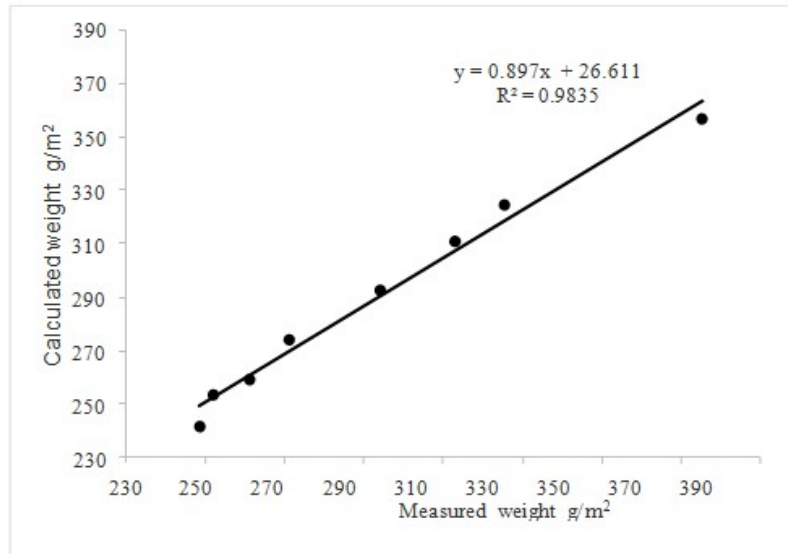


Figure 1 Regression curve of measured and calculated areal densities

4. CONCLUSION

From the experimental and theoretical study of terry woven fabrics, it was found that the fabric properties are affected by wet processing and these properties include areal density, warp and weft density, yarn crimp and dimensional stability. These properties also depend on each other thus a change in any of them result in a change in others. In this study it was seen that fabrics experience dimensional shrinkage which differ from fabric to fabric depending on the structure. The study proved that dimensional changes affect areal density. Since terry fabrics should be produced at a required areal density, it is therefore essential to know the fabric dimensional changes so as to attain an optimum in fabric areal density. It is also concluded that the calculation approach can be used to quickly determine an approximation in fabric areal density without cutting out samples for measurement.

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