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The Effect of Mercerization Treatment on Dimensional Properties of Cotton Plain Weft Knitted Fabric

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Abstract: In this paper mercerization is suggested as effective chemical treatment to stabilize the structure of plain knitted fabric produced from cotton yarn. Knitted samples were mercerized considering variation in concentration of alkali solution and bath temperature. Then, numerical values of constant geometry of the samples were calculated. Individual and simultaneous effects of the variables on dimensional properties were assessed. Study shows that, the area geometry constant values (K_s) achieved for mercerized samples were higher than the dry and the wet relaxed samples. Dimensional stability of the sample mercerized in alkali concentration of 200g/l and temperature of 20°C is not very high. Increase in alkali concentration had a positive effect when temperature was 20°C. But, for the samples mercerized at temperature more than 20°C increase in NaOH up to 240g/l improved stability and further increase shows destroying impacts. In alkali concentration of 200g/l, temperature of 20°C had the least impact on K_s . Stability of the samples mercerized in 200g/l increases by increase in temperature but optimum value for the temperature was 40°C. The area geometry constant value of the samples mercerized in alkali concentration of 250g/l and temperature of 20-80°C is high. Consequently, increase in temperature when alkali concentration is 300g/l cause a reduction in dimensional stability.

Key words: Weft knitted fabric · Dimensional stabilization · Mercerization treatment · Fabric relaxation · Area geometry constant

INTRODUCTION

The behavior of fabrics in end products is decisively influenced by their performance characteristics. These characteristics can be optimally adapted to the quality requirements by varying physical and technological parameters of the finishing process.

Various chemical treatments are in existence to improve the performance characteristics of the fabric. Among these, mercerization is of major interest to the researchers as it improves the processing quality of the yarns and the quality of the products produced from them [1].

Extensive knowledge and experience on this subject already exists as there are numerous publications reported by various researchers. For example, Hebsiba and Thambidurai have reviewed tensile properties of cotton yarns after slack swelling [2]. Performance characteristics of mercerized ring and compact spun yarns have been investigated as well [1]. The effect of mercerization on the tensile properties of rotor spun yarn has been reported by Hari *et al.* [3].

The influence of mercerization treatment on the properties of woven fabrics e. g dye absorption, weight reduction and dimensional stability is another field that has been evaluated by researchers [4-8]. The findings of all the researches confirmed improvement in tensile characteristics, sorption properties and dimensional stability of the yarns and fabric samples after treatment. However, processing parameters that are involved in mercerization bath, yarn kind, fiber kind and fabric structure affect results of these studies [9, 10].

Besides woven fabrics, the plain knitted fabric is another structure that is ideal for next-to-the-skin wear, since it possesses high extensibility under low loading conditions which allows it to fit snugly and without discomfort on any form on which it is pulled. These properties, together with the fact that the knitted fabric is often very slow to recover to its undistorted state, make it impossible to measure accurately its dimensions. Therefore stabilization of knitted fabrics and introducing suitable method to stabilize knitted structure is a major subject that has received significant attention. In this regard researchers

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have defined the dry, wet and the fully relaxed states in which fabric takes up a fixed geometrical shape and stable state [11].

However, different fibers react in different ways to these treatments, so that the equilibrium values of the geometry constant (K_s) vary [12]. Also, previous considered models for dimensional properties of the plain knitted fabric showed that, the theoretical K_s value (25.986) was higher than the experimental value for fully relaxed plain weft knitted fabric [13, 14]. Therefore, more suitable relaxation methods should be used in finishing treatment. Steam setting and using ultrasonic waves are in existence to improve dimensional stability of the plain knitted fabric [15].

Though a few researchers have investigated properties of the hot mercerized knitted fabric [16], the work in the field of chemical treatment in relation to processing parameters and their effect on dimensional properties of cotton plain weft knitted fabric is scanty. In this connection an understanding of the behavior of mercerized cotton plain knitted fabric is of fundamental importance and would be worthwhile to be studied. The present study was therefore aimed at investigating the influence of mercerization process and its two important parameters on dimensional characteristics of the plain knitted fabric.

MATERIALS AND METHODS

The fabrics studied were knitted on a Piylong circular knitting machine (gauge 24 and diameter 30 inch) with positive yarn feed. It was of 30/1(tex) rotor cotton yarn with twist multiplier of 4792.6(α_{tex}). Rotor spun yarn is used widely for producing weft knitted fabric due to its good uniformity, bulkiness, less hairiness and absorption. Therefore, in the present work this kind of yarn was selected to knit sample fabrics. Plain knitted fabric was produced with the loop length of 0.294 cm.

Preparing Dry Relaxed, Wet Relaxed and Mercerized Fabric Samples: Knitted fabric was divided in 14 groups. Two groups of them were used for obtaining numerical values of constant dimensional parameters in wet and dry relaxation states and others were treated with alkali solution (NaOH) as mercerized fabrics.

Six samples with dimensions of 40cm×40cm were taken from each group. In the middle of each fabric, two squares with dimensions of 35cm×35cm and also 25cm×25cm were measured by means of a template and marked by points in length (wale) and width (course) directions by a permanent marker, so that during the relaxation treatment these mark still remain [15]. Then, prepared fabrics were subjected to the following relaxations and chemical treatments.

Dry relaxation state; Six samples were placed on a flat surface at room conditions for 24 hr after coming out of the machine to release knitted stresses [15].

Wet relaxation state; Six samples were placed in water at 40°C for 24hr, rinsed gently by hand and dried on a flat surface for 24hr at room conditions [15].

Mercerization treatment; After preparing 72 samples (12 groups) according to dimensions discussed above, wooden frames were made. Dimensions of the frames were 38.5cm×38.5cm calculated with respect to the marked dimensions on the samples (35cm×35cm) and mercerizing tension according to the Figure 1.

Fabrics were drawn equally and uniformly in both course direction and wale direction till marked line 35cm×35cm on the fabrics reached to the dimensions of 38.5×38.5cm on the frames and fitted to the line 1. Then, fabrics were fixed on the new position by staples firmly.

Prepared samples were placed in a mercerization bath respectively. Area with dimensions of 35cm×35cm marked on the fabrics was completely in contact with mercerization solution in the bath. Variation in alkali concentration and bath temperature were considered during processing while mercerizing tension (MT) and time of treatment (TT) were 10% and 300sec respectively.

The abbreviations (CAS) and (BT) are used throughout the text to stand concentration of alkali solution (g/lit) and bath temperature (°C). Fabric samples were treated according to the specifications shown in Table 1. The values of the considered parameters were selected in consistence with possibilities of the laboratorial work.

Table 1: Experimental plan and specifications of the prepared mercerized samples

TT	MT	BT	CAS	Sample code	TT	MT	BT	CAS	Sample code	TT	MT	BT	CAS	Sample code
300	10	20	300	9	300	10	20	250	5	300	10	20	200	1
300	10	40	300	10	300	10	40	250	6	300	10	40	200	2
300	10	60	300	11	300	10	60	250	7	300	10	60	200	3
300	10	80	300	12	300	10	80	250	8	300	10	80	200	4

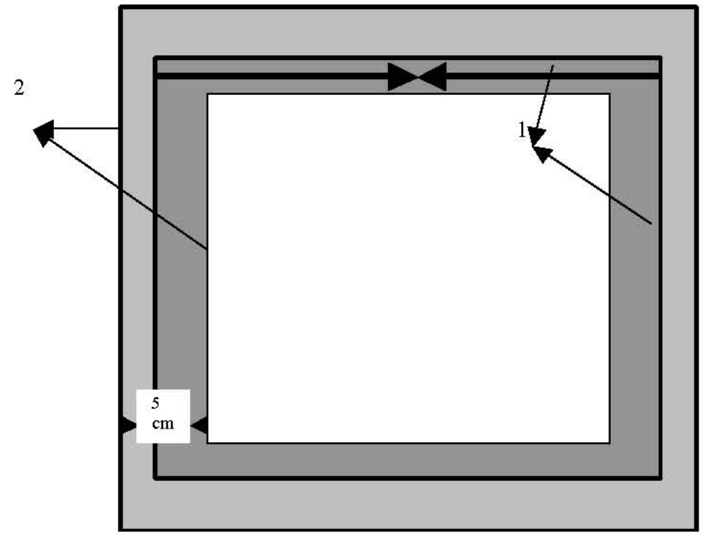

Fig. 1: A schematic of wooden frame used to fix samples in mercerization treatment
(1) Line 38.5 cm× 38.5 cm marked on the frame to fix fabrics after applying mercerization tension
(2) Border lines of the frame

After treatment, in order to rinsing and neutralization, fabric fixed on the frame was put in water with temperature of 60°C and then sample was neutralized in a bath containing Acetic acid 2% for 240 sec. At next step, fabric was rinsed in warm water. Fabric was drained in cold water after removing from the wooden frame and then was dried for 24 hr on a flat surface at room atmosphere. Contain of the mercerizing bath was replaced with new solution after 3 treatments due to change in concentration of alkali solution.

RESULTS AND DISCUSSION

Calculating Values of the Constants Termed the Fabric Dimensional Parameters: After each relaxation state and mercerization treatment the change in length (wale direction) and width (course direction) of the fabrics called shrinkage was measured (Equation 1) at the area with dimensions of 25cm×25cm marked on the fabrics. Then average of six measurements for each sample was calculated and is shown in Table 2.

$$Shrinkage\ (\%) = ((25-L_2)/25) \times 100 \quad (1)$$

Where; L_2 is dimension of the fabric after mechanical relaxation and mercerization treatments measured by ruler.

Then, the number of courses per cm (*CPC*), the number of wales per cm (*WPC*) and stitch density or the number of loops per unit area (*SD*) of the samples were calculated. Stitch density was calculated by multiplying (*CPC*) by (*WPC*). At the end, the constants termed the fabric dimensional parameters were calculated according to Munden's equations (Equations 2, 3, 4) [11] and the results are shown in Table 2.

$$CPC=K_c/L \quad (2)$$
$$WPC=K_w/L \quad (3)$$
$$SD=K_s/L^2 \quad (4)$$

Where L is the length of the loop; K_c, K_w, K_s are the constant dimensional parameters of the fabric.

Independent Effects of the Processing Parameters on Dimensional Properties of the Fabric: In the first phase of the research, the effects of each processing parameter itself on dimensional properties of plain weft knitted fabric (K_s value) were investigated. In this case, one parameter was selected as a variable and the rest of the parameters were chosen as constants. Specification of the samples in each group is shown under Figures 2, 3.

A statistical analysis (one way ANOVA) was carried out to analyze the differences between the test results for different groups of samples at 95% level. Also, a Tukey's procedure multiple range test was performed for a better analysis within groups.

The mercerization treatment causes shrinkage in fabric and by making progress in mercerization process the fabric tended to shrink more. It means that the fabric loops tended to become displaced towards each other, like the threads contact more and more with each other.

Table 2: Dimensional parameters of plain weft knitted fabrics at different relaxation states and mercerization treatments

Sample code	Shrinkage % CD	Shrinkage % WD	K_c mean	K_c St.d	K_w mean	K_w St.d	K_s mean	K_s St.d
1	16.80	7.20	5.9893	0.324	3.4300	0.311	20.5433	0.298
2	17.20	10.00	6.5417	0.281	3.5317	0.361	23.1083	0.119
3	14.00	12.80	6.6794	0.345	3.4267	0.284	22.8883	0.170
4	14.40	10.00	6.3740	0.284	3.5200	0.267	22.4367	0.218
5	22.00	8.00	6.0553	0.356	3.7383	0.352	22.6367	0.537
6	20.00	8.00	6.4762	0.311	3.6433	0.269	23.5950	0.331
7	26.00	10.00	6.0164	0.368	3.9417	0.301	23.7150	0.331
8	19.60	12.00	6.1242	0.276	3.8100	0.352	23.3333	0.281
9	23.60	9.20	5.9737	0.286	3.7500	0.279	22.4017	0.337
10	24.00	9.60	5.8100	0.293	3.7033	0.353	21.5183	0.222
11	14.00	8.00	5.9367	0.345	3.6367	0.299	21.5900	0.206
12	16.40	11.60	6.2445	0.381	3.2483	0.325	20.3817	0.254
dry	8.64	3.21	5.8500	0.244	3.0000	0.365	17.6000	0.311
wet	10.40	3.60	5.6900	0.310	3.2600	0.269	18.5400	0.281

CD: course direction of the sample; WD: wale direction of the sample

Table 3: Results of the ANOVA statistical analysis to show the significance of the effect of each variable and their interaction on dimensional stability of the samples (K_s)

Dependent Variable: K_s

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	85.860[a]	11	7.805	71.894	.000
Intercept	36447.300	1	36447.300	3.357E5	.000
CAS	16.709	2	8.354	76.950	.000
BT	12.329	3	4.110	37.854	.000
CAS * BT	56.822	6	9.470	87.229	.000
Error	6.514	60	.109		
Total	36539.675	72			
Corrected Total	92.375	71			

This is clear from obtained values of shrinkage (Table 2) for dry relaxed, wet relaxed and mercerized samples. Shrinkage of the mercerized samples is more than the dry and the wet relaxed samples. Similar results have been reported by other researchers [15, 17]

Knitted structure has different elasticity in wale and course directions that is inherent property of the fabric. However, fabric shrinkage is considered when *CPC* and *WPC* are calculated. Also, the trend of the change in shrinkage is divergent in wale and course directions (due to fabric structure) and also under different mercerization conditions.

According to the literature, K_s value is indicator of dimensional stability of the weft knitted fabric. This factor is calculated by using stitch density and loop length. Stitch density is calculated by multiplying *CPC* by *WPC*. These two parameters are increased by increase in fabric shrinkage after relaxation and mercerization treatments. Reflection of the change in fabric shrinkage after treatments is shown in *CPC* and *WPC* values and consequently affects K_s values of the samples.

Besides, Significance of the main effect of each processing parameter mentioned in Table 1 and their interaction on K_s value was assessed as well. ANOVA test was performed by using "Univariat" from "General Linear Model" which is in "Analyze menu" of SPSS software. The results of the statistical analysis are shown in Table 3.

The Effect of Concentration of Alkali Solution: The effect of concentration of alkali solution has been shown in Figure 2. Based on the results it was cleared that, change in dimensional stability of the sample No. 1 in which considered values for both CAS and BT were the lowest at the level that used in this study is very low in comparison with other samples probably due to incomplete mercerization. In this condition considering higher values for BT is mandatory to achieve complete processing purposes. Dimensional stability improvement is observed for the samples No. 2, 3 and 4 in which mercerization is carried out in 200g/l of caustic soda (NaOH) and temperature higher than 20°C. However,

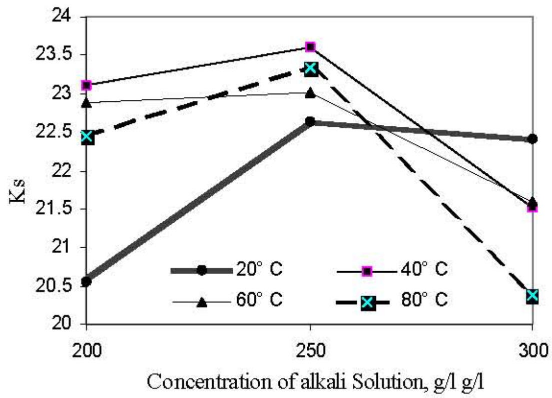

Fig. 2: Effect of concentration of alkali solution on K_s

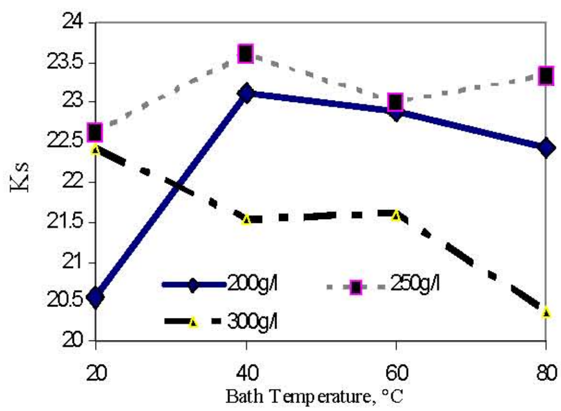

Fig. 3: Effect of bath temperature on K_s

BT has an optimum value in these samples that was 40°C. On the other hand, dimensional stability (K_s value) of the sample N0.2 that mercerized in 40°C was the highest and decreases towards sample No.4 that mercerized in 80°C.

Increase in CAS had a positive effect on dimensional stability for the samples mercerized at temperature of 20°C But, for the samples mercerized at temperature higher than 20°C, increase in CAS (240g/l) improved dimensional stability of the fabrics. Further increase in CAS had a destroying influence on K_s value.

In addition, at the temperature higher than 20°C alkali concentration of 200g/l was profitable in comparison with the alkali concentration of 300g/l. Alkali Concentration of 300g/l shows destroying effect when bath temperatures were 60, 80°C (samples No. 10, 11, 12). Consequently, for the samples mercerized at the temperature higher than 20°C regardless of the alkali concentration value, the proper temperature to achieve the highest K_s value was 40°C.

The Effect of Bath Temperature: The effect of bath temperature on dimensional stability of the samples has been shown in Figure 3. According to the results and statistical analysis it was concluded that, the effect of the temperature must be discussed in each alkali concentration separately. Figure 3 shows that, in concentration of 200g/l, bath temperature of 20°C had the least impact on dimensional stability in comparison with three other temperatures. Difference between K_s value of the sample No. 1 mercerized at temperature of 20°C and alkali concentration of 200g/l is very sensible in comparison with the K_s value of the samples No. 2, 3, 4 mercerized at temperature of 40, 60, 80°C respectively and alkali concentration of 200g/l. Dimensional stability of these samples increases by increase in bath temperature from 20°C towards 80°C but optimum value for the temperature was 40°C.

For the samples mercerized in alkali concentration of 250g/l and bath temperature of 20, 40, 60, 80°C dimensional stability is high and close to each other. Dimensional stability increases even at the temperature of 20°C when alkali concentration increases from 200g/l to 250g/l. The highest K_s value is obtained in temperature of 40°C when alkali concentration is 250g/l. In this condition difference between K_s value for the samples mercerized at temperature of 20, 60, 80°C is not meaningful statistically.

In mercerization conditions in which concentration of alkali solution was selected as 300g/l the optimum temperature to complete mercerizing purposes was 20°C. Increase in bath temperature from 20°C towards 80°C when considered value for alkali concentration is 300g/l cause a reduction in dimensional stability. Reduction in K_s value was less for the sample mercerized at temperature of 40°C and increases by increase in bath temperature. Consequently, it was concluded that, among three considered temperature, 40°C is the proper value to carrying out the process and to achieve suitable dimensional stability.

Simultaneous Effect of All the Variables on Dimensional Stability of the Fabrics: Value of the area geometry constant (K_s value) which is related to the stitch density or the number of loops per square centimeter is obtained from multiplying K_s value by K_s value. One way analysis of variance shows that, there is a meaningful difference in K_s values of the samples in 0.05 levels of significance.

Research showed that, sample No.7 has the highest value of K_s (23.7). More dimensional stability of the sample is the result of carrying out mercerization process at the temperature of 60°C, tension of 10%, alkali concentration of 250(g/l) and time of 300sec. But statistical analysis showed that, the mean value of K_s has no significant difference between samples No. 6, 7, 8 and 2. It means that, the same qualified properties can be obtained in easy condition. Sample No.6 (K_s = 23.59) was mercerized in alkali concentration of 250 (g/l) and temperature of 40°C with 10% tension and time of 300 sec. This sample has easier better process condition compared with samples No. 7, 8, 2.

Finally the results confirm that, the mercerization process improved dimensional stability of plain weft knitted fabric, close to the theoretical value. Compared with other dimensional stability improvement methods, in which the K_s value was raised to 24.35 [15], mercerization treatment is considerable as a method for dimensional stabilization of cotton plain weft knitted fabric. Also, K_s values for all mercerized samples are more than that of for dry relaxed (K_s =17.60) and wet relaxed (K_s =18.39) fabric samples. More investigation is in progress concerning a wider domain of variables in order to increasing the K_s factor and achieving more accurate results.

CONCLUSION

Knitted fabrics from cotton rotor yarn were subjected to dry relaxation, wet relaxation and different mercerizing treatments. Two main processing parameters were considered in mercerization treatments. After preparing relaxed and mercerized fabric samples, values of termed constants dimensional parameters of the fabrics were calculated. The effect of each variable itself and simultaneous effect of them on K_s value of the fabrics was assessed.

Study Showed That:

- Change in dimensional stability when considered values for both alkali concentration and temperature were low is very little.
- Increase in alkali concentration had a continual positive effect for the samples mercerized at 20°C But, for the samples mercerized at temperature higher than 20°C increase in alkali only up to 240g/l improved dimensional stability.
- At the temperature more than 20°C, alkali concentration of 200g/l was profitable in comparison with 300g/l. Alkali concentration of 300g/l shows destroying effects when bath temperature was 60 and 80°C.
- In concentration of 200g/l, temperature of 20°C had the least impact on dimensional stability. But stability will improve by increase in bath temperature from 20°C towards 80°C.
- For the samples mercerized in alkali concentration of 250g/l and any temperature dimensional stability is high and close to each other.
- When concentration is selected as 300g/l, the optimum temperature to complete mercerizing purposes is 20°C. Increase in bath temperature when considered value for alkali concentration is 300g/l cause a reduction in dimensional stability.

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