Dimensional Stability and Sewing Performance of Single Jersey Knitted Fabrics

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Abstract: The dimensional stability of cotton weft knitted fabrics has a significant effect on their quality. The characteristics of yarn, the characteristics of knitwear structure, and conditions of technological processes influence geometrical and dimensional stability of knitwear's. The goal of this work was to investigate the dimensional stability and seam quality of single jersey knitted fabrics. The effects of loop length, yarn twist factor and the number of washing cycles were intended to be studied. The experimental results were assessed using two way–Anova statistical analysis. The findings of this study revealed that both loop length and number of washing cycles were found to have a positive influence on dimensional stability of the fabrics at all levels of twist factors. It was also found that loop length and yarn twist factor had a positive effect on seam elongation. On the contrary, both factors have a negative influence on seam strength and efficiency.

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1. Introduction

Dimensional stability refers to a fabric's ability to resist a change in its dimensions A fabric or garment may exhibit shrinkage, i.e. decrease in one or more dimensions or growth, i.e. increase in dimensions under conditions of refurbishing [1]. Changes occur because tension in some materials that developed during, yarn spinning, fabrication, and finishing may be relaxed when a material is wetted and dried without tension [2]. Many problems are related to dimensional changes of materials. Poor dimensional stability can create problem with fit, size, appearance, and suitability for end use [3].

Dimensional stability of weft-knitted fabrics is a serious problem in view of fabric quality control [4,5]. There are reports available on the geometry and dimensional properties of plain knitted fabrics. Mokhopadhyay [6] and Doyle [7] found that the stitch density of plain knitted fabrics in the dry relaxed state is dependent only on the loop length, and independent of other yarn and knitting variables.

Dimensional stability of a knitted structure is generally investigated by calculating dimensional constants. Required expressions for a single jersey structure have been introduced by various workers, based on theoretical models and empirical studies [8-12].

In apparel industry, the sewing process is one of the critical processes in the determination of productivity and the quality of the finished garment [13]. Recently, the performance and appearance of garments and sewing techniques – especially seam strength, seam efficiency and seam puckering – have become important [14-17].

The major aims of the research were, therefore, to systematically study the effect of principal variables on the dimensional stability and sewing properties of single jersey knitted fabrics. Twist factor of the yarn, number of washing cycles and loop length were intended to study its effects on dimensional stability. The effects of twist factor and loop length on seam strength, seam elongation and seam efficiency were also studied.

2.Material and Methods

Nine single jersey fabric samples were knitted on 24 gauge, 26 inch diameter high speed circular knitting machine equipped with positive feeder. The fabric samples were produced from Egyptian cotton yarns of count 30/1 Ne with three twist factors, i.e. 2.8, 3, and 3.3 respectively. Also each fabric sample was knitted with three different loop lengths i.e. 2, 2.5, and 3 mm. After removing from knitting machine, all fabric samples were bleached using hydrogen peroxide and dried in accordance with current manufacturing practices. After that, the bleached knitted fabric samples were left lying on smooth flat surface in standard atmospheric for 3 hours. Then, samples were washed in super capacity washer at different numbers of washing cycles, i.e. 3, 6, 9, and 12 respectively. After washing, the fabric sample were rinsed in cold water and then line dried for 24 hours.

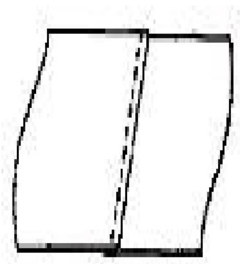
Dimensional stability of knitted fabric samples was characterized as fabric shrinkage. In this study, dimensional stability of washed and dried knitted fabric samples was taken in wale and course direction. The shrinkage in longitudinal and transverse directions of laundered samples was calculated after each cycle of washing and drying.

The shrinkage value was defined by equation (according to standard ISO 26330:1993 [18] :

$\lambda = (L - L_o) / L_o * 100$

where λ is the fabric shrinkage percent, L_o is the dimension of the sample before washing and drying; L is the dimension of the sample after washing and drying.

Weft knitted fabric sample was sewn with Lsa-1 seam type, which illustrated in fig. 1. Sewing thread of 100 % cotton was used at lockstitch with stitch density, i.e., 5 stitches per cm was used.



LSa-1

Figure 1: Photograph of the seam used in the study

Seam strength and seam elongation were measured on an Instron 4411 device according to the ISO 13935-2 standard [19]. The speed of the device was 100 mm/min. Samples were cut to the dimensions of 100 ×150 mm. Two samples were sewn together on the short side by putting one right above the other. Each sample was sewn using the above seam type.

Seam efficiency measures the durability along the seam line. Durability is identified as necessary to satisfactory seam's functional performance, and efficient seams are assumed to be more durable than weak ones [20, 21]. Seam efficiency was measured according to the ASTM 1683-04 standard method. In this method, seam efficiency was measured by using the following equation:

Seam efficiency = (seam strength / fabric strength) × 100

Statistical Analysis

To detect the influence of the desired parameters on fabric dimensional stability and sewing quality, Two-way analysis of variance was conducted by using SPSS statistical package. The experimental results were assessed for significance at 0.01 and 0.05 statistical security.

In order to predict the fabric shrinkage in wale and course direction at the number of washing cycles and loop length, and to predict the seam performance at different level of loop length and yarn twist factor; a non-linear regression analysis was conducted. The regression models were validated by the coefficient of determination, i.e. R^2 value, which ranges between 0 and 1.

3. Results and Discussion

Dimension stability in wale direction

The relationships between dimension stability (shrinkage) of single jersey knitted fabrics in wale direction and loop length and the number of washing cycles at different levels of the yarn twist factors were illustrated in figures 2 - 4. The statistical analysis showed that both factors have a significant influence at 0.01 statistical security on fabric dimensional stability.

Figure 2 shows the response surface of dimensional stability, shrinkage, in wale direction of weft knitted samples at different levels of washing cycles and loop lengths at yarn twist factor 2.8. From this figure it is seen that both variables have a positive effect on fabric shrinkage. As the loop length and the number of washing cycles increases the fabric shrinkage increases. The statistical analysis proved that single jersey knitted fabrics shrinkage increased by 28% and 26% with the increase in loop length and washing cycles respectively.

The regression relationship between fabric shrinkage and the number of washing cycles and the loop length for the fabrics knitted from yarn of twist factor 2.8 is as follows.

Shrinkage, % = $-27.3+23.1x+0.7y-4.14x^2-0.12x*y-0.01y^2$

Where,

X= loop length, mm, and

y= number of washing cycles

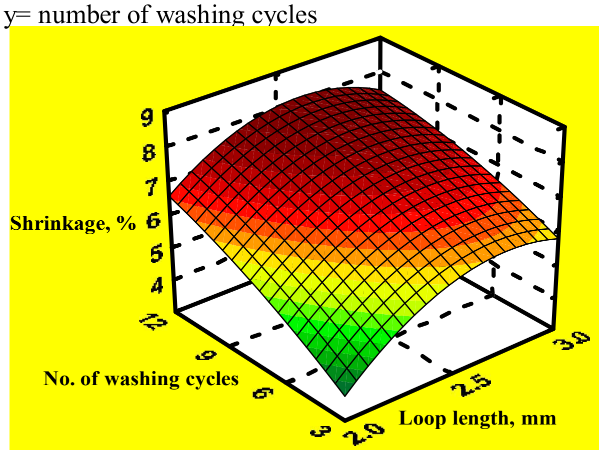


Figure 2: Response surface of the effect of loop length and the number of washing cycles on the dimensional stability in wale direction of single jersey fabrics knitted from yarns with twist factor 2.8.

The statistical analysis proved that the coefficient of determination for this model is 0.87, which means that this model fits the data very well.

Shrinkage of single jersey fabrics knitted from yarns of twist factor 3 at different levels of loop length and number of washing cycles was depicted in figure 3. From this figure, it is noticed that both factors has a positive effect on the knitted fabric shrinkage. As the both factors increases the fabric shrinkage also increases. Increasing loop length from 2 to 3 mm leads to an increase of knitted fabrics shrinkage by 28%. Whereas, the fabric shrinkage increased by 27 % approximately with the increase of washing cycles from 3 to 12 cycles.

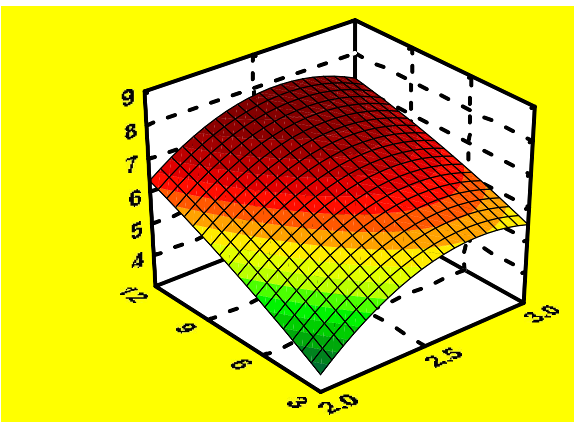


Figure 3: Response surface of the effect of loop length and the number of washing cycles on the dimensional stability in wale direction of single jersey fabrics knitted from yarns with twist factor 3.

The regression relationship which correlates the shrinkage of single jersey knitted fabric with loop length and washing cycles has the following non linear form:

Shrinkage, % = $-26.3+22.8\,x+0.7\,y-4.x^2-0.1\,x*y-0.01y^2$

The statistical analysis confirming that this model fits the data very well with a high coefficient of determination value, i.e. 0.92.

Fabric shrinkage at different levels of loop length and the number of washing cycles of single jersey knitted fabric made from yarns with twist factor 3.3 is illustrated in figure 4. The statistical analysis proved that both factors have a positive impact on fabric dimensional stability. As the both factors increases the fabric shrinkage increases.

Fabric shrinkage was increased from 4.5% to 6.4 % and from 4.6% to 7% with the increased loop length and the number of washing cycles respectively.

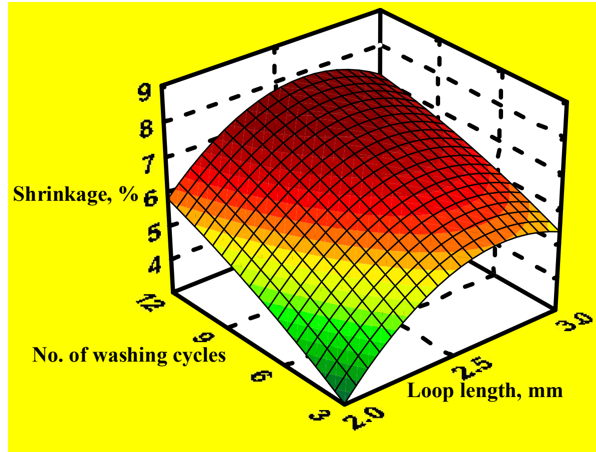


Figure 4: Response surface of the effect of loop length and the number of washing cycles on the dimensional stability in wale direction of single jersey fabrics knitted from yarns with twist factor 3.3.

The regression relationship which correlates both loop length and number of washing cycles to knitted fabric shrinkage is as follows:

Shrinkage, % = $-34.9 + 28.74\,x + 0.67y - 5.2\,x^2 - 0.11x*y -0.01\,y^2$

The coefficient of determination for this model equals 0.85, which means that it fits the data very well.

The increased shrinkage of the knitted fabric samples with the increase in loop length may be attributed to the fabric become more open and the yarn will be more freedom to shrink with the increased loop length.

Dimension stability in course direction

Dimension stability, i.e. shrinkage of cotton single jersey knitted fabrics in course direction at different levels of washing cycles and loop length with different yarn twist factors were illustrated in figures 5 through 7. The statistical analysis showed that both variables have a significant influence on the fabric shrinkage at all different twist levels at 0.01 statistical security.

Figure 5 shows the shrinkage of single jersey knitted fabric at different levels of washing cycles and loop length with 2.8 twist factor. From this figure, it is seen that both factors have a positive effect on fabric shrinkage. The effects of both factors look like its effects on dimensional stability in wale direction. As the number of washing cycles increases, single jersey knitted fabric shrinkage increases. The effect of the number of washing cycle on fabric shrinkage has the same effect of loop length.

Increasing loop length from 2 mm to 3mm leads to the increase in knitted fabric shrinkage in course direction from 5.52% to 6.96%. Whereas, the increase of the number of washing cycle from 3 to 12 cycles leads to increasing knitted fabric shrinkage by approximately 42%.

The effects of loop length and the number of washing cycles on knitted fabric shrinkage in course direction can be formulated by the following regression formula:

Shrinkage, % = -25.7 + 21.96 x + 0.69 y – 3.9 x^2 - 0.13x*y -0.008 y^2

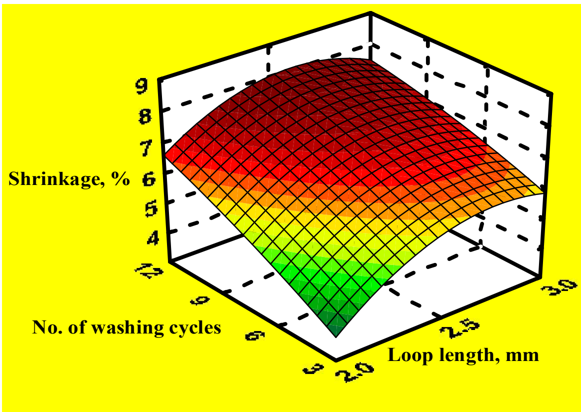


Figure 5: Response surface of the effect of loop length and the number of washing cycles on the dimensional stability in course direction of single jersey fabrics knitted from yarns with twist factor 2.8.

Where,
X= loop length, mm, and
y= number of washing cycles

This regression formula fitted the experimental data very well with a high R^2 value, i.e. 0.89.

The effects of loop length and number of washing cycles on single jersey fabrics knitted from yarns of twist factor 3 were illustrated in figure 6. From this figure, it is noticed that loop length and the number of washing cycles have a significant impact at 0.01 significant level on fabric shrinkage. As the both variables increases the single jersey knitted fabrics shrinkage follows the same trend.

The statistical analysis assuring that the increased loop length causes the increase in fabric shrinkage by 28%. Whereas the increased number of washing cycles leads to an increase in fabric shrinkable by 43%.

The regression model, which describes the correlation between loop length and number of washing cycles with fabric shrinkage, has the following form:

Shrinkage, % = -27.4 + 23.46 x + 0.7 y – 4.2 x^2 - 0.14 x*y -0.01 y^2

The coefficient of determination of this model was 0.82, which means that this model fits the data very well.

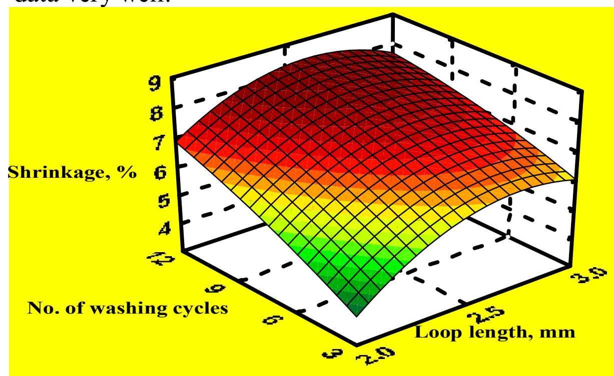


Figure 6: Response surface of the effect of loop length and the number of washing cycles on the dimensional stability in course direction of single jersey fabrics knitted from yarns with twist factor 3.

The effect of loop length and number of washing cycles on the shrinkage in course direction of single jersey fabric knitted from yarns with twist factor 3.3 is depicted in figure 7. The statistical analysis sowed that both factors have a significant impact on fabric shrinkage. As the both variables increase the knitted fabric shrinkage increases. Increasing washing cycles from 3 to 12 causes an augmented of fabric shrinkage by 70%. Whereas the increase in loop length leads to an increase of fabric shrinkage by 38%.

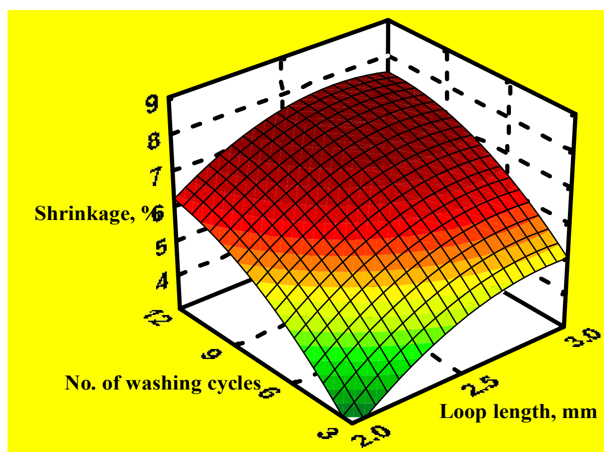


Figure 7: Response surface of the effect of loop length and the number of washing cycles on the dimensional stability in course direction of single jersey fabrics knitted from yarns with twist factor 3.3.

The regression relationship which correlates the fabric shrinkage with loop length and number of washing cycles has the following form:

Shrinkage, % = -21.8 + 16.7 x + 1.1 y – 2.82 x^2 - 0.11x*y -0.03 y^2

The statistical analysis proved that the R^2 value of this model equals 0.93.

The positive impact of loop length on knitted fabric shrinkage in course direction may be due to the fabric will be loose and the yarns have more freedom to shrink in course direction with the increase in loop length.

Seam strength

The effects of loop length and yarn twist factor on seam strength of single jersey knitted fabrics were illustrated in figure 8. The statistical analysis assured that both factors have a significant effect on seam strength at significance level 0.05.

From this figure, it is seen that both variables have a negative influence on seam strength of single jersey knitted fabric, assuring that as the both variables increases the seam strength decreases. The statistical analysis showed that the increase of loop length from 2 to 3 mm leads to a reduction of seam strength of single jersey knitted fabric from 15 to 13.4 kg. Whereas, the increased twist factor from 2.8 to 3 leads to increasing of seam strength from 15 to 16.96 kg and then decreased to 13.84 kg with the increase in twist factor to 3.3.

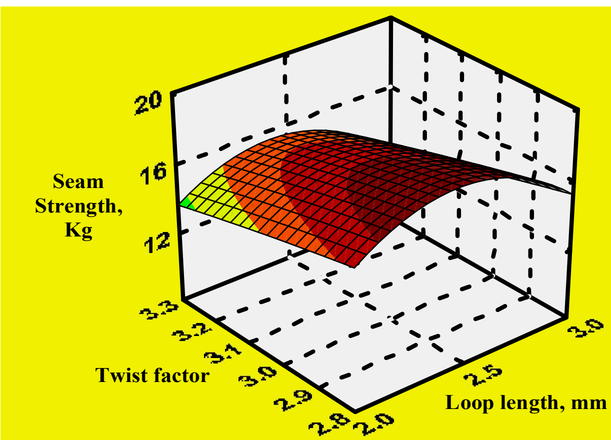


Figure 8: Response surface of the effect of loop length and the twist factor on seam strength of single jersey fabrics knitted.

The regression relationship which correlates both of twist factor and loop length to seam strength of single jersey knitted fabrics has the following form:

Seam strength, kg = - 47.02 + 52.6 x – 5.4 y – 10.1x^2 – 1.1 x*y -1.3 y2

Where,
X= loop length, mm, and
y= yarn twist factor

This model fitted the data very well with a high value of coefficient of determination, i.e. 0.80.

The lower seam strength with the increased loop length may be attributed to the lower strength of the knitted fabric with the increase in loop length.

Seam elongation

The Response surface of seam elongation for single jersey knitted fabric at different levels of loop length and yarn twist factor was plotted in figure 9. The statistical analysis proved that seam elongation was affected significantly at 0.01 significance level with loop length and twist factor. From this figure it is noticed that both factor have a positive impact on seam elongation of single jersey knitted fabrics.

As the twist factor and loop length increases the seam efficiency increases. The statistical analysis proved that increasing loop length leads to an increase of seam elongation by 52%. Whereas the increase of yarn twist factor from 2.8 to 3.3 leads to an increase of seam efficiency by 60%.

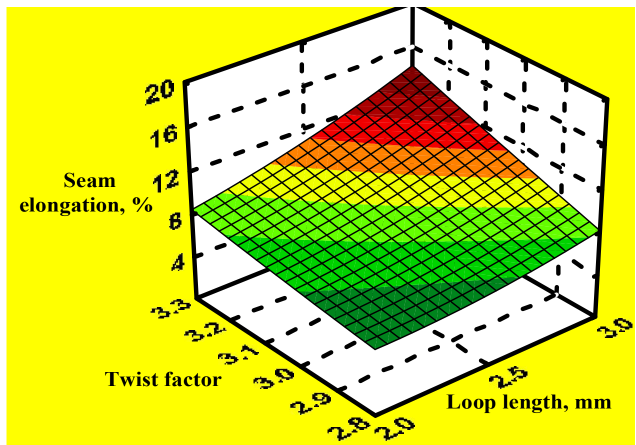


Figure 9: Response surface of the effect of loop length and the twist factor on seam elongation of single jersey fabrics knitted.

The regression relationship which correlates the loop length and twist factor to seam elongation has the following form:

Seam elongation, % = 54.74 – 28.7 x –18.3*y +2 x^2 +7.4 x*y +1.3 y^2

The R^2 value of this model was approximately 0.83.

Increasing twist factor will leads to an increase of yarn elongation, which in turn the increase of the knitted fabrics elongation. Thus the increased twist fabric causes the increase in seam elongation. Increasing loop length will also increases fabric elongation, which reflects in the higher seam elongation.

Seam efficiency

The values of seam efficiency of single jersey knitted fabric at different levels of loop length and yarn twist factor was plotted in figure 10. The statistical analysis assured that both factors have a significant influence on seam efficiency. It is shown that the loop length and yarn twist factor have a negative impact on seam efficiency of single jersey knitted fabrics, as the both factors increase the seam efficiency decrease.

The statistical analysis proved that increasing loop length from 2 to 2.5 mm leads to an increase of seam efficiency from 75% to 85% and then reduced to 69% with the increase of loop length to 3 mm. But the increase of yarn twist factor from 2.8 to 3.3 causes a reduction of seam efficiency by 16%.

The regression model which correlates both loop length and twist factor to seam efficiency has the following formula:

Seam efficiency, % = $- 235+263.2 x +26.9 y - 50.4 x^2 – 5.7 x*y -6.7 y^2$

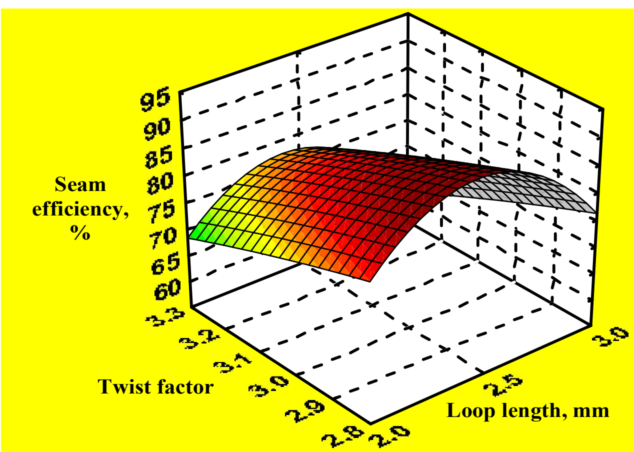


Figure 10: Response surface of the effect of loop length and the twist factor on seam efficiency of single jersey fabrics knitted.

The coefficient of determination of this model equals 0.91.

Increasing yarn twist factor will increase the strength of constituent yarns, which in turn increases the knitted fabric strength. Thus, the increased twist factor will lower seam efficiency.

Conclusion

In this study, the number of washing cycles, loop length and yarn twist factor were key factors for the quality of cotton single jersey knitted fabrics. The statistical analysis proved that these factors shave a significant impact on the dimension stability and seam performance of single jersey knitted fabrics. Dimensional stability of these fabrics was characterized by its shrinkage.

Dimensional stability was evaluated at different twist factors and measured in Wales and course directions. It was found that for all levels of yarn twist factors, loop length and numbers of washing cycles have a positive effect on shrinkage of single jersey knitted fabric in wale and course directions. As the loop length and the number of washing cycles increases the fabric shrinkage increases.

Seam quality was evaluated by measuring seam strength, seam elongation and seam efficiency. The effects of loop length and yarn twist factors on seam performance were studied. It was found that seam elongation was positively affected by loop length and yarn twist factor. By contrast, seam strength and seam efficiency were negatively affected by both factors. As the loop length and yarn twist factor increases, seam strength and efficiency decreases.

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