SEAM SLIPPAGE AND PUCKERING OF SEWN COTTON FABRICS

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Abstract: *Seam puckering and slippage are the main parameters which determine the seam and sewn fabrics quality. This study sheds light upon the effects of weave structure, sewing needle size and weft yarn density on seam slippage and puckering. A full factorial design with 3^3 experiments was executed to investigate this study. Non-linear regression models were derived to correlate seam quality with stitch density and needle size for all weave structures. From the experimental results, it was revealed that all parameters under study were found to have a significant impact on seam slippage and puckering.*

Keywords: *Seam slippage, puckering, seam performance, sewn fabrics, stitch density, seam type.*

1 INTRODUCTION

The quality of sewn textile products is largely determined by their sewing qualities. Some of the moist important characteristics which are used to determine and evaluate the quality of sewn garment are seam slippage, puckering, seam strength and efficiency. When the sewn fabrics at their both sides of seams undergo dynamic or static stresses, the slippage of their constituent yarns away from these seams refers mainly to seam slippage. This slipping of the seams generally deteriorates the sewn fabric appearance and reduces its usage life. When sewn fabrics undergo applied forces, which result in slipping weft yarns over warp ones or the vice versa, causes what called seam slippage. This mechanical characteristic of the seam generally relies on type and content of the constituent fibers, type and structure of the constituent yarns, seam size, seam type and allowance, stitch density and constituent yarn densities, sewing threads linear density and tension, and the woven fabric constructional parameters [1-9].

Many research studies related the seam slippage to fabric and sewing parameters. Kalaoglu, et al. [10] related seam slippage to the fabric weaves and weft yarn density. Meric and Durmaz [11] investigated the influence of sewing thread structure and lubrication ratio on seam slippage. In their study, sewing threads were made up of multifilament, staple and core-spun polyester with different lubrication ratios range between 2 and 4% and with different twist factors. They have found that seam opening was more related to fabric structure than sewing thread structure. Sewing thread structure and the value of twist multipliers were found to have no influence on seam slippage. However, core-spun sewing thread exhibited more resistance to seam slippage than other sewing thread types. Bharani, et al. [12] studied the influence of cotton woven fabric structures treated with silicon softener on seam slippage. The results obtained from this study revealed that the finishing of cotton woven fabrics with silicon softener reduced the seam slippage significantly. Also it was found that cotton fabric with plain structure has a higher seam slippage than twill and satin woven structures. In another research study [13], the higher seam slippage associated with plain woven fabrics is attributable to the highest intersections and friction between warp and weft yarn in the weave repeat. It was also stated that not only fabric structure, sewing thread structure and sewing machine condition but also dyestuffs significantly affect the seam slippage [14]. Sewing thread tension, displacement of sewing fabrics' yarns, machine feeding and sewn fabric shrinkage which occur after or during sewing or laundering processes results in gathering seams of sewn garment which causes what so called seam puckering. This undesirable phenomenon leads to unwanted appearance of the seam line and consequently reduces the aesthetic value of sewn products. Therefore it is acquired much attention from researchers in the last two decades [15]. Nguyen, et al. [16] evaluated seam puckering objectively using fuzzy logic. The data of seam pucker in this study were obtained from 3D designed scanning. The measurement process determined the amplitude, wavelength and wave generating points. The correlation coefficient between these shape parameters of the seam puckering and objective grade was found to be 0.94. In another study [17] it was found that less extensible sewing threads do not affect the seam puckering. While sewing thread and fabric shrinkage have a huge influence on seam puckering.

Finally, the seam performance mainly depends upon the mechanical properties of the sewing threads and sewn fabrics. Fabric and their constituent yarn mechanical properties have been investigated in numerous studies [18-28]. While seam slippage and puckering still need more investigation. Therefore, this paper focuses on studying the slippage of the seams and their puckering during sewing process. The effects of sewing thread linear density, stitch densities and weave structure of woven fabrics were intended to be investigated on seam slippage and seam puckering.

2 EXPERIMENTAL PART

2.1 Materials

Throughout this study, twenty seven sewn cotton fabric samples were produced. These sewn fabrics under study made from 100% Egyptian cotton yarn fabrics with warp and weft yarns of count 30/1 Ne. The warp yarn densities were kept constant at 60 end/inch while the weft density was varied as 50, 60 and 70 ppi respectively. The fabrics samples were woven with different weave structures, i.e. plain-1/1, twil-2/2 l, and satin-4. After leaving the weaving machine, all fabric samples were desized, scoured and bleached. The general view of weave repeat for all structures was shown in Figure 1.

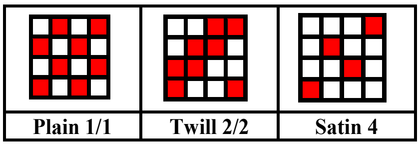

Figure 1 Weave repeats used in this study

The cotton fabric samples were cut in the warp direction with a dimension of 10 cm length and 10 cm width; thereafter the width of all samples was raveled to be 5 cm. Each tow raveled samples were put on each other and sewn in the weft direction. The sewing process was accomplished using a Joki DDL-5550 Lockstitch sewing machine with stitch density 7 stitches per cm; while sewing needle size was varied. All fabrics were sewn using stitch of type 301 Lockstitch (shown in Figure 2) and superimposed seam of type SSa as shown in Figure 3. A sewing thread made of 100% polyester core spun yarn with linear density 22 tex was also used to sew the specimen samples. The levels of fabric and sewing parameters were listed in Table 1.

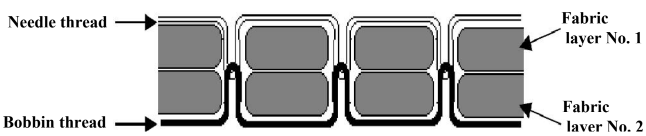

Figure 2 Lockstitch of type 301

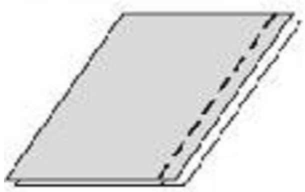

Figure 3 General view of superimposed seam of type SSa

Table 1 Sewing parameters used in this study

Weave structure	Weft density [ppi]	Sewing needle count (needle size)
Plain 1/1	50	80
Twill 2/1	60	90
Satin 4	70	100

2.2 Laboratory testing

Before testing, all fabric samples were conditioned in 20±2°C temperature and relative humidity 65±2% for one day. For each test method, ten readings were carried out for each sample and then their average was calculated.

In this study, seam puckering of different sewn garments was evaluated and measured objectively using the seam thickness strain which is considered an indicative to seam puckering. This test was done according to standard ISO 9073-2: 1997-02. The seam thickness strain measures the percentage increase in the sewn fabric thickness over the thickness of woven fabrics without sewing under a constant compression of load 2 kPa. The seam puckering can be calculated using thickness strain as follows:

$$\textit{Thickness strain [\%]} = \frac{S-2F}{2F} \times 100 \qquad (1)$$

where: *S* - seam thickness and *F* - fabric without seam thickness.

Throughout this study, seam slippage resistance in weft direction, in which warp yarns slipping over weft ones, was carried out using Instron of model 4411 testing tester in accordance with International standard ISO 13936-1-2004.

2.3 Statistical analysis

In order to disclose the influence of independent parameters, i.e. weave structure, weft density and sewing needle size on seam slippage and puckering, a 3^3 full factorial design was implemented. This factorial design was statistically analyzed using Analysis of variance (ANOVA) to detect the significant effect of each factor on seam quality parameters. The significance level was determined as 0.05 ≤ α (significance level) ≤ 0.01. In order to detect the regression relationship between each of seam slippage and seam puckering and the independent variables, i.e. weft density and sewing needle size, a non-linear regression model was derived. The regression models in this study were derived for each type of weave structure; and these models have the following form:

$$Z = a_0 + a_1 x + a_2 y + a_3 xy + a_4 x^2 + a_5 y^2 \quad (2)$$

where: Z - seam quality parameter, i.e. seam slippage or seam puckering; x - weft density [ppi]; y - sewing needle size [Nm]; a_0 – constant; a_1, a_2 - regression coefficients.

3 RESULTS AND DISCUSSION

Throughout this study, the effects of independent parameters i.e. weave structure, sewing needle size and weft density on seam quality which lies in seam slippage and puckering will be discussed. The effect of weft density and sewing needle size on seam quality parameters for each weave structure will be plotted and investigated.

Generally, the sewing needle diameter is called needle count or needle size. To express the sewing needle size, there are two well-known systems in the apparel industry. These are metric and singer systems. Metric system, which abbreviated as Nm was used to express sewing needle size or count in this study. In this system, as the metric count increases, the sewing needle size also increases and also the needle diameter increases. One Nm is equal to one hundredth of millimeter that is the needles of count 80, 90 and 100 Nm corresponds to the diameter of 0.8, 0.9 and 1 mm respectively.

3.1 Effects on seam slippage

Seam slippage is a pulling away or separation of fabric yarns at the seam, resulting in gaps or holes to develop without yarn breakage. The values of seam slippage resistance against both weft density and sewing needle size for different weave structure were depicted in Figures 4-6. The results of the statistical analysis were listed in Tables 2-4. It can be proved that weft density and sewing needle size have a huge influence at 0.01 significance level on seam slippage.

From Figures 4-6 it can be noticed that as the sewing needle size increases, the seam slippage resistance decreases. By contrast, as the weft density increases, the seam slippage resistance has the same manner. The resistance to seam slippage of plain, twill and satin weaves increased by 22, 25 and 13% respectively with the increase in weft density from 50 to 70 ppi. Increasing the contact points between sewn fabric yarns and sewing thread occurs with increasing the stitch density, which in turn giving a strong gripping of fabric yarns which preventing them from slippage.

For plain, twill and satin weaves, a reduction in seam slippage resistance was exhibited by 12, 11 and 17% with the increase in sewing needle size from 80 to 100 Nm. Regardless the influence of the weft density, increasing sewing needle size from 80 to 100 Nm leads to a reduction of seam slippage resistance by approximately 12, 11 and 17% for plain - twill and satin sewn fabrics.

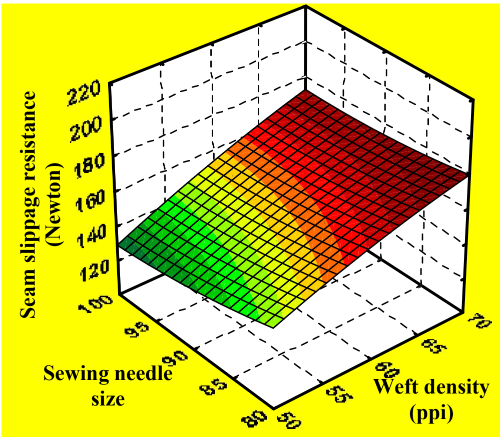

Figure 4 Response surface of the influence of weft density and sewing needle size on seam slippage resistance of sewn ***plain fabrics***

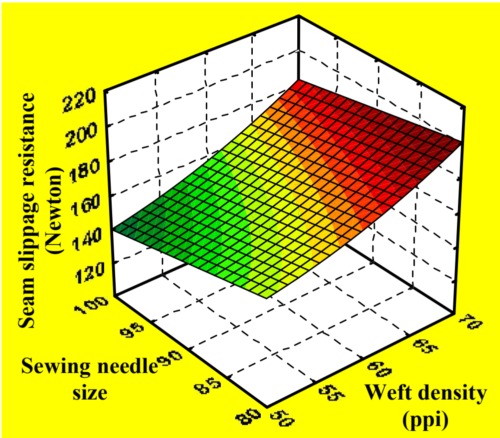

Figure 5 Response surface of the influence of weft density and sewing needle size on seam slippage resistance of sewn ***twill fabrics***

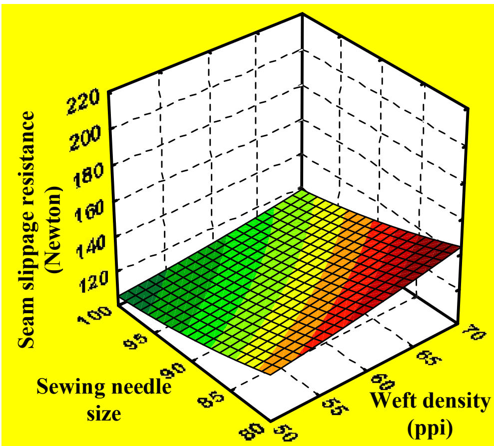

Figure 6 Response surface of the influence of weft density and sewing needle size on seam slippage resistance of sewn ***satin fabrics***

Table 2 ANOVA results for the effects on seam slippage of ***plain fabric***

Source of variation	Sum - Squares	Degree of freedom	Mean squares	F value	P value	F_{crit} value
Weft density	1688.889	2	844.444	76.000	0.001	6.944
Sewing needle size	705.556	2	352.778	31.750	0.004	6.944
Error	44.444	4	11.111			
Total	2438.889	8				

Table 3 ANOVA results for the effects on seam slippage of ***twill fabric***

Source of variation	Sum - Squares	Degree of freedom	Mean squares	F value	P value	F_{crit} value
Weft density	1777.556	2	888.778	192.747	0.000	6.944
Sewing needle size	450.889	2	225.444	48.892	0.002	6.944
Error	18.444	4	4.611			
Total	2246.889	8				

Table 4 ANOVA results for the effects on seam slippage of ***satin fabric***

Source of variation	Sum - Squares	Degree of freedom	Mean squares	F value	P value	F_{crit} value
Weft density	402	2	201	46.385	0.002	6.944
Sewing needle size	914.667	2	457.333	105.538	0.000	6.944
Error	17.333	4	4.333			
Total	1334	8				

The negative impact of sewing needle size on seam slippage resistance may be due to increase the opening in the sewn fabric when penetrating the needle in the fabric which results in the reduction of seam slippage resistance.

The regression relationships which correlate the resistance to seam slippage with both weft density and sewing needle size have the following non-linear forms:

$$\text{Seam slippage (Newton)-plain weave} = 384.2 - 5.1x - 1.8y + 0.05x^2 + 0.013xy \quad (3)$$

$$\text{Seam slippage (Newton)-twill weave} = 341.7 + 2.7x - 6.6y - 0.03x^2 + 0.03xy + 0.03y^2 \quad (4)$$

$$\text{Seam slippage (Newton)-satin weave} = 368.4 + 0.51x - 5.2y + 0.01x^2 - 0.01xy + 0.03y^2 \quad (5)$$

3.2 Effects on seam puckering

One of the most frequent sewability problems confronting the garment industry is the seam puckering. This phenomenon can adversely affect the garment appearance at the seam line. Seam puckering affects significantly by sewing thread tension, structural jamming, finishing type, seam and sewing parameters.

The values of seam puckering at the levels of weft yarn density and sewing needle size for different weave structures were plotted in Figures 7-9. The results of the statistical analysis listed in Tables 5-7 showed that weft density and dewing needle size have a significant impact on seam puckering. It was also proved that there is a significant difference among the three weave structures in relation to seam puckering.

Table 5 ANOVA results for the effects on seam puckering of ***plain fabric***

Source of variation	Sum - Squares	Degree of freedom	Mean squares	F value	P value	F_{crit} value
Weft density	300.222	2	150.111	57.489	0.001	6.944
Sewing needle size	160.222	2	80.111	30.681	0.004	6.944
Error	10.444	4	2.611			
Total	470.889	8				

Table 6 ANOVA results for the effects on seam puckering of ***twill fabric***

Source of variation	Sum - Squares	Degree of freedom	Mean squares	F value	P value	F_{crit} value
Weft density	317.556	2	158.778	21.817	0.007	6.944
Sewing needle size	166.889	2	83.444	11.466	0.022	6.944
Error	29.111	4	7.278			
Total	513.556	8				

Table 7 ANOVA results for the effects on seam puckering of ***satin fabric***

Source of variation	Sum - Squares	Degree of freedom	Mean squares	F value	P value	F_{crit} value
Weft density	192.889	2	96.444	66.769	0.001	6.944
Sewing needle size	112.889	2	56.444	39.077	0.002	6.944
Error	5.778	4	1.444			
Total	311.556	8				

From these figures it can be noticed that as the sewing needle size increases, the seam puckering also increases; while seam puckering decreases with increasing the weft yarn density. Increasing the weft yarn density from 50 to 70 ppi cm leads a reduction in the seam puckering by 38, 35 and 35% for plain 1/1, twill 2/2 and satin 4 respectively. Decreasing the seam pucker with weft yarn density may be attributed to increasing woven fabrics weight, which in turn decreases the seam puckering.

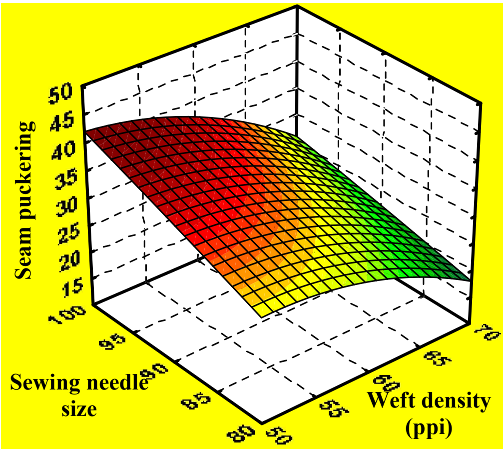

Figure 7 Response surface of the influence of weft density and sewing needle size on seam puckering of sewn ***plain fabrics***

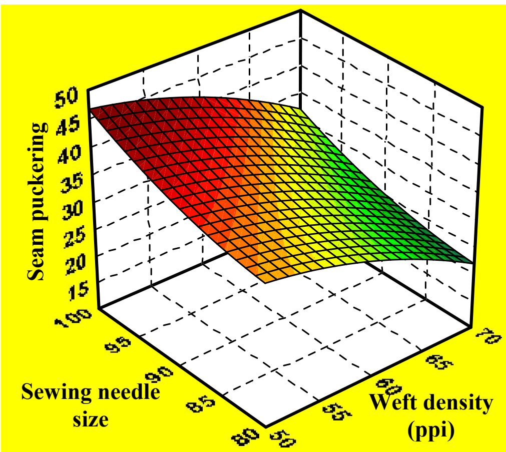

Figure 8 Response surface of the influence of weft density and sewing needle size on seam puckering of sewn ***twill fabrics***

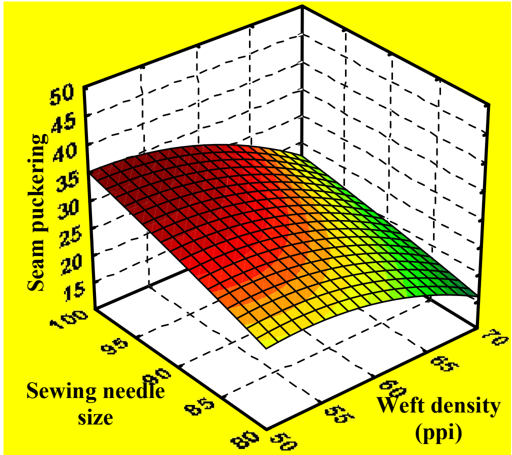

Figure 9 Response surface of the influence of weft density and sewing needle size on seam puckering of sewn ***satin fabrics***

The effect of sewing needle size was found to have an inverse trend to the effect of stitch density. The higher the needle size the higher is the seam puckering values for all weave structures. Increasing the sewing needle size from 80 to 100 Nm results in increasing the seam puckering by 41% for plain weave, 34% for twill weave and 40% for satin weave. It was also deduced that twill woven fabric associated with higher seam puckering values, while satin weaves accompanied by lower seam puckering values.

The relationships which correlate the seam puckering with both weft density and sewing needle size have the following non-linear forms:

$$\textit{Seam puckering-plain weave} = -168.4 + 4.2x + 1.6y - - 0.03x^2 - 0.01xy - 0.002y^2 \quad (6)$$

$$\textit{Seam puckering-twill weave} = 87.9 + 2.1x - 2.6y - 0.02x^2 - 0.03xy + 0.023y^2 \quad (7)$$

$$\textit{Seam puckering-satin weave} = -179.8 + 4.4x + 1.6y - 0.03x^2 - 0.01xy - 0.003y^2 \quad (8)$$

4 CONCLUSION

Seam slippage and seam puckering are the main factors influencing the appearance of garment. These seam quality parameters are affected by many sewing process and seam variables. In this study the effect of weft yarn density, weave structure and sewing needle sized on seam slippage and puckering were investigated. A full factorial design of 3^3 experiments was performed and analyzed using ANOVA. In order to derive regression relationships between seam quality, sewn woven fabric and sewing parameters, a regression analysis was also used. The findings of this study can be sum up as follows:

- Weave structure, weft yarn density and sewing needle size were found to have a huge influence on seam slippage resistance and seam puckering.
- As the weft density increases, the seam slippage resistance increases. On the contrary, the higher the sewing needle size, the lower is the resistance to seam slippage.
- Increasing the weft density enhances the seam appearance by lowering the values of seam puckering.
- Increasing sewing needle size results in yarn jamming, which in turn increases the values of seam puckering.
- Sewn fabrics from plain weave structure associated with higher seam slippage resistance compared to other weave structures. While twill structures exhibited higher seam puckering.

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