Investigation of the Effects of Sewing Machine Parameters on the seam quality

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Abstract: This study is aimed to determine the influence of sewing machine parameters on seam performance and quality for cotton woven fabrics. The effects of needle size, stitch density, sewing thread tension and sewing direction on the seam quality will intended to be investigated. The seam quality and performance of the woven cotton fabrics was characterized by seam tensile strength, seam elongation and seam efficiency. The experimental results were statistically analyzed using the analysis of variance technique. The regression analysis was also used to derive the regression lines which correlate the seam quality to each of the sewing machine variables. The results of this study showed that sewing machine parameters have a profound influence on the seam quality of the cotton woven fabrics.

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Keywords: Seam quality, seam performance, stitch density, needle count, sewing direction, sewing thread tension, seam strength, seam efficiency.

1.Introduction

In cut and sewn apparel products, seams are formed when two or more pieces of fabrics are held together by stitches. As the seam is one of the basic requirements in the construction of apparel, seam quality has great significance in apparel products. The seam performance and quality depends on various factors such as seam strength, elasticity, durability, puckering, appearance and yarn severance [1-4]. In general, seam quality relies on the type of the seam and stitches per unit length of the seam, the thread tension and the seam efficiency of the fabric [5].

Seam efficiency which is the ratio of seam strength to fabric strength of the fabrics sewn. In general, it ranges between 85% and 90%, which can be optimized through various factors, such as seam type, type and density of stitches, and the selection of sewing threads and needles. Hence, the quality of the seam is partly affected by the sewing thread characteristics. Seam quality is also measured by seam size, seam slippage strength and seam strength [6,7].

Seam strength refers to the load required to break a seam. This measures the strength and tenacity of a seam. Seam strength results from the breakage of either fabric or thread or, in more case, both simultaneously. Research has revealed that the load required to rupture the seam is usually less than that required to break the unsewn fabric [8,9]. A number of studies [10-14] have determined the seam strength according to ASTM 1683-04 standards, which express the value of seam strength in terms of maximum force (in Newton (N)) to cause a seam specimen to rupture. This is measured by using the following equation:

$S_s = K \times S_b$

Where:

S_s= sewn seam strength (N)

K= a Constant equal to 1000 for SI units

S_b= observed seam breaking force (N).

Seam elongation evaluates the elasticity, flexibility of a seam. Seam elongation is defined as the ratio of the extended length after loading to the original length of the seam [15]. According to many researchers, there are various factors affecting the seam quality. These comprise sewing thread, fabric, sewing condition and others. Some researchers showed that high strength sewing thread always gives better seam functional performance, namely seam strength and seam efficiency [16,17]. Fabric properties such as cover factor, weight, thickness, extensibility and bending rigidity were found to have a significant influence on seam quality. Behera [18] and Miguel *et al.* [19] emphasized that fabric cover factor has considerable effect on seam strength and / or seam efficiency. Their study revealed that fabrics with high cover factor have an increased tendency to break the fabric yarns at the time of sewing.

Since much research work has done on the effects of sewing thread and fabric properties on seam quality, this study will concentrate on the impact of sewing machine parameters on the seam performance and quality for cotton woven fabrics. The effects of needle size, stitch density, tension of sewing thread and sewing direction on seam strength, seam elongation and seam efficiency will be investigated.

2- Experimental Work

2.1- Material

In the course of this study, 100% cotton fabric samples were used. All fabric samples were woven on Flexible Rapier weaving machine of Picanol Gamamax model with the following particulars:

Weave structure: plain 1/1.
Warp yarn count: 16/1 Ne.
Weft yarn count: 16/1 Ne.
Warp yarn density: 66 ppi
Weft yarn density: 58 ppi
No. of harness frames: 6
Machine speed: 420 rpm

2.2- Sewing Machine Parameters

To study the effects of sewing machine variables on the seam performance of the cotton woven fabrics, the studied samples were sewn with super imposed seam type, SSa-1, on a high speed sewing machine with different sewing parameters. Figure A shows the seam type used to sew the cotton fabric samples.

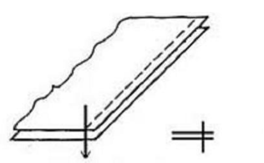

Figure A: seam of type SSa-1 used in this study

The sewing thread used in this study was made from 100% cotton with linear density 14.8 tex, breaking tenacity 42.9 cN/ tex and 6% breaking elongation.

A high speed industrial lockstitch machine – Juki- was selected for sewing samples with the following specifications:

Type of stitch: Lockstitch type 301
Machine speed: 2000 stitches per minute
Seam allowance: 1 inch

The sewing machine parameters were varied to study its effects on seam performance for the sewn cotton woven fabrics. Needle size was used with three counts, and stitch densities were with three different values. The tension of sewing thread was at low, medium and high levels. Cotton woven fabrics were sewn in three directions according to the weft direction. Table 1 lists the levels of the parameters varied on sewing machine.

Table 1: Levels of the parameters used on sewing machine

Needle size, Singer system	Stitch density, Stitches/cm	Sewing thread tension	Sewing direction, degrees
12	3	Low	0
14	5	Medium	45
16	7	High	90

2.3- Seam Performance

In this study, seam performance was characterized by the seam tensile strength, seam elongation and seam efficiency. Seam tensile strength and elongation were measured using an Instron 411 tester according to ASTM D 1683-81.

Seam efficiency was measured according to ASTM-D 1683 -81 method on the Instron tensile tester. Seam efficiency was calculated as the percent seam strength over fabric strength by using the following formula:

Seam efficiency, % = (Seam Tensile Strength/Fabric Tensile Strength) × 100

2.4- Statistical Analysis

One-Way ANOVA statistical technique was used to analyze the significant effects of needle size, stitch density, sewing thread tension, and sewing direction on the seam performance of cotton woven fabrics. The statistical analysis was performed using SPSS statistical package. A regression analysis was also used to predict the regression relationship between the sewing machine parameters and the seam performance, i.e. seam tensile strength, seam elongation and seam efficiency. The coefficient of determination was used to validate the regression lines.

3- Results and Discussion

3.1- Effects on seam strength

The effects of the studied parameters on the seam tensile strength were shown in figures 1-4. The statistical analysis proved that the sewing machine parameters have a significant impact on the seam tensile strength.

Figure 1 shows the effect of needle size on the seam tensile strength. The analysis of variance results presented in table 2 show the significant effect of needle size on the seam strength at 0.05 significance level. As seen from figure 1, a decreasing trend is detected assuring that as the needle sizes increases the seam strength decreases. The statistical analysis proved that increasing needle size from 12 to 16 leads to a reduction of seam tensile strength by approximately 5%. A higher needle size may be the cause of seam damage because there is more possibility of breaking the fabric yarn when using a needle with greater diameter.

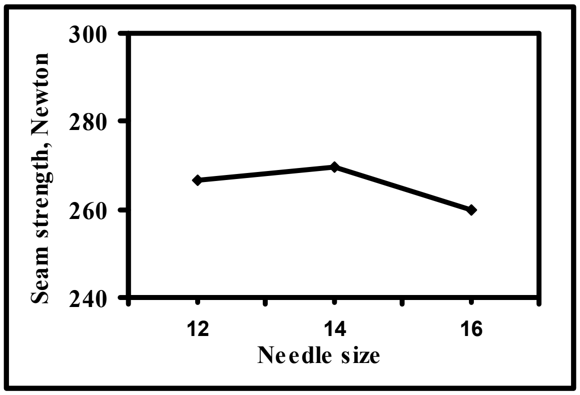

Figure 1: Effect of needle size on the seam tensile strength.

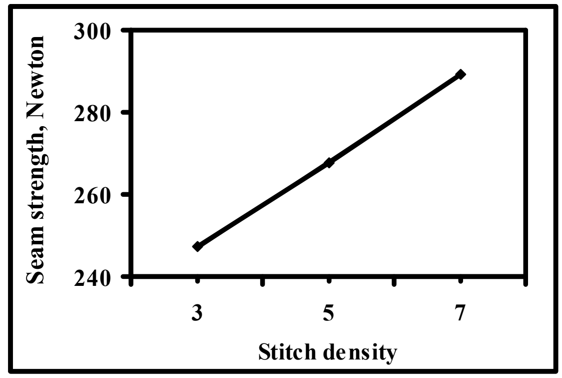

Figure 2: Effect of stitch density on the seam tensile strength

Table 2. Analysis of variance results for the effects of needle size on seam strength

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.875	2	1.938	5.471	0.028	4.256
Within Groups	3.188	9	0.354			
Total	7.063	11				

The regression analysis proved that the regression line which correlates the seam strength to needle size is as th following linear form:

Seam strength, Newton = - 5 × Needle size + 27.4

The coefficient of determination of this regression model equals 0.83, which means that this model fits the data very well. The coefficient of correlation between needle size and seam strength approaches -0.95 which signifies a strong negative correlation between the two variables.

Figure 2 shows the effect of stitch density on the seam tensile strength. The statistical analysis introduced in table 3 revealed the significant effect of stitch density on the seam strength at 0.01 significance level. An increasing trend was detected confirming that as the stitch density increases the seam strength follows the same manner. Increasing stitch density from 3 to 7 stitches / cm leads to increasing seam strength by 17%. It was found that high stitches per inch or cm means short stitches; and low stitches per inch or cm means long stitches. Shorter stitches produce more stable an less obviously line of stitches, which means greater seam strength.

Table 3. Analysis of variance results for the effects of needle size on seam strength

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between Groups	35.562	2	17.781	46.587	0.000	4.256
Within Groups	3.435	9	0.382			
Total	38.997	11				

The regression relationship which correlates the seam tensile strength to stitch density has the following linear form:

Seam strength, Newton = 21.1 × Needle size + 226

The coefficient of determination of this regression model equals 0.99, which means that this model fits the data very well. The coefficient of correlation between the needle size and seam strength approaches 0.99, which signifies a strong positive correlation between the two variables.

At the time of sewing, sewing thread should be guided through tension devices to control the thread tension. Improper thread tension will create seam quality problems. Due to high thread tension the chance of sewing thread strength loss and / or breakage become high, which ultimately reduces the seam strength. The relationship between sewing thread tension and seam tensile strength was depicted in figure 3. The results of the statistical analysis listed in table 4 proved the significant influence of the thread tension on the seam strength. As seen from figure 3, a decreasing trend is detected assuring that low sewing thread tension was associated with higher seam strength and high thread tension caused lower seam strength. The average values of the seam strength were 255, 264 and 284 Newton for low, medium and high sewing thread tension respectively.

Table 4. Analysis of variance results for the effects of sewing thread tension on the seam strength

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between Groups	7.851667	2	3.925833	16.37659	0.001002	4.256492
Within Groups	2.1575	9	0.239722			
Total	10.00917	11				

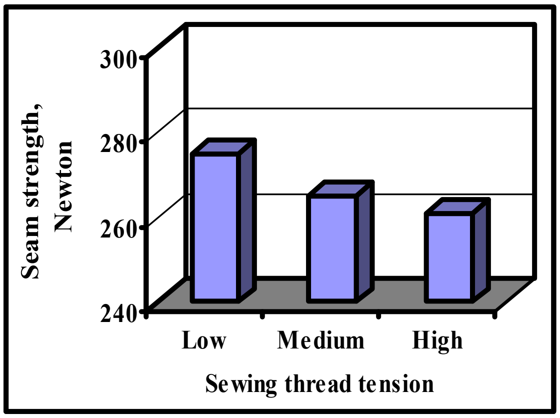

Figure 3: Effect of sewing thread tension the seam tensile strength.

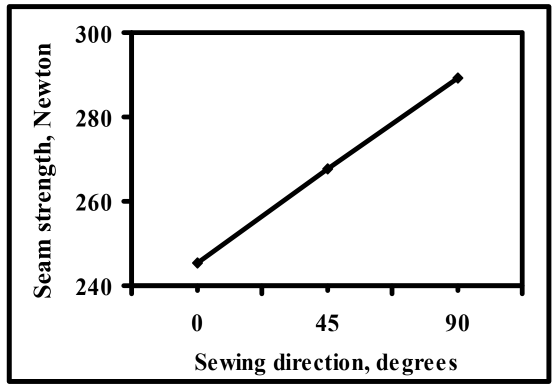

Figure 4: Effect of sewing direction on the seam tensile strength.

Sewing direction according to the weft yarns in the woven fabrics was conducted at angles 0, 45 and 90 degrees. The zero degree means the sewing was taken in the weft direction, while 90 degrees means the sewing was performed in the warp direction. The relationship between sewing direction and seam tensile strength was introduced in figure 4. The statistical analysis proved that the sewing direction has a profound effect on seam tensile strength at 0.01 significance level.

Table 5. Analysis of variance results for the effects of sewing direction on the seam strength

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between Groups	34.03167	2	17.01583	24.48321	0.000229	4.256492
Within Groups	6.255	9	0.695			
Total	40.28667	11				

From figure 4 it is shown that sewing direction has a positive influence on the seam strength. As the sewing direction increases the seam tensile strength also increases. The statistical analysis proved that increasing the sewing direction from zero to 90^{o} leads to an augment of the seam tensile strength by approximately 18%. It is clear from figure 4 that the effect of sewing direction on seam strength is very similar to the effect of stitch density on seam strength depicted in figure 2.

The regression relationship between sewing direction and the seam strength is a straight line of the following form:

Seam strength, Newton = 22 × sewing direction + 223

The coefficient of determination of this model equals 0.99 which means that this model fits the data very well. The positive sign of sewing direction in this model signifies its positive effect on the seam strength.

3.2- Effects on seam elongation

Seam elongation evaluates the elasticity, flexibility of a seam. Seam elongation is defined as the ratio of the extended length after loading to the original length of the seam. The extension of the fabric in the specimen, the slippage of the thread in the seam and the extension of the sewing thread itself can all contribute to how much a seam elongates before it breaks**.**

The values of the seam elongation versus the sewing machine parameters were plotted in figures 5-8. The statistical analysis revealed that the seam elongation was significantly affected by the sewing machine parameters.

Figure 5 shows the effect of needle size on the seam elongation. The analysis of variance results listed in table 6 show the significant influence of the needle size on the seam elongation at 0.01 significant level.

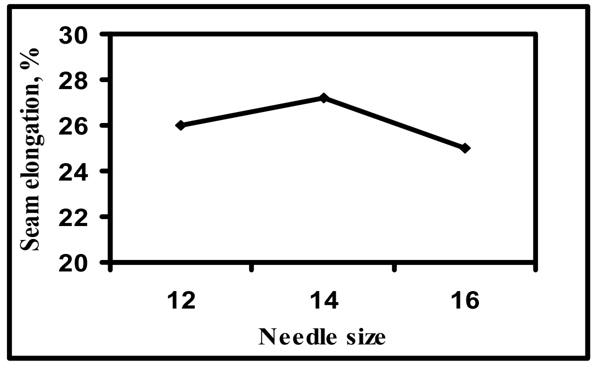

Figure 5: Effect of needle size on the seam elongation.

Table 6. Analysis of variance results for the effects of needle size on seam elongation

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10.815	2	5.407	17.585	0.001	4.256
Within Groups	2.767	9	0.307			
Total	13.582	11				

As shown from figure 5, the decreasing trend is detected assuring that as the needle size increases the seam elongation decreases. Seam elongation was increased with the increase in needle size from 12 to 14 and then slightly decreased with increasing needle size to 16. In general, it was found that increasing needle size from 12 to 16 leads to a reduction of the seam elongation by approximately 3.8%.

The regression relationship between the needle size and the seam elongation is a parabola of the following form:

Seam elongation, % = -1.7 × (Needle size)^2 + 6.3 × Needle size + 21.4

The coefficient of determination for this model is typically 1, which means that this model fits the data very well. This regression model can be used reliably to predict the seam elongation at the different values of needle sizes.

Stitch density is specified as the number of stitches per inch or cm and has a significant effect on the seam quality. High stitches per inch means short stitches; and low spi means long stitches. The variation of seam elongation according to the different values of stitch density was depicted in figure 6. The ANOVA results which are tabulated in table 7 shows the significant influence of the stitch density on the seam elongation at the significance level 0.01. The relationship between the two variables was depicted in figure 6. It is shown from this figure that stitch density has a positive influence on the seam elongation. As the stitch density increases the seam elongation reacts in the same manner. The statistical analysis proved that increasing the stitch density from 3 to 7 stitches / cm leads to an increasing the seam elongation by approximately 14.4%.

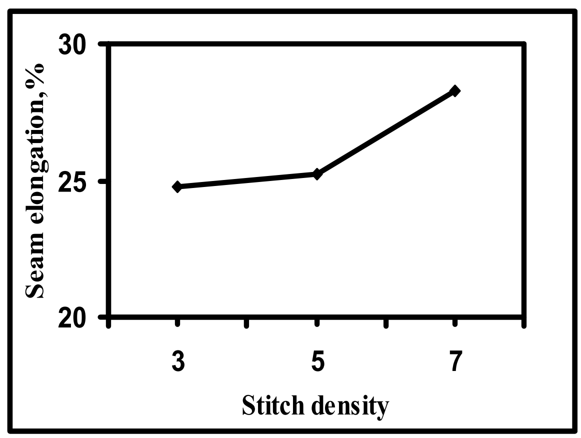

Figure 6: Effect of stitch density on the seam elongation.

The regression relationship between the stitch density and the seam elongation is a non-linear with the following form:

Seam elongation, % = 1.4 × (Needle size)^2 – 3.7 × Needle size + 27.1

The coefficient of determination of this model is typically 1, which means that this model fits the data very well.

Table 7. Analysis of variance results for the effects of stitch density on seam elongation

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between Groups	32.607	2	16.303	36.960	0.000	4.256
Within Groups	3.970	9	0.441			
Total	36.577	11				

The variation of seam elongation at the different values of sewing thread tension was plotted in figure 7. The analysis of variance results tabulated in table 8 showed the significant effect of the sewing thread tension on the seam elongation. It is seen from figure 7 that a decreasing trend is detected assuring that the increase in sewing thread tension lowers the seam elongation significantly. Higher sewing thread tension associated with lower seam elongation, while lower sewing thread tension accompanied the higher seam elongation. The statistical results revealed that the average values of seam elongation are 27%, 25.6% and 25.8% for low, medium and high thread tension respectively.

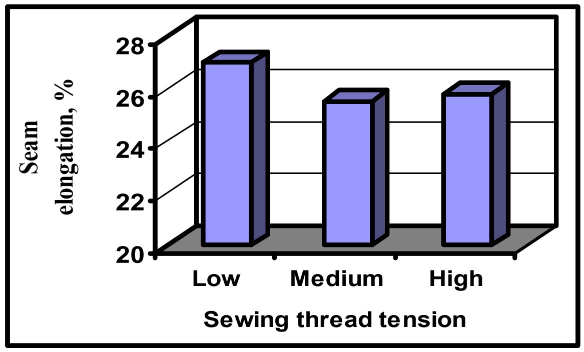

Figure 7: Effect of sewing thread tension on the seam elongation.

Table 8. Analysis of variance results for the effects of sewing thread tension on the seam elongation

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between Groups	6.207	2	3.103	15.262	0.001	4.256
Within Groups	1.830	9	0.203			
Total	8.037	11				

The influence of sewing direction on the seam elongation was plotted in figure 8. The analysis of variance results in table 9 proved the significant effect of sewing direction on the seam elongation at 0.01 significant level. From figure 8 it is shown that sewing direction has a positive impact on the seam elongation. An increasing trend is detected confirming that as the sewing direction increases the seam elongation follows the same manner.

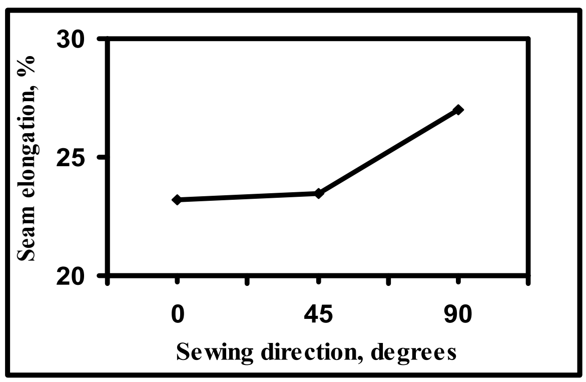

Figure 8: Effect of sewing direction on the seam elongation.

Table 9. Analysis of variance results for the effects of sewing direction on seam elongation

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between Groups	35.707	2	17.853	62.279	0.000	4.256
Within Groups	2.580	9	0.287			
Total	38.287	11				

Increasing the sewing direction from zero to 90 degrees may have led to increase the seam elongation to nearly 16%. The regression relationship between the sewing direction and the seam elongation is a parabola of the following form:

Seam elongation, % = $1.6 \times (\text{Needle size})^2 - 4.5 \times \text{Needle size} + 26.1$

The coefficient of determination of this model is typically 1, which means that this model fits the data very well. This regression model can be used to predict the seam elongation efficiently at different sewing directions.

3.3- Effects on seam efficiency

Seam efficiency measures the durability along seam line. Durability is defined as necessary to satisfactory seam's functional performance, and efficient seams are assumed to be more durable than weak ones. The effect of sewing machine parameters on the seam efficiency was presented in figures 9-12. The statistical results proved that sewing machine variables have a huge influence on the seam efficiency.

Figure 9 illustrates the impact of needle size on the seam efficiency. The analysis results listed in table 10 show the significant influence of needle size on the seam efficiency at 0.01 significant level. From this figure it is apparent the negative effect of the needle size on the seam efficiency. A decreasing trend is detected assuring that the increase in the needle size leads to a reduction of the seam efficiency. It is also shown that increasing the needle size from 12 to 14 leads to a slight increase in the seam elongation and then seam efficiency sharply decreases with the increase in the needle size up to 16. In general, the statistical analysis proved that the increase in the needle size leads to a reduction of the seam efficiency by nearly 4 %.

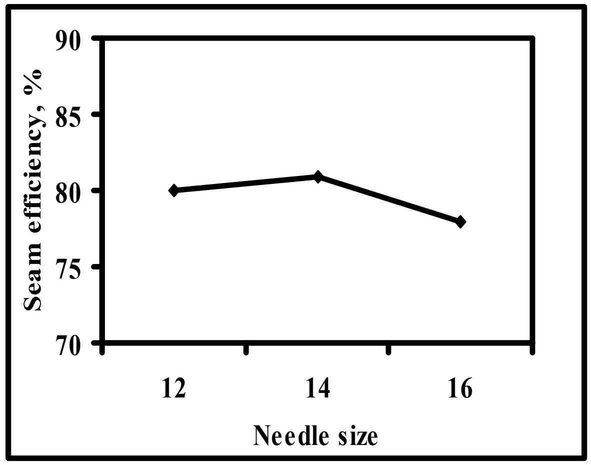

Figure 9: Effect of needle size on the seam elongation.

Table 10. Analysis of variance results for the effects of needle size on the seam efficiency

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between Groups	334.854	2	167.427	3701.623	0.000	4.256
Within Groups	0.407	9	0.045			
Total	335.261	11				

The statistical analysis proved that the regression line which correlates the seam efficiency to the needle size is a parabola of the following form:

Seam efficiency, % = 1.9 × (Needle size)^2 + 6.6 × Needle size + 75.3

The coefficient of determination of this model equals 1 which means that this model fits the data very well.

The variation of the seam efficiency according to the levels of stitch density was plotted in figure 10. The statistical analysis proved the significant effect of the stitch density on the seam efficiency at 0.01 significant level. An increasing trend was detected assuring that as the stitch density increases the seam efficiency increases. Increasing stitch density from 3 to 7 stitches/cm leads to an increase in the seam efficiency by 16%.

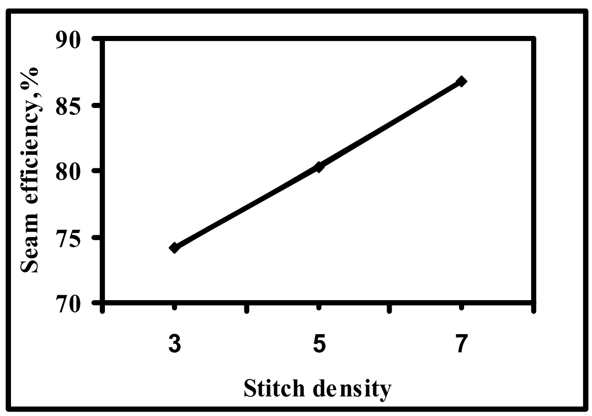

Figure 10: Effect of needle size on the seam efficiency.

Table 11. Analysis of variance results for the effects of needle size on the seam efficiency

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between Groups	334.854	2	167.427	3701.623	0.000	4.256
Within Groups	0.407	9	0.045			
Total	335.261	11				

The linear relationship between the stitch density and the seam efficiency has the following form:

Seam efficiency, % = 6.3 × Stitch density + 67.7

The coefficient of determination of this model equals 0.99 which means that this model fits the data very well. The correlation coefficient between the two variables is 0.99 which represents a positive and high strong correlation.

Te seam efficiency versus the sewing thread tension was illustrated in figure 11. The statistical analysis proved the significant effect of the thread tension on the seam efficiency. Form this figure it is noticed that the sewing thread tension has a negative impact on the seam efficiency. As the thread tension increases the seam efficiency decreases. The higher sewing thread tension associated with the lower seam efficiency and the vice versa. The average values of the seam efficiency were 82.5% and 79% and 79% for the sewing thread tension low, medium and high respectively.

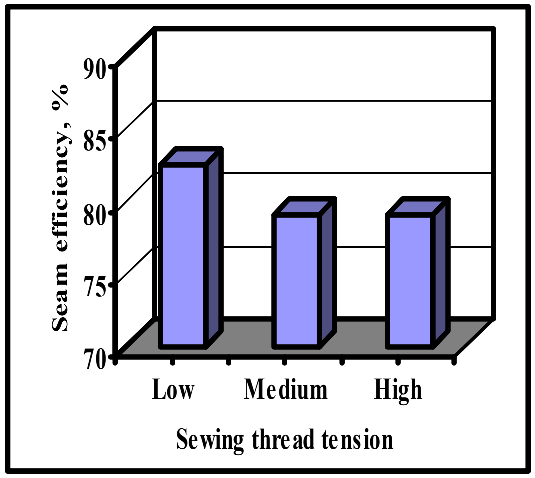

Figure 11: Effect of sewing thread tension on the seam efficiency.

Table 12. Analysis of variance results for the effects of sewing thread tension on the seam efficiency

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between Groups	36.369	2	18.185	434.494	0.000	4.256
Within Groups	0.377	9	0.042			
Total	36.746	11				

Figure 12 illustrates the effect of sewing direction according to the weft yarn direction on the seam efficiency. The analysis of variance results shown in the table 13 illustrates the significant effect of the sewing direction on the seam efficiency at 0.01 significant level. From figure 12 the increasing trend was detected confirming that as the sewing direction increases the seam efficiency follows the same manner. Increasing the sewing direction leads to the increase in the seam efficiency. Increasing the sewing direction from 0 to 90 degrees leads to the increase in the seam efficiency by nearly 18.5%.

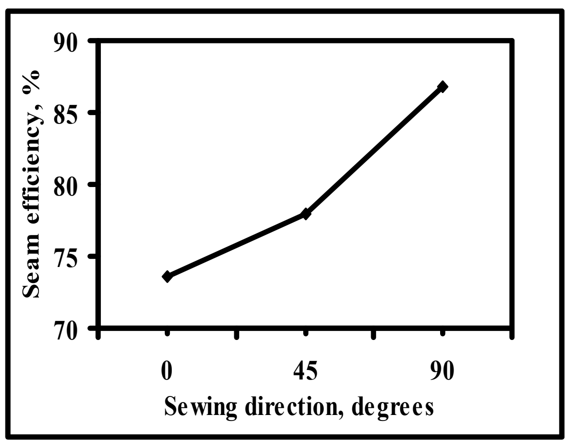

Figure 12: Effect of sewing direction the seam efficiency.

Table 13. Analysis of variance results for the effects of sewing direction on the seam efficiency

Source of Variation	SS	df	MS	F	*P*-value	F crit
Between Groups	349.039	2	174.520	944.021	0.000	4.256
Within Groups	1.664	9	0.185			
Total	350.703	11				

The regression line which correlates the sewing direction to the seam efficiency is a parabola of the following form:

Seam efficiency, % = 2.15 × (Needle size)^2 – 1.9 × Needle size + 73.3

The coefficient of determination of this model equals 1 which means that this model fits the data very well.

4. Conclusion

Seam quality has great significance in apparel products. The seam performance and quality depends on various factors such as seam strength, elasticity, durability, puckering, appearance and yarn severance. In this study, the effects of sewing machine parameters such as needle size, stitch density, sewing thread tension and sewing direction on the quality and performance of the seamed cotton woven fabrics were investigated. The seam quality and performance were characterized by seam tensile strength, seam elongation and efficiency.

The statistical analysis proved the significant effect of the sewing machine parameters on the seam strength at 0.01 significant level. The stitch density and sewing machine direction were found to have a positive impact on the seam tensile strength. As the both parameters increases the seam strength increases. By the contrast, the needle size and sewing thread tension have a conversely impact on the seam strength. In the case of seam elongation, it was found that needle size and sewing thread tension have a negative effect on it. Whereas the rest of the sewing machine parameters have a positive influence on the seam elongation. The statistical analysis also showed the significant and positive impact of the stitch density and sewing direction on the seam efficiency, while the effect of needle size and thread tension exhibit an opposite manner.

References

1- Gurarda, B. Meric., The Effects of Elastane Yarn Type and Fabric Density on Sewing Needle Penetration Forces and Seam Damage of PET/Elastane Woven Fabrics., Journal of Textile and Apparel Technology and management., Volume 6, Issue 3, Springer 2010.
2- Vaida Dobilaite and Milda Juciene., The influence of mechanical properties of sewing threads on seam pucker ., International Journal of Clothing Science and Technology, Vol. 18 No. 5, 2006, pp. 335-345
3- Carr H. and Latham B., Technology of Clothing Manufacturing, (BSP Professional Books, Oxford), 1992.
4- Midha, V.K., Mukhopadhyay, A., Kaur, R., An approach to seam strength prediction using residual thread strength, Research Journal of Textile and Apparel, 2009.
5- Ayca Gurarda ., Investigation of the Seam Performance of PET/ Nylon-elastane Woven Fabrics. Textile Research Journal Vol 78(1): 21–27.
6- Ukponmwan, J. O., Mukhopadhyay, A., and Chatterjee, K. N., "Sewing Thread," The Textile Institute, **91**, 168–171 (2000).
7- Solinger, J., "Apparel Manufacturing Handbook," Van Nostrand Reinhold Company, pp. 168 (1980).
8- Behera, B. k. and Sharma, S. Low Stress Behavior and Sewability of Suiting and Shirting Fabrics. Indian Journal of Fiber and Textile Research. 1998, 23 (4), 233-241.
9- Choudhury, P. K. Improvement in Seam Performance of Jute bags. Indian Journal of Fiber and Textile Research. 2000, 25(3), 206-210.
10- 10-Shimazai, K. Studies on seam strength – tensile seam strength sewed by hand. Japanese Resource Association of textile End-Uses. 1976, 20, 317-327.
11- 11-Bhalerao, S., Budke, A. S. and Borkar, S. P. Seam Performance in Suiting, Indian Textile Journal, 1997, 107(11), 78-81.
12- 12-Lin, T. H. Construction of predictive model on fabric and sewing thread optimization. Journal of Textile Engineering, 2004, 50(1), 6-11.
13- 13-Mohanta, R. A study on the influence of various factors on seam performance. Asian Textile Journal. 2006, 15(10),57-62.
14- 14-Tarafdar, N. Karmakar, R. and Mondol, M. The effect of stitch density on seam performance of garments stitched from plain and twill fabric. Man-made Textiles in Indian, 2007, 50(8), 298-302.
15- Korthari, V. k. Testing and quality management. New Delhi: IAFL publication, 1999.
16- Bhatnagar *et al.* Coton sewing thread and siro system. Indian Textile Journal, 1991, 102 (2), 30-31.
17- Sundaresan *et a.*. Strength reduction in sewing thread during high speed sewing in industrial lockstitch machine part II: Effect of thread and fabric properties. International Journal of Clothing Science and Technology, 1998, 10 (1), 61-79.
18- Behera, B. K., Evaluation and selection of sewing thread. Textile Trends, 1997, 39 (12), 33-42
19- Miguel *et al.* Fabric design considering the optimization of seam slippage0 International Journal Clothing of Science and Technology, 2005, 17 (3/4), 225-231.