A Study on the Effect of Sewing Thread Count and Stitch Density on the Seam Performance of Denim Fabric

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ABSTRACT
Seam quality is very important aspect of any form of textile assembly using seam. Seam quality is characterized by seam strength, seam elongation, seam efficiency and seam puckering. The purpose and objective of this study was to investigate and scrutinize the impact of commercial sewing thread counts and stitch densities on seam strength, seam elongation and seam efficiency on medium-heavy and heavy weight cotton denim fabrics. For the experimental work, core spun polyester sewing thread in three different counts (Tex-60, Tex-90, and Tex-150) was selected. Superimposed seam using Stitch Class-300 (Lock Stitch) at two different stitch densities (SPI 10 and SPI 13) were used on 3/1 right handed warp face twill woven cotton fabric. The effect of different sewing thread size and different levels of stitch densities was assessed on the selected seam parameters. The interaction effect of the independent variables was also investigated. The experimental results were evaluated statistically using variance analysis (ANOVA) and regression models which correlate seam quality with stitch density and sewing thread size for both the type of fabrics. The findings of the study revealed that for all the three seam parameters, an increasing trend was seen with the increase in the sewing thread count at higher value of stitch density on both the fabrics. Statistically, it was found that for heavy weight denim fabric, the independent variables do not have any significant effect on the seam quality whereas for medium-heavy weight denim fabric some of the independent variables have significant effect on the seam quality. It was seen that statistically there was significant interaction between stitch density, sewing thread count and fabric weight on strength, elongation and efficiency of superimposed seam.

1. Introduction
Quality of the product has been given major importance in the garment assembly (Fernando & Jayawardena, 2014). The relationship between the raw material properties, sewing performance and seam quality becomes very important. There are many elements which impact the garments quality such as fabrics, sewing threads, needles, sewing machine and there are some elements such as sewability.

Stitches and seams are two important basic constituent of structure of apparel product. Stitches are used to join the apparel component together and seams give the shape of the apparel for wear (Brown & Rice, 2001). Seams are the joints between two or more fabric pieces (Yassen, 2016). These two factors together with their performance properties add to the quality of the apparel (Brown & Rice, 2001).

The primary function of a seam is to provide uniform stress transfer from one piece of fabric to another, thus preserving the overall integrity of the fabric assembly. For proper appearance, seam should not contain any defects. The overall quality of a seam depends on its strength, elongation, efficiency and puckering (Hasan, 2017).

As seam is one of the basic requirements in the construction of apparel, seam quality has great significance in apparel products (Nassif, 2013). It is necessary to determine the most appropriate seam for each type of fabric to achieve a desired product quality. Distinct seams are suitable for particular fabrics because each fabric has its own unique properties. The fiber content influences the overall characteristics of a fabric (Lapere, 2006).

Thus the present study was planned to investigate the effect of sewing thread count & stitch density on the seam quality of 3/1 twill woven cotton denim fabric of medium-heavy & heavy weights using superimposed seam. The specific objectives of the study were:

1. To investigate the performance of different sewing thread counts on seam quality.
2. To determine the effect of different levels of stitch density on seam strength, elongation and efficiency.
3. To find out the interaction between stitch densities, sewing thread counts and fabric weights and its effect on seam quality.

2. Methodology
2.1. Selection of Fabrics

100% cotton 3/1 right handed warp faced twill woven denim fabrics in two different weights medium-heavy and heavy weight were used. The constructional parameters of the test fabric are presented below in Table 1.
2.2. Selection of Sewing Thread

100% Core spun polyester sewing thread in three different counts (60 Tex, 90 Tex and 150 Tex) was used for the seam construction.

2.3. Selection of Sewing Parameters

**Seam Selection:** Superimposed (Seam Type – Plain Seam) has been used in this research work.

**Stitch Selection:** Among the six classes of stitch, stitch class 300 lockstitch with stitch type 301 was selected.

**Sewing Needle Selection:** Sewing needle was selected according to ASTM D 1683-04 standard. This method however asserts that if fabric mass is over 270 g/m² then the needle size should be Metric 110/18.

**Stitch Density Selection:** The sewing of denim fabric can be done with different density levels, but in this study two different stitch levels were considered i.e., 10 and 13 SPI.

**Sewing Machine Selection:** Industrial single needle lock stitch (Stitch Class 300) machine of USHA Company was used in this research.

2.4. Seam Preparation

In the present research work, the seam samples were prepared according to ASTM D1683-04 method. Each specimen of the fabric was cut in the warp and weft direction into 350 mm (14 inches) length and 100 mm (4 inches) width.

For seam strength testing, five specimens each for warp and weft was prepared from each fabric type for all the three different counts of sewing thread at both the stitch densities level.

Before cutting the specimens, template for the above size was prepared. After spreading the fabrics on the table, the required dimensions of the specimens were marked randomly with the template along the warp and weft directions.

The specimen was folded at 100mm (4") from one end with the fold parallel to the short direction of the fabric. The superimposed seam was then applied using lock stitch with two different types of stitch densities, parallel to warp and weft direction. The seam allowance was fixed at 0.625” as per the ASTM D 1683-04. Seam strength, seam elongation and seam efficiency was tested using the MAG Unistretch 250 tester according to method ASTM D1683 – 04. As per the method the following parameters were set for testing:

- Test Type: Grab Test
- Extension Range: 300 mm/min
- Test Speed: 100mm/min
- Gauge length: 75mm
- Load cell: 250 kg
- Jaw return rate: 20%
- Pretension: 100 gms

The fabric in the open front position is held into the clamp with the seam line centrally located between the clamps and perpendicular to the pulling force. Maximum force needed to break the seam perpendicular to the direction of extension was recorded. Observation was made in order to make sure that the seam failure is due to break not due to fabric tears. A seam was rupture at the seam line due to sewing thread breakage. The mean of the recorded maximum forces for seams to rupture for all the samples of one fabric was calculated.

**Analysis of Data**

To find out the performance and interaction between two levels of stitch density and three levels of sewing thread count on the superimposed seam quality of medium – heavy and heavy weight cotton denim fabric: Two-Way ANOVA, Multi-Way ANOVA and Regression equation was used.

3. Results and Discussion

3.1 Medium-Heavy Weight Denim Fabric

3.1.1 Effect on Seam Strength

The strength of the superimposed seam was checked in both the warp and weft direction. Perusal of Graph 1 & 2 reveals that overall seam strength is higher in warp direction as compared to weft direction. The graph with average seam strength for superimposed seams produced by using Tex 60, Tex 90 & Tex 150 sewing thread counts with stitch densities 10 & 13 show a definite trend. As it is evident that the average seam strength for superimposed seam increases with the increment of sewing thread size at higher value of stitch density (13 SPI) for medium-heavy weight cotton denim fabric.

![Graph 1: Superimposed Seam Strength Comparison at Different Stitch Density using Different Sewing Thread Counts for Medium-Heavy Weight Cotton Denim Fabric (Warp Direction)](image)

The statistical analysis revealed that stitch density has significant effect on the seam strength whereas three types of sewing thread size do not have significant effect on seam tensile strength in warp direction. For weft direction, both stitch
density and sewing thread count do not have any significant effect on the seam strength.

The regression relationship which correlates the seam tensile strength, with stitch density and sewing thread size in warp direction, has the following linear form: seam strength (Newton) = 681 + 1.71 sewing thread count + 34.1 stitch density, whereas in the weft direction, seam strength (Newton) = 269 + 0.592 sewing thread count + 0.98 stitch density. The calculated $R^2$ value for these models is 96.6% (warp direction) and 90.0% (weft direction). This means that these models fit the data very well.

### 3.1.2 Effect on Seam Elongation

Seam elongation is defined as the ratio of the extended length after loading to the original length of the seam.

Graph 2: Superimposed Seam Strength Comparison at Different Stitch Density using Different Sewing Thread Counts for Medium-Heavy Weight Cotton Denim Fabric (Welt Direction)

The regression relationship which correlates the seam elongation (mm) in the warp direction with stitch density and sewing thread size is: 

$Seam\ Elongation (mm) = 24.0 + 0.0167 \times \text{sewing thread count} + 0.072 \times \text{stitch density}$

The statistical analysis revealed that for warp stitch density and sewing thread count has no significant effect on seam elongation. For weft direction, stitch density has significant effect on the seam elongation whereas there is no significant effect of sewing thread on seam elongation.

Graph 4: Seam Elongation Comparison at Different Stitch Density using Different Sewing Thread Counts for Medium-Heavy Weight Cotton Denim Fabric (Welt Direction)

The regression relationship is of the linear form in both warp & weft directions. The linear regression model has the following form: seam elongation (mm) = 15.6 + 0.0167 sewing thread count + 0.072 stitch density for the weft. The calculated $R^2$ values for these models are 73.3% and 65.1% for warp and weft directions of medium-heavy weight cotton denim fabric respectively. This means that these models do not fit the data.

### 3.1.3 Effect on Seam Efficiency

The increase in sewing thread count (60, 90 & 150 Tex) at higher stitch density level leads to the increase in the seam efficiency from 72.42 per cent to 85.89 per cent in the warp direction and from 53.01 per cent to 69.79 per cent in the weft direction.

Graph 5: Seam Efficiency Comparison at Different Stitch Density using Different Sewing Thread Counts for Medium-Heavy Weight Cotton Denim Fabric (Warp Direction)

The average seam efficiency is higher in warp direction as compared to weft direction, this may be due to the fact that both seam strength and fabric strength is more in the warp direction of the denim fabric.

Graph 3 & 4 clearly shows effect of sewing thread size at two different stitch densities on the seam elongation for the medium-heavy weight fabrics. It can be seen from Graph 3 that increasing the sewing thread size from 60 to 150 Tex increased the seam elongation in general but then decreased at 90 Tex. It is also apparent that the seam elongation is augmented with the increase in the stitch density. As the sewing thread count increases the seam elongation also increases. The increase in sewing thread count from 60 to 150 Tex leads to the increase in seam elongation from 24.0 mm to 26.3 mm (warp direction) and 16.2 mm to 17.7 mm (weft direction) at stitch density of 13.

Graph 3: Seam Elongation Comparison at Different Stitch Density using Different Sewing Thread Counts for Medium-Heavy Weight Cotton Denim Fabric (Warp Direction)
Statistically, the two levels of stitch density have a significant effect in warp and non-significant effect in weft directions. The three levels of sewing thread size for both warp & weft directions do not have any significant effect on seam efficiency.

The linear regression for medium-heavy weight cotton denim fabric in warp direction has the following form: seam efficiency (%) = 82.3 + 0.206 sewing thread count + 4.13 stitch density. In weft direction, the linear regression model has the following form: seam efficiency (%) = 58.5 + 0.147 sewing thread count + 0.460 stitch density. It was found that these models fit the data very well with a high $R^2$ values in warp direction is 96.6% and in weft direction is 93.2%.

3.2 Heavy Weight Denim Fabric

3.2.1 Effect on Seam Strength

The result of seam strength of heavy weight denim fabric is depicted in Graph 7 and 8. The data clearly elucidate the increase of seam tensile strength with the increase of the liner density of the sewing thread at higher value of the stitch density.

Strength values were checked in both warp and weft directions with more strength value in warp as compared to weft. The strength value of heavy weight denim fabric for stitch per inch 13 was maximum when sewn using superimposed seam and 150 Tex thread (641.84 N -warp & 405.99 - weft direction).

The analysis proves that for both the independent variables (two levels of stitch density & three levels of sewing thread size) there is no significant impact on the seam strength in both the directions (warp & weft).

The regression relationship which correlates the seam tensile strength, with which stitch density and sewing thread size in warp direction, has the following linear form: seam tensile strength = 811 + 1.86 sewing thread count + 43.5 stitch density. In weft direction, the regression model has the following form: seam tensile strength = 453 + 0.578 sewing thread count + 13.5 stitch density. The $R^2$ value for these models in warp direction is 87.6% and for weft direction is 84.9%. This means that these models fit the data very well.

3.2.2 Effect on Seam Elongation

The data in Graph 9 & 10 clearly shows that the seam elongation has increased with the increase in sewing thread number from 60 to 150 Tex at high stitch density level in warp and weft direction but little decreases in sewing thread count 90 Tex. Seam elongation values are more in the warp direction than in the weft direction and there is a constant increasing trend. The elongation value of heavy weight denim fabric at 150 Tex for stitch per inch 10 was found to be 32.7 mm in warp and 19.5 mm in weft direction.

The statistical analysis revealed that the P-Value regarding the test of two levels of stitch density and three levels of sewing thread size does not have any significant effect on seam elongation.
The linear regression relationship in warp direction, has the following linear form: Seam Elongation (mm) = 53.0 + 0.0488 sewing thread count + 2.30 stitch density. In case of heavy weight denim fabric in weft direction, the regression model has the following form: Seam Elongation (mm) = 22.1 + 0.0109 sewing thread count + 0.311 stitch density. The $R^2$ value for these models in warp direction is equal 54.4% and in weft direction is equal to 24.5% respectively. This means that these models do not fit the data well.

3.2.3 Effect on Seam Efficiency

Seam efficiency has increased with the increase in sewing thread count from 60 to 150 Tex at higher value of stitch density for heavy weight denim fabric. The average seam efficiency is higher in warp direction as compared to weft direction and follows the similar trend as the seam strength. Seam efficiency increases from 79.29 per cent to 94.19 per cent in the warp direction and 65.28 per cent to 77.62 per cent in the weft direction for SPI 13. Stitch density was found to have a positive influence on the seam efficiency.

3.3 Interaction between Stitch Density, Sewing Thread Count and Fabric Weight on Seam Parameters

To study the effect of fabric type, sewing thread count and stitch density on seam quality, and to determine the interaction between them, a factorial ANOVA was implemented. According to the studied parameters a 2 X 2 X 3 mixed factorial ANOVA was used.

3.3.1 Effect on Seam Strength

The relationship between sewing thread size and seam tensile strength at different levels of stitch density for both medium-heavy and heavy weight cotton denim fabrics is statistically analyzed and it was found that stitch density, sewing thread size and fabric type all have a significant influence on seam tensile strength at 0.05 significant level, since the P-value is smaller than the level of significance.

The regression relationship which correlates the seam tensile strength with stitch density and sewing thread size for
medium-heavy denim fabric has the following linear form:
Seam Strength (Newton) = 727 + 1.78 sewing thread count + 38.8 stitch density + 38.1 fabric weight. The calculated R² value for this model is 90.9%. That means this model fits the experimental data very well. For heavy weight fabric, the linear regression model has the following form: Seam Strength (Newton) = 353 + 0.585 sewing thread count + 6.27 stitch density + 15.7 fabric weight. The R² values for this model are 73.7%. This means that the model do not predict the experimental data.

3.3.2 Effect on Seam Elongation

The statistical analysis revealed that the two levels of stitch density and three types of sewing thread count do not have significant difference on seam efficiency.

The linear regression model which correlates the independent variables to the seam efficiency in warp direction has the following form: seam efficiency (%) = 98.1 + 0.225 sewing thread count + 5.26 stitch density. In case of heavy weight denim fabric in weft direction, the linear regression model has the following form: seam efficiency (%) = 105 + 0.134 sewing thread count + 3.13 stitch density. It was found that these models fit the data very well with a high R² values in warp direction is 87.7% and in weft direction is 84.9%.

3.3.3 Effect on Seam Efficiency

The variations in seam efficiency along with sewing thread size and stitch density for both the medium-heavy and heavy weight cotton denim fabrics was statistically analyzed.

The P-Value regarding the interaction between two levels of stitch density, three levels of sewing thread count and two types of fabric weight is smaller than the level of significance (0.05). So, there exist an interaction of stitch density, sewing thread count and fabric weight on seam efficiency.

The regression relationship for medium-heavy weight cotton denim fabric, has the following linear form: Seam Efficiency (%) = 87.9 + 0.216 sewing thread count + 4.69 stitch density + 4.61 fabric weight. The calculated R² value for this model is 90.9%. That means this model fits the experimental data very well. In case of heavy weight cotton denim fabric, the regression model has the following form: Seam Efficiency (%) = 79.8 + 0.141 sewing thread count + 1.34 stitch density + 3.99 fabric weight. The calculated R² value for this model is 73.8%. That means this model do not fit the experimental data.

4. Conclusion

This study will thus provide information on proper sewing thread selection in the manufacturing of apparel. By defining the relation between seam qualities and sewing thread counts and stitch density in relation to the weight of the fabric, apparel manufacturers can make decision about the optimal sewing thread selection in apparel manufacturing. Comprising the knowledge of a specific seam that produces the greatest seam strength will be highly beneficial for new tests and products.

References