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Interaction between Sewing Thread Size and Stitch Density and Its Effects on the Seam Quality of Wool Fabrics

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ABSTRACT

The purpose of this study was to analyze the seam quality with commercial sewing threads and different stitch densities. Seam quality was characterized by seam strength, seam elongation, seam efficiency and seam puckering. The interaction effect of the independent variables was also investigated. Two types of wool fabrics were used throughout this study, namely heavy and light ones. The experimental results were assessed statistically using variance analysis (ANOVA) and regression models which correlate seam quality with stitch density and sewing thread size. The findings of this study revealed that all independent variables and most of interactions affect significantly on the seam strength, seam elongation, seam efficiency and seam puckering.

Key words:

Introduction

In the apparel industry, overall seam quality defined through various functional and aesthetic performances desired for the apparel product during their end use. The functional performance mainly refers to the strength, tenacity, efficiency, elasticity, elongation, flexibility, bending stiffness, abrasion resistance, washing resistance and dry cleaning resistance of the seam under conditions of mechanical stress for a reasonable period of time (Mehta, 1985, Solinger, 1989 and Carr H. et al., 1955). Basically, seam quality may be examined from two main aspects: functional and aesthetic performance. Most previous studies (Chmielowice, 1987 and Taraďár N, et al., 2007) investigated the functional performance of seam mainly in terms of the seam strength and/or seam efficiency. The cut and sewn apparel product industry convert a two-dimensional fabric into three-dimensional apparel. Many processes are involved during apparel production, till the stage of finished apparel to be seen in a shop-window, on a tailor's dummy, or on a coat hanger is reached. While there are other methods of shaping fabrics into apparel products, stitch seaming is by far the most common method used worldwide.

Properties like as, strength, tenacity and efficiency is required for determining the serviceability of apparel. Elasticity, elongation, flexibility, and low bending stiffness of seam are needed to easily elongation, flexibility, and low bending stiffness of seam are needed to easily bend, shift, and fold without damage to the seam or change to the silhouette of the garment (Choudhry K., 1995).

Many previous studies (Behera B.K., et al., 2000 and Mukhopadhyay A., et al., 2004) showed that seam appearance and performance depend on the interrelationship of fabrics, threads, the stitch and seam selection, and sewing conditions, which include the needle size, stitch density, the appropriate operation and maintenance of the sewing machines etc. The combination of materials that are assembled with the sewing thread and sewing conditions vary from individual to individual. Selection of sewing thread and sewing condition for a particular type of material is an integral part of producing a quality seam.

The different parameters of sewing thread such as the thread type, size and finish would have a definite effect on the functional and aesthetic performance of the seam (Rengasamy R.S., et al., 2003 and Gribaa S., et al., 2006). If there is no special requirement, the apparel industry mainly selects the spun-polyester, 3-Ply, normal twist and standard finish sewing thread for all types of sewing fabrics (Solinger, 1989). However, the size of the sewing thread is the most crucial for that seam quality as the improper selection of sewing thread size directly affects the seam quality of apparel products. There are also a lot of sewing conditions such as stitch type, seam type, stitch density, sewing machine speed, needle size, pressure of pressure foot, feed dog. Thread tension and needle plate, which affect the seam quality. Among the above mentioned sewing conditions, stitch density is the only attribute, which can vary at different seam locations and has a direct impact on the quality level of apparel products (Chmielowice, 1987 and Sundaresan, et al., 1998). Therefore, stitch density deemed to be a most important sewing condition in the course of garment manufacturing. The remaining sewing conditions...
are adjusted during the course of apparel manufacturing based on the thread size and/or the material to be sewn (Bharani and Mahendra, 2012).

This paper sheds light upon the interaction between sewing thread size and stitch density and its effects on seam performance of the wool woven fabrics. The seam quality and performance are characterized by seam strength, elongation Seam and efficiency and the seam puckering.

**Experimental Work:**

**Materials:**

Two types of twill 2/1 wool fabrics were produced. The first type of the samples was woven with light weight i.e. 140 gm/m² and the second type of the fabrics was produced with heavy weight (280 gm/m²). The warp yarns count of the light fabrics were of 43.8 text, while the weft ones were of 35.7 tex. The warp yarns of heavy fabrics were spun with 110 tex, whereas the weft yarns were produced with 90 tex.

Woven fabric samples were sewn with SSa seam type. This seam type is the most common form of superimposed seams, and the most common for joining garment pieces. The used seam is illustrated in figure 1.

**Fig. 1:** Photograph of SSa seam.

The strength of sewing thread is critical to the performance of stitches and seams. The sewing thread should be comparable to the wear and care of the garment. It is important to compare the strength of the fabric with the strength of the sewing thread. The sewing thread should never be stronger than the fabric. Besides being compatible in strength, the sewing thread should be extensible against the stress of the garment (Bharani and Mahendra, 2012).

In this study, Core spun sewing threads produced with polyester filament core and polyester sheath fibers have been introduced to join the wool fabric samples in this study. The sewing thread has been used with four different counts i.e. 18, 24, 27 and 30 tex. The fabric samples were sewn using lockstitch with different three stitch densities (6, 10 and 13 stitches / inch). The sewing needle of a DB.1 (ball point type), no. 11 size (Organ Co.) was used. A 1- needle lockstitch sewing machine Juki DL-5550 was also used with an average sewing speed of 2850 stitch/min. The levels used in this study were tabulated in table 1.

**Table 1:** Levels of the used parameters.

<table>
<thead>
<tr>
<th>Fabric type</th>
<th>Stitch density (stitches/inch)</th>
<th>Sewing thread count (tex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light weight (-1)</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>Heavy weight (+1)</td>
<td>13</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
</tr>
</tbody>
</table>

**Laboratory Testing:**

In this study, seam quality is evaluated based on various dimensions: seam strength, seam elongation, seam efficiency and seam puckering. Seam strength, seam elongation and seam efficiency are considered the dimensions for the functional performance of the seam. In contrast, seam puckering is mainly evaluated for better aesthetic performance of the seam.

Mechanical tests were carried out after conditioning of the fabrics for 24 hours under the standard atmospheric conditions (20 ± 2 °C temperature, 65 ± 2% relative humidity). Ten individual readings were averaged for each sewn fabric property. The fabrics were tested for the following characteristics; seam strength, seam elongation, seam efficiency, and seam puckering.

**Seam strength and elongation:**

Seam strength expresses the maximum force (in Newton) to cause a seam specimen to rupture. 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 seam elongation was measured according to the following formula:

\[
SE = \frac{EL}{OL} \times 100
\]

Where, \(SE\) = Seam Elongation %.
\(EL\) = Extended length
\(OL\) = original length

The evaluation of seam elongation was measured in accordance to ASTM standard.

The tensile strength of the woven fabrics, the seam strength and elongation were all measured on an Instron Tensile Tester, model 4411 (Figure 2). The ASTM D 5034 was used to determine the fabric tensile strength and ASTM D 1683-04 was used to determine the seam strength and elongation.

![Photograph of Instron Tensile Tester model 4411.](image)

**Seam efficiency:**

Seam efficiency measures the durability along the 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 evaluation of seam efficiency from ASTM standard is well accepted by the apparel industry because it is an international standard

\[
\text{Seam efficiency (\%) = } \frac{\text{Seam tensile strength}}{\text{Fabric tensile strength}} \times 100
\]

Seam efficiency was measured according to ASTM standard D 1683-04.

**Seam puckering:**

Seam puckering in a garment is the uneven appearance of a seam in a smooth fabric. Seam puckering appears along the seam line of garment when the sewing parameters and sewn materials properties are not properly selected.

There are different methods of measuring seam puckering for the evaluation of seam quality. These are the international standard method, laser scanner method, seam length method and thickness strain method. In this study thickness strain method as evaluation for seam puckering was used. In this method, seam puckering is calculated by measuring the difference between fabric and seam thickness under constant compressive load. Seam puckering is calculated by using the following formula.

\[
\text{Seam puckering (\%) = } \frac{t_s - 2t}{2t} \times 100
\]

Where, \(t_s\) = seam thickness, \(t\) = fabric thickness. This method is widely used for evaluating seam puckering because it is well referred and can give more accurate than any other method. It is also easy to calculate and is less time consuming than other methods.
Statistical Analysis:

To study the effect of fabric type, sewing thread count and stitch density on seam quality, a full factorial design was implemented. According to the studied parameters listed in table 1, a 2×3×4 mixed factorial design was implemented. Also, the multiple regression models were selected in this study. They were linear or non-linear models. To compare the performance of these models, the coefficient of determination ($R^2$) will be used.

The regression models correlate stitch density and sewing thread count to each seam properties (seam strength, seam elongation, seam efficiency and seam puckering) for each type of wool fabrics. The non-linear models have the following form:

$$Z = a + b \times X + c \times Y + d \times X \times Y + e \times X^2 + f \times Y^2$$

Where,

- $Z$ = seam properties (seam strength, seam elongation, seam efficiency and seam puckering).
- $a$ = constant.
- $b$, $c$, $d$, $e$, and $f$ = regression coefficients
- $X$ = seam density, stitches/inch.
- $Y$ = Sewing thread size, tex.

In the case of linear models, the regression coefficients, i.e. $d$, $f$, and $f$ equal to zero.

Results and Discussion

Effects on seam strength:

Seam strength refers to the load required to break a seam. This measure the strength and tenacity of a seam. Research has revealed that the load required to rupture the seam is usually less than required to break the unsewn fabric. The relationship between sewing thread size and seam tensile strength at different levels of stitch density for both light and heavy weight of wool fabrics are demonstrated in figures 3 and 4 respectively. The statistical analysis tabulated in table 2 revealed that stitch density, sewing thread size and fabric type all have a significant influence on seam tensile strength at 0.01 significant level. The two-way and three-way interaction effects all have a significant impact on seam tensile strength too.

<table>
<thead>
<tr>
<th>Effects</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stitch density</td>
<td>2290066</td>
<td>2</td>
<td>1145033</td>
<td>3296.21</td>
<td>0.000</td>
</tr>
<tr>
<td>Sewing thread size</td>
<td>55362</td>
<td>3</td>
<td>18454</td>
<td>419.41</td>
<td>0.000</td>
</tr>
<tr>
<td>Fabric weight</td>
<td>163800</td>
<td>1</td>
<td>163800</td>
<td>3722.73</td>
<td>0.000</td>
</tr>
<tr>
<td>Stitch density*Sewing thread size</td>
<td>9273</td>
<td>6</td>
<td>1543</td>
<td>34.99</td>
<td>0.000</td>
</tr>
<tr>
<td>Stitch density*Fabric weight</td>
<td>19480</td>
<td>2</td>
<td>9740</td>
<td>221.37</td>
<td>0.000</td>
</tr>
<tr>
<td>Sewing thread size*Fabric weight</td>
<td>59450</td>
<td>3</td>
<td>19817</td>
<td>450.38</td>
<td>0.000</td>
</tr>
<tr>
<td>Stitch density<em>Sewing thread size</em>Fabric weight</td>
<td>6068</td>
<td>6</td>
<td>1011</td>
<td>22.98</td>
<td>0.000</td>
</tr>
<tr>
<td>Error</td>
<td>1056</td>
<td>24</td>
<td>44</td>
<td>359438</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>604519</td>
<td>47</td>
<td></td>
<td>359438</td>
<td></td>
</tr>
</tbody>
</table>

It is noticed from figure 3 that the seam tensile strength have increased with the increase in sewing thread size from 18 to 24 tex and then decreased with the increase in sewing thread size up to 30 tex for light weight wool fabrics. Higher sewing thread size was subjected to greater friction during sewing, which ultimately reduced its strength. This consequently led to poor seam strength.

In the case of heavy weight fabrics, the seam tensile strength swiftly increases with the increase in sewing thread size for all stitch densities (Figure 4). This means that the lower sewing thread sizes are suitable for light weight wool fabrics, whereas coarser sewing threads suit the heavy weight wool fabrics. The statistical analysis also proved that fabric weight has a positive effect on seam tensile strength. As the fabric weight increases the seam tensile strength also increases. The heavy weight wool fabrics associated with higher seam strength, whereas the low weight one yields the lower seam tensile strength. The increase in fabric weight leads to the increase in seam tensile strength from 150 Newton to 257 Newton.

The regression relationship which correlates the seam tensile strength with stitch density and sewing thread size for light weight wool fabric, has the following non-linear form:

$$\text{Seam tensile strength (Newton)} = -366.697 - 63.326 \times x + 49.431 \times y + 8.031 \times x \times x + 0.740 \times x \times y - 1.111 \times y \times y$$

In the case of heavy wool weight, the regression model has the following form:

$$\text{Seam tensile strength (Newton)} = 60.852 - 29.010 \times x - 4.655 \times y + 2.437 \times x \times x + 2.576 \times x \times y$$

The $R^2$ values for these models are 0.85 and 0.81 respectively. This means that these models fit the data very well.
Effects on seam elongation:

Seam elongation evaluates the elasticity and flexibility of a seam. Seam elongation is defined as the ratio of the extended length after loading to the original length of the seam. Figures 5 and 6 illustrate the relationship between sewing thread size and stitch densities on seam elongation for light weight and heavy weight wool fabrics. The results of the variance analysis listed in Table 3 proved the significant effect of stitch density, sewing thread size and fabric weight on seam elongation at 0.01 significant level. The two-way interaction (Sewing thread size* Fabric weight) have a significant effect at 0.01 significant impact on the seam elongation, whereas there is no significant effect for the three-way interaction.

Table 3: Analysis of variance for the effects of stitch density and sewing thread size on seam elongation for wool weight fabrics.

<table>
<thead>
<tr>
<th>Effects</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stitch density</td>
<td>951.17</td>
<td>2</td>
<td>475.58</td>
<td>42.910</td>
<td>0.000</td>
</tr>
<tr>
<td>Sewing thread size</td>
<td>118.00</td>
<td>3</td>
<td>39.33</td>
<td>3.549</td>
<td>0.029</td>
</tr>
<tr>
<td>Fabric weight</td>
<td>161.33</td>
<td>1</td>
<td>161.33</td>
<td>14.556</td>
<td>0.000</td>
</tr>
<tr>
<td>Stitch density*Sewing thread size</td>
<td>83.50</td>
<td>6</td>
<td>13.92</td>
<td>1.256</td>
<td>0.314</td>
</tr>
<tr>
<td>Stitch density*Fabric weight</td>
<td>7.17</td>
<td>2</td>
<td>3.58</td>
<td>0.323</td>
<td>0.726</td>
</tr>
<tr>
<td>Sewing thread size*Fabric weight</td>
<td>218.00</td>
<td>3</td>
<td>72.67</td>
<td>6.556</td>
<td>0.002</td>
</tr>
<tr>
<td>Stitch density<em>Sewing thread size</em>Fabric weight</td>
<td>31.50</td>
<td>6</td>
<td>5.25</td>
<td>0.474</td>
<td>0.821</td>
</tr>
<tr>
<td>Error</td>
<td>266.00</td>
<td>24</td>
<td>11.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>47</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It can be seen from figure 5 that the effect of sewing thread size at different stitch densities on the seam elongation for the light weight fabrics resembles to some extent the effect on the seam tensile strength. Increasing the sewing thread size from 18 to 24 tex increased the seam elongation which then decreased with the
increase in the sewing thread size up to 30 tex. This means that finer sewing threads yield good seam elongation. It is also apparent that the seam elongation is augmented with the increase in the stitch density.

The regression relationship which correlates the seam elongation with stitch density and sewing thread size has the non-linear form:

\[ \text{Seam elongation(%) = } -53.5925-3.5929 \times x+6.2918 \times y+0.375 \times x \times x+0.1048 \times x \times y-0.1439 \times y \times y \]

The calculated $R^2$ value for this model is equal to 0.79 that means this model predict the experimental data very well.

For heavy weight wool fabric, the relation between sewing thread size and the seam elongation at different levels of the stitch density is well represented graphically in figure 6. From this figure the increased sewing size leads to the increase in the seam elongation. Stitch density also has the same effect on the seam elongation. The higher sewing thread size and the higher stitch density are suitable factor to enhance seam quality especially the seam flexibility and elasticity for the heavy weight wool fabrics.

The regression model which correlates sewing thread size and stitch density with the seam elongation of the heavy weight wool fabrics is of the following form:

\[ \text{Seam elongation(%) = } 29.6625-0.1232 \times x-2.0299 \times y-0.0313 \times x \times x+0.1262 \times x \times y+0.0421 \times y \times y \]

The $R^2$ for this model approaches 0.90 this means that this model fits the data very well.

**Fig. 5:** Effect of sewing thread size on seam elongation at different levels of stitch densities for light weight wool fabrics

**Fig. 6:** Effect of sewing thread size on seam elongation at different levels of stitch densities for heavy weight wool fabrics.

**Effects on Seam efficiency:**

The variations in seam efficiency along with sewing thread size and stitch density for both the light and heavy weight wool fabrics are graphically represented in figures 7 and 8.
Table 4: Analysis of variance for the effects of stitch density and sewing thread size on seam efficiency for wool weight fabrics.

<table>
<thead>
<tr>
<th>Effects</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stitch density</td>
<td>16840.2</td>
<td>2</td>
<td>8420.1</td>
<td>419.257</td>
<td>0.000</td>
</tr>
<tr>
<td>Sewing thread size</td>
<td>2759.0</td>
<td>3</td>
<td>919.7</td>
<td>45.793</td>
<td>0.000</td>
</tr>
<tr>
<td>Fabric weight</td>
<td>2523.0</td>
<td>1</td>
<td>2523.0</td>
<td>125.627</td>
<td>0.000</td>
</tr>
<tr>
<td>Stitch density*Sewing thread size</td>
<td>360.5</td>
<td>6</td>
<td>60.1</td>
<td>2.992</td>
<td>0.025</td>
</tr>
<tr>
<td>Stitch density*Fabric weight</td>
<td>408.5</td>
<td>2</td>
<td>204.2</td>
<td>10.170</td>
<td>0.000</td>
</tr>
<tr>
<td>Sewing thread size*Fabric weight</td>
<td>2805.7</td>
<td>3</td>
<td>935.2</td>
<td>46.567</td>
<td>0.000</td>
</tr>
<tr>
<td>Stitch density<em>Sewing thread size</em>Fabric weight</td>
<td>698.8</td>
<td>6</td>
<td>116.5</td>
<td>5.799</td>
<td>0.000</td>
</tr>
<tr>
<td>Error</td>
<td>482.0</td>
<td>24</td>
<td>20.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4748.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 7: Effect of sewing thread size on seam efficiency at different levels of stitch densities for light weight wool fabrics.

Fig. 8: Effect of sewing thread size on seam efficiency at different levels of stitch densities for heavy weight wool fabrics.

The statistical analysis introduced in table 4 proved the significant influence of all independent variables and its interactions whether the two-way and three-way interactions all have a significant impact on the seam efficiency. In order to understand the effects of sewing thread size, stitch density and fabric weight on the seam efficiency, the variations on the seam efficiency against sewing thread size at different levels of stitch densities were graphically illustrated in figures 7 and 8 for low and heavy weight fabrics respectively. From figure 7 it is shown that seam efficiency of low weight wool fabrics increased with the increase in sewing thread size from 18 to 24 tex and then decreased with increased sewing thread size. Stitch density was found to have a positive influence on the seam efficiency. Higher seam efficiency is associated with higher stitch densities.

The multiple non-linear regression model which correlates the independent variables to the seam efficiency of low weight wool fabrics has the following form:

Seam efficiency (%) = -121.529 - 20.6875*x + 16.3652*y + 2.5938*x*x + 0.25*x*y - 0.3687*y*y

It was found that this model fits the data very well with a high R² value that equals 0.93.

Figure 8 portraits the relation between sewing thread size and seam efficiency at different levels of stitch densities for heavy weight wool fabrics. From this figure it is shown that as the sewing thread size increases the
Seam efficiency increases. It was emphasized that lower sewing thread size is the cause of poor seam efficiency. Generally, lower sewing thread size represents lesser strength than coarser sewing threads, which in turn reduces the seam efficiency of any apparel product.

The effect of stitch density on the seam efficiency is similar to a large extent the effect of the sewing thread size for this type of fabric. Increasing stitch density swiftly increases the seam efficiency.

The non-linear relationship between independent variables and the seam efficiency is as the following form:

Seam efficiency (\%) = -81.5619+15.7857*x+3.3754*y-0.5*x*x+0.0238*x*y-0.0093*y*y

The statistical analysis proved that $R^2$ value for this model is almost 0.76.

**Effects on Seam puckering:**

Seam puckering is related to the compressive forces generated on the fabric during sewing from interaction between the sewing thread, fabric and sewing conditions. It was also found that seam puckering depends mainly on the thickness properties of the fabric [15, 16]. As a result, thickness strain method was chosen as an accurate one to evaluate the puckering of the seams after stitching for woven wool fabrics.

Seam puckering of low and heavy weight wool fabrics against sewing thread size and snitch densities are graphically depicted in figures 9 and 10 respectively. The results of the Analysis of Variance introduced in table 5 revealed the significant influence of all independent variables except for the two interaction effect (Stitch density*Sewing thread size) and three interaction effect (Stitch density*Sewing thread size*Fabric weight) on the seam puckering.

**Table 5:** Analysis of variance for the effects of stitch density and sewing thread size on seam puckering for wool weight fabrics.

<table>
<thead>
<tr>
<th>Effects</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stitch density</td>
<td>496.81</td>
<td>2</td>
<td>248.41</td>
<td>75.671</td>
<td>0.000</td>
</tr>
<tr>
<td>Sewing thread size</td>
<td>797.41</td>
<td>3</td>
<td>265.80</td>
<td>80.971</td>
<td>0.000</td>
</tr>
<tr>
<td>Fabric weight</td>
<td>1070.69</td>
<td>1</td>
<td>1070.69</td>
<td>326.159</td>
<td>0.000</td>
</tr>
<tr>
<td>Stitch density*Sewing thread size</td>
<td>17.03</td>
<td>6</td>
<td>2.84</td>
<td>0.864</td>
<td>0.534</td>
</tr>
<tr>
<td>Stitch density*Fabric weight</td>
<td>76.59</td>
<td>2</td>
<td>38.30</td>
<td>11.666</td>
<td>0.000</td>
</tr>
<tr>
<td>Sewing thread size*Fabric weight</td>
<td>122.17</td>
<td>3</td>
<td>40.72</td>
<td>12.406</td>
<td>0.000</td>
</tr>
<tr>
<td>Stitch density<em>Sewing thread size</em>Fabric weight</td>
<td>13.69</td>
<td>6</td>
<td>2.28</td>
<td>0.695</td>
<td>0.655</td>
</tr>
<tr>
<td>Error</td>
<td>78.79</td>
<td>24</td>
<td>3.28</td>
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<tr>
<td>Total</td>
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<td></td>
</tr>
</tbody>
</table>

**Fig. 9:** Effect of sewing thread size on seam puckering at different levels of stitch densities for light weight wool fabrics.

From these figures it can be seen that sewing thread size has a positive influence on seam puckering. As the sewing thread size increases the seam puckering of both types of fabrics increases. The significant impact of sewing thread size on seam puckering may be due to the higher diameter of sewing thread leads to seam puckering by structural jamming along the seam line. It also shown from the above figures that increasing the stitch density leads to an increase in the seam puckering of the both types of wool fabrics. The effects of sewing thread size and stitch density on seam puckering are more pronounced in the light weight fabrics than in the case
of heavy weight fabrics. The statistical analysis also proved that fabric weight has a profound effect on the seam puckering. The negative correlation between the two variables was detected, confirming that as the fabric weight increases the seam puckering decreases. Fabrics with a very light weight display less stability, have handling problems in the course of garment manufacturing, and reduce the aesthetic performance of the seam in terms of seam puckering.

Fig. 10: Effect of sewing thread size on seam puckering at different levels of stitch densities for heavy weight wool fabrics.

The regression relationship which correlates seam puckering of light weight wool fabrics to stitch density and sewing thread size is of the linear form:

\[
\text{Seam puckering} (\%) = -25.186 - 1.767 \times x + 2.105 \times y
\]

Whereas in the case of heavy weight fabrics the same relationship is as follows:

\[
\text{Seam puckering} (\%) = 14.766 - 0.762 \times x - 1.207 \times y
\]

The \(R^2\) values of these models are 0.94 and 0.96 for light weight and heavy weight fabrics respectively.

**Conclusion:**

In this study four different sewing thread sizes and three stitch densities were applied on two types of wool fabrics, i.e. low and heavy weight fabrics using SSa seam type to understand its effects on the seam quality. The statistical analysis using ANOVA was conducted to detect the significant influence of such variables on the seam quality such as, seam strength, seam efficiency, seam elongation and seam puckering. Regression models which correlate each dependent variable with stitch density and sewing thread size for both types of fabrics were derived. The conclusion can be drawn as follows:

- The trace of seam tensile strength and seam elongation according to the variations in sewing thread sizes and stitch densities for low weight and heavy weight wool fabrics looks like of each other. Seam tensile strength and elongation increases with the increase in sewing thread size from 18 to 24 tex and then decreased with the increase in sewing thread size up to 30 tex.
- For heavy weight wool fabrics the increase in sewing thread size and stitch densities lead to the increase in seam strength and elongation. It was also revealed that the finer sewing threads suit the light weight fabrics, whereas the coarser one is suitable for the heavy weight fabrics.
- In relation to the seam efficiency, which measures the durability along the seam line, it was proved that all independent variables and its interactions have a significant influence on the seam efficiency. As the sewing thread density and stitch density increases the seam efficicncy follows the same trend for heavy weight wool fabrics. In the case of light weight fabrics, the sewing thread of count 24 tex yields the higher seam efficiency, which confirms that this linear density of the sewing thread is the best with respect to the seam quality.
- For the study of the effects of the independent variables on the seam puckering, the statistical analysis proved that stitch density and sewing thread size have a positive and profound impact on the seam puckering. Light weight fabrics display less stability in the course of garment manufacturing, and reduce the aesthetic performance of the seam in terms of seam puckering.

**References**


