A Study of Seam Performance of Micro-Polyester Woven Fabrics

Thanaa Mustafa AL Sarhan

Faculty of Art & Design, King Abdul-Aziz University, Jeddah, Kingdom of Saudi Arabia
thanaa12@yahoo.com

Abstract: This paper presents an experimental study of the seam performance of micro-polyester woven fabrics. In this study plain micro-polyester fabrics were woven with three different weft densities. Three different seam types were used during the sewing of the fabrics, each with three stitch densities. Therefore, 27 samples having different specifications were obtained. Seam strength, seam elongation, sewing needle penetration force and seam efficiency were determined for these fabrics for seam performance. The purpose of this study was to identify the suitable sewing conditions in order to achieve good seam performance.

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1. Introduction

In apparel industry, the sewing process is one of the critical processes in the determination of productivity and the quality of the finished garment [1]. Recently, the performance and appearance of garments and sewing techniques – especially seam strength, seam efficiency and seam puckering – have become important [2-5]

Seam strength refers to a load required to break a seam. Every seam has two components, fabric and sewing thread. Therefore, seam strength results from the breakage of either fabric or thread or, in more cases, both simultaneously. It was found that the load required to rupture the seam is usually less than that required to break the unsewn [6, 7].

There are various factors which can affect the seam strength and seam appearance. Many previous studies [8-11] showed the seam appearance and performance depends on the interrelationship of fabrics, threads, the stitch and seam selection, and sewing conditions, which include the needle size, stitch density, the appropriate maintenance of the sewing machine etc.

A microfiber is defined as a fiber (including staple fibers and filaments) of linear density approximately 1 dtex or less, and above 0.3 dtex [12]. Microfibers are used in various applications, for example, in high-grade woven and knitted fabrics, such as towels and typewriter ribbons. Wiping clothes, filter clothes, and clean-room garments utilize the large fiber surface [13, 14]. Microfiber fabrics are generally lightweight, resilient or resist wrinkling, have a luxurious drape and body, retain shape, and resist pilling. Also, they are relatively strong and durable in relation to other fabrics of similar weight [15]. They are also used as moisture-permeable, water-proof, and water-repellent high density woven fabrics.

The objective of this study was to investigate seam characteristics, i.e. seam strength and elongation, seam efficiency, and sewing needle penetration force of micro polyester fabric woven with different warp densities.

Materials

Plain micro-polyester woven fabrics with weft yarn count 70 d /144 f (fineness of monofilament, 0.48 d), and warp yarn count 75 d /144 f, i.e. 0.52 dpf , and with three weft densities 25, 28 and 32 ppcm were used. The warp density of the fabric samples was 24 picks/cm. Each fabric sample was sewn with Lsa-1, SSa-1, and SSn-1 seam types. Sewing thread of 100 % PET of continuous filament with 74/2 dTex was used at lockstitch with different three stitch densities, i.e. 3, 5 and 7 stitches per cm. Therefore the total fabric samples in this study were 27 samples. The photographs of the seams used were shown in figure1.

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.

Laboratory Testing

Mechanical tests were carried out in weft direction 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 sewing needle penetration force.

Seam strength and seam elongation were measured on an Instron 4411 device according to the ISO 13935-2 standard [16]. The speed of the device was 100 mm/min. Samples were cut to the dimensions of 100 ×150 mm. Two samples were sewn together on the short side by putting one right above the other. Each sample was sewn using the above three seams types.

Seam efficiency measures the durability along the seam line. Durability is identified as necessary to satisfactory seam's functional performance, and efficient seams are assumed to be more durable than weak ones [17, 18]. Seam efficiency was measured according to the ASTM 1683-04 standard method. In this method, seam efficiency was measured by using the following equation:

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

Measurement of the sewing needle penetration force is performed with a L&M Sewability Tester, which was shown in figure 2. The needle penetration action in the L&M sewability tester was 100 r.p.m. and the test was normally run without sewing thread. The L&M sewability test determined the force required for a 90's ball point needle to penetrate a fabric. 100 penetrations were made. This test was conducted to detect the relationship between weft density of micro polyester woven fabric and penetration force.

Figure 1: Photographs of the seam used in the study

Figure 2: The L+M sewability Tester [19]

Statistical analysis

To explore the effects of weft density, stitch density, and seam design on the different sewing properties; a 3^3 full factorial design was performed. All test results were assessed at significance level $0.05 \leq \alpha \leq 0.01$. To predict the properties of SSa, LSa and SSn seams at different weft densities and stitch densities, a multiple non-linear regression analysis was executed. The regression relationship between seam properties and levels of filling weft density and stitch density has the following non-linear form;

$$Z = a_0 + a_1 x + a_2 y + a_3 x^2 + a_4 y^2 + a_5 x y$$

Where:

Z - Seam property, i.e. seam strength, seam elongation, ---etc.

x - Weft density, picks/cm,

y- Stitch density; stitches/cm,

a_0 = Constant,

a_1, a_2, a_3, ---- Regression coefficients.

The validation of the regression models was performed using the coefficient of determination, R^2. R-square (the coefficient of determination), measures the reduction in the total variation of the dependent variable (seam properties) due to the independent variables (weft density and stitch density)

3. Results and Discussion

Seam strength

The plots of seam strength at different levels of weft density and Stitch density for seam types SSa, LSa, and SSn were shown in figures 3-5. The statistical analysis proved that weft density and stitch density have a significant influence on seam strength for all seam types. It is shown that weft density has a positive effect on seam strength. As the weft density increases, seam strength increases for all seam types. The same trend was detected with the effect of stitch density on seam strength.

The statistical analysis proved that increasing weft density from 25 to 32 picks/ cm leads to an increase in seam strength by 78%, 62% and 57% for the seam types SSa, LSa and SSn respectively. Increasing stitch density from 3 to 7 stitches/cm increased the strength of seam types SSa, LSa and SSn with 52%, 42% and 37% respectively. Increasing seam strength with the increase in stitch density and weft density may be related to increasing the join between the fabrics and sewing thread with the increase in these parameters.

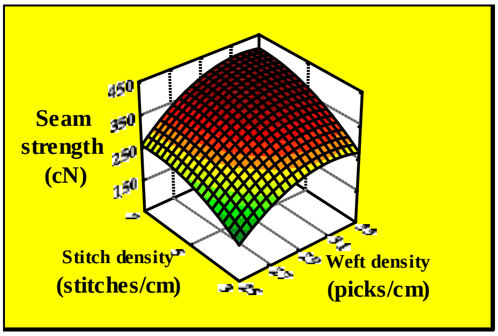

Figure3: Response surface of seam strength at different levels of stitch density and weft density for seam of type SSa.

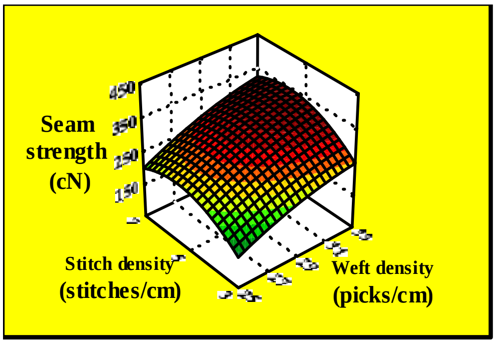

Figure 4: Response surface of seam strength at different levels of stitch density and weft density for seam of type LSa

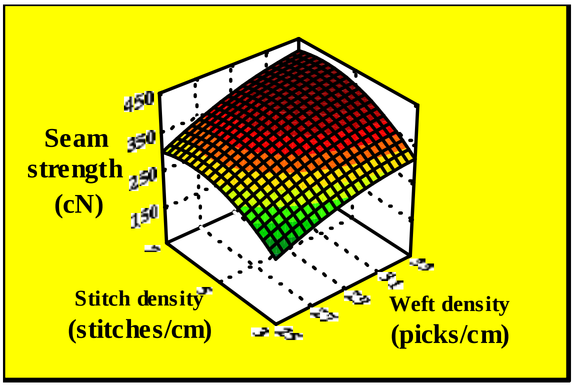

Figure 5 Response surface of seam strength at different levels of stitch density and weft density for seam of type SSn

The regression relationship which correlates seam strength to weft density and stitch density for the seam of type SSa is as follows:

Seam strength (cN) = $-3219+213*x+77*y-.5036*x^2+1.3*x*y-8.4*y^2$

While for the seam type LSa, the regression line is as follows:

Seam strength (cN) = $-1313+71*x+134*y-x^2+0.7*x*y-14*y^2$

Whereas in the case of SSn seam, the regression line has the following form:

Seam strength (cN) = $-1201+73*x+112*y-1.1*x^2+0.97*x*y-11.7*y^2$

The statistical analysis proved that the coefficient of determination for the three models is 0.85, 0.92, and 0.89 respectively, which means that these models fit the data very well.

Seam elongation

The results of fabric seam elongation were depicted in Figures 6-8. The statistical analysis proved that weft density and stitch density have a significant influence on elongation of seams of types SSa, LSa and SSn. It is shown that stitch density has a positive effect on seam elongation; on the contrary weft density has negative influence on seam efficiency. The statistical analysis also revealed that seam efficiency of the three seam types differs significantly. Fabrics sewn with seam of type SSn had higher seam elongation followed by seam of types SSa and LSa respectively. This is due to the complex structure of SSn seam, which produces a stronger joint in the fabric, and then provides a higher frictional resistance between the fabric panels.

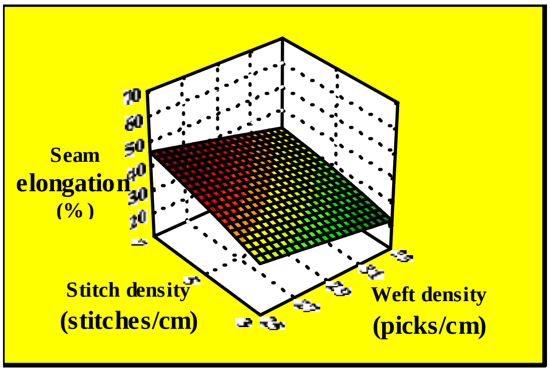

Figure 6: Response surface of seam elongation at different levels of stitch density and weft density for seam of type SSa .

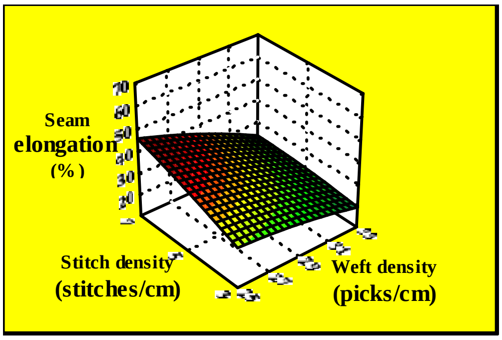

Figure 7: Response surface of seam elongation at different levels of stitch density and weft density for seam of type LSa.

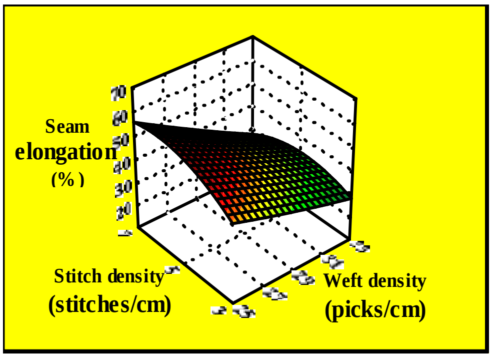

Figure 8: Response surface of seam elongation at different levels of stitch density and weft density for seam of type SSn

The statistical analysis assured that increasing the stitch density leads to an increase in seam elongation with 37%, 39% and 25% for the seams of type SSa, LSa and SSn respectively. On the other hand, increasing weft density leads a reduction of seam efficiency with 35%, 32% and 35% respectively for the same seam types.

The multiple regression model that correlates seam elongation of SSa seam to weft density of micro polyester fabric and stitch density was found to be of the second order and of the following form:

Seam elongation (%) $=28-0.29*x+9*y-0.008*x^2-0.13*x*y-0.22*y^2$

In the case of LSa seam, the regression model which correlates seam elongation with independent variables has the following form:

Seam elongation (%) $=67+5.3*x+17.4*y-0.008*x^2-0.4*x*y-0.22*y^2$

Whereas, for SSn seam the same relationship has the following form:

Seam elongation (%) $=52-2.8*x+27.6*y+0.04*x^2-0.4*x*y-1.4*y^2$

These regression models demonstrate a very good fit with a high R^2 values of 0.98, 0.88 and 0.95 for SSa, LSa and SSn seams respectively. These statistical models can be used to predict seam elongation of micro polyester fabrics at different levels weft density and stitch density.

Seam efficiency

It is more obvious that the trend of seam efficiency at different levels of weft density and stitch density, as shown in figures 9-11, is nearly the same as the seam strength for SSa, LSa and SSn seam types. The statistical analysis proved that both variables had a significant effect on the seam efficiency. Generally, the greater the stitch density in a seam, the greater the seam efficiency.

The statistical analysis proved that the seam efficiency of SSa, LSa, and SSn seam types differs significantly. The seam of type SSn has highest value of seam efficiency followed by seam of types SSa and LSa respectively. It is shown that increasing weft density leads to an increase in seam efficiency of seam types SSa, LSa and SSn with 38%, 25% and 29% respectively. Efficiency of the seams has increased by 35%, 29% and 13% with the increase in stitch density

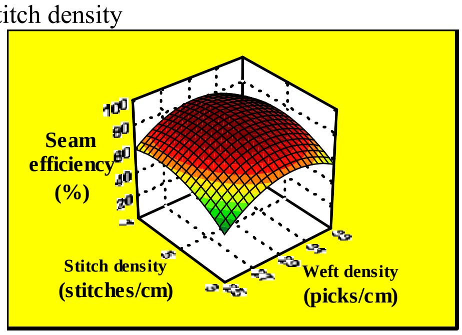

Figure 9: Response surface of seam elongation at different levels of stitch density and weft density for seam of type SSa

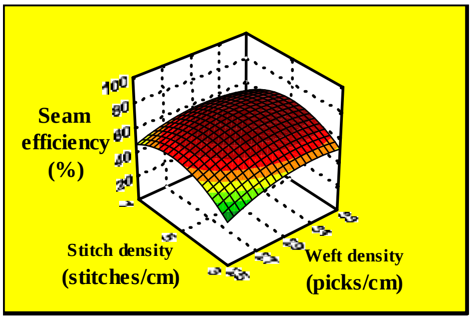

Figure 10: Response surface of seam elongation at different levels of stitch density and weft density for seam of type LSa

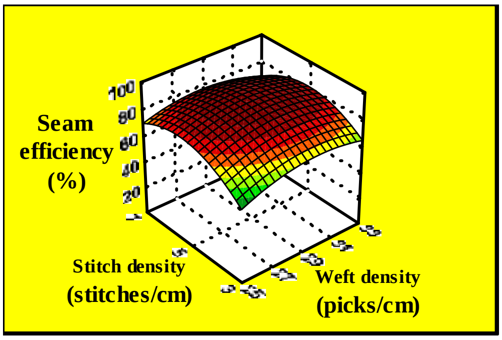

Figure 11: Response surface of seam elongation at different levels of stitch density and weft density for seam of type SSn

The multiple regression model which correlates the efficiency of SSa seam to the independent variables has the following form:

Seam efficiency (%) =-999+65.7*x+40.3 *y -1.1*x^2-0.25*x*y-2.9*y^2

For LSa seam, the relationship between its efficiency and the independent variable is as follows:

Seam efficiency (%) =-506+29.5*x+49*y -0.46*x^2-0.30*x*y-3.9*y^2

While the same relationship for the seam of type SSn has the following form:

Seam efficiency (%) =-519+32.5*x+49.4*y -0.52*x^2-0.33*x*y-3.7*y^2

These models demonstrate a very fit with values of R^2 0.98,0 .99 and 0.99 for the seam of types SSa, LSa and SSn respectively.

Sewing needle penetration force

Figure 12 shows the variation of needle penetration force in SSa and SSn seams according to the weft density of micro polyester of micro polyester fabric. The statistical analysis showed that penetration force has affected significantly by the weft density. It is also proved that the differences between SSa and SSn seams were significant with respect to needle penetration force. The seam of type SSn showed a higher penetration force compared to SSa seam. An increasing trend was detected for both types of seam assuring that as the weft density increases the penetration force reacts in the same manner.

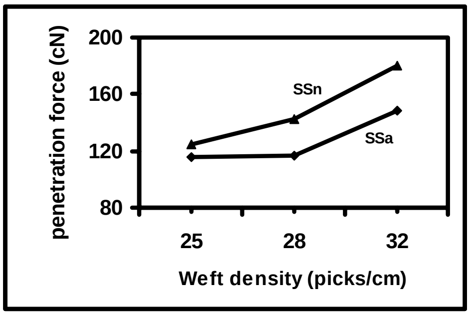

Figure 12: Sewing needle penetration force versus weft density for SSa and SSn seams

It is also apparent that the increasing trend of the penetration force of SSn seam is is more obvious than that belong to SSa seam. Increasing weft density from 25 to 32 picks/cm leads to an increase in penetration force with 29% and 44% for the seam of types SSa and SSn respectively.

The regression relationship which correlates sewing needle penetration force to weft density of micro polyester fabric of the seam SSa has a parabola of the following form:

Penetration force (cN) = $15.743x^2 - 46.358x + 146.26$

Whereas for the seam of type SSn the relationship between sewing needle penetration force and weft density of micro polyester fabrics is as follows:

Penetration force (cN) = $10.5x^2 - 14.5x + 129$

The coefficient of determination for both models equals 0.89 and 0.94 for the seams of type SSa and SSn respectively. These regression models can be used to predict sewing needle penetration force of micro polyester fabric of SSa and SSn seams at different levels of weft density.

Conclusion

In this study, we have shown that weft density of micro polyester fabrics, and stitch density have a significant influence on its sewing properties. It is also proved that micro polyester fabrics which sewn using SSa, LSa and SSn seams differ significantly regarding seam strength, seam elongation and efficiency and penetration force. The statistical analysis showed that the seam of type SSn was superior to the other two seam in relation to sewing properties. Finally, The statistical analysis proved that SSn seam with stitch density 7stitches/cm was found to have the best performance regarding the sewing of micro polyester fabrics.

Corresponding author
Thanaa Mustafa AL Sarhan
Faculty of Art & Design, King Abdul-Aziz University, Jeddah, Kingdom of Saudi Arabia
thanaa12@yahoo.com

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