Investigating the Performance of Sewn Seams from Woven Fabrics

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Research Article

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Abstract

Seam performance ensures the durability, attractiveness, strength etc. of the sewn garments. Fabric types, fabric densities, fabric strength, seam types, sewing thread count, thread strength, stitch densities and stitch types influence the performance of a sewn seam. This paper investigates the performance of sewn seam of various structure of woven fabric. The variables of this research are stitch densities (SPI), sewing thread count, seam types and woven structures. We conduct our research over plain, twill 2/1, twill 2/2, oxford and poplin woven structure. Firstly, we apply lockstitch (301) to produce superimposed, lapped and bound seam on the woven sample by using thread count 27 Tex, 30 Tex, 20/2 Tex, 40 Tex, 40/2 Tex, 40/3 Tex having stitch densities (SPI) 8, 10 and 12. Then according to ASTM D1683 standard, we measured the tensile strength test and recorded the seam breaking strength (N). We apply error bars over each diagram to investigate the standard deviation. Finally, we discuss four hypothesis to conclude our research work. We found higher seam breaking strength with the increase of thread count and SPI. The bound seam samples has shown superior seam breaking strength than superimposed and lapped seam; poplin structure surpassed to others. The seam efficiency of the samples varies from 60–90% and do not exceeds 100%. Finally, we found some significant alternatives hypothesis of the population since F values exceeded F critical values for the sewn seam.

1.0 Introduction

According to British standard BS 3870-2 (1991) and ISO standard ISO 4916 (1991), a seam is produced when a series of stitches are applied on any material irrespective to their number and thickness. Sewn or stitched seams and integral part of garment manufacture and they hold the different components of a garment together to form a three-dimensional shape that a garment is intended to have. Stitches are classified in eight groups which the BS and ISO standards identify as Class 1, 2, 3, 4, 5, 6, 7 and 8. However, industrial literature names them as Superimposed, Lapped, Bound, Flat, Decorative stitching, Edge neatening, ‘Attaching of separate items’, and ‘Single ply construction’ respectively (Carr and Latham, 1995; Smith, 2013). A stitch is defined as a unit of geometrical structure formed by one or more strands or loops of thread by a mechanism of intra-looping, inter-looping or passing into or through material (BS 3870-1, 1991; ISO 4915, 1991). Stitches are divided into six classes, namely: Class 100 (Chain Stitch), Class 200 (Hand Stitch), Class 300 (Lock Stitch), Class 400 (Multi-thread Chain Stitch), Class 500 (Over-edge Chain Stitch) and Class 600 (Covering Chains Stitch), which include further subclasses within each of them. In traditional apparel manufacturing, different sewing threads are used to join fabrics using different configuration of stitches and seams. Sewing threads can be made of different fibre types – natural or synthetic, yarn types -spun, mono or multifilament, twist types -S or Z twist, and different strand configurations – single, double, core-spun etc (Ukponmwan et al., 2000; Sayem and Haider, 2020)

The fineness of sewing thread is usually expresses by ‘Tex’ system or ‘Ticket’ numbers. The Tex system expresses the weight in grams of 1,000 metres of thread, which means higher the Tex number, heavier and thicker the thread. On the hand, Ticket numbering is a commercial system that represents manufacturers’ reference numbers for the size of a given thread. In traditional practice, higher the ticket number, finer the thread.

Textile Fabrics are main component of apparel and have a broad range of classifications and features. Broadly, fabrics are groups in three categories: woven, knitted and non-woven. Woven fabrics consist of mainly two sets of yarns, namely warp and weft, which are interlaced in different pattern patterns and designs commonly known as plain, twill and satin fabrics. There are many possible derivatives of each weave design, which directly influence the properties and behaviour of woven fabrics.

Sewn seam is a function of stitch, thread and fabrics. Different combinations of these produce seam with different performance and behaviour, which have been an interest of academic and industrial research conducted in the past decades. (Usha and Donna, 2006) studied how stitch density affects seam strength, seam elongation and seam efficiency using 100% cotton plain woven fabric of 101 g/m^2. They prepared sewn seams (but did not mention the type of seams) using cotton covered polyester thread (of 32 Tex) at an SPI (stitch per inch) of 6-8, 10-12 and 14-16 and found that seam sewn with 10-12 SPI being the strongest and more efficient and seam with 14-16 SPI had the highest elongation. (Gurarda, 2008) studied seam performance of PET/nylon-elastane plain and twill fabric of 104 gm/m^2(weave design 70/72 x 70/40). Superimposed seams were prepared by using 100% PET sewing thread (ticket number 80 and 140) and it was observed that seams from plain woven fabric had greater performance than that of twill because of denser structure. They also noticed higher seam strength of the seam sewn with thread of 80 ticket number since the sewing thread strength increases with thread size. (B. Kordoghli et al., 2011) explored the mechanical behaviour of superimposed seam of 100% cotton fabric a density of 32 Ends per centimetre (EPCm) and 28 Picks per centimetre (PPCm) after successive treatments such as desizing, scouring, bleaching, dyeing and sueding. The seams both the warp and weft direction were stitched with 32 Ne polyester thread at the stitches per centimetre (SPCm) 3, 5 and 7. The researches have been noticed the breaking strength increased with stitch densities. Moreover, the chemical treatment increased the breaking force significantly whereas reduced the breaking elongation precisely.

(Bulut and Sülar, 2013) compared the performance of superimposed seam made of 100 Cotton plain woven fabric (51 EPCm x 29 PPCm / 14.8 Tex X 14.8 Tex; 122 g/m^2) with and without Polyurathane and silicone coating. Both uncoated and coated fabrics were stitched by 100% PET core spun thread at a SPCm of 5. The findings revealed that the tensile strength of unsewn coated fabrics is stronger than the sewn coated fabrics in both directions. Moreover, coating increased the breaking strength values, rigidity and inflexibility but decreased in the breaking elongation values.

(Choudhary and Goel, 2013) investigated the seam properties of blended 2/1 twill suiting fabrics of 100% Cotton with fibre content of Polyester/Cotton - 65/35 and 15/85 and having a weight of 210 g/m^2 by examining the fabric composition, sewing thread, and needle characteristics. The superimposed seams were made by using polyester/cotton core spun sewing threads of 40, 60, and 80 Tex at the SPI of 10. They noticed that the polyester dominated fabric had low seam strength efficiency, high drape-ability, high rigidity and high puckering with coarser threads (density 1.40g/cc) and low needle thread tension. (Nayak et al., 2013) analysed the sew-ability 2/1 and 3/1 twill denim fabrics by 100% Polyester and 50/50 Polyester/Viscose air-textured sewing threads of ticket number 90. Sewn seam was prepared at SPI 8 using lock stitch machine and found polyester sewing thread resulted in the higher seam efficiency and seam pucker. Besides heavyweight fabric had the highest formability, shear rigidity but the lowest in bending rigidity.

(Vildan et al., 2013) studied on how fabric structure, weft setting and type of sewing thread impact on seam strength, seam elongation, seam efficiency, seam slippage, and seam pucker of cotton and polyester fabrics (plain and 3/1 twill) of different weight ranging between 105 and 190 gm/m^2. The superimposed seam was prepared by using core-spun polyester thread of 45 Tex and mercerized cotton sewing thread of 41 Tex. They detected that the seam strength increased with the increase of weft setting; however, lower efficiency found for the seam of polyester fabric in weft direction.

(Wona and Agnieszka, 2016) identified the impact of lockstitch on various types of lapped seam strength and efficiency over plain and twill fabrics having 45% wool and 55% polyester. The seams were sewn by core spun threads and cut polyester threads and found that fabric structure, fabric thickness and stitch density influenced the seam strength and efficiency significantly.

(Hui et al., 2017) investigated the influence of the modulus of elasticity, elongation at break, tensile strength, breaking strength of seam of four identical types of waterproof fabric samples; coating, film, double-layer composite and denim fabrics. They produced lapped and superimposed seam by using core spun thread (lockstitch 301) at 4 SPCm and found that the denim had the highest seam strength and coating increased the strength but reduced flexural rigidity significantly. Moreover, Lapped seam showed the higher seam breaking strength whereas superimposed seam with five layers had the higher seam efficiency.

(S. Malek et al., 2017) determined the impact of sewing thread's linear density, stitch density and fabric properties on seam strength and efficiency of 3/1 twill fabrics having different fibre content such as 100% cotton, 95% cotton and 5% elastane fabric, and 71% cotton, 24% polyester and 5% elastane. The superimposed seams were made by using 100% PES sewing threads (50, 64 and 95 Tex) at SPCm 3, 4 and 5. Their regression model showed that seam efficiency increased with the increased of sewing thread's linear density and stitch density; elastane (lycra %) increased seam efficiency but polyester content decreased it.

(D. Vijay and Renuka, 2017) analysed the performance behaviour of nylon canopy fabrics i.e. plain (GSM 109), rip top (GSM 100), and 2/1 twill (GSM 104). They prepared the lapped seam (2 rows and 4 rows lockstitch, chain and zigzag) by using nylon sewing thread (ticket number 75) at SPCm 5 and 6 at warp way, 45° bias and weft way direction. The bias direction showed the higher tensile strength and elongation; seam with lockstitch was the weakest; chain stitch was the strongest and zigzag being the middle. However, seam with lockstitch exhibited the highest efficiency. They also decided that the efficiency is basically a cost related factor as the seam efficiency increases the cost of the canopy factor increases.

(Mallika et al., 2017) measured the seam performance of plain-woven shirting fabrics having weights of 110, 130 and 150 g/m^2. They prepared the superimposed seam by using 100% spun polyester sewing thread (of ticket number 40, 60 and 80) at SPI 10, 12 and 14. They found the optimum seam efficiency for the fabrics with 110 g/m^2; most suitable stitch density lied between 13-13.5 and ticket number 40.

This paper aims to extend the contemporary work by investigating the seam performance of five different cotton fabrics sewn with threads of a variety of linear densities and different seam types including bound seam, which had not been studied before.

2.0. Materials And Methodology

2.1: Sample specifications

For the research, we have taken five different types of woven samples based on their weave construction. The specifications of the samples have been given in the table 1.

Table 1: Sample fabric specification

Parameters	Plain	Twill 2/1	Twill 2/2	Oxford	Poplin
EPI	110	65	120	100	100
PPI	65	46	8	50	76
Warp Count	40	10	40	40/2	40/1
Weft Count	40	8	40	30/2	30/1
GSM	132.3	145.5	122.5	149.16	124.16
Fabric Tensile strength, N	190.5	178.6	182.83	285.68	280.25

Table 2: Sampling and other parameters

Seam types	Sewing thread count	SPI	Sample size	Stitch types	No. of samples
Superimposed seam	27 Tex	8	10 x 10	Lockstitch, 301	3
Lapped seam	30 Tex	10			
Bound seam	20/2 Tex	12			
	40 Tex				
	40/2 Tex				
	40/3 Tex				

Table 3: Sewing Thread specification

Thread count	Breaking Strength, cN	Thread Construction	Brand Name
27 Tex	979		
30 Tex	1032	Spun Polyester	A&E
20/2 Tex	1615		
40 Tex	1432		
40/2 Tex	3154		
40/3 Tex	4693		

2.2. Methods

2.2.1. Sample preparation

At first, three samples from all woven fabric in the warp direction were cut; the sample size was 10 cm length and 10 cm width. Then the samples were sewn using the mentioned thread count, various SPI and different types of the seam (superimposed, bound and lapped seam). Here lockstitch, 301 was used to form stitch.

2.2.2. Determination of seam strength test

According to ASTM D1683 standard seam strength of the samples were measured. The force, which has broken the seam of the samples, recorded and considered as the breaking strength of the seam. This method is also known as tensile strength measurement (ASTM D1683, 2018).

2.2.3. Measurement of the efficiency of seam strength

By using following formula, seam efficiency were measured. The formula followed ASTM D1683 method.

$$\text{Seam Efficiency (\%)} = \frac{\textit{Tensile strength of the seam}}{\textit{Fabric tensile strength}} \times 100$$

2.3. Accessories

i. Measuring Tape, ii. GSM Cutter, iii. Scissor

2.4. Machinery

Table 4: Machines specifications

Machine Specification	Lock stitch sewing machine	Tensile Testing Machine
Brand Name	Juki High Speed sewing Machine	Titan Universal Strength Tester
Origin	China	USA
	2500-300 RPM	James Heal
	Stitch class. 300	Test item, strength and efficiency
	Two thread	

2.5. ANOVA test and Hypothesis Analysis

Due to several population groups in the research, we have developed four null hypotheses for the reported benchmark study. We used excel sheet for ANOVA analysis.

Hypothesis 1 No difference will exist between seam strength at various SPI.

Hypothesis 2 No difference will exist between seam strength among various seam types

Hypothesis 3 No difference will exist between fabric strength and seam strength.

Hypothesis 4 No difference will exist between the seam efficiency and stitch density

In this research a multiple numbers of independent variables were used namely as- weave structure, stitch densities, seam types and sewing thread count. On the other hand, seam strength and seam efficiency were dependent variables. Sewing machine, its speed, needle size were used as control.

3.0 Results And Discussion

The seam performance specially seam breaking force, seam efficiency, seam slippage etc. properties depended on the types of weave structure and construction, fabric thickness, sewing thread types and count, seam types, stitch types, stitch densities etc. Thicker structure of fabric increased the seam performance. At the same time, higher sewing thread count, stitch densities increased the performance properties of seam. Polyester based sewing thread also increased the strength of the seam than cotton or blended.

3.1 Effects of different SPI and a fixed count 27 Tex on Super Imposed Seam strength and Efficiency

Figure 3.1 shows the impact of sewing thread 27 Tex and varies SPI over superimposed seam of woven fabrics. From the graph it is clearly seen that the seam breaking strength and efficiency increased significantly for SPI 8 to 10 for all the samples. Seam of poplin fabric had the highest breaking point than others; later plain woven fabric; and oxford fabric had the lowest breaking strength. The main reasons behind thus is the compactness of the structure of poplin and plain woven fabrics than others. Besides, samples of plain fabric reflected the highest seam efficiency and oxford had the lowest. Around 8% seam efficiency increased for twill 2/2 and oxford fabric whereas 3%, 5% and 3% increased efficiency found for plain, twill 2/1 and poplin respectively for higher SPI.

3.2 Effects of different SPI and a fixed count 27 Tex on Lapped Seam strength and efficiency

The impact of 27 Tex over lapped seam of various woven samples at SPI 8, 10 and 12 had been determined (figure 3.2). The seam breaking strength and efficiency significantly increased while increased in stitch densities. The sequence of breaking strength starts with poplin, plain, twill 2/1, twill 2/2 and oxford. Therefore, plain and twill 2/1 samples had higher seam efficiency; oxford had the lowest value. SPI 10 had the highest seam efficiency than other stitch densities.

3.3 Effects of different SPI and a fixed count 27 Tex on Bound Seam strength and efficiency

The seam breaking strength and efficiency of 27 Tex over bound seam had measured at various SPI (figure 3.3). The dense structure of poplin fabric required higher breaking force to break the seam (176.9N to 201.2N); 151.5-160.1, 135.1-148, 109.2-121.4 and 108.9-114.6 N for plain, twill 2/1, twill 2/2 and oxford fabric respectively at various SPI. The seam efficiency increased 5%, 7%, 6%, 2% and 8% for plain, twill 2/1, twill 2/2, oxford and poplin at SPI 8 to 12.

3.4 Effects of different SPI and a fixed count 30 Tex on Super Imposed Seam strength and efficiency

The superimposed seam impact of 30 Tex at various SPI over different woven fabric had been measured (figure 3.4). The poplin fabric had the highest seam breaking force whereas oxford had the lowest but increased significant amount than before. Around 8%, 6%, 5%, 5% and 3% higher seam efficiency noticed for twill 2/1, oxford, twill 2/2, plain and poplin fabric respectively considering the increased of SPI.

3.5 Effects of different SPI and a fixed count 30 Tex on Lapped Seam strength and efficiency

From figure 3.5, a more significant breaking force were recorded for lapped seam case, samples of poplin had the highest seam breaking load (194-202.9 N); 150.1-157.2N, 140.7-155.5 N, 117.6-127.5 N and 114.9-119.1 N for plain, twill 2/1, twill 2/2 and oxford respectively at SPI 8-12. Besides, Once again, higher seam efficiency tendency has been determined with increased in stitch densities. Around 5%, 4%, 3%, 3% and 2% better increased efficiency determined for twill 2/2, plain, twill 2/1, poplin and oxford fabric samples respectively.

3.6 Effects of different SPI and a fixed count 30 Tex on Bound Seam strength and efficiency

A more effective seam breaking strength and efficiency had been measured in case of bound seam (figure 3.6); around 15 N, 8 N, 15 N, 8 N and 5 N higher seam strength found for poplin, plain, twill 2/1, twill 2/2 and oxford samples sewn with SPI 8-12 respectively. Interestingly, twill 2/2 had the highest seam efficiency and oxford had the lowest seam efficiency.

3.7 Effects of different SPI and a fixed count 20/2 Tex on Super Imposed Seam strength and efficiency

A coarser sewing thread increased the overall performance of the seam for all except poplin (figure 3.7). Due to the dense construction, samples from poplin fabric required higher load to break the load. Approximately, 10N, 16N and11N extra load is required if the stitch density increased from 8 to 12 for superimposed seam of plain, twill 2/1 and twill 2/2 respectively. Unexpectedly, breaking strength decreased for poplin fabric for higher stitch densities and oxford samples showed negative for SPI 12 only.

3.8 Effects of different SPI and a fixed count 20/2 Tex on Lapped Seam strength and efficiency

For lapped seam case, similarly a higher tendency of increased breaking load had been observed with the increased of SPI. This time very little amount of excess load is required with the increased stitch densities except twill 2/1 samples. Around extra 6N, 10N, 4N and 5N was required to break seam for plain, twill 2/2, oxford and poplin samples. Similarly, a little increased efficiency was observed for all the case.

3.9 Effects of different SPI and a fixed count 20/2 Tex on Bound Seam strength and efficiency

According to the figure 3.9, more increased properties required to break the bound seam with the increased of stitch densities, however, very poor values had recorded for the samples of plain, oxford and poplin fabric. Approximately 9N and 16N extra load was required to break twill 2/1 and twill 2/2 respectively. Twill 2/1 had shown the highest seam efficiency then plain>poplin>twill 2/2>oxford fabric.

3.10 Effects of different SPI and a fixed count 40 Tex on Super Imposed Seam strength and efficiency

A significant amount of seam strength has been noticed for superimposed seam when stitched with 40 Tex. About 28N and 19N of excess breaking load had required to break the twill 2/2 and oxford fabric whereas 5N, 11N and 3N excess load was required for plain, twill 2/1 and poplin fabric. Therefore, twill 2/1 had the highest seam efficiency whereas seam efficiency recorded as plain>twill 2/2>oxford>poplin.

3.11 Effects of different SPI and a fixed count 40 Tex on Lapped Seam strength and efficiency

From the figure 3.11, the tendency of higher seam strength and efficiency has been determined for lapped seam than superimposed seam. Poplin and twill 2/2 fabric sample had shown the higher seam strength than others where it’s seam strength increased by 29N for changed in stitch densities. Approximately 8N, 11N and 17N seam breaking force increased for poplin, twill 2/1 and oxford fabric respectively. Besides, around 5%, 6%, 16%, 6% and 10% seam efficiency increased for SPI 8 to 12 for plain, twill 2/, twill 2/2, oxford and poplin fabric respectively.

3.12 Effects of different SPI and a fixed count 40 Tex on Bound Seam strength and efficiency

Bound seam has also shown the highest increased breaking load and efficiency for mostly woven samples for 40Tex than other types of sewn seam. As generally poplin and twill 2/2 has the highest seam breaking force (around 25N). Around 5N, 6N and 15N extra load is required for plain, twill 2/1 and oxford design samples with higher increased stitch densities. Therefore, 5%, 3%, 13%, 5% and 8% more seam efficiency recorded when it was subjected to increased densities.

3.13 Effects of different SPI and a fixed count 40/2 Tex on Super Imposed Seam strength and efficiency

Samples from oxford weave had shown the highest increased seam breaking strength (around 50N) for higher stitch densities than others. Twill 2/2 fabric had moderate seam breaking strength with the increased of densities (22N). Around 5N, 9N and 7N excess load was required to break for higher stitch densities for plain, twill 2/1 and poplin samples respectively. Similarly, seam efficiency increased with increased in stitch densities; approximately 3%, 5%, 18%, 17% and 2% better seam efficiency found for plain, twill 2/1, twill 2/2, oxford and poplin fabric respectively.

3.14 Effects of different SPI and a fixed count 40/2 Tex on Lapped Seam strength and efficiency

Sewing thread count 40/2 Tex had a moderate increased seam breaking force and efficiency for higher stitch densities except twill 2/2 (37N) and oxford (29N), since the samples had significant development of seam breaking property for changed in SPI from 8 to 12. Others had moderate impact. Similarly, twill 2/2 and oxford fabric samples of lapped seam had seen the highest improved seam efficiency.

3.15 Effects of different SPI and a fixed count 40/2 Tex on Bound Seam strength and efficiency

For bound seam sewn with 40/2 Tex, each samples had a significant improved in breaking strength and efficiency with SPI. The highest breaking load and efficiency determined after increased SPI for poplin (34N) and twill 2/2 (15%) respectively.

3.16 Effects of different SPI and a fixed count 40/3 Tex on Super Imposed Seam strength and efficiency

The overall seam strength and efficiency had increased with the increase of thread count and SPI, however, at some point performance properties fall down. It is observed that the performance property significantly improved for the samples of twill 2/2, poplin and oxford where breaking strength improved compared to any cases. Therefore, plain, twill 2/1, twill 2/2, oxford and poplin fabric samples had improved breaking strength by 5N, 10N, 34N, 64N and 43N respectively. Moreover, 31%, 22%, 28%, 6% and 2% seam efficiency increased with the increased of SPI for oxford, twill 2/2, poplin, twill 2/1 and plain fabric respectively.

3.17 Effects of different SPI and a fixed count 40/3 Tex on Lapped Seam strength and efficiency

Until now, 40/3 Tex had more efficient and improved properties than others thread count and the impact is more significant for twill 2/2, oxford and poplin fabric case. Around 55N, 58N, 46N, 9N and 4N breaking load required to break the seam with the increased SPI. Besides, significant amount of seam efficiency recorded and overall improved compared to others.

3.18 Effects of different SPI and a fixed count 40/3 Tex on Bound Seam strength and efficiency

From the figure 3.18, more significant values of seam performance had been measured with the increased of stitch densities. It is aimed that both the properties like seam breaking strength and efficiency significantly rise with the SPI at this higher thread count. More precise impact had been determined by the samples of poplin, oxford and twill 2/2 samples.

4.0 Anova Test And Hypothesis Analysis

4.1. General discussion

The f value is the ratio of two mean square values and compares the joint effect of all the variable together. If f value is closer to 1 then the null hypothesis is true, there exists no alternatives. However, f value greater than 1 rejects the null hypothesis. But if any f value in a table found greater than f critical value indicates that there exists something significant and possibilities of alternatives hypothesis.

The p-value signifies the probability of a statistical hypothesis test where $p>0.05$ indicates that the null hypothesis is true, no alternatives exists and not strong enough to suggest an effect on the population. If $p\leq0.05$ defines the test hypothesis is false or should be rejected for entire population and there exists alternative hypothesis.

T-value is the calculated differences in units of standard error. The greater the magnitude of t-value, the greater the evidence against the null hypothesis, the hypothesis can be rejected and there exists significant difference. The closer t value is to 0, the more likely there isn't a significant difference and hypothesis can be accepted. The larger the t value the smaller the p value (i.e. the most significant data).

4.2. Hypotheses analysis

Hypothesis 1 No difference will exist between seam strength at various SPI.

From the analysis of variance (ANOVA) seam strength were found significant for three stitch densities in warp direction ($p < 0.05$) (see table 5, 6, 7). Thus, the null hypothesis can be rejected and there might have alternatives hypothesis.

The f value for plain, twill 2/1, twill 2/2 and oxford found lower than f critical value, however, f value for poplin fabric samples exceeds the f critical value. Thus, there exists something significant and possibilities of alternative hypothesis (see table 5, 6, 7). The larger the t value the smaller the p value (i.e. the most significant data) (see table 5, 6, 7).

There existed no previous work compared seam strength for various stitch densities, so, no comparison could be made. Further review of data revealed that Bound seam at SPI 12 with thread count 40/3 found the strongest and there existed significant differences among groups.

Table 5: Mean, standard deviation, and F-values for seam strength at SPI 8

Parameters	Mean	Standard Deviation	t-value	p-value	F-value	F critical
Plain						
SPI 8					**1.353**	
Super Imposed	153.4367	8.056634	0.000155	0.00000132		4.964603
Lapped Seam	155.09	8.044532	0.000191	0.00000197		4.964603
Bound Seam	161.1867	7.215508	0.000283	0.00000415		4.964603
Twill 2/1						
SPI 8					**1.033**	
Super Imposed	144.2667	10.08062	0.000635	0.0000189		4.964603
Lapped Seam	148.2517	9.673177	0.00093	0.0000381		4.964603
Bound Seam	153.39	10.2765	0.002804	0.000277		4.964603
Twill 2/2						
SPI 8					**1.507**	
Super Imposed	127.9167	7.26072	0.000013847	0.000000012		4.964603
Lapped Seam	119.6667	6.750226	0.00000487	0.00000000153		4.964603
Bound Seam	123.7833	8.251751	0.000018	0.00000002		4.964603
Oxford						
SPI 8					**2.091**	
Super Imposed	133.1167	6.571998	0.000003422	0.00000000076		4.964603
Lapped Seam	118.7333	5.447544	0.000000076	0.00000000000039		4.964603
Bound Seam	122.8167	7.190815	0.000000276	0.0000000000512		4.964603

Poplin						
SPI 8					**7.20381**	
Super Imposed	174.8333	11.66786	0.000005596	0.000000002		4.964603
Lapped Seam	202.6666667	18.34590478	0.000225	0.00000268		4.964603
Bound Seam	214.3667	19.57104	0.000659	0.0000202		4.964603

Table 6: Mean, standard deviation, and F-values for seam strength at SPI 10

Parameters	Mean	Standard Deviation	t-value	p-value	F-value	f-critical
Plain						
SPI 10					**1.31**	
Super Imposed	157.3333	7.940963	0.000246	0.00000318		4.964603
Lapped Seam	160.625	6.800965	0.000196	0.00000206		4.964603
Bound Seam	164.3167	5.243223	0.00011	0.000000677		4.964603
Twill 2/1						
SPI 10					**0.955**	
Super Imposed	150.84	9.149135	0.001087	0.0000508		4.964603
Lapped Seam	153.5017	7.471435	0.000689	0.000022		4.964603
Bound Seam	157.76	6.987942	0.001199	0.0000607		4.964603
Twill 2/2						
SPI 10					**0.305**	
Super Imposed	136.3833	13.26102	0.000564	0.0000152		4.964603
Lapped Seam	130.6167	15.70514	0.000332	0.00000561		4.964603
Bound Seam	138.0833	18.09341	0.00051	0.0000126		4.964603
Oxford						
SPI 10					**0.915**	
Super Imposed	139.7333	19.49373	0.000014	0.0000000123		4.964603
Lapped Seam	126.2333	12.8435	0.00000115	0.0000000000879		4.964603
Bound Seam	130.0833	15.64549	0.00000345	0.000000000774		4.964603
Poplin						
SPI 10					**9.55**	
Super Imposed	176.2167	11.06969	0.000004613	0.00000000138		4.964603

Lapped Seam	212.25	19.43431	0.00055	0.0000145	4.964603
Bound Seam	224.5	22.05168	0.002417	0.000213	4.964603

Table 7: Mean, standard deviation, and F-values for seam strength at SPI 12

Parameters	Mean	Standard Deviation	t-value	p-values	F-value	f-critical
Plain						
SPI 12					**1.314**	
Super Imposed	160.3705	7.20149	0.000246	0.00000318		4.964603
Lapped Seam	162.8833	5.841066	0.00014	0.00000109		4.964603
Bound Seam	166.4895	4.362524	0.0000071	0.000000293		4.964603
Twill 2/1						
SPI 12					**0.765**	
Super Imposed	155.6933	9.599352	0.003173	0.000344		4.964603
Lapped Seam	159.61	8.23447	0.00371	0.000451		4.964603
Bound Seam	162.2117	6.92919	0.00337	0.000382		4.964603
Twill 2/2						
SPI 12					**0.052**	
Super Imposed	147.85	15.21247	0.003674	0.000444		4.964603
Lapped Seam	144.0833	19.64225	0.006988	0.001324		4.964603
Bound Seam	146.4833	20.91143	0.011617	0.003048		4.964603
Oxford						
SPI 12					**0.943**	
Super Imposed	161.445	32.93876	0.000385	0.00000742		4.964603
Lapped Seam	138.4567	26.47302	0.00005983	0.00000021		4.964603
Bound Seam	140.9217	27.31266	0.0000756	0.000000331		4.964603
Poplin						
SPI 12					**6.093**	
Super Imposed	182.85	22.1357	0.000186	0.00000186		4.964603
Lapped Seam	226.85	29.52196	0.0099	0.002352		4.964603
Bound Seam	238.6017	27.60384	0.019856	0.007103		4.964603

Hypothesis 2 No difference will exist between seam strength among various seam types

From the analysis of variance (ANOVA) seam strength were found significant for six types of sewing thread for all three seam types ($p<0.05$) except thread count 40/3 for twill 2/2 for all seam types and poplin for Lapped and Bound seam case (see table 8, 9, 10). Thus, the null hypothesis is true and no alternative exists for those cases.

Further, f value for plain fabric for all seam types and twill 2/1 samples for superimposed and bound seam exceeds f critical values. Others remain between f critical values (see table 8, 9, 10). Thus, there exists something significant and possibilities of alternatives hypothesis for those. Others can reject the null hypothesis and exists no alternatives.

Due to the lack of previous published work, no comparison can be made out.

Table 8: Mean, standard deviation, and F-values for seam strength over superimposed seam

Parameters	Mean	Standard Deviation	t-value	p-values	F-value	f-critical
Plain					**16.07**	
27 Tex	142.79	2.237307	0.001317	**0.0000104**		7.708647
30 Tex	151.903	4.080771	0.005873	0.000203		7.708647
20/2 Tex	156.9	3.914929	0.007153	0.000299		7.708647
40 Tex	162.333	1.780137	0.002617	0.000407		7.708647
40/2 Tex	163.413	2.165369	0.003854	0.0000879		7.708647
40/3 Tex	164.933	1.717233	0.003007	0.0000537		7.708647
Twill 2/1					9.03	
27 Tex	133	3.616776	0.003369	0.0000673		7.708647
30 Tex	143.7	5.477834	0.01249	0.000895		7.708647
20/2 Tex	149.5333	6.96866	0.028101	0.004289		7.708647
40 Tex	156.9	4.554119	0.022314	0.002759		7.708647
40/2 Tex	158.7333	3.166842	0.013686	0.00107		7.708647
40/3 Tex	159.7333	4.120949	0.024341	0.00326		7.708647
Twill 2/2					3.634	
27 Tex	122.0667	5.876129	0.004777	0.000135		7.708647
30 Tex	129.3333	4.261716	0.003331	0.0000658		7.708647
20/2 Tex	132.0667	4.192321	0.003585	**0.0000761**		7.708647
40 Tex	141.1667	11.95668	0.039055	0.007982		7.708647
40/2 Tex	141.2667	9.642729	0.02614	0.003736		7.708647
40/3 Tex	158.4	14.67469	0.143293	0.07861		7.708647
Oxford					4.863	
27 Tex	114.0333	9.940601	0.00169	**0.000017**		7.708647
30 Tex	128.4333	6.537754	0.000883	0.00000467		7.708647
20/2 Tex	134.6667	2.159218	0.000124	0.0000000924		7.708647
40 Tex	146.8667	8.805806	0.002032	0.0000246		7.708647
40/2 Tex	168.1333	21.50028	0.016354	0.001513		7.708647

40/3 Tex	176.4567	26.89599	0.029045	0.004567		7.708647
Poplin					5.657	
27 Tex	159.5667	3.62062	0.000484	**0.0000014**		7.708647
30 Tex	168.6333	3.869826	0.000641	0.00000246		7.708647
20/2 Tex	173.8	9.189487	0.003749	0.0000432		7.708647
40 Tex	177.4	2.325224	0.000303	0.000000549		7.708647
40/2 Tex	185.9333	2.372528	0.000372	0.000000831		7.708647
40/3 Tex	202.4667	18.44313	0.027054	0.003989		7.708647

Table 9: Mean, standard deviation, and F-values for seam strength over lapped seam

Parameters	Mean	Standard Deviation	t-value	p-values	F-value	f-critical
Plain					**9.43**	
27 Tex	147.7967	5.375998	0.008099	0.000382		7.708647
30 Tex	154	2.765261	0.003229	0.0000618		7.708647
20/2 Tex	158.5667	2.851121	0.004446	0.000117		7.708647
40 Tex	163.5333	3.2968	0.008062	0.000379		7.708647
40/2 Tex	166.0333	3.126588	0.008881	0.000458		7.708647
40/3 Tex	167.2667	1.344949	0.002592	0.0000399		7.708647
Twill 2/1					6.977	
27 Tex	137.9267	4.945761	0.007607	0.000338		7.708647
30 Tex	148.7	6.070146	0.020518	0.002347		7.708647
20/2 Tex	153.8	4.91596	0.019852	0.002202		7.708647
40 Tex	159.4667	4.550702	0.028393	0.004374		7.708647
40/2 Tex	160.9333	4.191526	0.028482	0.0044		7.708647
40/3 Tex	161.9	3.650571	0.024736	0.003362		7.708647
Twill 2/2					3.017	
27 Tex	113	5.468699	0.003154	0.000059		7.708647
30 Tex	122.0333	3.983577	0.002274	0.0000308		7.708647
20/2 Tex	125.8	4.022437	0.002631	**0.0000411**		7.708647
40 Tex	134.3	12.43302	0.031478	0.00532		7.708647
40/2 Tex	138.1	16.29499	0.060613	0.017921		7.708647
40/3 Tex	155.5	19.50761	0.186433	0.118978		7.708647
Oxford					4.314	
27 Tex	111.4133	2.897877	0.000155	**0.000000143**		7.708647
30 Tex	117.1333	1.405545	0.0000524	0.000000165		7.708647
20/2 Tex	116.9667	1.078064	0.000038	0.00000000865		7.708647
40 Tex	126.2	7.248448	0.001051	0.0000066		7.708647
40/2 Tex	138.4	11.57267	0.003096	0.0000569		7.708647

40/3 Tex	156.7333	24.46499	0.017555	0.001736		7.708647
Poplin					7.649	
27 Tex	177.0667	8.515215	0.003434	**0.0000699**		7.708647
30 Tex	198.9667	3.568691	0.001038	0.00000644		7.708647
20/2 Tex	209.7667	3.386575	0.001253	0.00000937		7.708647
40 Tex	223.0333	12.27527	0.022391	0.002777		7.708647
40/2 Tex	230.6333	11.16015	0.024564	0.003317		7.708647
40/3 Tex	244.0667	22.86195	0.15484	0.089004		7.708647

Table 10: Mean, standard deviation, and F-values for seam strength bound seam

Parameters	Mean	Standard Deviation	t-value	p-values	F-value	f-critical
Plain					**12.01**	
27 Tex	156.4857	3.477075	0.005609	0.000185		7.708647
30 Tex	157.2333	3.20347	0.00505	0.00015		7.708647
20/2 Tex	163.4667	2.710883	0.005664	0.000189		7.708647
40 Tex	165.7	1.74547	0.003274	0.0000635		7.708647
40/2 Tex	169.6	0.852447	0.001971	0.0000231		7.708647
40/3 Tex	171.5	Error	0.00012	0.0000000864		7.708647
Twill 2/1						
27 Tex	142.19	5.272817	0.010689	0.00066	9.571	7.708647
30 Tex	153.0333	6.047773	0.02756	0.004133		7.708647
20/2 Tex	158.9667	3.749074	0.018975	0.002018		7.708647
40 Tex	163.5667	1.874981	0.009843	0.000561		7.708647
40/2 Tex	164.0333	2.239544	0.013881	0.0011		7.708647
40/3 Tex	164.9333	2.239544	0.015725	0.001402		7.708647
Twill 2/2					4.495	
27 Tex	115.8667	4.944582	0.002826	0.0000474		7.708647
30 Tex	124.5667	3.216969	0.001667	0.0000166		7.708647
20/2 Tex	130.5333	6.294089	0.007344	0.000315		7.708647
40 Tex	134.9333	10.5522	0.023622	0.003078		7.708647
40/2 Tex	147.8667	12.47379	0.058488	0.0168		7.708647
40/3 Tex	162.9333	20.44021	0.302913	0.241133		7.708647
Oxford					6.48	
27 Tex	112.3867	2.280721	0.000103	**0.0000000639**		7.708647
30 Tex	118.6233	1.81432	0.0000769	0.0000000355		7.708647
20/2 Tex	120.7667	Error	0.0000183	0.00000000201		7.708647
40 Tex	128.6667	6.564721	0.000893	0.00000477		7.708647
40/2 Tex	143.5333	12.34135	0.003772	0.0000842		7.708647

40/3 Tex	163.6667	21.66108	0.015428	0.001351		7.708647
Poplin					7.615	
27 Tex	188.4367	9.912653	0.005836	0.0002		7.708647
30 Tex	210.2	5.891236	0.003619	0.0000775		7.708647
20/2 Tex	220.5667	2.280838	0.000869	0.00000452		7.708647
40 Tex	232.7333	11.3884	0.027744	0.004186		7.708647
40/2 Tex	248.1667	13.96957	0.083516	0.031684		7.708647
40/3 Tex	243.15	26.55791	0.162	0.643567		7.708647

Hypothesis 3 No difference will exist between fabric strength and seam strength.

The findings further revealed that fabric was significantly stronger than the seam strength for every case. Thus, the null hypothesis can be rejected and there existed no alternatives. However, comparison cannot make due to the lack of previous data.

Hypothesis 4 No difference will exist between the seam efficiency and stitch density

According to Amoco Fabrics and Fibres Company, seam efficiency varies between 60-90%. From our test no seam efficiency did approach or exceed 100% rather than lies between the stipulated ranges mostly. The highest seam efficiency was observed for bound seam of poplin fabric samples at SPI 12 stitched with sewing thread count 40/3.

4.3 Findings

We have noted the following findings from the discussion-

1. The seam breaking strength increased with the increase of SPI and thread count for all types of woven fabric though poplin fabric have shown higher breaking strength than others have.
2. Highest seam strength was observed on bound seam of poplin fabric at higher SPI.
3. Error bars have shown higher standard deviation for the tested samples.
4. F-value exceeds F-critical values (at hypothesis-1) for poplin fabrics, which indicates presence of alternative significant hypothesis on the population.
5. F-value exceeds than F-critical value for all seam types of plain fabric; twill 2/1 for superimposed and bound seam case (hypothesis-2). Thus, showing alternatives hypothesis for those on the population.
6. There existed no alternatives hypothesis between fabric strength and seam strength (Hypothesis-3).

5.0 Conclusion

Seam has a great influence on the performance property of garments. Seam types, stitch types, stitch densities, sewing thread count and fabric structure affects the quality and the appearance of garments. That’s why those should be selected according to the exact requirements to get optimum performance. In this study, we worked on multiple factors like fabric structure, SPI, sewing thread count and seam types. We found the higher seam breaking strength is required with the SPI and thread count. Therefore, bound seam required higher breaking force to break than superimposed and lapped seam. Poplin fabrics has shown highest increase of breaking strength with increase of other parameters. The error bars showing the less precession on the results and higher standard deviation of the population. The significant number of alternatives hypothesis was found during hypothesis analysis. Unfortunately, having no previous published work, we cannot made comparison of our findings that is considered the only limitation of the work.

This work can be recognized as a novel work by the researcher. The researcher have studied multiple criteria of the sewn seam performance along with bound seam, which have not yet analysed. The outcome of this research will grow interest to the factory practitioners and researchers to make especial attention over the performance of sewn seam study over woven fabrics.

Declarations

The article is based on original research work and implies that the work has not published previously and not under consideration for publication to elsewhere. Moreover, there is no conflict on ethical issues while conducting the research. Further, no animals were harmed during the research work.

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Conflicts of interest/Competing interests: There is no conflict of interest of the research work as there is no relationship of commercial, legal, or professional relationship with other organizations.

Availability of data and material: The data and table included in this manuscript is design by the author and nothing taken from any other source or previous publish work.

Code availability: To draw the figure and table, author used Microsoft word document. For hypothesis analysis and formation of data on table 5 to 10, author used formula of ANOVA test in excel sheet and taken value for the test.

Authors Contribution (Single author)

Md. Shamsuzzaman: Conceptualization, Methodology, Data collection and investigation, Original draft preparation, Validation, Manuscript Editing and Reviewing.

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Figures

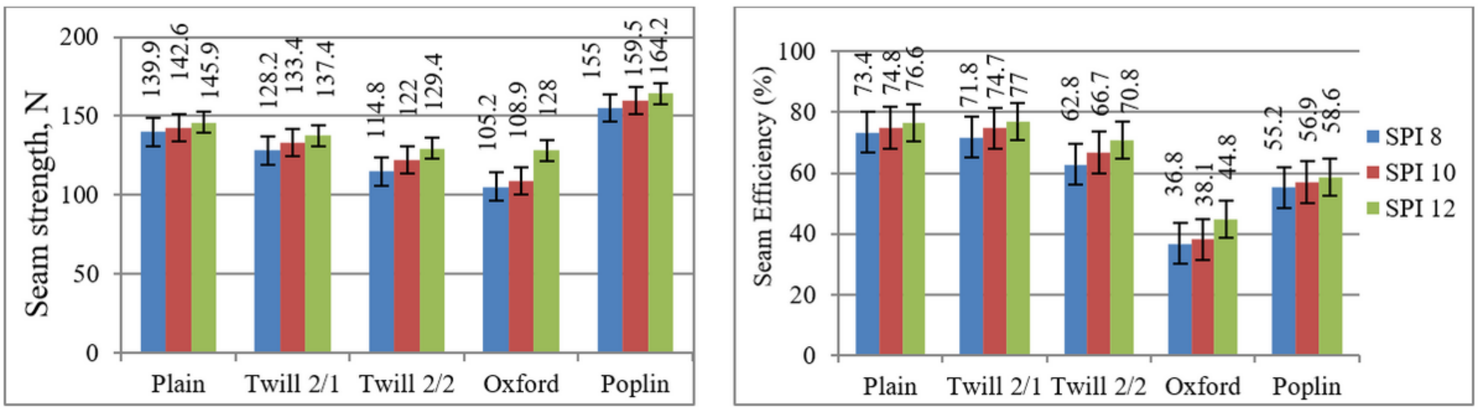

Figure 1

Impact of 27 Tex at varies SPI over super imposed seam strength and efficiency

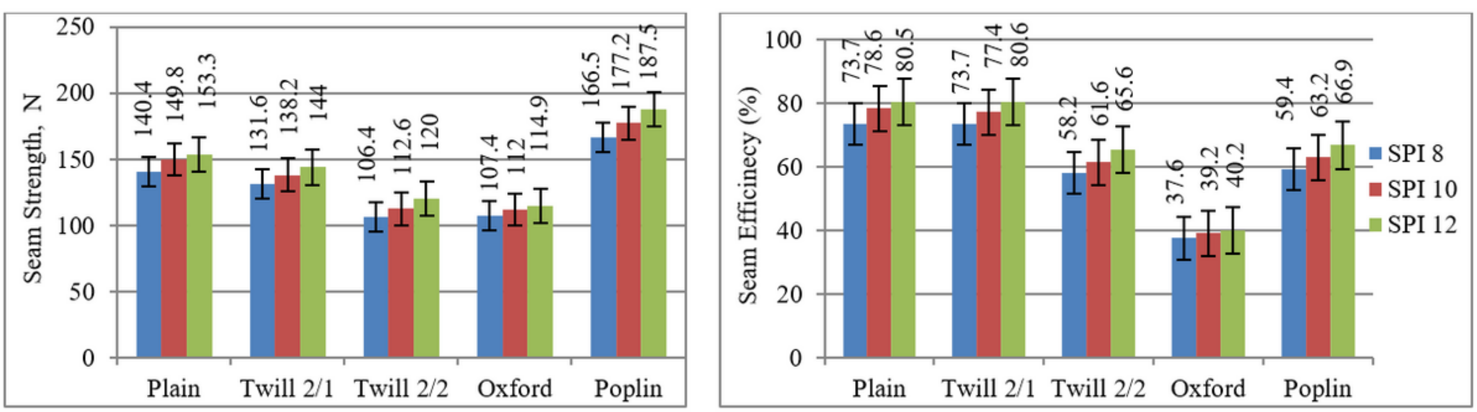

Figure 2

Impact of 27 Tex at varies SPI over lapped seam strength and efficiency

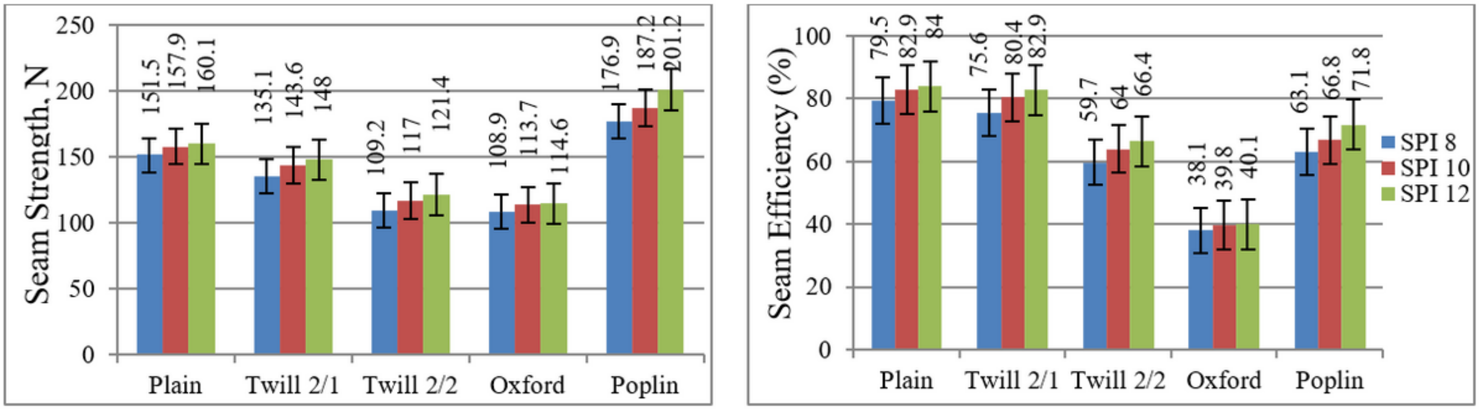

Figure 3

Impact of 27 Tex at varies SPI over bound seam strength and efficiency

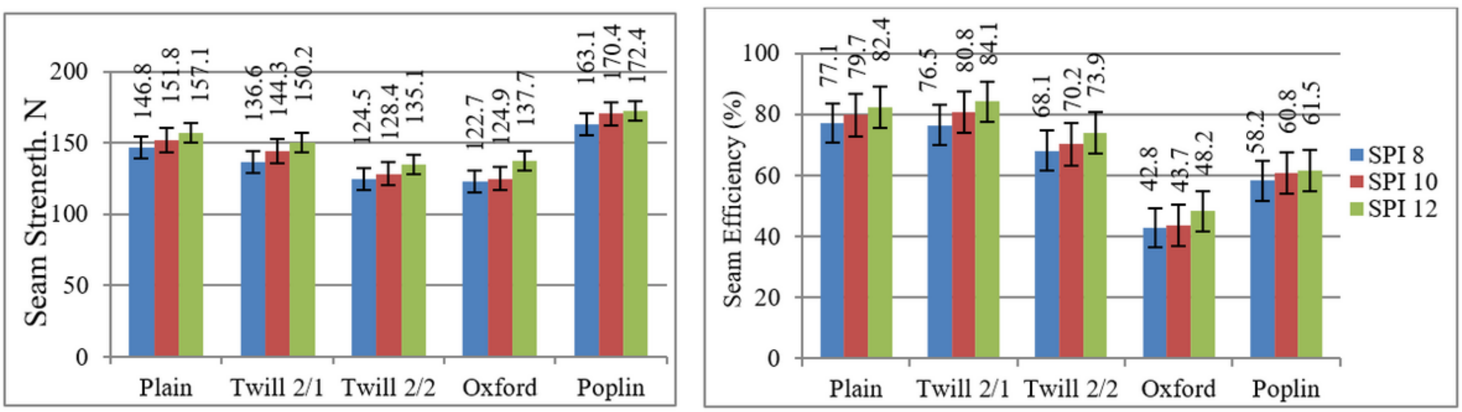

Figure 4

Impact of 30 Tex at varies SPI over Super Imposed seam strength and efficiency

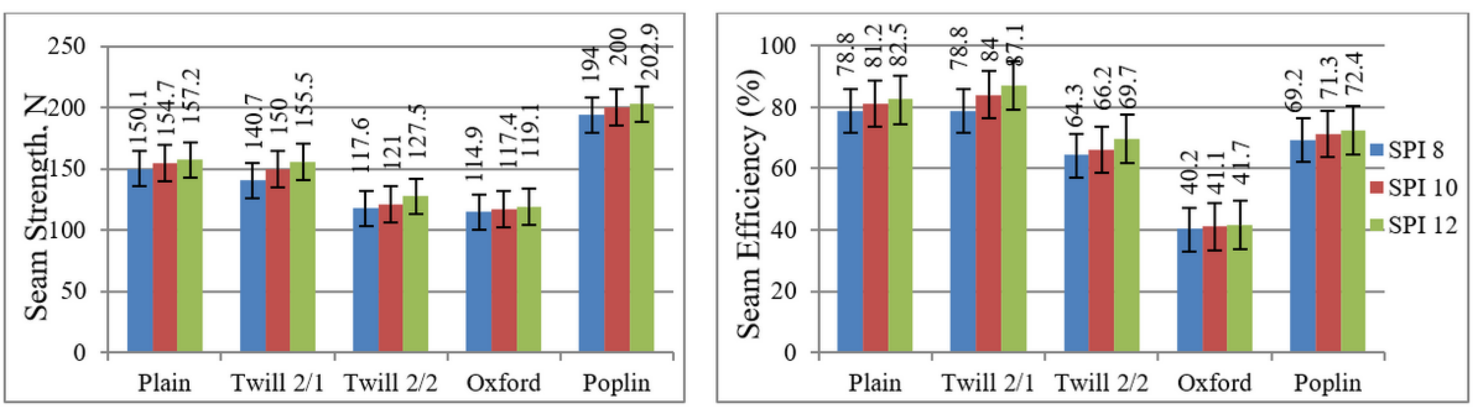

Figure 5

Impact of 30 Tex at varies SPI over Lapped seam strength and efficiency

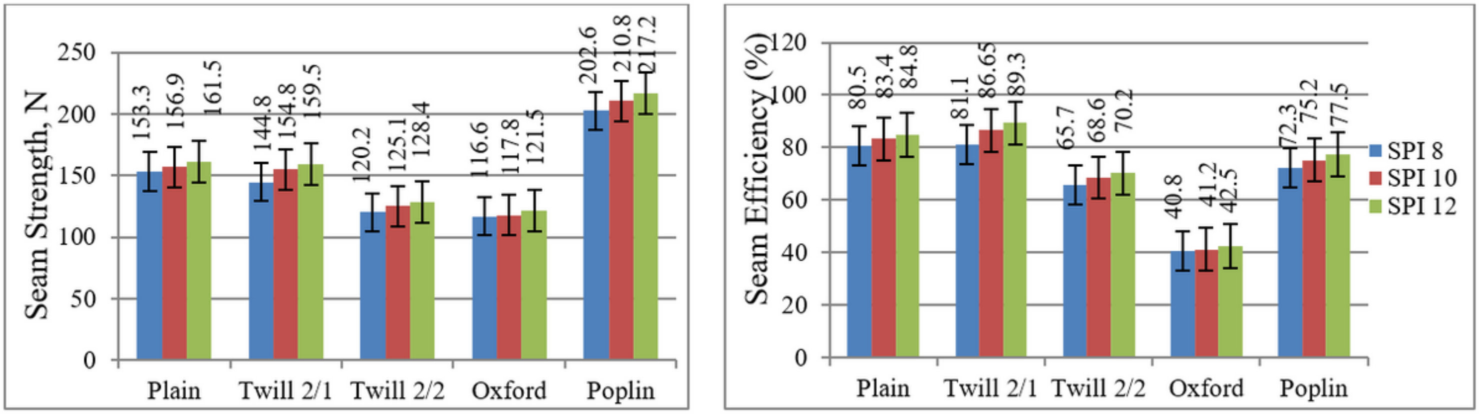

Figure 6

Impact of 30 Tex at varies SPI over Bound seam strength and efficiency

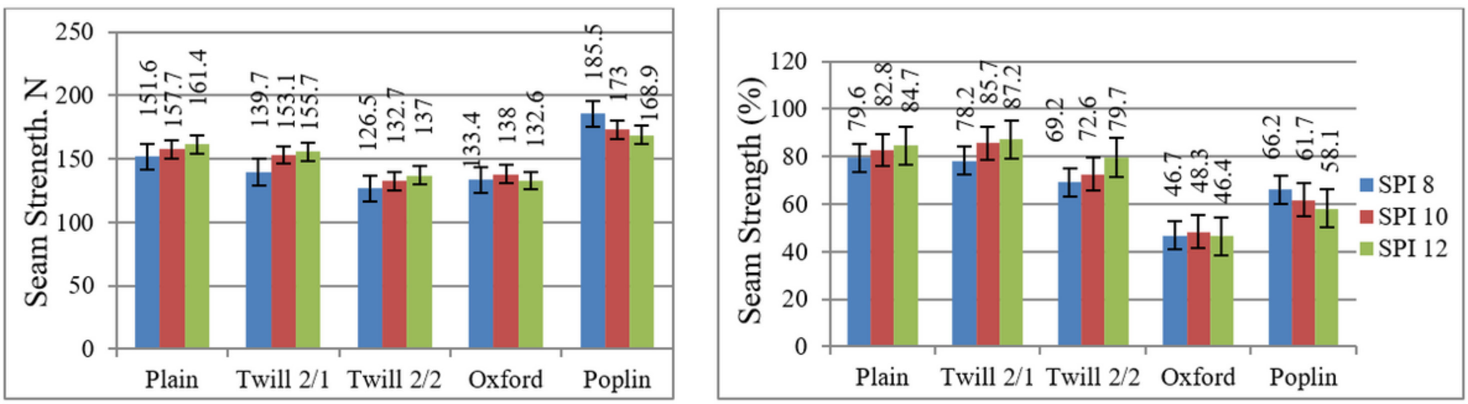

Figure 7

Impact of 20/2 Tex at varies SPI over Super Imposed seam strength and efficiency

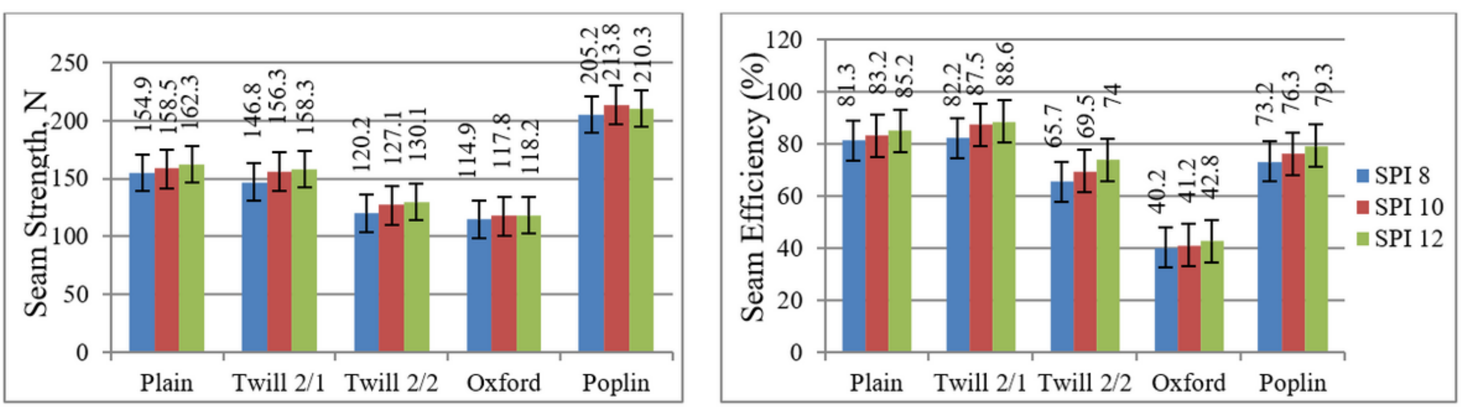

Figure 8

Impact of 20/2 Tex at varies SPI over Lapped seam strength and efficiency

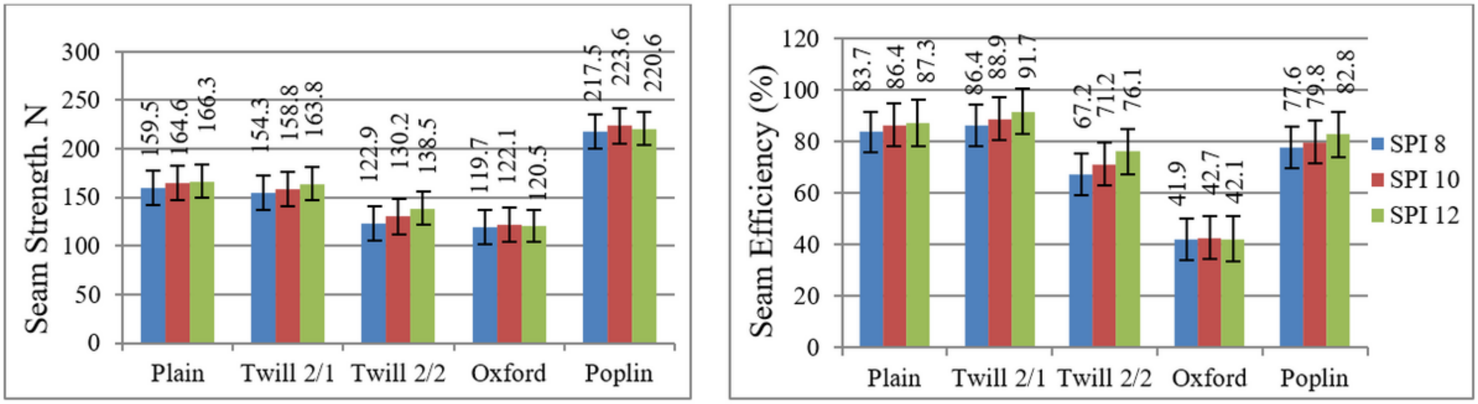

Figure 9

Impact of 20/2 Tex at varies SPI over Bound seam strength and efficiency

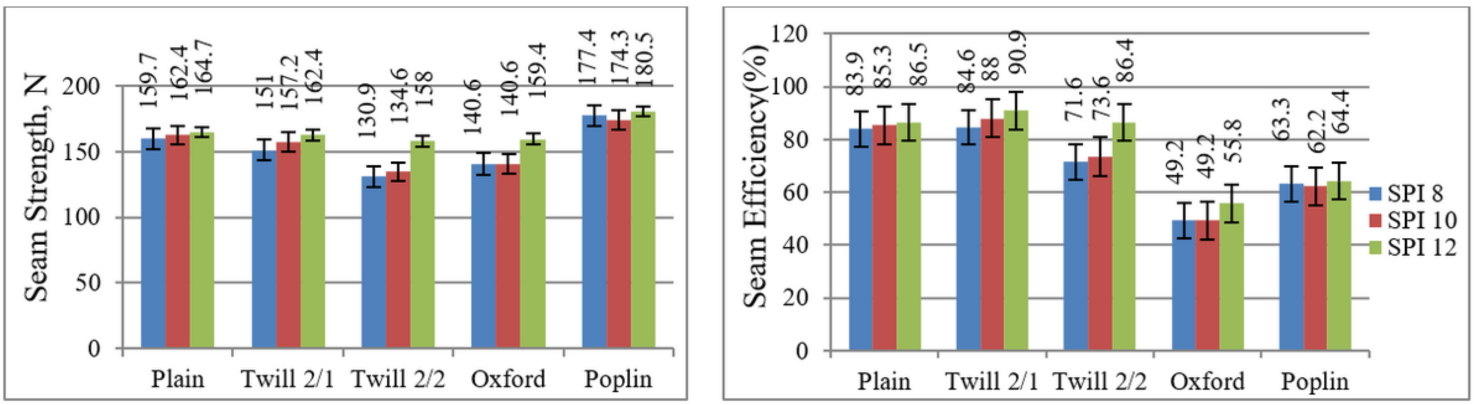

Figure 10

Impact of 40 Tex at varies SPI over Super Imposed seam strength and efficiency

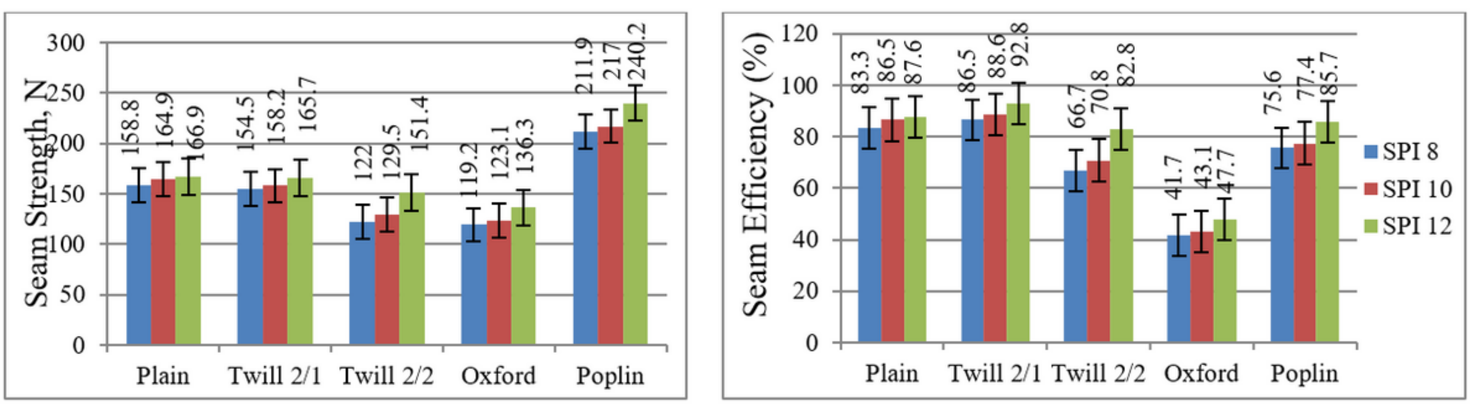

Figure 11

Impact of 40 Tex at varies SPI over Lapped seam strength and efficiency

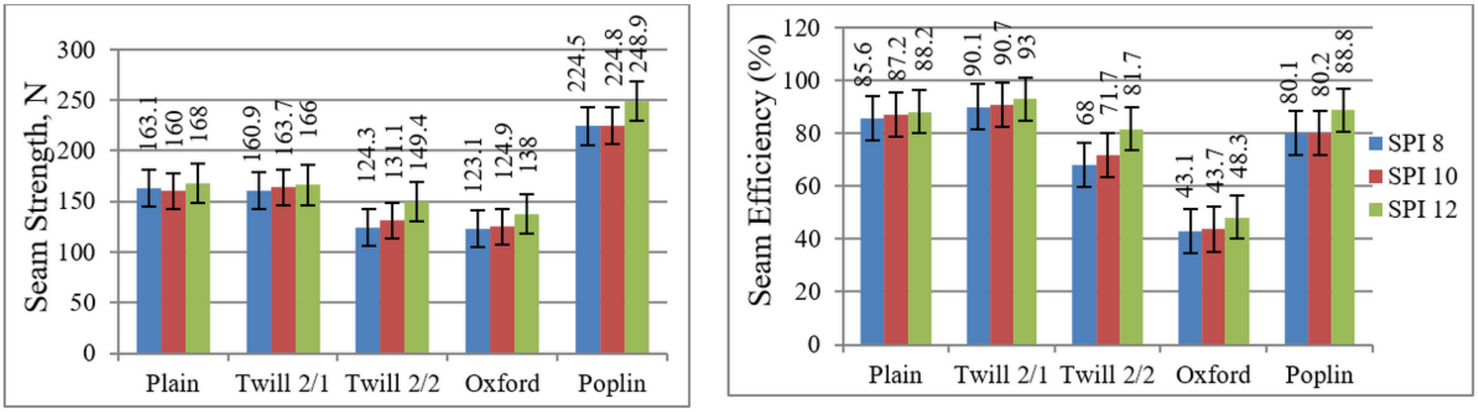

Figure 12

Impact of 40 Tex at varies SPI over Bound seam strength and efficiency

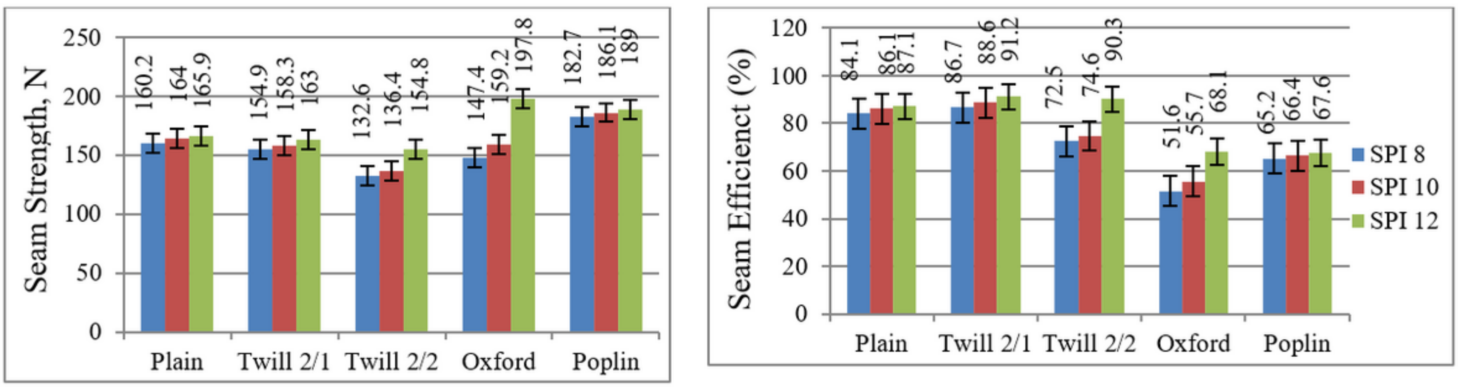

Figure 13

Impact of 40/2 Tex at varies SPI over Super Imposed seam strength and efficiency

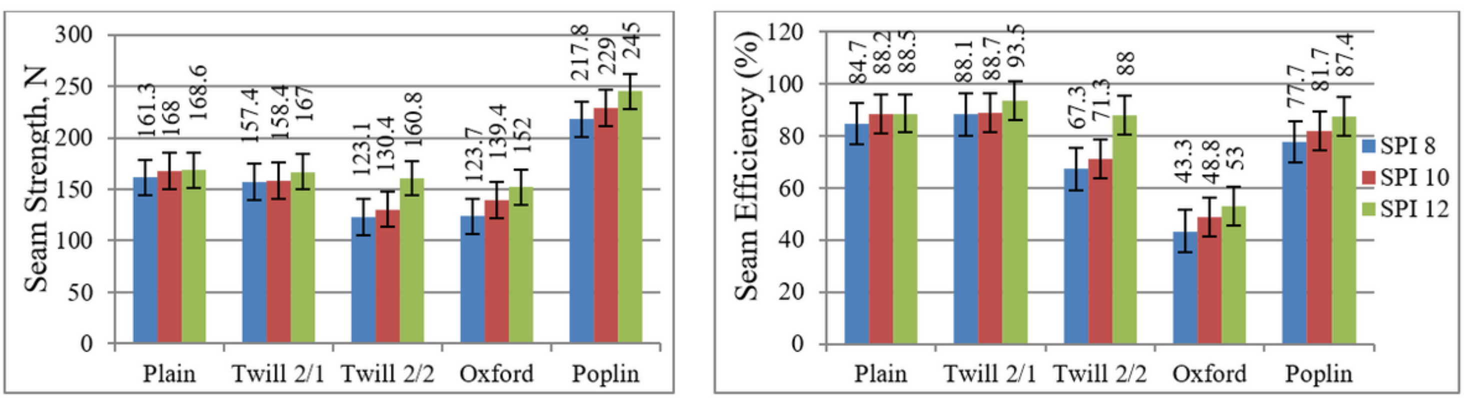

Figure 14

Impact of 40/2 Tex at varies SPI over Lapped seam strength and efficiency

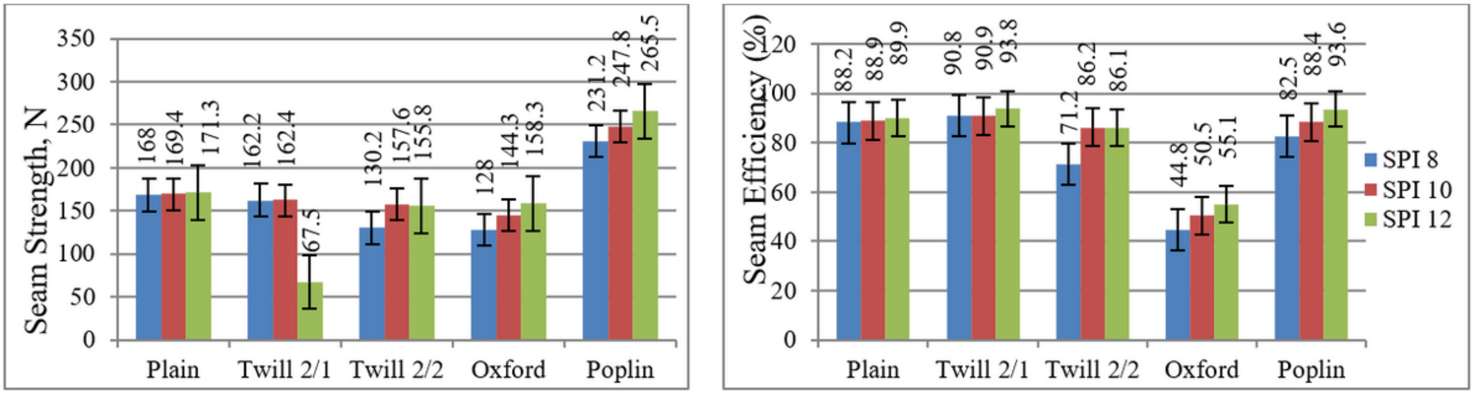

Figure 15

Impact of 40/2 Tex at varies SPI over Bound seam strength and efficiency

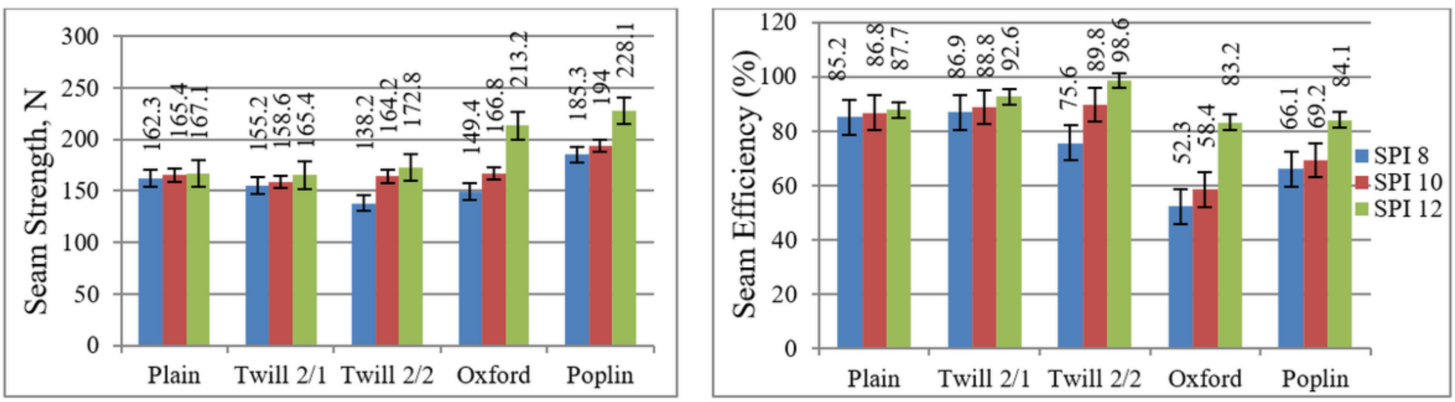

Figure 16

Impact of 40/3 Tex at varies SPI over Super Imposed seam strength and efficiency

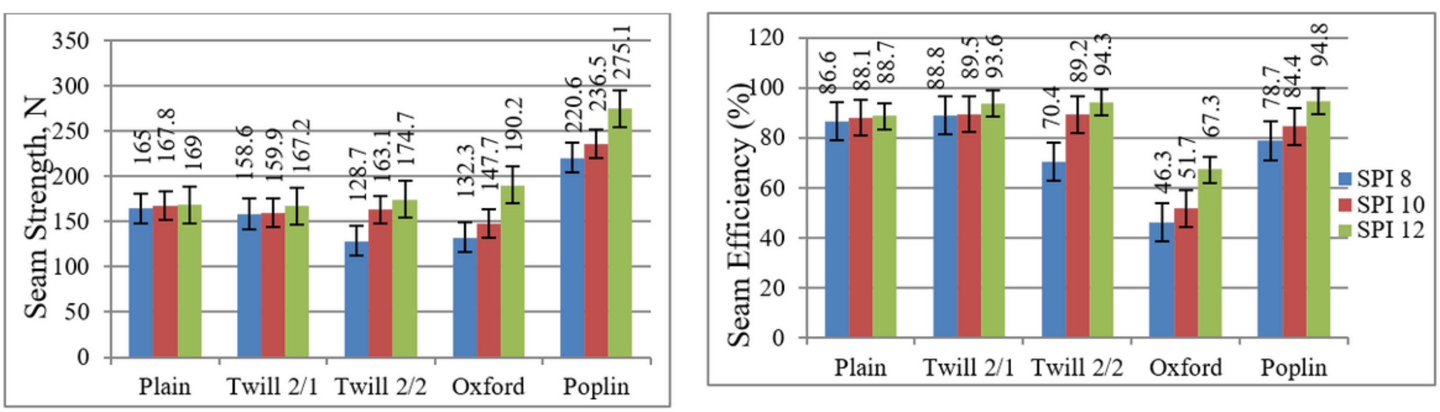

Figure 17

Impact of 40/3 Tex at varies SPI over Lapped seam strength and efficiency

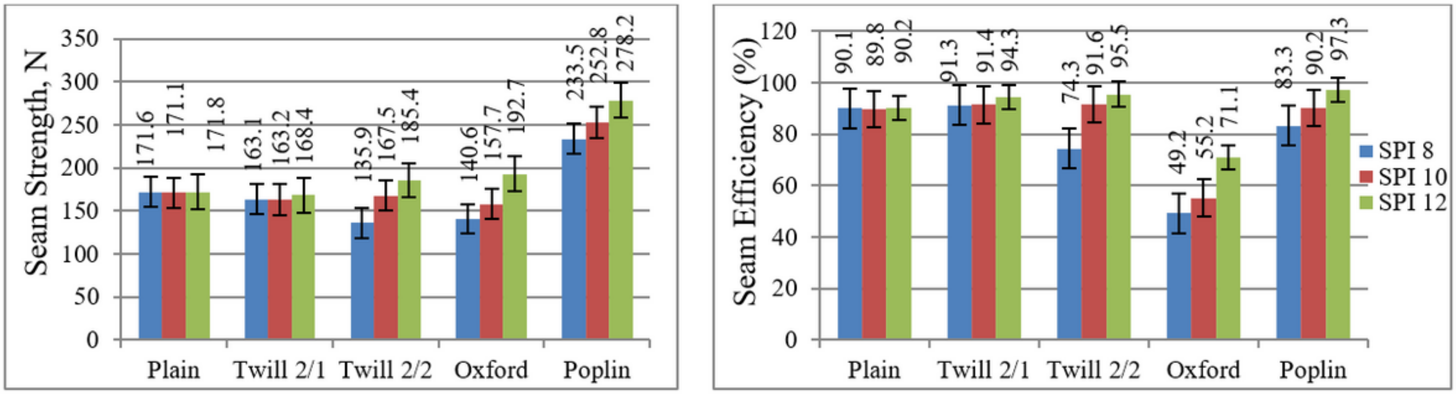

Figure 18

Impact of 40/3 Tex at varies SPI over Bound seam strength and efficiency