Load Extension Behavior of Spun Sewing Threads on Seam Slippage

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Abstract

The present research is focused to develop the relationship between the seam slippage and mechanical properties of sewn fabric by considering the spun thread and fabric configuration in the stitched assembly. Plain and twill weave fabric was used for the sample development stitch with the spun thread while the sewing machine setting was kept constant to produce a balanced seam. Different stitched samples are prepared in warp and weft direction for investigation by considering superimposed, flat, and bound seam classes with multi-thread chain, lock, and cover stitches. Experiment findings highlight the optimum load of seam slippage in N at 6 mm seam opening at stitched assembly by employing mentioned seam classes and stitch types. The results showed that 189.97 N maximum load was found at 6 mm seam opening for plain weave fabric in warp direction at flat seam sample with a lock stitched while in weft direction 80.65 N minimum load at the bound seam with multi-thread chain stitch. For twill weave fabric 94.72 N minimum slippage load at a 6 mm seam opening was observed in the weft direction at the bound seam with multi-thread chain stitch while in the warp direction maximum slippage load of 200 N was reported at the superimposed, flat and bound seam with multi-thread chain, lock and cover stitches. Established findings have a significant coefficient of determination ($R^2 > 0.90$) between sewing thread extension and seam slippage load at 6 mm seam opening in both directions. The present research provides the guidelines to select the spun sewing thread which was possessed the minimum extension (%) against the respective load (N) to overcome the seam slippage in the stitched garment.

Keywords—Seam slippage, garment appearance, tensile strength, seam classes, stitch types

1 Introduction

Seam slippage often occurs in garments affecting the appearance of the garment and also influencing its quality. The appearance of the garment was affected due to the fabric resistance to seam slippage (1). Physical and mechanical properties of woven fabric were explored and established that in stitched assembly high seam slippage magnitude in weft direction instead of warp direction but seam classes and stitch types concept had less consideration (2-4). The effect of weft density and weft yarn count of woven fabric in the stitched assembly had a direct relation with the magnitude of seam slippage in the warp direction (5, 6). A low magnitude of seam slippage was reported for the Lapped seam class in the stitched assembly of twill fabric (7). The effect of stitch density on plain and twill weave woven fabric was explored on the performance of seam slippage while seam classes and stitch types implication were underestimated (8). In the sewing process, the energy consumption of the mechanical forces in stitched chenille fabric was investigated to overcome the seam slippage without the implication of the tensile behavior of sewing thread (9). Seam slippage was explored based on the seam deformation model which was established on fabric weave type and direction without considering the implication of sewing thread in the stitched assembly (10). A customized load extension tester was designed and used to evaluate the seam slippage of wool and blended fabric construction without considering the importance of the load-extension behavior of sewing thread in the stitched garment (11). Fabric construction parameters (3, 12, 13), and sewing machine parameters (14, 15) had prominent consideration for seam slippage determination. However, the estimation of load extension behavior of spun sewing thread and fabric was underestimated in the stitched assemblies. The demand for plain and twill weave fabric in the garment industry

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for top and bottom articles is increasing day by day. Therefore, the present research is focused to fill the gap in the seam slippage aspect of plain and twill weave fabric due to fabric and sewing thread load-extension behavior with seam class and stitch types while sewing machine setting and spun sewing thread kept constant.

2 Machine and Methods

2.1 Fabric

Commercially available 100 % cotton of plain and twill weave woven fabric is selected for the investigation. ISO 3801 standard was exercised to calculate gram per square meter (g/m^2). ASTM D3775-17 was used to calculate the number of threads per inch in the warp (EPI) and weft (PPI) direction of selected fabrics. ASTM D5304 standard method was used to investigate the load (N) and extension (%) behavior of plain and twill weave is woven fabric by the grab test method.

2.2 Sewing thread

Commercially available three different compositions of identical liner density of spun sewing threads are used to prepare the different stitched samples. ISO 2060 standard method was used to determine the thread count and evaluated tensile strength according to the standard ASTM D2256 at the tensile testing machine. The implication of spun sewing thread according to seam slippage was investigated in warp and weft direction at different prepared stitched samples.

2.3 Sewing

Among six stitch classes and eight seam classes; lock stitch, cover stitch, and multi-thread chain stitch sewing machine was used to prepare the stitched samples of fabric configuration at the superimposed seam, flat seam, and bound seam. All prepared stitched samples for each thread have 5 stitches per cm and kept the machine setting constant to produce the balanced seam. ISO 13936-1 standard method was used to evaluate the seam slippage load at 6 mm seam opening on prepared stitched samples for each spun thread. Prepared representative seam samples are shown in Figure 1.

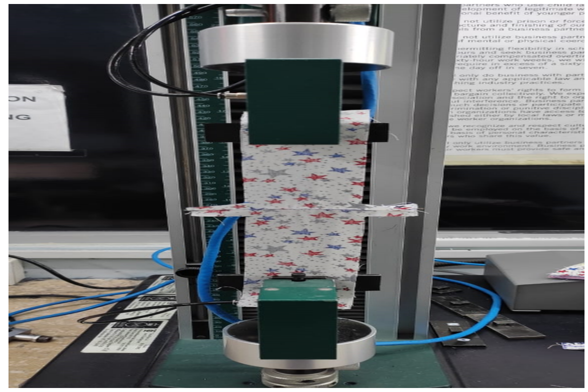


Fig. 1: Prepared seam slippage samples

3 Results and Discussion

3.1 Fabric evaluation

Fabric structural parameters and load extension behavior is evaluated. As per ISO 3901, Table 1 (a) presents the selected fabric specification in terms of grams per square meter. As per ASTM-D 3775-17, Table 1 (b) presents the selected fabric specification in terms of ends and pick per inch.

The warp and weft yarn count of plain and twill fabrics was estimated through the formula(16) :

$$Count = No.\,of\ ends\ or\ picks * tape * length\ in\ yards\ /\ 840 * weight\ in\ lbs \tag{1}$$

while

$$Tape\ length\ (yards) = length\ in\ yards * (100 + Moisture\ Region\ /\ 100) \tag{2}$$

The yarn count of plain weave woven fabric in the warp and weft direction is determined by considering the length and weight of the fabric as 4 meters and 2 lbs. respectively. For Twill weave woven fabric yarn count in the warp and weft direction was calculated by considering the length and weight of the fabric as 4 meters and 8 lbs. respectively. The Warp and weft yarn count of each fabric is reported in Table 2 by exercised equations (1) and (2) with consideration of the aforementioned data in Table 1 (b).

The weave cover factor is an important factor to analyze the fabric extension behavior under tensile loading. The weave cover factor in the warp and weft direction of plain and twill woven fabric is tabulated in Table 3 by using data from Table 1 and Table 2 through exercised equation no 3 (16).

$$Cover\ factor = \frac{no.\,of\ threads\ per\ inch}{\sqrt{thread\ count\ (Ne)}} \tag{3}$$

From Table 3, it was advocated that the under load-extension behavior of mentioned fabric possessed a low magnitude of extension % against the respective load (N) in the weft direction in contrast to the warp direction because of the respective cover factor magnitude. The low magnitude of the cover factor in

TABLE 1: (a) ISO 3901 Gram per square meter (g/m^2)

Fabric Code	**Types of weave**	**Composition**	**Observations (g/m$^{2)}$ ISO 3901**					**Average**	**STDEV .P**	**Variance . P**
F1	Plain	100 % Cotton	71.00	72.00	69.50	69.50	73.00	71.00	1.54	1.90
F2	Twill	100 % Cotton	278.00	276.00	277.00	279.00	280.00	278.00	1.58	2.00

TABLE 1: (b) ASTM-D3775-17, Fabric picks (PPI) and ends (EPI) per inch

Fabric Code	**Types of weave**	**yarn per inch**	**Average based on five Observations ASTM-D 3775-17**
F1	Plain	EPI	80.00
		PPI	60.00
F2	Twill	EPI	117.00
		PPI	56.00

TABLE 2: Estimation of warp and weft yarn count (Ne)

Fabric Code	**Types of weave**	**Direction**	**Average based on five Observations, Ne Count**
F1	Plain	Warp	35.00
		Weft	26.00
F2	Twill	Warp	13.00
		Weft	6.00

TABLE 3: Weave cover factor

Fabric Code	**Types of weave**	**Direction**	**Cover factor**
F1	Plain	Warp	15.69
		Weft	10.14
F2	Twill	Warp	32.45
		Weft	22.86

the weft direction will be negatively influenced by the seam slippage load magnitude of stitched assemblies at a 6 mm seam opening.

ASTM D5304 standard method was used to investigate the load (N) and extension (%) behavior of plain and twill weave is woven fabric by a grab test method. Table 4 presents the tensile machine setting configuration for fabric load-extension testing.

Table 5 presents the load (N) and extension (%) relationship based on the average of five samples on each fabric.

Table 5 revealed that plain and twill fabric has less extension magnitude in the warp direction against the respective load in contrast to the weft direction because of the fabric cover factor magnitude in the respective direction. Seam slippage load at a 6 mm seam opening is dependent on the number of threads per inch and the respective count in the direction of stitched assembly (5). It is suggested that seam slippage load at the stitched assembly will be observed more in the warp direction in comparison to the weft direction due to the fabric cover factor in the respective direction.

TABLE 4: Tensile testing machine setting

Serial No	**Machine Setting**	**Specification**
1	Sample size	6x1.5 inches
2	Pretension	2 N
3	Rate of extension	150 mm/min

3.2 Sewing thread

ISO 2060 standard method was used to determine the thread count and the average count is shown in Table 6.

Thread tensile strength was evaluated according to the standard ASTM D2256 at the tensile testing machine with the pretension of 5 cN and a speed of 330 mm/sec at break detection of 20%. Tabulated data based on average magnitude is shown in Table 7.

Table 7 demonstrated that the composition characteristic of selected identical spun sewing threads has been influenced by the extension (%) magnitude against a respective load (N). From Figure 2, it is revealed that sewing thread composition has a significant coefficient of determination (R^2 = 0.8704) between respective load (N) and extension (%). The sewing thread composition factor will be a predictive tool at stitched assembly for the seam slippage load

TABLE 5: ASTM D5304, Load (N) and extension % of woven fabric

Fabric Code	**Types of weave**	**Direction**	**Observations**					**Average**	**STDEV .P**	**Variance . P**
			1	2	3	4	5			
F1	Plain	Load (N) in warp	251.90	253.50	249.50	251.50	253.50	251.98	1.66	2.20
		Extension % in warp	8.15	8.35	8.15	8.55	8.55	8.35	0.20	0.03
		Load (N) in the weft	162.75	165.05	162.45	162.45	165.00	163.54	1.36	1.48
		Extension % in the weft	23.35	25.10	23.00	22.65	25.15	23.85	1.19	1.13
F2	Twill	Load (N) in warp	831.00	834.00	834.00	829.00	832.00	832.00	2.12	3.60
		Extension % in warp	18.00	18.15	18.00	18.30	18.15	18.12	0.13	0.01
		Load (N) in the weft	512.50	515.00	511.00	514.50	515.50	513.70	1.89	2.86
		Extension % in the weft	24.20	26.00	26.00	24.00	25.50	25.14	0.97	0.76

TABLE 6: ISO 2060 standard method for spun thread count

Thread code	**Spun thread composition**	**Observations (tex)**					**Average (tex)**	**STDEV.P**	**Variance. P**
		1	2	3	4	5			
T1	Polyester - Cotton (PC) (50/50) %	77.50	76.45	75.40	77.75	77.90	77.00	0.95	0.90
T2	100 % Polyester	77.40	78.50	76.40	75.70	79.50	77.50	1.38	1.89
T3	100% Cotton	76.50	74.50	77.50	75.50	78.50	76.50	1.41	2.00

TABLE 7: ASTM D2256 load extension behavior of spun sewing thread

Thread code	**Spun thread composition**	**Load & extension**	**Observations**					**Average**	**STEDV .P**	**Variance .P**
			1	2	3	4	5			
T1	Polyester -Cotton (PC) (50/50) %	Load (N)	42.15	45.45	46.55	43.55	44.5	44.44	1.52	2.30
		Extension %	39.5	37.9	36.95	39.5	40.5	38.87	1.27	1.62
T2	100 % Polyester	Load (N)	53.5	56	54	57.5	54.05	55.01	1.51	2.28
		Extension %	43.5	46.05	44.2	47.5	44.05	45.06	1.49	2.23
T3	100% Cotton	Load (N)	41.5	39.4	41.2	39.5	41.15	40.55	0.91	0.82
		Extension %	31.6	28.5	32.5	27.5	29.05	29.83	1.90	3.61

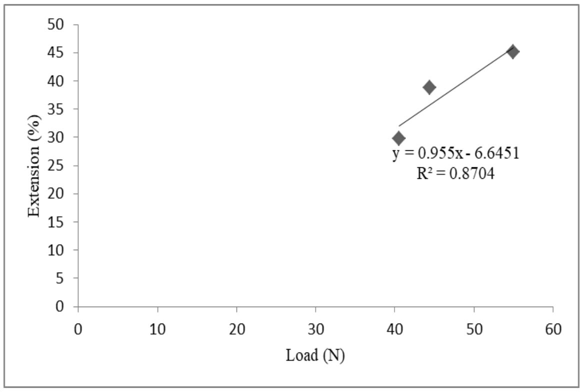


Fig. 2: Load-Extension relationship of different spun sewing threads

(N) magnitude at a 6 mm seam opening. The load extension behavior of woven fabric and sewing thread at the stitched assembly is influenced by the magnitude of seam slippage load at a 6 mm seam opening.

It is shown in Table 7 that 100 % cotton spun sewing thread (T3) possessed a low magnitude of extension (%) against the respective load (N) among the selected spun sewing threads. It is implied that a low magnitude of extension (%) against the respective load (N) of thread (T3) in comparison to selected threads will be possessed maximum seam slippage load at 6 mm seam opening in the stitched assembly.

3.3 Seam slippage

The standard method ISO 13936-1 was used to evaluate the seam slippage load at 6 mm seam opening on prepared stitched samples for each thread. Table 8 to Table 10 reported the seam slippage load (N) in warp and weft direction for the multi-thread chain, lock and cover stitched in a combination of the superimposed seam, flat seam, and bound seam respectively.

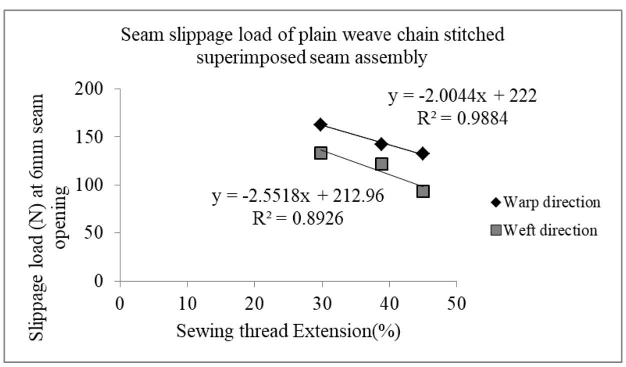
From table 8, Seam slippage load magnitude at stitched assembly with three spun sewing threads depicted seam configuration implication at multi-thread chain stitched plain and twill weave assemblies. It was revealed that different magnitudes of seam slippage load (N) emphasize the relationship of load extension behavior of fabric and spun sewing thread in the stitched assembly due to seam classes and stitch types. For twill weave, maximum seam slippage load (approximate 200 N) magnitude at 6 mm seam opening is observed at superimposed, flat and bound seam multi-thread chain stitched with sewing thread T1 and T3 assemblies in warp direction while minimum load magnitude (94.72 N) at bound seam chain stitched with sewing thread T2 assembly in weft direction due to high extension magnitude (%). For plain weave, maximum seam slippage load (175.85 N) magnitude at 6 mm seam opening is observed at flat seam stitched with sewing thread T3 assembly in warp direction while minimum load magnitude (80.65 N) at bound seam stitched with sewing thread T2 assembly in the weft direction. Established findings highlight that the load extension behavior of fabric and spun sewing thread influenced the seam slippage load at the 6 mm seam opening. In Figure 3, the significant coefficient of determination ($R^2 > 0.90$) of plain weave stitched assemblies is demonstrated among the different compositions of spun sewing threads extension (%) with seam slippage load (N) at 6 mm seam opening.

From table 9, Seam slippage load magnitude at stitched assembly with three spun sewing threads depicted seam configuration implication at chain stitched plain and twill weave assemblies. It was revealed that different magnitudes of seam slippage load (N) emphasize the relationship of load extension behavior of fabric and spun sewing thread in the stitched assembly due to seam classes and stitch types For twill weave, maximum seam slippage load (approximate 200 N) magnitude at 6 mm seam opening is observed at superimposed, flat and bound seam lock stitched with sewing thread T1 and T3 assemblies in warp direction while minimum load magnitude (94.72 N) at bound seam lock stitched with sewing thread T2 assembly in weft direction due to high extension magnitude (%). For plain weave, maximum seam slippage load (189.97 N) magnitude at 6 mm seam opening is observed at flat seam lock stitched with sewing thread T3 assembly in warp direction while minimum load magnitude (100.18 N) at bound seam lock stitched with sewing thread T2 assembly in the weft direction. The established findings highlight that the load extension behavior of fabric and spun sewing thread influenced the seam slippage load at the 6 mm seam opening. In Figure 4, the significant coefficient of determination ($R^2 > 0.90$) of plain weave stitched assemblies is demonstrated among the different compositions of spun sewing threads extension (%) with seam slippage load (N) at 6 mm seam opening.

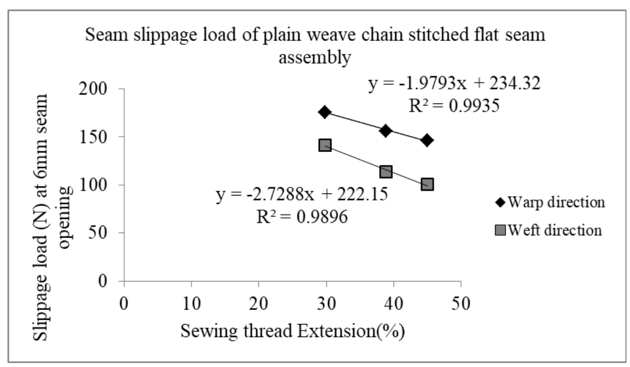
From table 10, Seam slippage load magnitude at stitched assembly with three spun sewing threads depicted seam configuration implication at chain stitched plain and twill weave assemblies. It was revealed that different magnitudes of seam slippage load (N) emphasize the relationship of load extension behavior of fabric and spun sewing thread in the stitched assembly due to seam classes and stitch types. For twill weave, maximum seam slippage load (approximate 200 N) magnitude at 6 mm seam opening is observed at superimposed, flat and bound seam cover stitched with

TABLE 8: Seam slippage load at 6 mm seam opening of multi-thread chain stitched samples with different seam classes

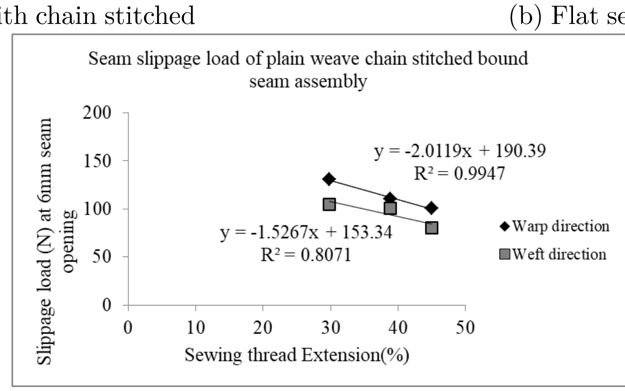
	Fabric assembly stitched with Sewing thread T1			
Seam classes	Slippage load (N) warp direction		Slippage load (N) weft direction	
	Plain Weave	Twill Weave	Plain Weave	Twill Weave
Superimposed seam	142.18	200	121.56	200
Flat seam	155.97	200	113.63	200
Bound seam	110.9	198.34	100.56	114.72
	Fabric assembly stitched with Sewing thread T2			
Seam classes	Slippage load (N) warp direction		Slippage load (N) weft direction	
	Plain Weave	Twill Weave	Plain Weave	Twill Weave
Superimposed seam	132.81	190.01	93.36	180.00
Flat seam	145.97	195.05	100.65	185.00
Bound seam	100.50	188.44	80.65	100.72
	Fabric assembly stitched with Sewing thread T3			
Seam classes	Slippage load (N) warp direction		Slippage load (N) weft direction	
	Plain Weave	Twill Weave	Plain Weave	Twill Weave
Superimposed seam	162.98	200.00	133.68	200.00
Flat seam	175.85	200.00	141.75	200.00
Bound seam	130.90	200.00	105.13	150.00



(a) Super-imposed seam with chain stitched



(b) Flat seam with chain stitched

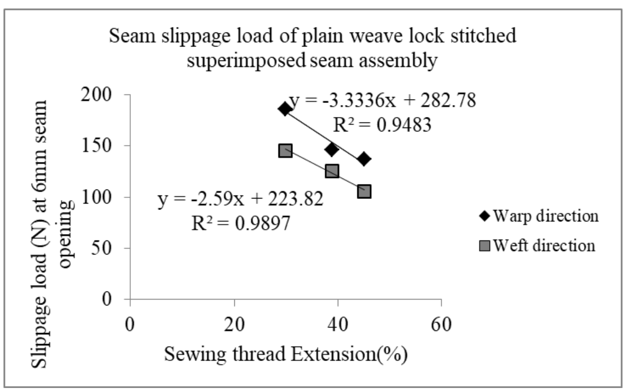


(c) Bound seam with chain stitched

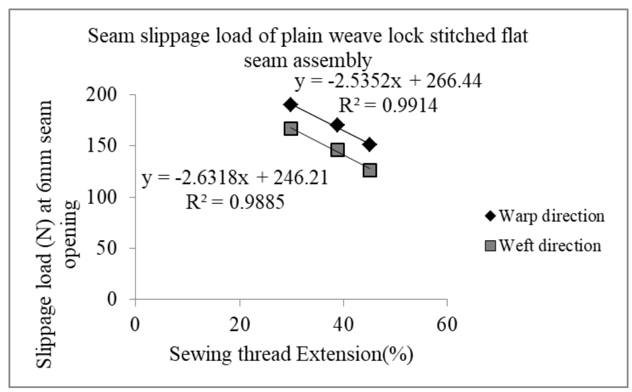
Fig. 3: Super-imposed, Flat and Bound seams with chain stitched

TABLE 9: Seam slippage load at 6 mm seam opening of lock stitched samples with different seam classes

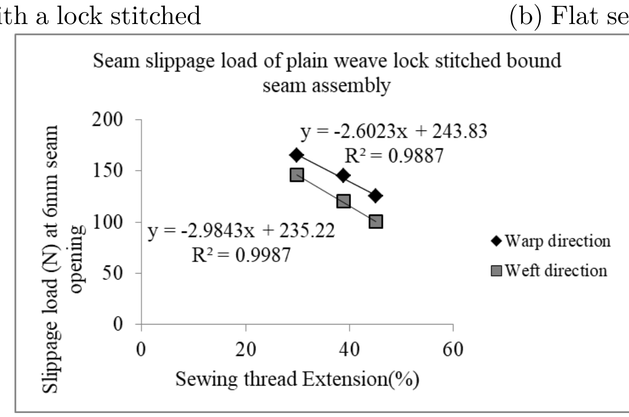
	Fabric assembly stitched with Sewing thread T1			
Seam classes	Slippage load (N) warp direction		Slippage load (N) weft direction	
	Plain Weave	Twill Weave	Plain Weave	Twill Weave
Superimposed seam	146.36	200	125.47	200
Flat seam	169.97	200	146.41	200
Bound seam	145.12	200	120.81	114.72
	Fabric assembly stitched with Sewing thread T2			
Seam classes	Slippage load (N) warp direction		Slippage load (N) weft direction	
	Plain Weave	Twill Weave	Plain Weave	Twill Weave
Superimposed seam	136.63	190.00	105.74	190.00
Flat seam	150.97	200.00	126.14	200.00
Bound seam	125.12	190.00	100.18	94.72
	Fabric assembly stitched with Sewing thread T3			
Seam classes	Slippage load (N) warp direction		Slippage load (N) weft direction	
	Plain Weave	Twill Weave	Plain Weave	Twill Weave
Superimposed seam	186.12	200	145.62	200
Flat seam	189.97	200	166.69	200
Bound seam	165.21	200	145.81	155



(a) Super-imposed seam with a lock stitched



(b) Flat seam with a lock stitched



(c) Bound seam with a lock stitched

Fig. 4: Super-imposed, Flat and Bound seams with lock stitched

TABLE 10: Seam slippage load at 6 mm seam opening of cover stitched samples with different seam classes

	Fabric assembly stitched with Sewing thread T1			
Seam classes	Slippage load (N) warp direction		Slippage load (N) weft direction	
	Plain Weave	Twill Weave	Plain Weave	Twill Weave
Superimposed seam	121.94	200	94.47	191.95
Flat seam	143.72	200	122.15	195.83
Bound seam	123.95	191.97	110.29	110.7
	Fabric assembly stitched with Sewing thread T2			
Seam classes	Slippage load (N) warp direction		Slippage load (N) weft direction	
	Plain Weave	Twill Weave	Plain Weave	Twill Weave
Superimposed seam	100.94	195.00	89.47	188.83
Flat seam	132.72	195.00	90.29	191.95
Bound seam	115.31	185.00	85.15	100.70
	Fabric assembly stitched with Sewing thread T3			
Seam classes	Slippage load (N) warp direction		Slippage load (N) weft direction	
	Plain Weave	Twill Weave	Plain Weave	Twill Weave
Superimposed seam	141.61	200.00	94.47	200.00
Flat seam	163.72	200.00	122.15	200.00
Bound seam	133.30	200.00	110.7	135.22

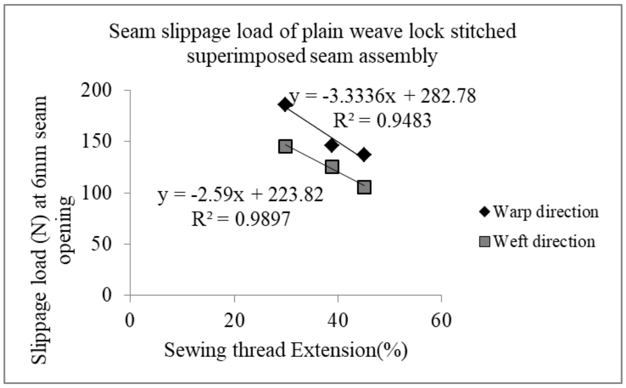
sewing thread T1 and T3 assemblies in warp direction while minimum load magnitude (100.7 N) at bound seam cover stitched with sewing thread T2 assembly in weft direction due to high extension magnitude (%). For plain weave, maximum seam slippage load (163.72 N) magnitude at 6 mm seam opening is observed at flat seam cover stitched with sewing thread T3 assembly in warp direction while minimum load magnitude (85.15 N) at bound seam cover stitched with sewing thread T2 assembly in the weft direction. Established findings highlight that the load extension behavior of fabric and spun sewing thread influenced the seam slippage load at the 6 mm seam opening. In Figure 5, the significant coefficient of determination ($R^2 > 0.90$) of plain weave stitched assemblies is demonstrated among the different compositions of spun sewing threads extension (%) with seam slippage load (N) at 6 mm seam opening.

It is established that seam slippage load (N) magnitude at 6 mm seam opening of multi-chain stitched, lock stitched and covers stitched assemblies incorporation of sewing threads T1, T2, and T3 in a combination of superimposed, flat, and bound seam classes have influenced with the respective thread extension (%) behavior against a respective load (N) due to its composition (17-19).

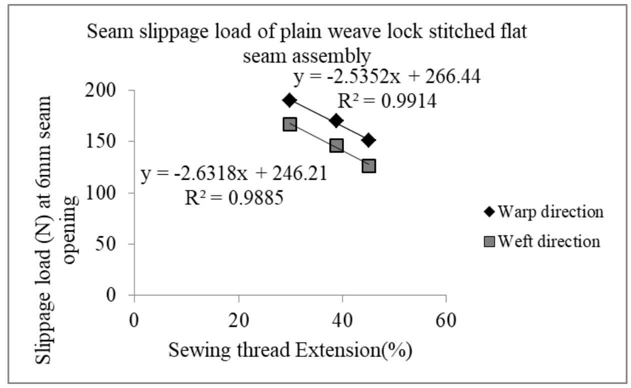
It is revealed from Figure 2 that 100% polyester spun thread (T2) has a high magnitude of extension (%) against a respective load (N) in comparison to PC spun thread (T1) and 100% cotton spun thread (T3). From Table 8 it is evident that seam slippage of stitched samples possessed maximum load at 6 mm seam opening for sewing thread (T3) at the flat seam with lock stitched assemblies which have a minimum extension (%) against a respective load (N).

In a comparison of stitch and seam classes of all stitched samples incorporation of sewing threads T1, T2, and T3 (Table 8 to Table 10) revealed that stitched sample of lock stitch in the configuration of flat seam possessed maximum seam slippage load at 6 mm seam opening for both plain and twill weave fabric in both directions. Lock-stitched samples possessed a high magnitude of seam slippage load (N) because of the interlacing mechanism of stitch configuration. It is established that stitch types and seam classes also have a greater influence on seam slippage load magnitude along with the load-extension behavior of fabric and sewing thread.

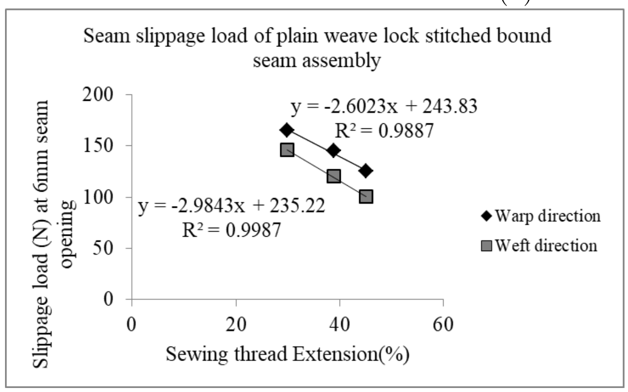
Among the three spun sewing threads (Table 7), 100 % cotton thread (T3) has a lower magnitude of extension (%) against the respective load (N). It was observed that sewing thread that had a lower magnitude of extension (%) possessed maximum seam slippage load (N) at 6 mm seam opening technique for all seam types and stitch classes for plain and twill woven fabrics in warp direction because of the high magnitude of cover factor.



(a) Super-imposed seam with cover stitched



(b) Flat seam with cover stitched



(c) Bound seam with cover stitched

Fig. 5: Super-imposed, Flat and Bound seams with cover stitched

4 Conclusion

The present research established the relationship of load-extension behavior of sewing thread and fabric for the prediction or evaluation of maximum seam slippage load (N) at 6 mm seam opening by considering different seam and stitch classes. It is revealed that stitched samples of 100% cotton spun sewing thread possessed maximum seam slippage load (N) at 6 mm seam opening at plain and twill fabric in warp direction due to its load extension behavior and interlacing stitch mechanism. Established findings have a significant coefficient of determination ($R^2 > 0.90$) between sewing thread extension and seam slippage load at 6mm seam opening in both directions. It is also emphasized that lock stitched sample in flat seam configuration possessed a high magnitude of seam slippage load (N) at 6 mm seam opening for both twill and plain woven fabrics in warp direction because of high magnitude cover factor and low extension (%) at respective load (N).

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