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Sustainable solution of sewing thread attributes on seam pucker

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K E Y W O R D S

Seam Pucker

Sewing Thread

Bending Rigidity

Thread Cyclic Recovery

Static Thread Tension

Sustainable Solution

A B S T R A C T

Bending rigidity magnitude of sewing thread provides a sustainable solution on the appearance of single needle lock stitched lightweight woven fabrics which are prone to pucker. Comparison of sewing thread bending rigidity with thread count, thread diameter, thread cyclic recovery and their resultant implication in the single lock stitched assemblies were given less consideration for the prediction and reduction of seam pucker severity. The resultant implication of physical and mechanical properties of sewing thread with rising trend of static thread tension magnitude at lock stitched sewing machine has significant impact on lightweight lock stitched fabric assemblies to predict and elude seam pucker. The present research is focused to investigate impact of the thread bending rigidity on count, diameter and cyclic recovery at 4^{th} cycle of four cores spun sewing threads. The study concluded that sewing thread bending rigidity has high coefficient of determination of sewing thread; diameter (R^2 =0.81), count (R^2 =0.73) and cyclic recovery (R^2 =0.77). Single needle 400 lock stitched samples of two cores spun sewing threads (t_2 and t_4) were prepared with ten plain weave lightweight woven fabric samples prone to pucker at four different static needle thread tensions. It is also established that combined effect of sewing thread static tension and cyclic recovery at sewing machine has significant coefficient of determination (R^2>0.85 at low static thread tension and R^2>0.73 at very high static thread tension) to predict and elude seam pucker severity. Research finding provides a sustainable solution to select the fine count sewing thread attuned with lightweight woven fabrics prone to pucker severity. It was observed that the Fine count sewing thread has lowest bending rigidity and 4^{th} cyclic recovery magnitudes (R^2 close to 1) to reduce or predict pucker severity for prone to pucker plain weave lightweight woven fabrics at minimum static thread tension ($25g_f$) on single needle lock stitched sewing machine (R^2>0.81).

1. Introduction

In the stitching of light weight woven fabric, consideration must be given to any changes that occur in appearance of the stitched assemblies. Specifically, it must be considered that whether the stitched assembly is maintaining a desirable flat and smooth appearance or exhibiting any deformation along the seam line. In the available literature, the severity of deformation along the seam line has been considered in

the context of fabric mechanics [1-3], thread implication [4-9] and machine setting [10-13].

In apparel industry, generally, the focus has been on the effects of fabric properties on seam. However, appropriate thread selection seems to have been given less importance [2, 3, 14, 15]. The yarn structures and densities of sewing threads were investigated to predict the seam pucker for lightweight woven fabrics [6, 9] and knitted fabric [16] prone to pucker while thread resultant behaviour with static thread tension at sewing machine setting was underestimated in the stitched assembly.

The magnitude of sewing thread characteristics in sewn fabric played a crucial role on the assessment of waviness along the seam line [5, 17]. Bending, contraction and extension properties of fabric and sewing thread by considering sewing machine parameters played a key role for the assessment of seam appearance [7, 15]. Bending behaviour of lightweight woven fabric along with thread static tension was explored for the prediction of seam pucker but implication of bending property and cyclic recovery of sewing thread were overlooked in the stitched assembly [8].

Load extension behaviour of spun sewing thread also influenced the seam performance but its impact on pucker severity was not considered [18].

The cyclic behaviour of sewing thread at 200 cN load was reported for the assessment of pucker severity but actual cyclic load on sewing thread was not considered [4]. A low magnitude of thread cyclic recovery at stitched machine was recommended for prone to pucker lightweight woven fabrics without considering the thread bending behaviour and magnitude of static thread tension implication in the stitched assembly [9, 11, 12].

Sustainable solution of fabric bending rigidity with tangible sewing thread attributes, as discussed above, should be considered in the stitched assembly with different static thread tension magnitude at single needle lock (SNL) stitch sewing machine. Correlation of sewing thread bending rigidity with respective; count, diameter and cyclic recovery and their implication in the stitched assemblies need to be explored to predict or reduce seam pucker severity.

The aim of the present work is to fill the research gap based on the experimental consideration of bending rigidity of sewing thread correlation with diameter, count and cyclic recovery magnitude. The correlation of sewing threads was further investigated for the seam pucker severity of stitched assembly. Ten plain weave lightweight woven fabrics were lock stitched with selected core spun threads using four different magnitudes of needle thread static tensions on a single needle lock (SNL) stitch sewing machine. Seam puckering was evaluated using standard test method AATCC-88 B.

2. Materials and Methods

2.1 Thread

Core spun threads are generally a popular choice in the stitching of light weight woven fabrics which are prone to pucker [4, 6, 7, 9]. Four commercially available core spun sewing threads of different composition were selected for the study. For the selected threads, an average of five tests was considered for the characterization of diameter, count, cyclic recovery at 4^{th} cycle and bending rigidity.

In the present study, the diameter was measured using scanning electronic microscopy to obtain highly accurate estimates [19]. Results were evaluated from the captured images of each core spun thread. The diameter is measured using the distance between the left hand edge and the right hand edge of the thread at separate points on the thread. Sewing thread weight to length ratio was evaluated followed by the ISO 2060 standard. KES-FB2 bending tester was used as per instruction manual to evaluate the threads bending rigidity (g_f. cm^2) [20]. Thread samples were prepared by arranging the 50 threads parallel to each other with equal force on the graph paper having 1.1 x 4 cm rectangular hole while one side of the graph paper has double sided adhesive tape. Both ends were fixed by adhesive tape. KES FB -2 configured with torque sensitivity (2x1, 20 g_f.cm /10v output), recorded sensitivity curvature at X-axis is 0.2v/cm and torque at Y-axis is 0.5v/cm, maximum curvature is 2.5 cm^{-1}/1.25 volt deformation rate of curvature is 0.5 cm^{-1}/sec.

The Instron tensile testing machine 3345K7484 was used to evaluate the sewing thread cyclic behaviour at 4^{th} cycle (Eq. 1) with 100 cN force of load cell by established procedure shown in Table 1.

$$\text{Elastic recovery (\%)} = \frac{\text{Elastic extension at } 4^{\text{th}} \text{ cycle}}{\text{Total extension}} \quad (1)$$

Table 1

Instron machine setting

Specification	Numerical values with units	Remarks
Gauge length	35.00 mm	Observed at single needle lock (SNL) stitch sewing machine at maximum displacement.
No of cycles	4.00	Thread experienced 4 no of cycles before incorporate in the stitched sample
Rate	350.00 mm/min	Test conducted

2.2 Plain Weave Lightweight Woven Fabrics

Ten different commercially available plain light weight woven fabrics [1, 8, 9, 15, 17] prone to pucker were selected for this study. As per the ISO 3801 standard, selected fabric weight (g/m^2) was calculated. Fabric bending rigidity was examined through FAST-2 system.

2.3 Single Needle Lock Stitch (SNL) Machine Setting – DDL9000c

Table 2 presents the fixed SNL machine settings for all the stitched samples that were prepared for analysis.

Table 2

SNL- DDL9000C setting

Particulars	Value	Units
Rotation	3000	Stitches per minute
Stitch density (SPC)	05	Stitches/cm
Needle (Acute point)	80	Nm
Presser foot pressure	5.10	Kg_f

SNL- DDL-9000c is the latest sewing machine based on Near Field Communication (NFC) technology, in which tablet was used to transfer the data without contact to the sewing machine to adjust the presser foot pressure and needle thread tension as needed. Same needle and bobbin threads were used to develop stitched samples; where ten plain weave lightweight woven fabric samples were stitched at different static needle thread tension 25cN, 50cN, 75cN and 100cN on each type with selected sewing threads. It was mandatory to make stitch at centre of the stitched assembly and fabric should be wrinkle free prior to sewing.

2.4 Visual Assessment of Seam Pucker

The AATCC-88B standard method for evaluation of seam pucker is frequently used in the industry. In this standard, three evaluators visually compare the stitched assemblies with the five standard photographs and subsequently assign grades between 1 and 5, where Grade 1 corresponds to 'Severe pucker' while Grade 5 corresponds to 'No pucker'. As per aesthetic requirement, it is recommended that stitched samples should have 1 or 2 pucker grades. The developed stitched samples were visually assessed according to the test method. Fig. 1 exemplifies a set of prepared samples compared against the standard replicas.

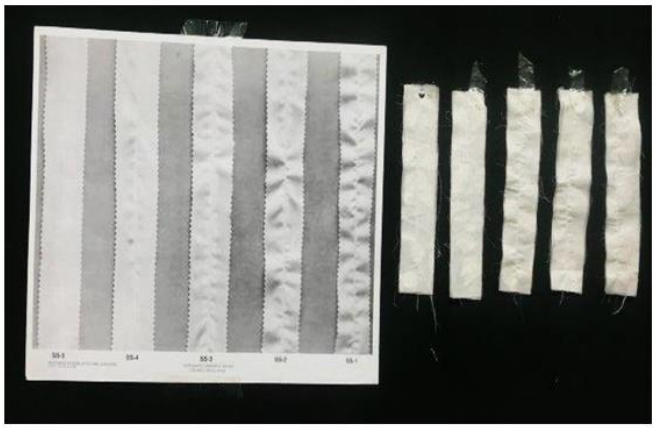

Fig. 1. AATCC -88B visual seam pucker grades

2.5 Linear Trend-Line Regression Analysis

Regression analysis is a statistical measure of how well the regression line approximates the actual data. The coefficient of determination (R^2) is a measure that provides information about the goodness of fit of a model. Coefficient of determination value should be between 0.0 and 1.0. The closer to 0.0 means the less correlated the dependent value and the closer to 1.0 means the more correlated the dependent value. A linear trend-line with two periods forecast statistical analysis test was done for the analysis of the observed research data; Thread bending rigidity against count, diameter and 4^{th} cyclic recovery and pucker severity against fabric bending rigidity on different static thread tension magnitude on single needle lock (SNL) stitch sewing machine for low and high cyclic recovery threads t_2 and t_4 respectively.

3. Results and Discussion

An average magnitude of sewing thread characteristics including diameter, count, bending rigidity and cyclic recovery at 4^{th} cycle are reported in the Table 3.

Table 3

Average value of sewing threads evaluation

Sewing Thread	Composition	Diameter (μm)	Count (dtex)	Bending rigidity (g_f. cm^2)	4th cycle recovery (%)
t_1	100 cotton	436.30	217.10	0.0041	69.69
t_2	Poly cotton	447.60	228.00	0.0042	75.78
t_3	Poly cotton	213.60	140.00	0.0023	40.18
t_4	Poly cotton	235.60	107.60	0.0012	37.43

Sewing thread evaluations results investigated the correlation of thread bending rigidity with thread count, thread diameter and thread 4th cyclic recovery and their resultant implication in the lock stitched assembles for the prediction and to elude seam pucker.

Table **3** that t_2 and t_4 threads possessed highest and lowest magnitude of thread bending rigidity and average recovery percentage at 4th cycle because of respective thread count and diameter. In comparison of thread t_2, thread t_1 possessed approximate same count, diameter and bending rigidity but cyclic recovery magnitude at 4th cycle is less. Hydrophilic nature of thread t_1 is responsible more prone to pucker in the stitched assemblies. That's why t_2 and t_4 threads were selected for experimental analysis to observe the implication of thread bending rigidity, thread count, thread diameter and thread average recovery at 4th cycle on different weight of plain weave stitched samples which are developed at different static thread tension magnitude at single needle lock stitched sewing machine.

Table **3** is also examined to explore the relationship of sewing thread bending rigidity with respective diameter, count and cyclic recovery at 4th cycle. Sewing thread bending rigidity has strong coefficient of determination (R^2), shown in Table **4** and pictorial presentation shown in Fig. 2-4.

It was revealed from

Presented data in

Table 4

Coefficient of determination (R^2)

Coefficient of determination (R^2) value			
Relation	Count (dtex)	Diameter (μm)	Cyclic recovery (%) at 4th cycle
Sewing thread Bending rigidity, g_f. cm^2	0.81	0.73	0.77

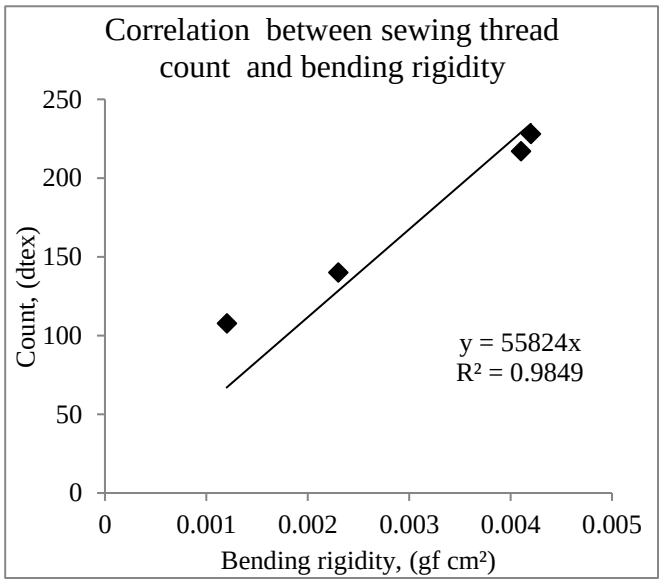

Fig. 2. Sewing thread bending rigidity and count

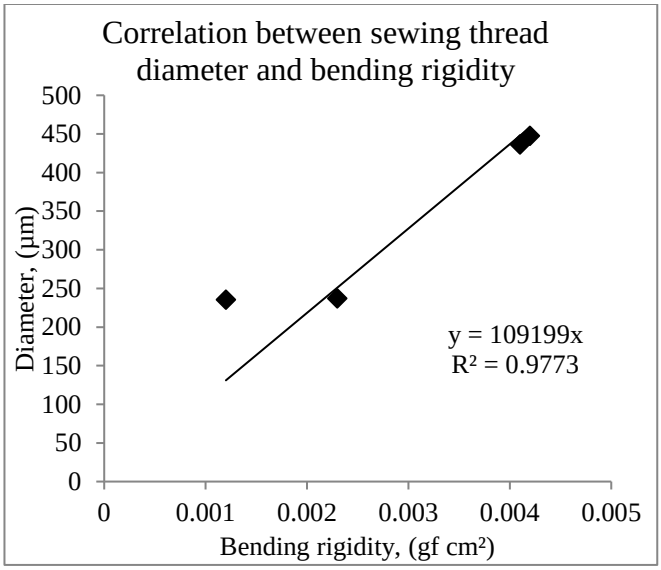

Fig. 3. Sewing thread bending rigidity and diameter

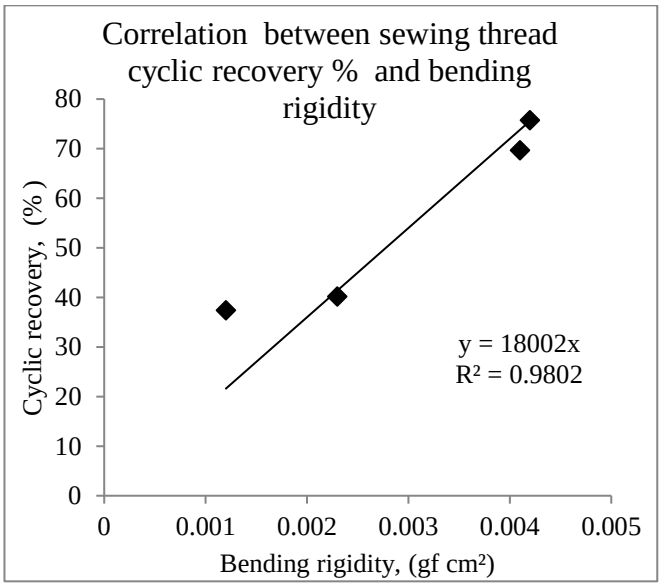

Fig. 4. Sewing thread bending rigidity and cyclic recovery

It shows in the analysis that sewing thread: count, diameter and cyclic recovery have direct relationship with sewing thread bending rigidity. In the light of present established knowledge that sewing thread count magnitude associated with diameter and cyclic recovery played a key role for the prediction of waviness along seam line of lightweight woven fabric. Low and high magnitude of bending rigidity sewing thread against respective cyclic recovery % magnitude has selected for seam pucker assessment of stitched assemblies because it possessed coarse and fine count respectively.

As per ISO 3801 standard, lightweight plain weave woven fabrics mas per unit area (g/m^2) were observed. FAST-2 device was used to evaluate the fabric bending rigidity (BR). Both testing result based on average of five tests is analysed to explore the relationship between plain weave woven fabric weight (g/m^2) and respective bending rigidity. Fig. 5 reflects the strong coefficient of determination (R^2 =0.83) between fabric weight (g/m^2) and fabric bending rigidity which were shown an agreement with established knowledge [15].

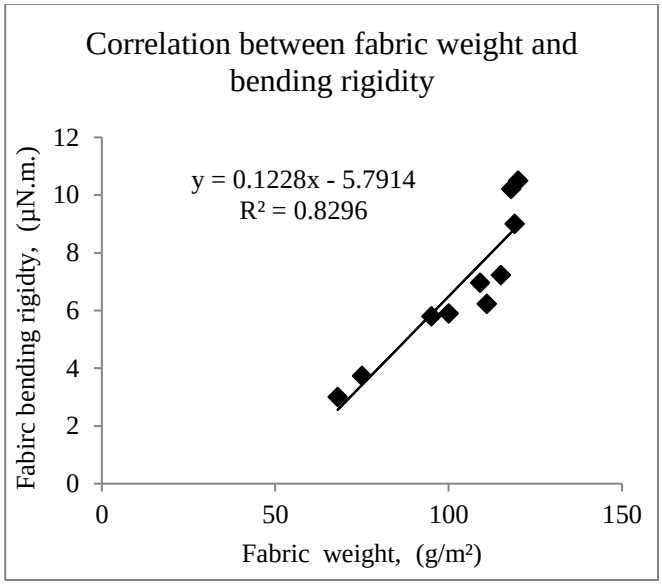

Fig. 5. Fabric weight and bending rigidity

On the basis of above findings, from Fig. 5, it is revealed that weight (g/m^2) of woven fabric influenced with the bending behaviour of fabric and which was important tool for the prediction or elude of seam pucker in the single needle lock (SNL) stitched fabric assembly. It is recognized that magnitude of bending rigidity and cyclic recovery at 4^{th} cycle of sewing thread is influenced by the bending rigidity magnitude of lightweight woven fabric and which is important tool for the prediction or elude of seam pucker in the single needle lock (SNL) stitched fabric assembly.

AATCC-88B visual seam pucker assessment tool was used for pucker severity elevation of developed samples. Pucker severity trend of stitched assemblies are shown in Fig. 6-13 due to resultant behaviour of threads mentioned attributes in relation with the bending rigidity of plain weave lightweight woven fabrics prone to pucker. The significant coefficient of determination of pucker severity (R^2>0.75) also reflects the implication of static needle sewing thread tension along with the thread count, thread diameter, thread bending rigidity, thread cyclic recovery and fabric bending rigidity.

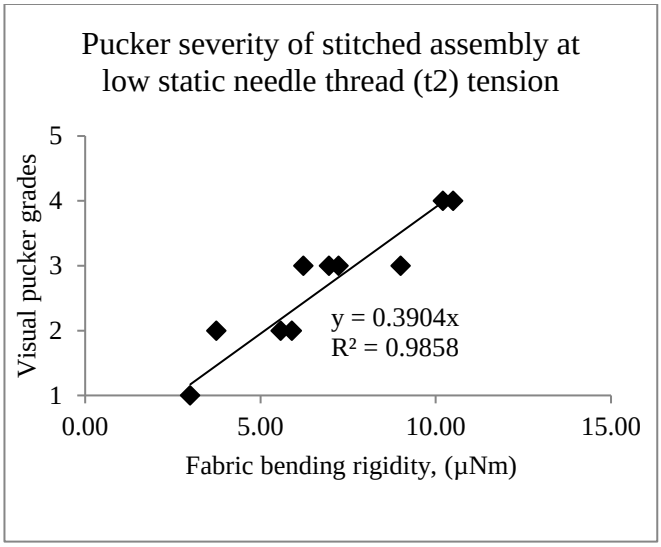

Fig. 6. Correlation at low static needle thread (t_2) tension

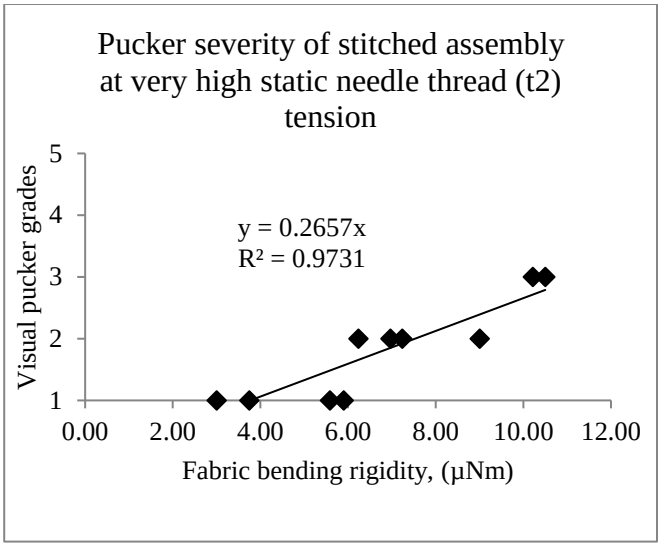

Fig. 9. Correlation at very high static needle thread (t_2) tension

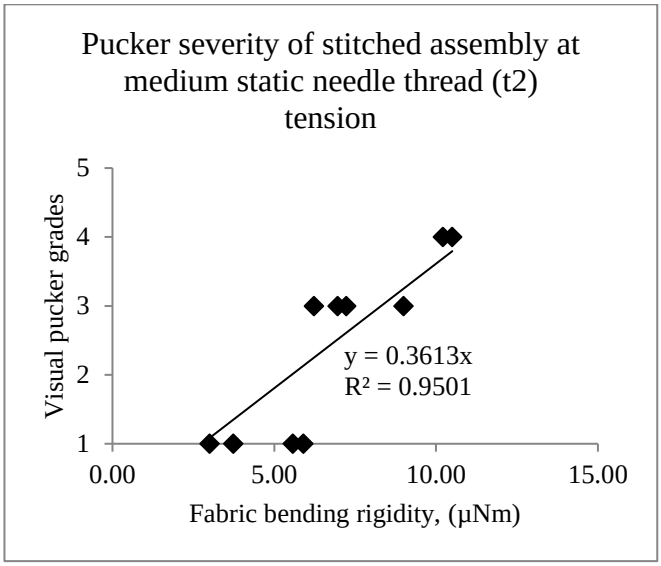

Fig. 7. Correlation at medium static needle thread (t_2) tension

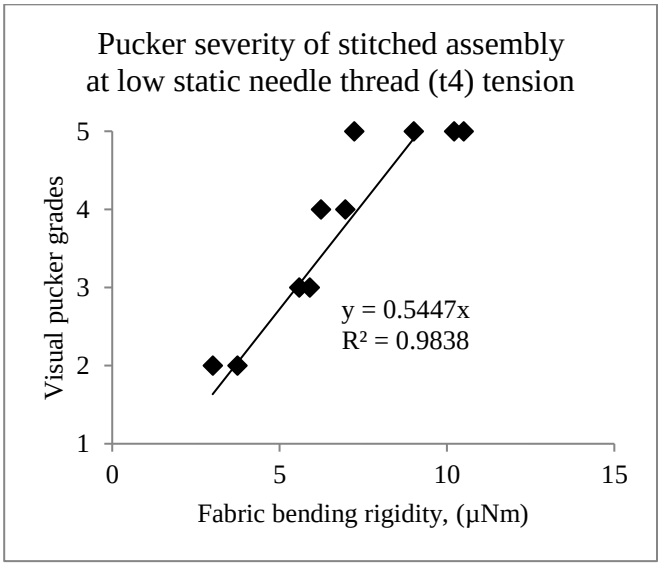

Fig. 10. Correlation at low static needle thread (t_4) tension

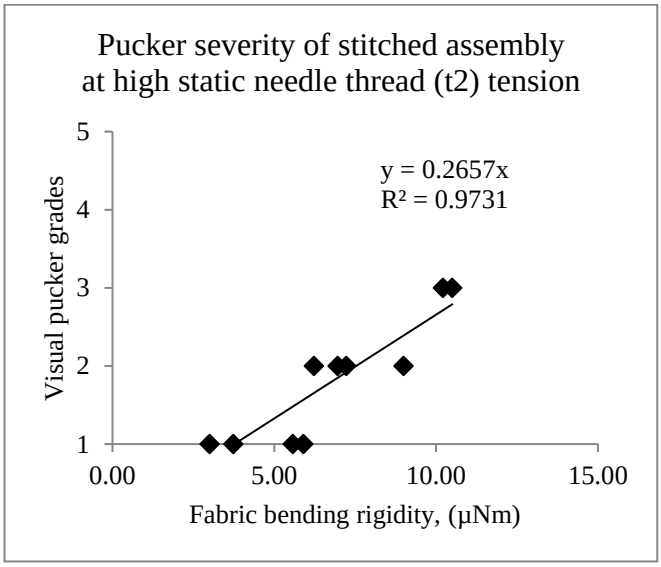

Fig. 8. Correlation at high static needle thread (t_2) tension

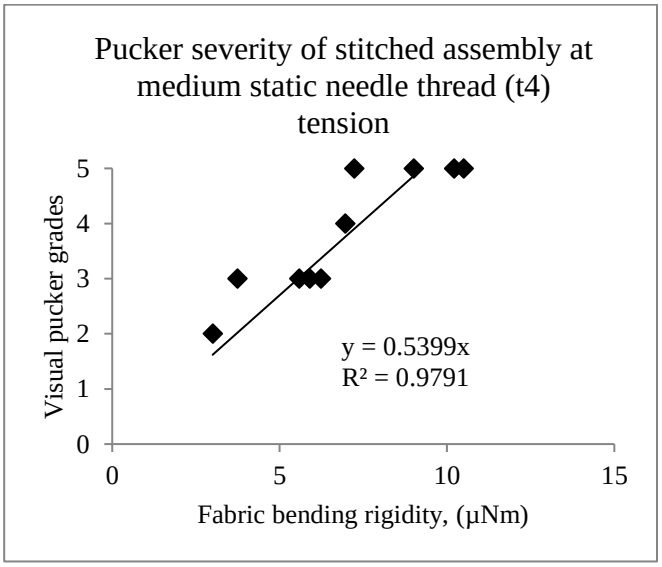

Fig. 11. Correlation at medium static needle thread (t_4) tension

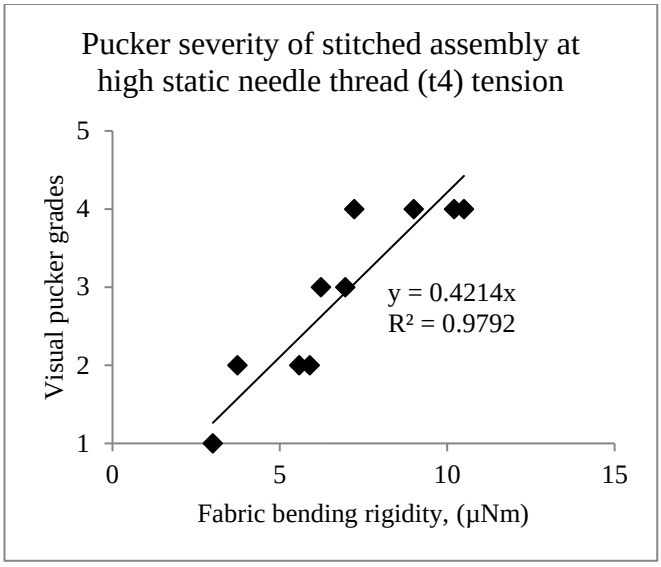

Fig. 12. Correlation at high static needle thread (t_4) tension

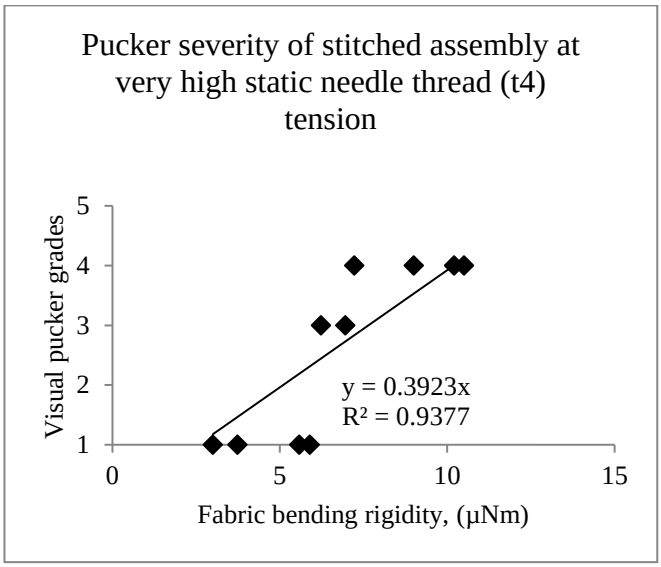

Fig. 13. Correlation at very high static needle thread (t_4) tension

Pucker severity of stitched assembly with sewing thread t_2 and t_4 from Fig. 6-9 and Fig. 10-13 respectively exhibit significant coefficient of determination and also exhibited the implication of combined effect of static thread tension magnitude at single needle lock stitched sewing machine with sewing thread 4th cyclic recovery magnitude on it. Sewing thread t_2 have 0.0042 (g_f. cm^2) bending rigidity with 75.78% cyclic recovery exhibited the highest pucker severity magnitude with increasing static tension trend of needle sewing thread at single needle lock stitched machine while in comparison of sewing thread t_4 have 0.0012 (g_f. cm^2) bending rigidity with 37.43 % cyclic recovery exhibited the lowest magnitude of pucker severity with increasing static tension trend of needle sewing thread at single needle lock stitched machine.

It is also established that seam pucker severity magnitude should not be considered only sewing thread static tension magnitude at single needle sewing machine and sewing thread cyclic recovery magnitude individually but its combine effect has significant implication to predict and elude seam pucker. Present findings extend the established knowledge by considering the mentioned sewing thread attributes with fabric bending rigidity in relation of rising static thread tension magnitude at single needle sewing machine with sewing thread cyclic recovery and bending rigidity magnitude to predict or elude seam pucker rather individual consideration [8, 9].

It has been revealed from Table 4 that sewing thread bending rigidity has strong significant of coefficient of determination (R^2) with sewing thread; diameter (R^2 =0.81), count (R^2 =0.73) and cyclic recovery (R^2 =0.77) at 4th cycle. The evidenced present researched findings strengthen the research outcomes to provide the industrial guideline to select the fine count sewing thread attuned with lightweight woven fabric. It is reported that fine count sewing thread possess lowest cyclic recovery at 4th cycle and bending rigidity magnitudes (R^2 close to 1) to reduce or predict pucker severity for prone to pucker plain weave lightweight woven fabrics at minimum static thread tension ($25g_f$) on single needle lock stitched sewing machine.

4. Conclusion

The study provides the sustainable solution based on the importance of sewing thread bending rigidity along with thread count, diameter and cyclic behaviour in combination of static needle thread tension at SNL stitch sewing machine on seam pucker severity magnitude in stitched assembly of plain weave lightweight woven fabric prone to pucker. It is also established that fine count thread exhibited low magnitude of bending rigidity and 4th cyclic recovery which have been influenced on seam pucker severity magnitude on plain weave lightweight stitched assembly in combination of mentioned minimum static thread tension of SNL stitch sewing machine. Sustainable solution is provided for the textile industry to select fine count thread attuned with fabric which possesses low magnitude of bending rigidity and 4th cyclic recovery in combination of mentioned minimum static thread tension to reduce or predict pucker severity for prone to pucker plain weave lightweight woven fabrics.

5. Acknowledgement

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