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Parameters affecting needle thread tension during lockstitch process

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Role of check spring and parameters, like fabric compressibility, feed rate, breaking elongation percentage of thread and needle thread pre-tension, on the thread tension profile and peak tension values of needle thread has been studied during the stitching cycle. Needle thread tension is measured at two different locations, viz Zone 1 and Zone 2. Zone 1 lies between guide element 1 and guide element 2, while Zone 2 lies between guide element 3 and needle bar. It is observed that the values of thread tension peaks developed in Zone 1 is higher than those developed in Zone 2. It is also observed that in a full cycle of a stitch forming process, tension profile of needle thread has four peaks, out of which tension peaks 1 and 3 occur due to the action of check spring and these two peaks almost vanishes on removal of check spring. The effect of different parameters on needle thread tension profile and its peak values are studied in Zone 1. It is found that the major tension peak values of needle thread reduces with the increase in fabric compressibility and thread extensibility but increases with the increase in feed rate and needle thread pre-tension.

Keywords: Check spring, Denim, Fabric compressibility, Feed rate, Lockstitch process, Nonwoven, Needle thread tension, Peak tension, Rib knitted fabric, Sewing thread, Thread elongation

1 Introduction

The stitch formation process in a lockstitch machine is a dynamic process and requires sewing thread to pass through several elements to form a stitch. The quality of a lockstitch depends on the coordination between different machine elements controlling the movement of sewing thread[1]. Most of the components of lockstitch machine are fixed, while three components viz. take up lever, sewing needle, and check spring are movable. Take up lever is the major part of the lockstitch machine controlling the movement of thread during sewing. The up-down movement of take up lever is responsible for the change in the thread tension in a stitch cycle, and thus contributes in the stitch quality.

The sewing needle helps in penetrating the material and form the loop underside the machine due to its up-down movement. Check spring is another part of the lockstitch machine which consists of a coiled spring with a loop extension. This looped extension of the check spring acts as a small reservoir of the needle thread and resists the thread movement due to the loop held by spring[2]. As the needle thread tension increases, the looped extension deflects flat and releases the stored needle thread at the check spring. The sewing thread passes through these machine components during the stitch formation process and undergoes continuous tension variations in a stitch cycle[1]. The tensions developed in needle and bobbin thread are considered as important factors for a good quality stitch. Improper tension may lead to unbalanced seam, which can ultimately cause various seam defects in garment like seam puckering, seam grinning and thread breakages[1].

Various researchers have tried to measure the needle thread tensions in a stitch cycle of lockstitch machine and observed four prominent needle thread tension peaks in a stitch cycle[1-10]. Few studies have been reported on the effect of different parameters on the needle thread peak tension values[1-10]. Ferreira *et al.*[1] studied the effect of different parameters on needle thread tension peaks and found that thread pre-tension and thread quality affect the tensions generated on needle and bobbin thread. Lojen and Gersak[4] reported that peak tension values increase with the increase in needle thread pre-tension and stitch velocity. They also studied thread tension profile in different positions and found that sewing thread experiences highest tension between tensioner and take up lever followed by tension between take up lever and needle, and lowest tension in front of the main tensioner[5]. Rengasamy and Wesley[8-10] studied the effect of different parameters on needle thread tension profile.

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They studied the effect of check spring tension on the needle thread tension peak and found that all peak values except tension peak 2 increases with increase in check spring tension[9]. Hayes[2] also studied the effect of check spring travel on the needle thread tension and needle thread consumption of lockstitch seam, and reported that the increase in check spring travel by 3 mm reduces needle thread consumption per stitch and increases peak needle thread tension. The effect of different thread structures and properties on thread tension peaks was analyzed and it was found that thread pre-tension and elastic modulus influence peak tension values, whereas thread properties like bending rigidity do not affect peak tension values[8]. It was also reported that with the increase in stitch length, all the tension peaks increases and for a shorter stitch length, the needle thread pre-tension must be increased to get a balanced stitch. They observed that fabric feed timing, needle thread in-take length, machine speed and thread linear density influence the highest peak tension value, i.e. peak 2 developed in a stitch cycle of lockstitch machine[9-10]. Koncer *et al.*[7] also studied the effect of sewing thread properties on needle thread tension and showed that sewing thread type, lubricant type and lubricant feeding rate (g/min) affect thread tension.

Although researchers have studied the impact of different parameters on tension peaks during sewing, but still there is a need to investigate the role of check spring in developing the needle thread tension profile and effect of parameters like fabric compressibility, feed rate and thread breaking elongation on needle thread tension profile in a stitch cycle during sewing. In this work, therefore, needle thread tension was measured with and without check spring to understand the role of check spring in the development of needle thread tension profile. For normal lock-stitching process, four significant tension peaks were obtained similar to those in previous studies[1-10] and it was identified that check spring is responsible for the formation of tension peak 1 and peak 3. These peaks get diminished in the absence of check spring, and the values of tension peak 2 and peak 4 reduce in the absence of check spring. Needle thread tension was measured at two positions, i.e. between guide element 1 and guide element 2 (Zone 1) and between guide element 3 and needle bar (Zone 2).

2 Materials and Methods

To understand the lockstitch process and to achieve a good quality seam, it is necessary to know the parameters influencing the tension profile of lockstitch seam. Hence, the needle thread tension variations in a stitch cycle of lockstitch machine have been measured with and without check spring at two different positions, i.e. between guide element 1 and guide element 2 (Zone 1) and between guide element 3 and needle bar (Zone 2), and the effect of fabric compressibility, feed rate, thread breaking elongation percentage and needle thread input tension on the tension profile of lockstitch machine were studied.

2.1 Materials

Three fabrics, viz. denim, rib knitted and nonwoven having different compressibility were taken for the experimental work. Sewing threads having same linear density (24 tex) were selected on the basis of differences in their breaking elongation values. All the experiments were carried out in BROTHERS S-7000 DD-403 single needle Lockstitch machine using sewing needle of size 11.

2.2 Methods

Fabric compressibility was measured in Prolific Thickness gauge at a pressure ranging between 2 kPa and 200 kPa using following equation:

$$\text{Compressibility}\,\% = \frac{t_i - t_f}{t_i} \times 100 \quad \text{... (1)}$$

where t_i is the initial thickness of the fabric at a pressure of 2 kPa; and t_f, the final thickness of the fabric after compressing it at a pressure of 200 kPa[11]. The compressibility values of all the fabrics selected are shown in Table 1.

Feed rate, defined as the amount of fabric fed to the machine per unit time, can be quantified by using following equation:

$$\text{Feed rate} = l/t \quad \text{... (2)}$$

where l (cm) is the length of the fabric stitched for a given time t (s). Feed rate is controlled by changing knob position and was calculated at different positions (feed rate 1.43 cm/s at position 2, 2.28 cm/s at position 3, and 2.96 cm/s at position 4).

The tenacity and elongation of sewing threads were measured in Zwick/Roell BZ1-MM14450.ZW01 tensile testing machine as per ASTM D2256[12]. The

Table 1 — Compressibility values of different fabrics

Fabric	Initial thickness (t_i), mm	Final thickness (t_f), mm	Compressibility %
Denim	0.75	0.61	18.67
Rib knit	0.86	0.59	31.39
Nonwoven	1.65	0.41	75.15

properties of sewing threads selected are given in Table 2.

A thread tension measuring instrument working on the basis of strain gauge principle was used for measuring needle thread tension at two different positions. Any deflection in the sensor reads the tension values (gf) and stores it in memory card inserted in the instrument. The data is then transferred in PC to plot the tension profile with respect to wheel rotation angle of the stitching machine.

Take up lever lies between two fixed guide elements (2 and 3) and is constantly moving upward and downward during the process of stitching and thus tends to form a triangle with varying altitudes by the thread between the two fixed guide elements and take up lever. This triangle is the active region of the take up lever action. To understand the tension variation of needle thread during the stitch formation process, thread tension was measured at two locations, i.e. in the region between guide element 1 and guide element 2 (Zone 1) and in the region between guide element 3 and needle bar (Zone 2) as shown in Fig. 1. These zones are selected to know the needle thread tension variations just before and after the active region of take up lever. Zone 1 is the region just before the sewing thread enters the take up lever zone and Zone 2 is the region just after the sewing thread leaves the take up lever zone.

Table 2 — Sewing thread specifications

Thread	Linear density tex	Breaking tenacity, cN/tex	Breaking elongation, %
Spun polyester	24	23.79	11.4
Nylon bonded	24	49.58	23.72

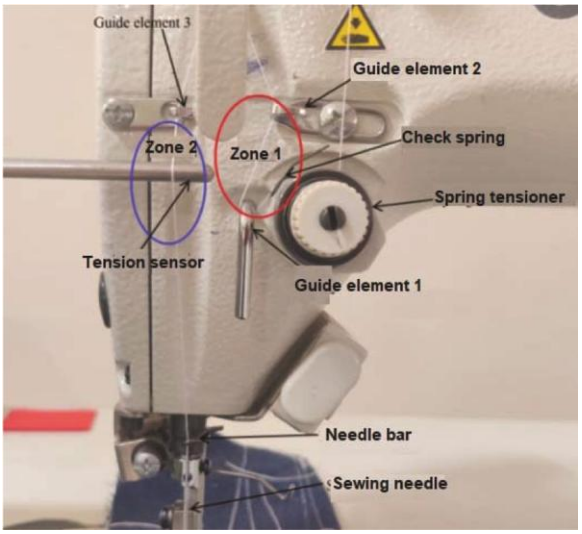

Fig. 1 — Tension measuring positions in lockstitch machine

Needle thread tension was measured in both zones with and without check spring to understand the role of check spring on the development of needle thread tension in a stitch cycle. To study the effect of fabric compressibility, feed rate, thread breaking elongation % and needle thread pre-tension value on the tension profile of lockstitch seam in a stitch cycle (0° - 360°), four experiments were carried out. The stitch cycle was started at a position when needle is at its topmost position, i.e. 0° or 360°, corresponding to the topmost position of needle. Needle thread pre-tension was varied as 30, 60 and 100gf. The effect of these parameters on needle thread tension profile and peak tension values was studied by varying one parameter at a time while keeping other parameters constant. The machine was run at a speed of 20 rpm and bobbin thread tension and sewing speed are kept constant for all the experiments.

3 Results and Discussion

Needle thread tension was measured using the tension meter in both the zones with and without check spring. The experiment was conducted on denim fabric at a feed rate of 2.28 cm/s and needle thread pre-tension of 60 gf, using nylon bonded sewing thread having breaking elongation of 23.72%.

3.1 Needle Thread Tension Profile in Zone 1 and Zone 2

The needle thread tension profile is plotted against wheel rotation angles in a stitch cycle for both Zone 1 and Zone 2 of lockstitch machine as shown in Fig. 2(a). This experiment was initially done in the presence of check spring.

The needle thread tension profile is given in Fig. 2(a). It can be seen that there are four prominent needle thread tension peaks occurring in a stitch cycle of lockstitch machine in both the zones as reported by other researchers[1,5,8]. Each peak indicates a specific action of take up lever, sewing needle, sewing thread movement and bobbin thread. It is clear from Fig. 2(a) that the values of minor peaks (peak 1 and peak 3) in both Zone 1 and Zone 2 are nearly similar to each other or slightly high in Zone 1, whereas the values of major tension peaks (peak 2 and peak 4) recorded in Zone 1 are always higher than peak tension values in Zone 2. This is similar to the findings reported previously[5]. The formation of these thread tension peaks in both the Zones is discussed hereunder.

(i) *Peak 1*—It is the small peak occurring at a position when wheel rotation angle lies between 30° and 50°. During this peak, take up lever is moving

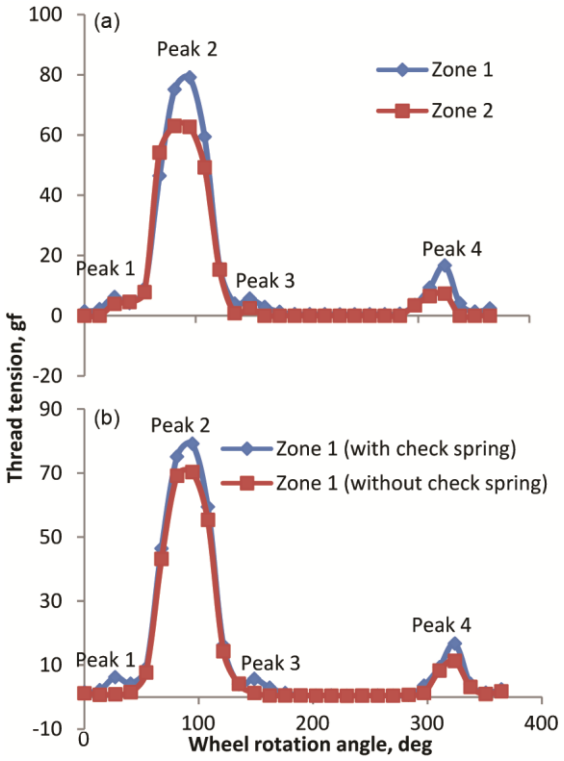

Fig. 2 — Needle thread tension profile (a) at different zones and (b) with and without check spring in lockstitch machine

upward and bobbin has rotated to its full amount along with the needle thread in its hook thus; increasing needle thread tension to some extent and develop this peak. After this peak, needle thread is released from the bobbin hook. Thread tension rises due to the upward movement of take up lever. When the thread tension value exceeds the check spring tension, the stored amount of thread gets released from check spring, thus reducing the thread tension. After this, thread tension again starts to increase after the formation of peak 1 due to upward movement of take up lever, and as the take up lever is moving upward, needle thread will also start moving in upward direction and withdraws bobbin thread from the bobbin case for the formation of new stitch.

From Fig. 2(a), it can be seen that Peak 1 is giving somewhat similar values in both the zones because tension value at this peak is developed mainly due to the movement of check spring[13].

(ii) *Peak 2*—It is the most important peak which is occurring at 80° - 110° wheel rotation angle and is known as the stitch tightening tension peak. It occurs when the take up lever reaches its topmost position withdrawing whole amount of needle thread from the bottom side of the machine. This leads to the tightening of both needle and bobbin thread at the center of the fabric layers[1].

Figure 2(a) shows higher values of tension peak 2 in Zone 1 than in Zone 2. Peak 2 is the place where the supply of fresh thread from the package takes place. As the spring tensioner is holding thread tightly before zone 1 and thread flows in backward direction across take up lever towards spring tensioner with upward movement of take up lever, so tension build up in the thread is transferred from Zone 2 to Zone 1, thus increasing the thread tension in Zone 1. A moment arises when the take up lever is approaching towards its topmost position and tension in Zone 1 has reached its maximum level (i.e. peak 2). As the thread tension in Zone 1 increases further, a time will come when the thread tension value in this zone exceeds the force or tension exerted by the disc tensioner on the needle thread and the fresh thread will flow from the package to Zone 1. This peak tension developed in Zone 1 is higher than the peak tension developed in Zone 2, as the supply of thread is only possible when peak tension 2 is higher in Zone 1 than in Zone 2. Due to the supply of fresh thread from the package, thread tension in both the zones starts falling.

The other reasons for the higher values of tension peak 2 in Zone 1 than in Zone 2 as stated previously by other researchers may be because, length of the thread available in Zone 1 is very low as compared to the length of thread available in Zone 2 as can be seen from Fig. 1. For any sewing thread, the amount of extension for a shorter thread length is less as compared to the longer thread length. Hence, the sewing thread in Zone 1 having shorter length extend less as compared to the sewing thread in Zone 2[5,9]. In addition, the sewing thread is held tightly from one end by the tensioner in Zone 1 leading to more chances of higher tension values[5].

(iii) *Peak 3*—It is another small peak generated in 140° - 160° wheel rotation angle when needle penetrates into the fabric layers. This needle thread tension peak is generated due to the rise in frictional force on the needle thread during penetration which pulls needle thread for penetrating the fabric layers. During this period, take up lever is moving in downward direction and thread flows from the take up lever across the needle to the bottom side of the machine, so that it can be picked up by the hook.

From Fig. 2(a), it can be seen that tension peak 3 is almost similar in both Zone 1 and Zone 2. This peak tension is developed due to the small rise in thread

tension at the needle penetration site. As the needle penetrates through the fabric, there is a small rise in thread tension, and this tension falls to zero when needle reaches its bottommost position. Also, this tension peak value is much lower than the input tension, so it remains unaffected and is similar in both zones[5].

(iv) *Peak 4*—It is the second highest peak occurring at 310° - 330° wheel rotation angle when the needle thread has reached the bottom side after penetrating through the fabric and is wrapped around the shuttle. During this peak, take up lever started moving upward and needle thread is moving in backward direction from bobbin area towards the take up lever and is about to release from bobbin hook.

Figure 2(a) shows that Peak 4 gives higher value in Zone 1 as compared to that in Zone 2. The reason being the same that thread first flows from take up lever to needle to get wrapped around the shuttle by hook, which requires more amount of needle thread. This requirement of excess thread results in an increase in needle thread tension. As there is no flow of thread from input or feeding side, there is a rise in thread tension which is reflected in the form of tension peaks 4. As the thread flows from Zone 1 to Zone 2, the value of thread tension peak in Zone 2 is lower than in Zone 1[5,9].

From this experiment, it is clear that Zone 1 is the zone where maximum tension is occurring for all the four peaks, so it may be proper to study the effect of different parameters on needle thread tension profile in this Zone. In this work, all the data is generated by measuring the thread tension in Zone 1 to study the effect of fabric compressibility, thread elongation, feed rate and needle thread input tension on needle thread tension profile.

3.2 Needle Thread Tension Profiles with and without Check Spring

An experiment was conducted on denim fabric by stitching it under identical conditions as mentioned in Section **3.1**. The needle thread tension variations in Zone 1 are recorded and plotted against wheel rotation angle with and without check spring [Fig. 2(b)] to see the impact of check spring on needle thread tension profile.

Figure 2(b) shows that needle thread tension profile developed with check spring in lockstitch machine gives four prominent thread tension peaks, whereas needle thread tension profile developed without check spring gives only two peaks, i.e. peak 2 and peak 4. The other two tension peaks of needle thread (peak 1 and peak 3) got diminished or vanished without check spring as also reported previously[13]. The needle thread passes though the looped extension of check spring and resists needle thread movement. The geometry of check spring is such that it can store some amount of extra needle thread in its looped extension when thread tension is low. With the movement of needle, the needle thread tension increases continuously. When the needle thread tension exceeds the check spring pressure, the stored thread is released by deflecting the check spring[2]. This action takes place in peak 1 and peak 3 where there is a small rise in thread tension. However, the thread tensions developed in peak 2 and peak 4 are much higher than check spring tension, and the check spring has already reached its flat position during the initial stages of peak 2 and peak 4. It is also observed that the values of major tension peaks i.e. peak 2 and peak 4 are more when recorded with check spring than without check spring. This may be due to more number of yarn-metal contact points with check spring and pressure exerted by check spring on thread[13].

3.3 Effect of Different Parameters on Needle Thread Tension Peaks

The effect of different parameters like fabric compressibility, feed rate, thread elongation percentage and needle thread input tension on needle thread tension profile in lockstitch machine are analyzed in Zone 1. Table 3 shows the average values of all the four tension peak values with their corresponding coefficient of variation.

From the Table 3, it is clear that the impact of different parameters on tension values of peak 1 and peak 3 are nominal. Hence, in this study the effect of different parameters on major tension peaks 2 and 4 are discussed in details.

3.3.1 Effect of Fabric Compressibility on Peak Tension Values

The effect of fabric compressibility on needle thread peak tension values is studied by stitching fabrics of different compressibility, keeping all other parameters constant [Fig. 3(a)].

Figure 3(a) shows that needle thread peak tension values reduce with increase in fabric compressibility. However, this effect of fabric compressibility on peak tensions is more prominent for peak 2 and peak 4. During the process of stitch tightening, take up lever is moving upward and needle thread flows from the bottom side of the fabric towards the center of fabric layer for interlacing with the bobbin thread. This

Table 3 — Needle thread peak tension values in Zone 1

Variable	Levels	Mean/ CV%	Average peak tension values in Zone 1, gf			
			Peak 1	Peak 2	Peak 3	Peak 4
Fabric compressibility, %	18.67	Mean	6.14	104.36	5.78	19.32
		CV%	11.59	2.36	18.00	9.65
	31.39	Mean	1.87	93.43	3.46	13.37
		CV%	20.00	3.17	20.43	15.11
	75.15	Mean	1.97	89.02	3.39	13.3
		CV%	21.15	1.59	20.91	14.93
Feed rate, cm/s	1.43	Mean	4.44	97.98	3.44	16.62
		CV%	19.30	2.09	19.53	8.98
	2.28	Mean	5.81	104.02	6.07	19.11
		CV%	15.34	1.68	19.92	8.84
	2.96	Mean	8.51	118.4	9.74	25.26
		CV%	19.99	2.33	14.33	9.74
Thread breaking elongation, %	11.4	Mean	2.63	102.73	2.6	14.67
		CV%	18.75	1.22	19.53	14.27
	23.72	Mean	5.65	84.13	6.2	19.95
		CV%	19.42	1.45	17.99	6.01
Needle thread pre-tension, gf	30	Mean	0	26.30	0	4.56
		CV%	-	8.29	-	20.32
	60	Mean	5.79	104.41	4.43	19.42
		CV%	16.88	2.41	20.15	10.02
	100	Mean	15.43	116.17	43.68	51.21
		CV%	12.38	4.87	8.78	11.07

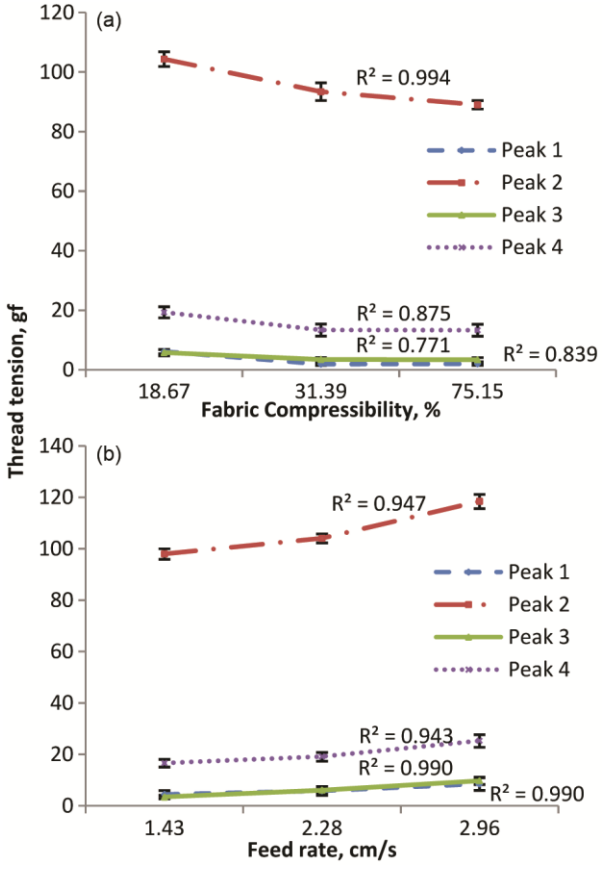

Fig. 3 — Effect of (a) fabric compressibility and (b) feed rate on needle thread peak tensions

process leads to a gradual tension build up on the fabric surface. Due to rise in thread tension of needle and bobbin thread, fabric will be compressed. Due to fabric compression during the process of stitching, the original thickness of the fabric goes on reducing[14].

A highly compressible fabric tends to reduce its thickness more and form elliptical stitch, whereas a less compressible fabric does not reduce its thickness much and forms either rectangular or racetrack stitch[15]. So, a highly compressive fabric needs less amount of thread due to lowering of fabric thickness value as compared to less compressible fabric. This leads to reduction of thread tension for highly compressible fabric due to backward flow of needle thread towards the take up lever. Thus, peak tension values reduce with increase in fabric compressibility.

3.3.2 Effect of Feed Rate on Peak Tension Values

The effect of feed rate on needle thread peak tension values of lockstitch machine has been studied on denim fabric by varying feed rate and keeping all other parameters constant [Fig. 3(b)].

From Fig. 3(b), it can be seen that all the peak tension values increase with increase in feed rate. At higher feed rate, longer length of fabric is fed to the machine which requires more amount of sewing thread for stitching[16]. So, thread requirement is more at higher

feed rate which will draw more amount of thread from the package. This need for drawing large amount of sewing thread from the package will increase thread tension until it overcomes the tension required for pulling fresh thread from supply package, thus increasing the peak tension values at higher feed rate[9]. On the other hand, at lower feed rate, the thread required from the package will be less which will develop lesser tension in the needle thread, so the peak tension values at lower feed rate will also be low.

3.3.3 Effect of Thread Breaking Elongation% on Peak Tension Values

The effect of sewing thread breaking elongation was studied by stitching denim fabric with threads having same tex but different extensibility, keeping all the other parameters same. The load extension behavior of threads is measured in Zwick/Roell BZ1-MM14450. ZW01 tensile testing machine and is given in Fig. 4. The effect of thread breaking elongation on needle thread peak tension values is depicted in Fig. 5.

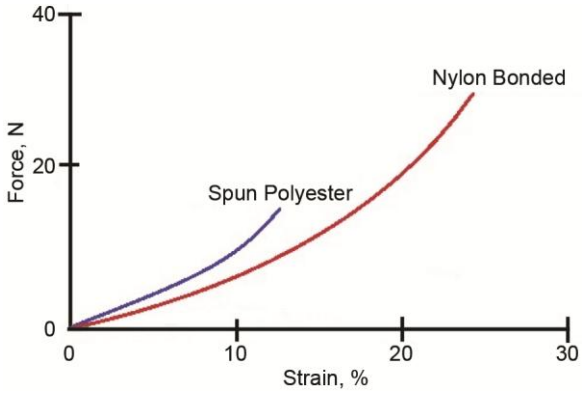

Fig. 4 — Load-extension curve of different threads

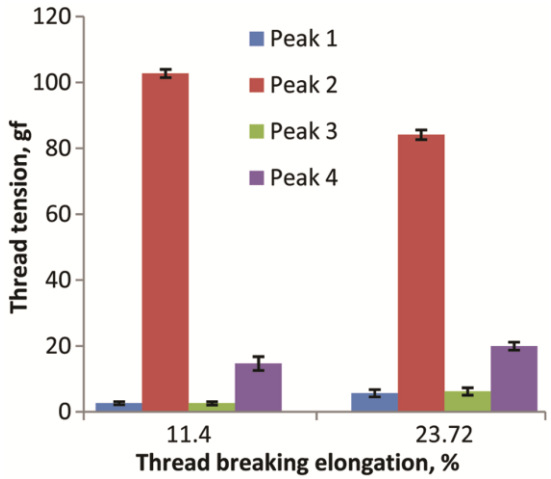

Fig. 5 — Effect of thread elongation on needle thread peak tension values

From Fig. 5, it can be seen that the values of tension peak 2 reduces as thread extensibility increases from 11.4% (spun polyester) to 23.72% (nylon bonded thread)[13]. It is known that there is a tension build up in the thread during the upward movement of take up lever till it reaches to a value higher than the resistance offered by the tensioner, causing the withdrawal of thread from the supply package. Sewing thread tends to stretch until the tension generated in the thread is more than the tension imposed by tensioner. A highly extensible thread will stretch to a large amount before withdrawing the supply thread. On the other hand, low extensible thread will stretch less and will increase the thread tension quickly. So, peak tension values for a more extensible thread (23.72%) is less as compared to peak tension values of low extensible thread (11.4%).

3.3.4 Effect of Needle Thread Pre-Tension

The effect of thread pre tension on the needle thread peak tension values is studied on denim fabric by varying needle thread pre tension, keeping all other parameters same (Fig. 6).

It can be seen that with the increase in needle thread pre tension values, peak thread tension values also increase considerably for all the peaks[1,4,10]. Peak 2 occurs when the take up lever reaches its topmost position and it is the point where the tension in the thread is so high that it withdraws fresh thread from the package for accomplishing the thread requirement from package. The needle thread in Zone 1 is held by spring tensioner just before guide element 1 which gives input tension to the needle thread. If this input

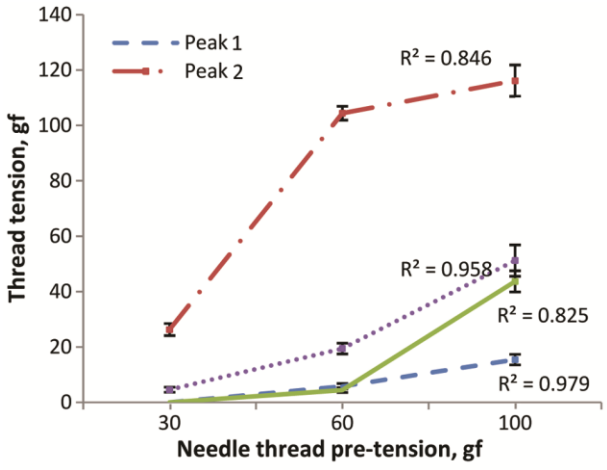

Fig. 6 — Effect of needle thread pre-tension on needle thread peak tension values

tension is low, then the tensioner will exert less pressure on sewing thread and will supply fresh thread from the package easily when take up lever reaches its topmost position. This gives a low value of peak thread tension. On the other hand, if this input tension is high, then thread will be held tightly by the tensioner. For such high input tensions, spring tensioner will not supply fresh thread from the package until the tension in the thread in Zone 1 exceeds the thread tension provided by tensioner pressure. So, there will be a stretching in the thread before a fresh thread supply comes from package, thereby increasing the peak tensions[10]. Thus, peak tension values increases with increase in thread tension.

4 Conclusion

In this study, four prominent tension peaks are developed on needle thread in lockstitch machine. From the results, it can be concluded that all the tension peaks of needle thread developed in Zone 1 (region between guide element 1 and guide element 2) are more than the tension peaks developed in Zone 2 (region between guide element 3 and needle bar). It is found that check spring is responsible for the development of tension peak 1 and tension peak 3; and these tension peaks diminish when needle thread tension is recorded without check spring. The effect of parameters like fabric compressibility, feed rate, thread elongation percentage and needle thread input tension on needle thread peak tensions in Zone 1 are analyzed. It is found that needle thread peak tension values reduce with increase in fabric compressibility and thread extensibility, but it increases with the increase in feed rate and needle thread input tension.

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