

## Dynamics of lockstitch sewing process

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### Abstract

During high speed sewing, the needle thread is exposed to dynamic loading, short strike loading, inertia forces, friction, rubbing, force of check spring, bending, pressure, friction, impact, shock and thermal influence. The dynamic thread loading/tension alters throughout the stitch formation cycle and along its passage through the machine. The greatest tensile force occurs at the moment of stitch stretching, when the take up lever pulls for required thread length through the tension regulator. These stresses act on the thread repeatedly and the thread passes 50-80 times through the fabric, the needle eye and the bobbin case mechanism, before getting incorporated into the seam, which result in upto 40% loss in tensile strength of the sewing thread. This damage in the sewing thread adversely affects its processing and functional performance. In this paper, the contribution of dynamic loading, passage through needle and fabric, and bobbin thread interaction in the loss in tensile properties has been studied. It is observed that the loss in tensile properties occurs mainly due to the bobbin thread interaction. Dynamic loading due to the action of take up lever also causes substantial loss in tenacity and breaking elongation of cotton threads.

*Keywords: sewing dynamics, tensile strength, tensile loading, thermal loading*

### I. Introduction

During the passage of sewing thread through the lockstitch machine, the needle thread is exposed to various stresses and strains at different guides, tension discs, tension spring, take up lever, needle eye and the fabric assembly. In the beginning, compression force of the tension discs, force of tension spring and the action of take up lever cause tensile loading of the thread. The thread is also subjected to the inertia forces due to rapid acceleration in forward and backward direction, besides friction at various guides. Further,

during the formation of stitch, it passes through the needle and fabric assembly and exposed to high tensile forces, frictional contact with the needle and fabric assembly, thermal loading due to heating of the needle, and bending through small radius of curvature. In the process, it also interacts with the bobbin thread and is subjected to bending, abrasion and tensile deformation before getting incorporated into the seam (Gersak & Knez, 1991). The lockstitch sewing process is so dynamic that the mechanical properties of the needle thread get altered during exposure to these stresses; and therefore predictability of performance characteristics of thread becomes difficult. The sewing thread mecha-

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nical properties are further responsible for the seam performance. If the thread mechanical properties get altered before the thread is incorporated into the seam, seam strength will be much lower than expected (Midha, Mukhopadhyay & Kaur, 2011). Increasing speed of the lockstitch machine for higher production further adds to the problems.

In this paper, lockstitch formation, dynamics of the process and its effect on mechanical properties of the needle thread have been discussed.

## II. Mechanism of Lockstitch Sewing

〈Fig. 1〉 shows the steps in a lockstitch cycle. Upper thread is carried through the substrate by the needle and a loop is formed on the underside of the substrate as the needle begins to withdraw. A hook rotating around the bobbin case and carrying the lower thread, passes through this loop so that the two threads interlace just as the needle thread begins to be withdrawn through the substrate to the upper surface (Weimer & Mitschang, 2001).

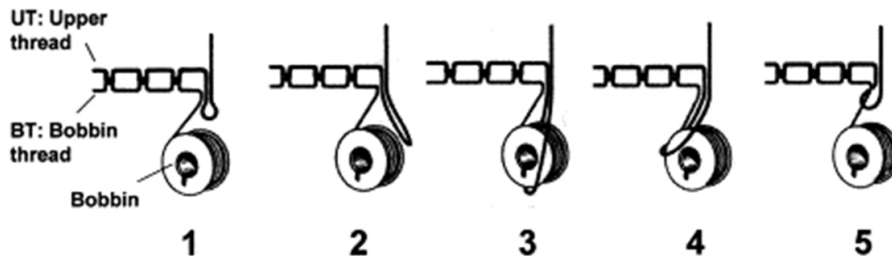
However, setting of the stitch is determined not in one stitch formation cycle, but in its cycle and the cycle of the subsequent stitch. When the thread take up lever completes its upward movement, drawing the slack needle thread through the fabric, the bobbin thread pulls out of the bobbin and is drawn right through the fabric to its upper side. As the fabric continues its forward movement and the needle moves down, the bobbin thread loop of the previous stitch

remains on the upper side of the fabric. Then as the take up lever moves upwards drawing the slack needle thread and the bobbin thread through the fabric to form a new stitch, the bobbin thread loop of the previous stitch starts moving down. This is when the previous stitch sets into the fabric assembly and bobbin thread of the next cycle is again drawn right through to the upper side of the fabric (Ferreira, Harlock & Grosberg, 1994a). The interlacing of two threads will be positioned approximately in the middle of the substrate if needle and bobbin thread tensions are adjusted appropriately. Improper tensions can cause various problems like puckered seams, thread breakage besides making the seam unbalanced.

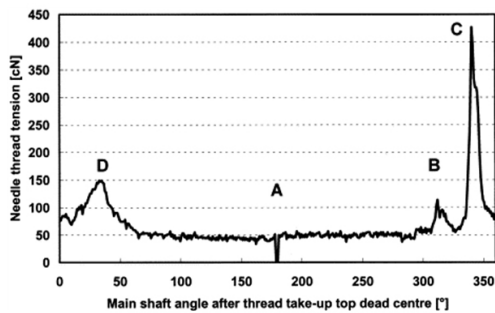
## III. Dynamics of Sewing

The stresses experienced by the sewing thread alter throughout the stitch formation cycle and keep on varying as the thread moves through different parts of the machine and gets incorporated into the fabric. Needle thread tensions are much higher than bobbin thread tensions. Four characteristic tension peaks are observed in the needle thread and two peaks are observed in the bobbin thread during the stitch cycle (Weimer & Mitschang, 2001; Ferreira, Harlock & Grosberg, 1994b).

The greatest tensile force (around 300 cN-425 cN) occurs in the needle thread, when the take up lever pulls the required thread length through the tension regulator for the stitch formation, also known as

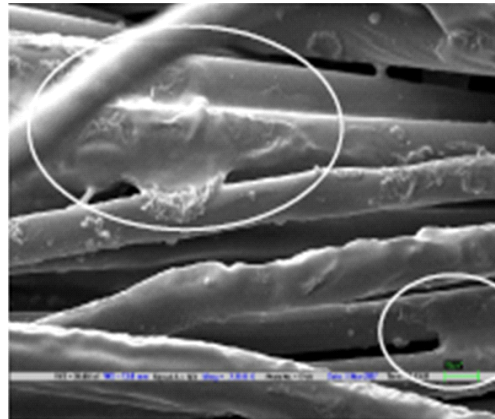


〈Fig. 1〉 Steps in lockstitch formation



<Fig. 2> Needle thread tension curve during a stitch cycle

tightening tension (Fig. 2). Lojen and Gersak (2005) measured needle thread tensions at different locations along the passage of the polyester core spun thread through the machine. The measuring positions were MP1-the region between the take up lever and the sewing needle, MP2-between tension regulator and take up lever, MP3-between tension regulator and pre-tensioner and MP4-between pre-tensioner and bobbin. It was observed that thread tension keeps on varying along the passage of thread through various machine parts. Highest tension forces occur in the region between the tension regulator and the take up lever due to the reason that the sewing thread is more rigidly clamped than the other side of the sewing thread. Further, as a result of needle passing at high speed through the substrate, and the thread passing at high speed through the needle eye, the thread is also subjected to thermal loading. A lot of heat is generated due to the needle penetrating the fabric substrate with high penetration force. Heat retained by the needle is concentrated in a small mass of metal and the temperature of needle may reach 300-350°C within 3 seconds of running the machine (Li, Liasi, Zou & Du, 2001; Li, Liasi, Simon & Du, 2001; Liasi, Du, Simon, Dimitrejevic & Liburdi, 1999). Such a high temperature is detrimental to the hardness of the needle and also causes harmful heating to the sewing thread as well as the material being sewn in the region of the needle penetration. High temperature of the needle may soften or melt the thread (Fig. 3). Softened polymer from



<Fig. 3> SEM image of polyester-polyester core spun needle thread after sewing

either the sewing thread or the fabric may get deposited in the needle eye, thus clogging the eye.

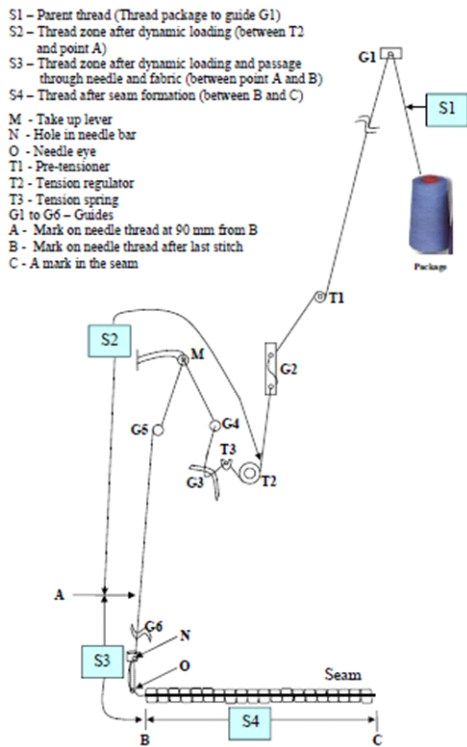
#### IV. Effect on Sewing Thread Properties

Repeated loading of the thread during the sewing process causes 30-40% loss in tensile strength of the needle thread. Cotton threads exhibit higher strength loss than polyester staple spun and core spun threads. Sundaresan, Hari and Salhotra (1997) in a study on cotton and polyester staple spun threads observed structural openness of the thread, pull-out of fibres and the displacement of the plies at the thread interlacing point to be the dominant factor influencing its strength reduction. Rudolf and Gersak (2006) in a study on the effect of twist on alteration in fibres' mechanical properties before and after sewing, on polyester-polyester core spun thread also confirmed the damage at the interlace point of the needle and bobbin thread and attributed it to the tensional, frictional and bending loadings of the thread during the sewing process. Rudolf and Gersak (2001) observed that thread failure is mostly preceded by isolated fiber breaks, initiating from the interlacing point of needle thread in the stitch, suggesting the presence of severe weak spots in some of the fibres. The fibre strength reduction has been found to be only 10% as

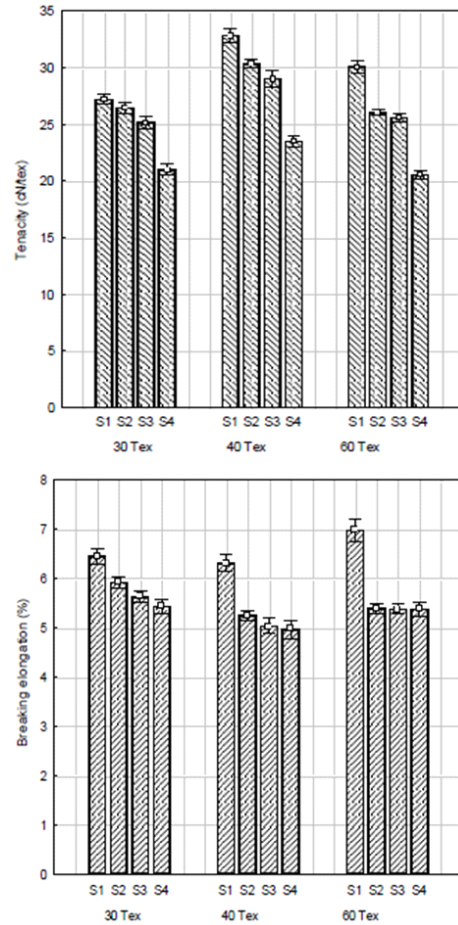
compared to 20% in the thread. Thermal loading, tensile loading, bending and repeated friction and rubbing through various machine elements and fabric have been identified as the reasons for the damage in tensile properties (Crow & Chamberlain, 1969; Sundaresan et al., 1997; Rudolf, Gersak, Ujhelyiova & Smole, 2007).

In recent studies, Midha, Kothari, Chattopadhyay and Mukhopadhyay (2009a; 2009b) reported the contribution of dynamic loading, passage through the needle and fabric, and bobbin thread interaction in the loss of tensile properties during sewing by measuring the tensile properties of needle thread at different sewing stages along the passage of thread through various machine parts (Fig. 4).

(Fig. 5) shows the tenacity and breaking elongation of 30 tex, 40 tex and 60 tex cotton threads at successive sewing stages. A progressive decrease in

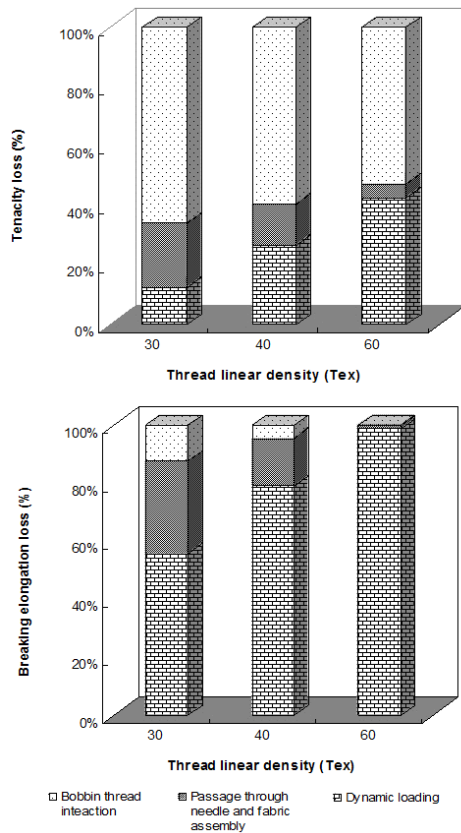


(Fig. 4) Passage of the needle thread through the sewing machine



(Fig. 5) Tenacity and breaking elongation for cotton threads during successive sewing stages

these properties was observed as the thread passes through different sewing stages. As the thread moves from stage S1 to S2, thread and fibre fatigue during repeated loading causes significant loss in fibres' mechanical properties, leading to strength and elongation loss. Dynamic loading has a contribution of 12% in 30 tex, 27% in 40 tex and 43% in 60 tex threads for tenacity loss. Dynamic loading is the major contributor in breaking elongation loss; the values being 51% for 30 tex, 79% for 40 tex and 99% for 60 tex threads (Fig. 6). The contribution of dynamic loading in total loss in tenacity and breaking elongation is



⟨Fig. 6⟩ Contribution of dynamic loading, passage through needle and fabric, and bobbin thread interaction in tenacity loss and breaking elongation loss for cotton threads

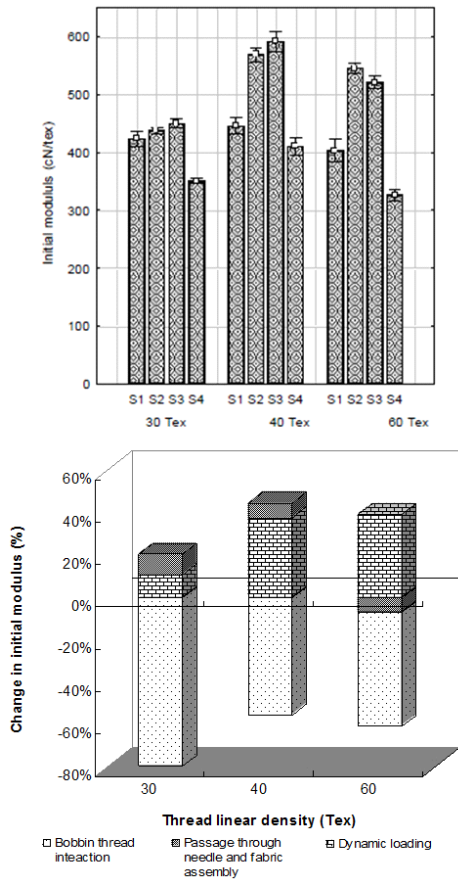
more for coarser threads as compared to finer threads. Usually shorter fibres are used in coarser threads, which make the thread intrinsically weak due to fibre-fibre slippage under dynamic loading. Therefore, coarser threads exhibit greater loss in tenacity, breaking elongation and breaking energy due to dynamic loading. As the thread passes from stage S2 to S3, the tenacity and breaking elongation decrease further, due to the abrasive action of the threads while interacting with the needle and fabric assembly during its repeated passage. The passage through the needle and the fabric assembly has relatively small contribution to the loss in tenacity and breaking elongation. It may be noted that the most appropriate size of the

needles was used in accordance to the size of the sewing thread.

Further, as the threads move to stage S4, a substantial fall in tenacity takes place (about 15%) for all threads. The breaking elongation changes insignificantly. At the time of interaction between the needle thread and the bobbin thread, displacement of plies and loosening of the structure takes place, which is responsible for loss in tensile properties. The contribution of bobbin thread interaction ranges from 53% to 66% in total tenacity loss. The contribution of bobbin thread interaction in breaking elongation loss is very small. Increase in fibre slippage due to opening up of thread plies and loosening of structure during bobbin thread interaction is likely to increase breaking elongation, and may therefore compensate the loss in elongation due to tenacity loss. Bobbin thread interaction has greater contribution in tenacity loss for finer threads. The finer thread in spite of its lower contact area and lower coefficient of friction, exhibits greater loss in tenacity during bobbin thread interaction. This may be attributed to sharper bending of finer thread (fine needle size is used for finer thread) at the time of interaction with bobbin thread.

## V. Initial Modulus

A significant loss in initial modulus of threads after sewing is observed. ⟨Fig. 7⟩ shows the mean initial modulus of threads at successive sewing stages. Initial modulus first increases at stage S2, changes marginally at stage S3 and decreases substantially at stage S4 for all threads. The increase in initial modulus during the dynamic loading is due to the realignment of fibres in the yarn during tensile loading. Tensile loading causes straightening of fibres and removal of crimp, leading to denser packing of the fibres in the yarn cross section, which generally results in higher elasticity modulus and consequently a greater load bearing capacity (Reumann & Offermann, 1993). As the thread moves from stage S3 to S4, a



<Fig. 7> Change in initial modulus at successive sewing stages and contribution of dynamic loading, passage through needle and fabric, and bobbin thread interaction

substantial fall in initial modulus is observed. Loosening of structure and displacement of plies occurs at the time of bobbin thread interaction and the non contribution of surface fibres to thread tension causes significant loss in initial modulus. Although a substantial loss in initial modulus is observed at this stage, the final loss in initial modulus after sewing is low (8-19%) because of the initial increase at stage S2. Bobbin thread interaction at final stage of sewing is the main cause of loss in tensile strength.

## VI. Conclusions

Lockstitch sewing process is a very dynamic process, wherein needle thread tensions keep on varying throughout the sewing cycle and along the passage through the machine. These stresses have a detrimental effect on the tensile properties of the needle thread. However, the change in tensile properties is different at three distinct stages viz after dynamic loading (S2), after passage through needle and fabric assembly (S3) and after bobbin thread interaction (S4). Tenacity and breaking elongation reduce progressively at all sewing stages, whereas initial modulus increases at stage S2, changes marginally at stage S3 and reduces substantially at stage S4. Bobbin thread interaction was a dominant factor in loss in tenacity and initial modulus of threads. Dynamic loading was a major factor in the loss in breaking elongation. The contribution of dynamic loading is high for coarser threads than finer threads. Passage through needle and fabric assembly has relatively small contribution in the loss in tensile properties.

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