Effects of shed formation on the loading of warp yarn

Helmut Weinsdörfer
Institut für Textil-und Verfahrenstechnik, Der Deutschen Institute für Textil- und Faserforschung Stuttgart,
Korschtaisstr. 26, D-73770 Denkendorf, Germany

During shed formation, several forces act on the warp yarn due to the complex motion of shed forming element. Apart from the axial loading, warp yarn also undergoes abrasion and surface damage. This paper describes the various loads acting on the warp yarn at different phases of shed formation and their effects on the weaving performance of the yarn and also on the fabric properties.

Keywords: Hairiness, Shed geometry, Thread twisting, Warp dynamic force, Warp thread tension, Yarn surface abrasion

1 Introduction

Besides weft insertion, the shed formation is one of the most important functional processes in weaving. The warp shedding can be effected by means of different shed devices, such as tappet, doby and jacquard mechanisms. The machine elements were optimized kinematically in the last decade for improving the efficiency of the weaving machine. For this, computer-based calculation and simulation methods were used to avoid extreme loadings on the machine elements. However, more work is needed to minimize the cloth degradation due to increased load on warp threads caused by forced high accelerations.

In this paper, the effect of the movement of the shed forming elements on the warp tension is reported.

The simple process of shed opening and closing causes a series of effects which influence:

- loading of the warp,
- performance of the warp, and
- strength of the fabric.

2 Effect of Shed Formation on Warp Tension

A dynamic component is superimposed on the static warp tension. It originates initially from the shed formation but it can be influenced by the warp sheet stroke, movement of the back rest, and the oscillation of the drop pins. Therefore, shed geometry plays a decisive role.

A commonly used shed geometry (Fig. 1) indicates the following characteristics:

- distance from front heald to cloth fell \( L_0 \), 120 mm;
- heald shaft gap \( h \), 12 mm;
- rear shed length \( L_h \), 360 mm; and
- stroke of 1st heald shaft \( h_1 \), 50 mm.

The shed is normally asymmetric and deep. The shed height is adjusted by the stroke of heald shaft and is the only constrained variable in most of the modern weaving machines (Gripper, Projectile, etc.). The adjustment of shed symmetry is advantageously effected by the back rest and the stroke of the heald shafts.

Let us examine a shed change cycle. When a heald shaft moves from the closed to open position, the warp threads get stretched corresponding to the changed geometry. Since the front shed is much smaller than the rear shed in the geometrical length, the change in the front shed is more. The thread is stretched more here and it picks a part from the rear shed over the heald wire. The warp thread is stretched onwards up to the warp beam. It moves then during shed opening from warp beam in the -direction of cloth fell. Therefore, the warp thread movement is position-de­pendent and of different magnitude. Also, the fabric seeks for a definite tension adjustment or compensation. During shed closing, the motions take place in reverse direction.

The geometrical change in the length of the warp threads from warp beam to the cloth fell is normally about 3 mm in the first shaft to 16 mm in the 16th shaft. This is equivalent to a tension of the warp thread from 0.2 to 1%, where the geometrical length change alone must be taken from the warp thread (Table 1). The resulting ex-
tensions are not really high and should be made actually ineffective by the warp threads.

The relative movement of the warp threads in the heald wire eye is about 1-2 mm in the front shaft. The thread movement is caused by the heald wires due to yarn flexibility. In the rear heald shaft, this relative movement is about 5 mm more so that the warp threads are pulled to and fro by the heald wire eyes and are scrubbed few times.

The shed opening, i.e. the stretching of the warp thread, causes a rapid increase in tension (Fig. 2, plain weave), which is desired to a certain extent to facilitate a clean shed. In the opening phase, the warp sheet stroke takes place which can be seen as peaks in Fig. 2. Because of the asymmetric shed, the warp thread tension is higher in the lower line than in the upper line. During shed change, the thread tension drops to zero. This is undesirable and should be avoided. When warp thread tensions are measured, then not only the high peaks but also the minimum values should be considered.

The shed asymmetry, which becomes visible in Fig. 2, has great significance for the fabric deficiency. However, it improves the fabric cover and warp streaks are reduced. The asymmetry of the shed is also advantageous, as is shown later, for the performance.

The warp thread tension is different for the threads on the first shaft than for the threads on the 8th or 16th shaft. Such differences between the shafts cannot be generally avoided. Despite, one should try in the interest of a good performance to load the threads equally on all the shafts. This is only possible when the warp thread
tensions on all shafts are measured. For this, a high frequency measurement on individual thread is necessary. Fig. 3 shows an apparatus developed by the Institute for Textile and Process Engineering, Denkendorf, Germany, which is available commercially. The natural frequency of the transducer is 7 kHz. Very important information is obtained from the individual thread measurement by a high frequency measuring apparatus over the thread loading and the adjustment of the shed geometry. These cannot be obtained by simultaneous measurement of many threads.

The back rest compensates the stretching of warp to a certain extent in many weaving machines, however with a phase shift. This is also basically desired, but the warp thread tension should not be reduced during the shed opening. The phase shift, however, should not be too large otherwise the warp threads are loaded additionally at the wrong moment.

In case of modern high-speed weaving machine, it has been established that a compensating movement should be avoided, because the inertia of the back rest beam makes quick compensation of tension impossible. This is the right approach since the resulting extensions cannot be tolerated. Moreover, a stretching compensation is achieved only in plain and panama weaves only to a certain extent, because the tension on the first heald shaft is much smaller than on the last heald shaft.

This raises a question, whether the tension represents the main loading for the warp threads. This means that most of the warp threads must break at the places where the greatest tensions dominate, i.e. in the middle of the warp sheet width (Fig. 4). However, it is not true as most of the threads break at the edge and selvage holder region where the warp tension is lower.

It raises another question, whether the dynamics of warp thread stretching loads the yarns more in high-speed weaving machines than in low-speed machines. Fig. 5 shows the fatigue of different warp threads at different frequencies of tension loading. The pure alternate tension loading of the yarn is more tolerable when it acts at high frequency. Also, in weaving, there is practically no rise in the warp thread tension with increasing rpm (Fig. 6). Nevertheless, in weaving at high rpm, additional problems and faults are observed which are relevant and play a role.

3 Effect of Shed Formation on Warp Thread Movements

The warp threads do not move continuously...
through the weaving machine. When one draws a line across the warp threads, the motion characteristic of warp is observed (Fig. 7). It was measured between back rest beam and drop wire guard and the shed geometry was adjusted asymmetric. The forward movement of warp and fabric is superposed as a to and fro movement, which is caused by the shed formation and the sheet stroke. \( Su \) is the motion amplitude of a thread at the formation of the lower shed line. The gradient of the curve is determined by the steady forward motion. In the present case, the instantaneous forward movement is actually smaller than the amplitude \( Su \).

From the measurement signal, we can determine:
- the relative motion between warp threads and drop pins of the warp thread guard, and
- the relative motion between neighbouring threads.

Both relative motions have effect on the behaviour of the fabric. In the region between back rest beam and drop pins it is frequently observed that the warp threads get entangled with each other. The threads must be separated by the drop pins.

For investigating these behaviours, the warp dynamic force was measured, which is exercised by the two neighbouring threads on the drop pin which separates these threads. The warp dynamic force is a measure of thread entanglement and should be possibly small. As a measurement variable that force is used which is exercised on a measuring reed, which is pinned in the warp thread sheet.

A series of factors influence the warp dynamic force, out of which only a few shall be described here. The weaving of the warp after the sizing by a fused wax has a very positive effect on the warp dynamic force (Fig. 8). The waxing smoothes the upper surface of the threads, whereby the friction is reduced and the threads get separated easily. The average warp dynamic force is designated as \( F_m \) and the maximum warp resistance appearing in a cycle is designated as \( F_r \).

Also, the machine adjustment affects the warp dynamic force (Fig. 9). If the drop pins guard is situated very close to the back rest beam, then the warp dynamic force increases distinctly. The reason is that the warp threads in the vicinity of
reversal have a constrained freedom of movement. The bunch of threads is still more compact and the threads cannot be easily separated. Moreover, the relative movements between the neighbouring warp threads in the region of back rest beam are still smaller than in the neighbourhood of drop pins. The relative movements of the warp threads go on increasing from the warp beam upwards to the drop pins. The relative movement between the warp threads should be sufficiently large so that the entanglement and sticking (thread bridges) between the neighbouring threads are broken. The warp dynamic force on the warp guard is again somewhat higher because the freedom of movement of the warp threads on the drop pins is constrained due to turning of weaver’s beam. It is evident from this result that the distance between the back rest beam and the warp thread guard should not be too small.

Generally, it is yet to be established that the relative movements of the warp threads contribute to loosening of the entanglements of the warp threads in the region between back rest beam and drop pins. For this, a certain amount of asymmetry of the shed is of advantage, similarly as not too small a distance of the warp threads guide from the back rest beam.

4 Effect of Shed Formation on Warp Thread Twisting

It is a widely accepted view that the twisting (twinning) of warp threads originates from the insufficient care in the warp preparation or in the knot tying. This is right but partly. Exact observations have shown that twisting can start on its own on the weaving machine—no turning but false twisting—specially between back rest and drop pins.

How does such twisting take place on the weaving machine? The relief for such twisting is the shed formation as it causes dynamic alternate tensile loading. When a thread is stretched, its turning moment response gets changed. It twists leftwards at one place and rightwards at another place. These local turning motions are due to the inhomogeneities of the yarn in respect to distribution of its mass, twisting and turning moment. This affects the weaving in the manner that the neighbouring threads, which entangle to a certain extent, form the groups which show the tendency to separate from the warp surface. These thread groups (packs) have a restricted collective twisting tendency, somewhere locally, in the same twisting direction. The warp threads then move not only in the warp plane, but also transversely; they tend to tilt over.

So, unnoticed false twisting develops and then disappears. Occasionally, it takes care of disturbances. When it gives a warp thread break in a twisted region, the weaver does not know always whether it is due to pure or false twisting. On retieing, he makes a pure twisting from false twisting.

The following points should be taken care of for avoiding the false twisting:

- A large variation in tension among the warp threads has a negative effect. A very loose thread is picked up by its neighbouring tight threads, which conducts directly a turning motion. A good warp preparation is therefore important. In the bunch or sheet frame lattice rail, one must be attentive to identical brake on the guide devices. Similarly, the back beams must be braked with equal force. During sizing, the division of the warp in different planes should not lead to different warp tensions. During beaming, one must be careful for uniform winding. A careful counting of the threads in the expansion reed minimizes the tension variation.

- Besides the tension variation among the warp yarns in warp beam, some variations are also being added on weaving machine itself. For example, a heald shaft installed incorrectly changes the tensions of warp threads pulled upwards or downwards. The reed and its dents have great influence on the tension difference of the neighbouring warp threads. The reed dents lead to local warp thread compressions. Besides, the lower thread tensions dominate significantly in the region of the gaps between the reed dents. Very low warp tensions get adjusted in the edge of the reed.

5 Effect of Shed Formation on Warp Thread Entanglement

By warp thread entanglement, one understands the hanging of the warp threads on one another during the opening of the shed\textsuperscript{13,16} (Fig. 10). Thereby, the shed becomes improper and it can cause interferences during weft insertion; shuttle or any other weft carrier can break the threads lying in the shed. In the jet type weaving machine, the weft insertion is disturbed, and it comes to wrong destination.

Fig. 11 shows an enlarged view of the yarn entanglement by protruding fibres of a neighbouring thread. The warp thread shown here is in a
real sense 'caught' by a fibre (PES) of a neighbouring thread. The Larro type loop is typical for this kind of entanglement. Such an entanglement does not occur between two neighbouring threads. At the minimum, three or more warp threads always participate in an entanglement (in plain weave). The entanglement usually occurs more frequently in the edge region of the reed because the warp thread tensions are lower here. High warp thread tensions are in a position to break the entanglement (Fig. 12). It is nearly impossible to adjust optimum warp thread tension as the level of warp thread tension is not constant along the warp width. The warp threads should not be loaded too much, and too low tension causes entanglement. The most appropriate compromise must be sought, which is different for different yarns and fabrics.

Measures which can be undertaken on the weaving machine to prevent the entanglement are:
- The rear shed should not be of more than 300-350 mm length (Fig. 13). The regulations also emphasize the significance of not too long front shed.
- Step shedding.
- Installation of a shed which is not too much asymmetric, because it avoids a too low warp thread tension in the upper line shed. A purely
symmetric shed is, however, not recommended, because it leads to a bad performance, entanglement between neighbouring threads (not easily avoidable) and a bad fabric cover. To achieve an optimum performance, in general, is to install such a shed symmetry that a ratio of 1.5-2.0 between the lower shed tension and upper shed tension \( F_L/F_U \) is obtained\(^7\). In order to achieve such an adjustment, an electronic thread tension measuring instrument, as shown in Fig. 3, is required which can measure and record high frequencies.

For reduction of the warp thread entanglement, preventive measures in spinning and weaving are very important. The hairiness of the yarn and the binding strength of the fibres are of significance. The sizing process as well as the sizing recipes are responsible for the performance of the warp in the weaving machine. Afterwaxing is proved to be advantageous\(^8\).

6 Effect of Shed Formation on Abrasion and Roughening of Warp Yarn

The warp threads move relative not only to functional elements but also to each other. This causes abrasion and fuzzing. Besides, there develops a roughening of the yarn upper surface.

The different zones of the weaving machine where the abrasion occurs are shown in Fig. 14. The investigations\(^9\) reveal what happens on the yarn during weaving.

The weaving process results generally in a roughening of the yarn. The roughened fibres are, however, torn off as per loading, whereby the hairiness again diminishes. For example, in shaft 8 more hairiness is obtained than in shaft 4 (Fig. 15). The fibre abrasion behaves in opposite manner. It is much higher in case of shaft 4 than in shaft 8. The less hairiness in case of shaft 4 is due to more intensive frictional loading consequent to higher thread density in the heald shaft and also during shedding process whereby more protruding fibres are torn off. A low hairiness may not be interpreted in each case as low friction loading; the latter is an indication for a strong fibre abrasion. The fibre abrasion in a certain way is a measure of the peak yarn loading.

The localization of the abrasion and its analysis gave interesting perceptions:
- If all the warp threads move in same phase, i.e. without forming a shed (a weft entry is thereby not possible), then 44% of the abrasion is in the drop pin region and 33% in the heald shaft region. The frictions on drop pins are responsible for it.
- If the warp threads move in opposite phase in the normal weaving (for comparison no weft was inserted), then the abrasion increases by a factor 9. About 75% of the abrasion is now in the rear shed region and about 20% in the heald shaft region.
- The abrasion in the regions I and II (Fig. 14) is mainly from sizing and in the regions III and IV it is mainly from fibres.
- The abrasion, and thereby the loading, during weaving originates mainly due to the contra rubbing of the warp threads on each other and due to the continuous tearing off of warp thread entanglement during shed change. The rubbing on the work elements is of minor importance.

7 Effect of Shed Formation on Yarn Strength and Elongation

The previous perceptions are confirmed by the strength investigation on the warp threads. The strength of the warp yarn is reduced during weaving, and indeed the strength reduction is more significant in the compact P/C yarn than in the
pure cotton yarn. It is clear from this that greater strength loss takes place in the yarn having a tendency to entangle which originates from greater loading during shed change, or in the tearing off of the entanglement.

It is known that in the cotton/viscose yarn, sizing increases the strength but causes a distinct reduction in elongation. The simulation of the pure tension and stretching loading (Fig. 16) have no measurable effect. In contrast, the weaving researches show that the sizing film is torn considerably and thereby the yarn properties tend to those of the raw yarn. With the increasing speed during weaving, a distinct increase in strength loss is observed with increasing yarn loading.

8 Conclusion

In weaving of fibrous yarns, the highest yarn loading is caused by the rubbing of the warp threads on one another due to shed change rather than from the tensions.

References