Influence of Delayed Timing on Knitted Fabric Characteristics

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ABSTRACT
Delayed timing is a complex adjustment of large-diameter circular knitting machine (LCKM). It corresponds to the delay between cylinder and dial needles knock-over. It is generally not well-known by machines users and its impact on fabric properties has not been enough studied in literature. Knitters generally use experience during delayed timing adjustment in order reach needed fabric characteristics. The aim of this paper was to investigate the relation between delayed timing intensity and yarn tension, yarn consumption, fabric weight as well as loop length and shape. The obtained results showed that delayed timing has an incidence on fabric weight and loop shape especially at fabric back side. The origin of this influence has been discussed and related to needles feeding mechanisms.

INTRODUCTION
Knitted fabrics are known for their high structural sensitiveness to machine adjustment parameters. The research work can focus on macro and micro level aspects of fabric quality control. Today the market demand is on micro level [1]. The improvement of knitted structure at micro level calls for better understanding of mechanisms of loop formation and their influence on fabric quality.

The adjustment parameters of a large-diameter circular knitting machine (LCKM) are very numerous and contribute collectively to fabric characteristics and quality. The literature relating to specific adjustments of the LCKM is extremely rare and generally limited to short instructions provided by machines manufacturers. These instructions are often brief and do not treat specifically the impact of the adjustments on fabric properties.

Some adjustment parameters such as yarn tension or yarn guide position have to be rigorously controlled; otherwise loop formation could be interrupted. In previous works [2, 3], we showed the influence of some knitting parameters on fabric quality such as elasticity and spirality. Other parameters, such as delayed timing between cylinder and dial, have a less obvious incidence on knitting process and fabric quality. The impact of delayed timing on fabric characteristics is not well-known by knitters who generally know roughly that this adjustment has a relation with yarn tension, yarn consumption and loop shape. In fact when the yarn is not enough resistant a delayed timing can be a solution to avoid cotton yarn breakage during knitting. This kind of yarn has generally low resistance when compared to synthetic yarns and causes sometimes breakage problems during knitting especially with double jersey machines.

In a double jersey machine, synchronised and delayed needle timing can be employed. Synchronised timing, called also simultaneous timing, is obtained when cylinder and dial needles reach the knock-over position at the same point. The knock-over position is the deepest needle position during loop formation. When delayed timing is set, the dial needles knock over their loops later than the cylinder needles lying opposite to them. Based on synchronised timing, the adjustment of delayed timing corresponds to a peripheral displacement of dial cam plate in the direction of rotation of the machine over a distance equalling about five to six needles pitches [4, 5] (*Figure 1*).

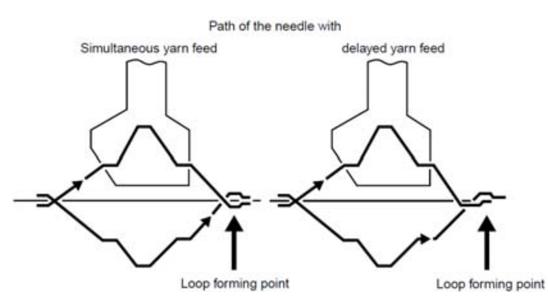

FIGURE 1. Path of the needle in synchronised and delayed timing.

Delayed timing is necessary in double jersey machines (ribbing technique or interlock technique) when plating with an elastane yarn. In fact elastane yarn is fed immediately to the dial needles via a guide roller. When the delayed timing technique is applied, the dial of the circular knitting machine is adjusted in such a way that its needles sink the loop later than the needles of the cylinder. This changed setting makes it possible to thread the elastane yarn only into the needles of the dial and to knit it in using the plating technique.

The aims of this research were, therefore, to study the effect of delayed timing on some fabric characteristics and on loop shape. This would permit to reduce machines adjustment duration and better understand the delayed timing mechanism.

MATERIAL AND METHODS

We produced a series of rib 1x1 fabrics commonly used in the clothing industry by using an industrial double jersey circular knitting machine (FLG II from Mayer & Cie, Diameter = 30 inch, gauge = 18, total number of feeders = 48). Used yarn was a 100% combed cotton yarn (Nm=50) and machine was equipped with positive yarn feeders supplying constant yarn quantity to feeders.

The adjustment of delayed timing is obtained by a rotation of dial cams with a control mechanism. A comparator displays the delayed timing corresponding to 1, 2 or 5 needles. *Figure 2* and *Figure 3* show the loop formation and needles positions in the case of delayed timing.

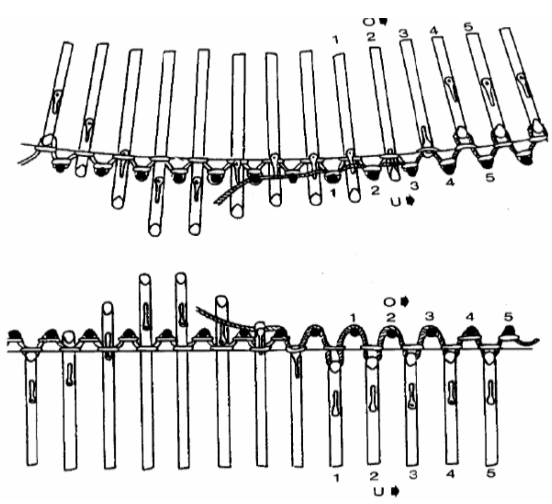

FIGURE 2. Loop formation in delayed timing case in dial (upper view) and cylinder (lower view).

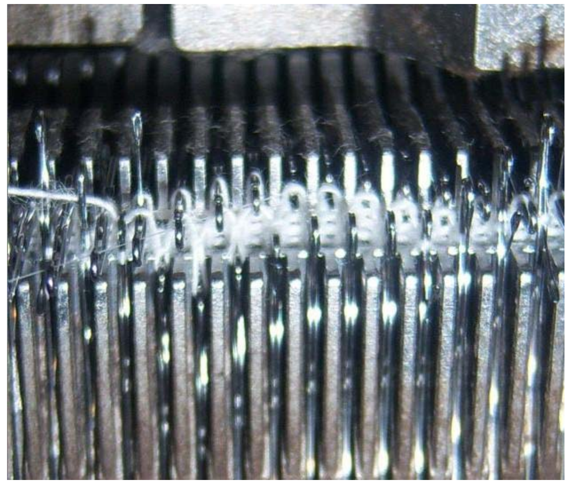

FIGURE 3. Photography of needles positions in delayed timing case.

The produced fabrics are characterized by different delayed timing intensities. An adjustment of yarn consumption was operated when increasing delayed timing intensity (from 0 to 4 needles) in order to keep a constant yarn tension of about 6 cN. This tension is necessary for a correct loop formation.

Yarn consumption as well as fabric weight, corresponding to each delayed timing, was measured at different sites of the tubular fabric. Yarn consumption was determined according to EN 14970 standard which consists in measuring the length of a yarn portion taken in the fabric sample under an adapted tension. Fabric weight was measured according to EN 12127 standard which consists in determining the weight of 100 cm² fabric by using a fabric cutter and an electronic balance. All measurements were performed 24 hours after fabric knitting, in order to enable fabric to relax, under standard textile testing conditions of 21°C ± 1°C, and 65% ± 2% relative humidity. Seven specimen of each sample were tested and the mean values of yarn consumption and fabric weight were calculated.

Preliminary tests were necessary in order to investigate the effect of delayed timing on yarn tension. Theses tests were operated at constant yarn consumption delivered by the positive yarn feeders and various delayed timings. For this purpose machine was running at low speed because yarn tensions corresponding to the different delayed timings were sometimes too high or too low and consequently inadequate for a correct loop formation.

The users of LCKM have generally a subjective appreciation of the effect of delayed timing on loop shape. They know that increasing the delayed timing involves a change of loop shape and fabric appearance but generally do not know how. That's why knitting technicians operate generally an increase or decrease of delayed timing till they reach an acceptable appearance of the fabric. In order to investigate the influence of delayed timing on loop length and shape, we developed a new technique allowing the measurement of loop length and shape. This method consists in dividing the loop into three parts in order to determine a function f(x) for each loop part, and calculate the length of theses loop parts by using a mathematical equation.

The key element of this method is the geometry of the knitted loop. Pierce [6], Leaf [7, 8, 9], Doyle [10, 11], Munden [12], Postle [13], Derminoz *et al.* [14], Araujo *et al.* [15], Semnani *et al.* [16] and Choi *et al* [17] have significantly contributed to the geometric analysis of knitted fabric. In most cases, knitted fabric was described with very simple geometrical shapes. The geometry of a knitted fabric loop was often described with simple theoretical models. That means that the loop shape was assumed to be composed of regular geometries such arcs of circle or segments. In our work, we tempted to model the stitch geometry using curves governed by mathematical functions. In order to come closer to the real geometric configuration of the stitch, the parameters of the mathematical functions were obtained from image processing of really existing knitted loops.

The shape of the produced rib 1x1 knitted fabric determined by using an optical microscope with adequate enlargement is given in *Figure 4*. Preliminary testing showed that each loop part can be modelled by a polynomial function of the second degree. The length of each loop part is given by the following equation:

$$L = \int_a^b \sqrt{1 + f'(x)^2}\,.dx \qquad (1)$$

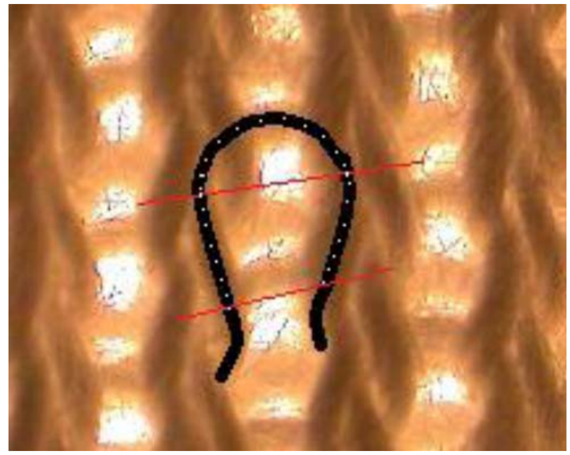

FIGURE 4. Rib 1x1 knitted fabric observed with an optical microscope.

RESULTS AND DISCUSSION

Figure 5 shows the influence of delayed timing on yarn tension at constant yarn consumption. During this test machine was running at low speed because yarn tensions corresponding to the different delayed timings were sometimes too high or too low and consequently inadequate for a correct loop formation. In fact, in order to run correctly without yarn or loop breakage in the circular knitting machine, yarn tension has generally to be adjusted between 5 or 6 cN for classical yarns.

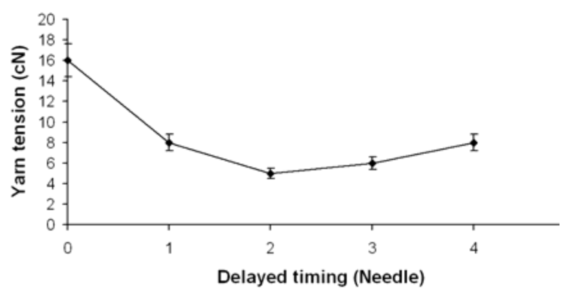

FIGURE 5. Influence of delayed timing on yarn tension.

The increase of delayed timing involves a decrease of yarn tension. From three needles delayed timing the tendency is inversed. This phenomenon is widely linked to yarn consumption and sharing between cylinder and dial needles. *Figure 6* shows the influence of delayed timing on yarn consumption at constant yarn tension. In this case the machine runs at standard and convenient yarn tension condition of 5 cN at the different delayed timing levels.

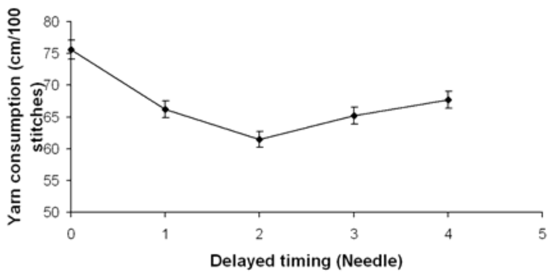

FIGURE 6. Influence of delayed timing on yarn consumption.

It can be seen that yarn consumption decreases when increasing the number of needles of delayed timing. This reflects the evolution of yarn tension with delayed timing. From three needles delayed timing, yarn consumption increases with delayed timing but remains lower than that of synchronised timing. This can be explained by the fact that during synchronised timing, cylinder and dial needles are directly supplied simultaneously and pull together yarn from positive yarn feeder. For this reason yarn consumption is the highest. During delayed timing of one or two needles, dial needle is partially supplied by positive yarn feeder. At the same time, cylinder needles provide the rest of yarn quantity necessary for loop formation. From three needles delayed timing, the quantity of yarn provided by dial needles to cylinder needles is not enough to form a loop because needles forming loop in cylinder moved away and consequently tension increases and yarn consumption has to be increased in order to avoid yarn rupture. *Figure 7* shows needles positions and yarn feeding in cylinder and dial in synchronised and delayed timing. It can be seen clearly that in synchronised timing cylinder and dial needle catch yarn and form loops simultaneously. In delayed timing case, cylinder needle goes up slightly and gives dial needle the quantity of yarn necessary for dial loop forming. In this case, yarn supplied by positive yarn feeder to dial needles has to slip through needles hooks. This slippage is harder when delayed timing is over two 2 needles. This explains why yarn delivered by positive yarn feeder has to be increased.

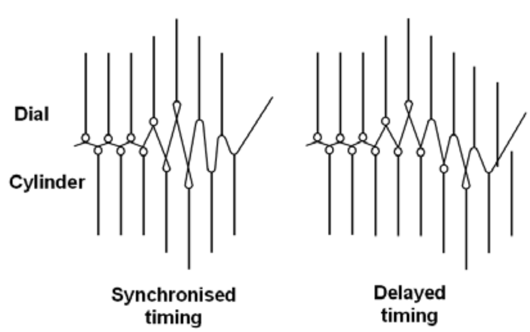

FIGURE 7. Needles positions in cylinder and dial in synchronised and delayed timing.

Figure 8 shows the influence of delayed timing on fabric weight. The increase of delayed timing involves an increase of fabric weight. Beyond two needles this tendency is inversed. This reflects the evolution of yarn consumption. In fact, a decrease of yarn consumption generates a reduction of stitches length. Consequently, rows and wales became closer to each other and fabric weight per surface unit is increased. It can also be seen that fabric weight increases after two days relaxation and specially after washing treatment. The curves have almost the same shape. Indeed, fabric removed from the LCKM is not in a stable state. After two days of rest, it starts to be stabilized but after washing, it reaches maximum relaxation and an increase of fabric weight is obtained.

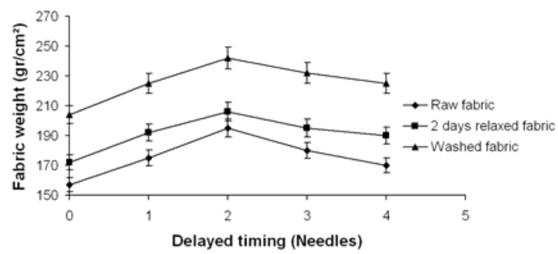

FIGURE 8. Influence of delayed timing on fabric weight.

The increase of delayed timing requires a reduction of yarn consumption; otherwise yarn becomes too loose and a yarn break is detected. Theses findings have a great interest at practical level. In fact, machines users has to know that when delayed timing is necessary for technical reasons such as a weakness of yam or elastane plaiting, an increase of fabric weight has to be considered. However, fabric weight is fundamental in the specifications of knitted fabric and must be respected with tolerances which are not particularly high (± 5%). The change of delayed timing usually involves a variation of fabric weight. This has to be taken into account during machine adjustment.

Figure 9 shows the influence of delayed timing on loop length. At synchronised timing, cylinder and dial loops have similar lengths since yarn catching and loops knock-over are simultaneous in cylinder and dial needles.

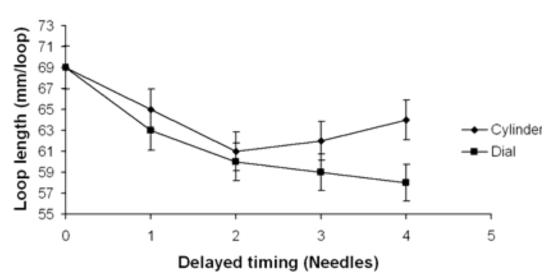

FIGURE 9. Influence of delayed timing on loop length.

The increase of delayed timing causes a decrease of cylinder loop length. Beyond two needles the tendency is inversed reflecting the behavior of yarn consumption and fabric weight. In the dial, loop length has a different behavior. In fact, the increase of delayed timing causes always a decrease of dial loop length. This is linked to the fact that at high delayed timing, dial needles have a difficulty to pull yarn from positive yarn feeder and make it slip inside needle hooks. For this reason dial loop length is as low as delayed timing is important. Another consequence of this phenomenon is that dial loop length is always lower or equal to cylinder loop length for all tested delayed timings because of the nature of needle feeding evoked previously. *Figure 10* shows the impact of delayed timing on cylinder and dial loop shapes.

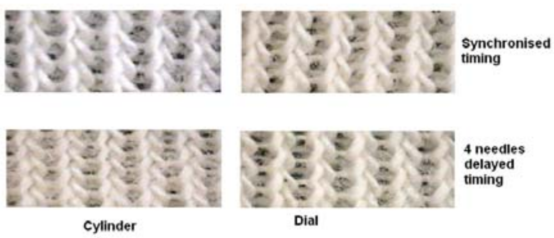

FIGURE 10. Influence of delayed timing on loop shape.

It can be seen that cylinder loops has almost the same shape, but dial loops has a V shape at synchronised timing and a rounder shape at four needles delayed timing. This is due to the fact that at delayed timing dial loops have a low length when compared to synchronised timing case. So their shape is round and has consequently a better aesthetic aspect because they receive a low quantity of yarn to form the loop. This explains why, during fabric cutting, dial loops which generally appear at the garment back side, are placed by garment manufacturers during quilting in the right side of the apparel because of the interesting aesthetic aspect of loops knitted by the dial.

CONCLUSION

Delayed timing in double jersey LCKM is a special adjustment which is generally not well-known by machines users. The results obtained in the present work indicated that delayed timing has a significant effect on some fabric properties such as yarn consumption, fabric weight and loop shape especially at the back side. Yarn consumption decreases and consequently fabric weight increases when delayed timing intensity increases. From 3 needles delayed timing, the tendency is inversed as a consequence of yarn tension increasing. This behavior is widely linked to needles yarn feeding mechanisms. In fact the yarn quantity supplied to dial needles depends on the difficulty that theses needles have to pull yarn though hooks and also on the quantity of yarn supplied by cylinder needles for loop formation. Loop length and shape depend also on delayed timing. Dial loop length is inversely proportional to delayed timing intensity. Consequently, in delayed timing case, loops have a rounded shape and fabric has a better aesthetic appearance at the back side that justifies its use as a right side of the garment.

A practical study of the effect of delayed timing on fabric dimensional stability after an industrial finishing process is necessary to better understand the impact of this machine adjustment on global fabric properties.

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