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ABSTRACT

The factors affecting stitch length on a fully fashioned plain machine have been investigated. It was found that the average distance between the needle stems and the throats of approximately the first three sinkers fully forward, at the instant of loop measuring, critically affects the stitch length. An instrument was designed which could be used to measure this distance quickly and accurately. It was shown that once this distance is identical for the different heads of the machine very little between head variation in stitch length occurred, provided the normal precautions were taken to ensure uniform yarn input tension and fabric take-up tension for the different heads. Both these factors were found to have an effect on stitch length, mainly due to their effect on the bending of the needles during loop measuring (and thus on the effective distance between needle stem and sinker throat). "Robbing back" did not play a significant rôle in determining stitch length. The predicted stitch length agreed very well with the actual stitch length provided the yarn input tension and fabric take-up tension were kept low.

KEY WORDS

Fully Fashioned Knitting Machine – Stitch Length Variations – Loop Measuring Device – Input Tension – Take-up Tension.

INTRODUCTION

A considerable amount of work[1–15] has been done on the basic loop-forming mechanisms of knitting machines with individually movable needles, these generally being latch needles with needle butts. Very little work, however, has been published on the "Straight Bar" (i.e. fully fashioned)-type knitting machine. The studies referred to above, together with studies on the geometry and dimensional properties of plain and double jersey fabrics[16–36], have led to a better understanding of the various factors involved in determining the stitch length and hence the dimensions, density, weight etc. of the fabric in the fully relaxed state. These studies have also led to a better understanding of the various forces acting on the yarn, needles and cam system during stitch formation. It was found that yarn to metal friction was of extreme importance in determining stitch length if positive feed is not used. It was also important in determining the build up of forces, especially the build up of tensions in the yarn, within the knitting zone. Yarn friction affects stitch length by changing the amount of "robbing back" which takes place so that an increase in friction is nearly always associated with a decrease in stitch length. No other yarn property was found to play nearly as an important a role as yarn friction in deciding the knitting performance of a yarn [11, 12]

In fully-fashioned knitting, however, the loop forming action differs considerably from that which is employed on the type of machines investigated above. Generally little is known about the factors which affect the stitch length and therefore the dimensions of the garments produced: it is therefore not surprising that many fully fashioned garment manufacturers complain of large variations in the sizes of garments produced on different heads of the same machine. In fact it is common practice in the industry to keep the garment sections made on different machine heads apart and not to mix these when assembling a garment.

It was therefore decided to investigate the mechanisms involved in loop formation on the fully fashioned type knitting machine with a view to improving our knowledge of the factors affecting stitch length and in so doing possibly overcoming the variations, mentioned above, between the different heads of a machine.

EXPERIMENTAL

An undyed R63.3 tex/2 (^{2}/28's w.c.) wool worsted yarn, waxed under optimum conditions with paraffin wax was used. The friction of the yarn, as measured on the SAWTRI Commercial Friction Tester, was 16.3 g. The yarn was knitted at

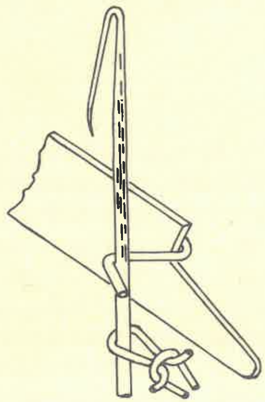

FIGURE 1
Needle and sinker shown in the loop measuring position

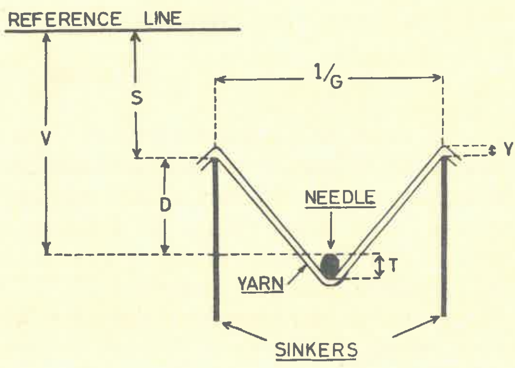

FIGURE 2
End view of needles and sinkers in the loop measuring position (not according to scale)

TABLE I

AVERAGE DISTANCE (V) BETWEEN REFERENCE LINE AND NEEDLE STEMS MEASURED AT LEVEL OF SINKER THROATS.

HEAD	QUALITY 4		QUALITY 7		QUALITY 8		QUALITY 13	
	V*	C.V.	V*	C.V.	V*	C.V.	V*	C.V.
	cm	%	cm	%	cm	%	cm	%
1	0.6574	0.65	0.6444	0.57	0.6406	0.56	0.6251	0.36
2	0.6972	0.30	0.6845	0.44	0.6817	0.50	0.6640	0.30
3	0.7005	0.38	0.6883	0.64	0.6835	0.71	0.6670	0.24
4	0.6947	0.23	0.6797	0.58	0.6774	0.65	0.6607	0.38

*Mean of 12 readings

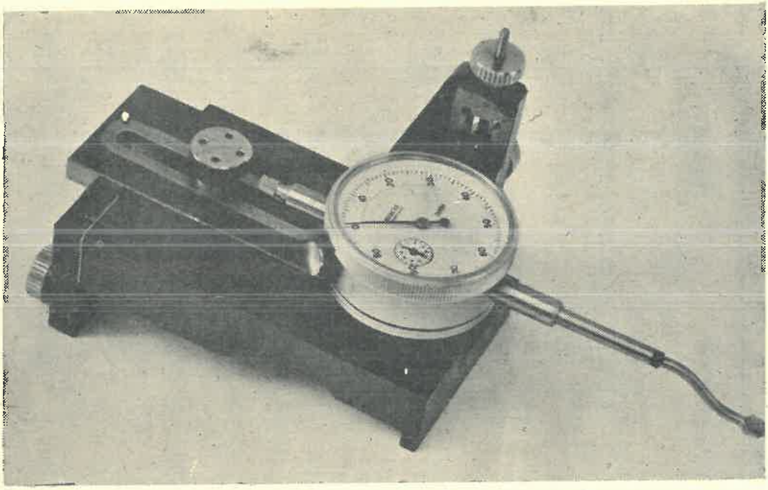

FIGURE 3
Instrument designed for measuring the distance between needle stem and sinker throat.

different quality settings and with various take-up and yarn input tensions on a 24 gauge (16 n.p.i.) Scheller (BV 4/24) fully fashioned machine having four knitting heads. This is a plain machine without dividers (i.e. there is no dividing action on this machine). The knitting width was kept constant at 360 needles.

The distance, D, between sinker throat and needle stem (shank) (see Fig. 2) was initially determined with the aid of a depth micrometer but this procedure was found to be extremely tedious and time consuming. An instrument (Fig. 3) was therefore designed which could be used to measure this distance quickly and accurately. The instrument essentially comprises a Mercer gauge (.01 mm) attached to a stand which can slide on the frame of the knitting machine. The height and depth of the springloaded probe are separately adjustable so as to enable the probe to be positioned at the correct level (i.e. at the level the yarn is kinked around the needle stems and sinker throats).

The distance from an arbitrary reference line, parallel to the needle bar, to the back of the needles was measured at approximately 16 different positions across the width of the needle bed with the needles in the loop measuring (i.e. highest) position. One set of measurements was made on each knitting head during a left to right traverse and one during a right to left traverse.

TABLE II.
DISTANCE (S)*, BETWEEN REFERENCE LINE AND THE SINKER THROATS (in cm).

HEAD	LEFT TO RIGHT TRAVERSE		RIGHT TO LEFT TRAVERSE	
	S	C.V.	S	C.V.
	cm	%	cm	%
1	0.7932	1.03	0.7686	1.00
2	0.7788	0.92	0.7813	0.95
3	0.8479	0.67	0.8237	0.63
4	0.8098	0.98	0.8120	0.79

*Mean of 30 readings

The distance from the same reference line referred to above, to the throats of each of the approximately 13 sinkers which are at any one time in contact with the surface, AA′, (see Fig. 4) of the slur cam, via the striking jacks, during the slur cam (slurcock) traverse, was also measured at a number of positions of the slur cam during both a left to right as well as a right to left traverse. The abovementioned measurements were made at each quality setting both before and after knitting had taken place but without any yarn being fed to the sinkers and with the sinkers, or more correctly the striking jacks in contact with the sinkers, held firmly against the slur cam while the measurements were made.

The first sinker which was fully forward at the extreme left hand side of the slur cam was arbitrarily numbered 1 irrespective of the position of the slur cam within the knitting width. During a left to right traverse number 13 (or sometimes number 12) always refers to the first sinker which is fully forward at the leading end of the slur cam irrespective of the position of the slur cam within the knitting width. Similarly, on a right to left traverse number 1 always refers to the first sinker fully forward at the leading end of the slur cam (see Fig. 4).

It may be mentioned that the average values shown in Tables II and IV were calculated from the measurements made on only the first three sinkers fully forward on a left to right and a right to left traverse, respectively. Thus, on a left to right traverse the average distance, S, was calculated (Fig. 2) from the values obtained for sinkers 13, 12 and 11 only while on a right to left traverse the average distance, S, was calculated from the measurements made on sinkers 1, 2 and 3 only. The reasons for this procedure will be given under "**Results and Discussion**".

The thickness of the needles, T, (in cm) (Fig. 2) at the level at which the yarn is kinked around the needles was measured with a micrometer screw gauge and found to be 0.1123 cm.

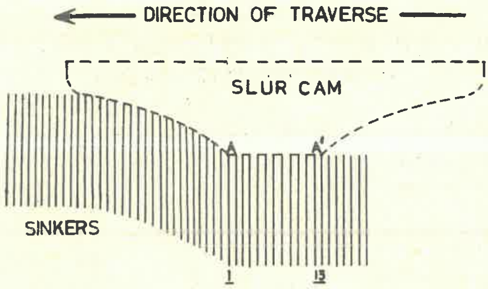

FIGURE 4
End view of slur cam advancing the sinkers (by advancing the striking jacks which in turn act upon the sinkers).

From Ashenhurst's formula

yarn diameter (Y) in cm $= 0.004\ (\text{tex})^{1/2}$

a value of 0.0320 cm was obtained for the yarn diameter.

The theoretically predicted stitch length, L, could therefore be calculated from

$$L = [\,4\,(D + T + Y)^2 + (\tfrac{1}{G})^2\,]^{1/2}$$

where D = S – V is the distance between the back of the needle stems and the sinker throats, T the thickness of the needles, Y the yarn diameter and G the machine gauge expressed as the number of needles per cm (Figs. 1 and 2). All the values are expressed in cms.

Initial knitting trials were carried out, using all four knitting heads, with the machine as set up by the knitting mechanic, after which further trials were conducted on three heads only because of technical reasons.

After the initial trials the average distance between needle stem and sinker throats was adjusted, by means of the instrument described previously, to be as nearly identical as possible for the three heads.

Yarn input tension was adjusted by adjusting the tension in the spring cymbal type pre-tensioning device. The spring type tensioning device on the machine was eventually replaced by a gravity type tensioning device which was easier to adjust to give the same input tension on the different heads since this merely entailed having equal weights supplying the tension at the different heads. The input tension and the fabric take-up tension was kept as low as possible throughout the knitting trials except when the effect of these two factors on stitch length was specifically investigated.

TABLE III.

AVERAGE DISTANCE (V)* BETWEEN REFERENCE LINE AND NEEDLE STEMS AT LEVEL OF SINKER THROATS (AFTER MACHINE ADJUSTMENT).

HEAD	QUALITY 27		QUALITY 22		QUALITY 18		QUALITY 13		QUALITY 8		QUALITY 4		QUALITY 0	
	V	C.V.	V	C.V	V	C.V.	V	C.V.	V	C.V.	V	C.V.	V	C.V.
	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%
1	0.0640	6.33	0.0823	5.00	0.1024	4.18	0.1255	3.41	0.1458	2.72	–	–	–	–
2	0.0632	7.73	0.0828	5.69	0.1008	4.78	0.1255	4.07	0.1450	3.30	–	–	–	–
2 repeat	0.0673	7.49	–	–	–	–	0.1270	4.39	0.1488	3.04	0.1600	3.00	.1765	2.77
3	0.0648	12.87	0.0833	9.75	0.1024	7.79	0.1255	6.67	0.1455	5.60	–	–	–	–

*Mean of 30 readings

TABLE IV.

AVERAGE DISTANCE (S)* BETWEEN REFERENCE LINE AND SINKER THROATS AFTER MACHINE ADJUSTMENT

HEAD	LEFT TO RIGHT TRAVERSE		RIGHT TO LEFT TRAVERSE	
	S	C.V.	S	C.V.
	cm	%	cm	%
1	0.2708	2.89	0.2611	3.00
2	0.2657	2.32	0.2695	2.35
3	0.2695	2.04	0.2634	2.33

*Mean of 54 readings

The influence of yarn input tension on stitch length was investigated (on Head 2) by altering the tension in the spring of the pre-tensioning device and knitting at the resulting different input tension values with and without take-up tension.

The influence of fabric take-up tension on stitch length was investigated at quality settings 8 and 13, on Head 2. The fabric take-up tension was changed by altering the setting of the take-up tension regulating device, yarn input tension being kept constant. The whole range of fabric take-up tensions which is possible on this machine was covered.

After knitting, the stitch length was determined over 358 needles (in some cases over 200 needles) by means of a H.A.T.R.A. course length tester.

All the tests were carried out in a room conditioned at 20°C and 65% R.H.

RESULTS AND DISCUSSION

When measuring the course lengths it was noticed that, for all four the knitting heads, the course lengths obtained on a left to right traverse differed consistently, and often considerably, from those obtained on a right to left traverse. On heads 1 and 3 the left to right traverse consistently gave longer course lengths than a right to left traverse while the reverse occurred on heads 2 and 4. Furthermore, the differences between the course lengths obtained on alternate traverses were quite different for the different heads. It was therefore concluded that the differences in course lengths could not be due to either the carrier lead, which is different for the two directions of traverse, or the slur bar (rail) since both these factors would have resulted in one direction of traverse always giving the longer course length on all four heads. In addition no significant differences were found between the positions of any of the needle bars during a left to right and a right to left traverse, respectively. Similarly no differences were found between the

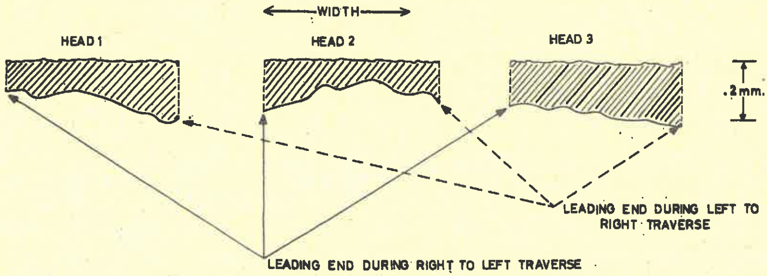

FIGURE 5
Profile of operative surface, AA', of slur cams 1, 2 and 3 (width of slur cams not drawn according to scale).

average distances that the sinkers were cammed forward on a left to right traverse compared with a right to left traverse.

The cause of the variation in stitch length, noticed above, was eventually traced to the slur cam itself. It was noticed, that for any one head, the sinkers at the leading end of the slur cam (i.e. those responsible for measuring off the stitch length) were advanced different distances on alternate traverses. This indicated that the two ends of the slur cam were at different distances from the needles which in turn implied that either the slur cams had worn to different extents at their ends or else that they were not clamped perfectly parallel to the needle bar. Profiles of the slur cams as deduced from the sinker movements are shown in Fig. 5. The differences in course length obtained on alternate traverses as well as a visual appraisal of the way the loops are measured off appeared to indicate that the loop length was actually determined by only the first 3 or 4 sinkers cammed fully forward by the leading end of the slur cam (Fig. 4). Indeed, when the predicted stitch lengths were calculated on the assumption that only the first **three** sinkers fully forward played a role in deciding the stitch length it was found that the predicted stitch lengths correlated very well with the actual stitch length obtained on the same head during alternate traverses.

From Fig. 7 it is apparent that the large differences in stitch length obtained on the different heads at the same quality settings (see Fig. 6) are essentially due to the differences in the average distance, D, between sinker throats and needle stems at the time loop measuring takes place (where $D = S - V$). The predicted stitch length, L, is in this instance solely a function of the one variable D since T, Y and G remained constant throughout the investigation.

The results given in Tables III and IV and Figs. 8 and 9, were obtained on Heads 1, 2 and 3 after the average distances, between the first three sinkers fully forward in any one direction of traverse and the needle stems were adjusted so as to be as nearly identical as possible for the three heads. From these results it is again

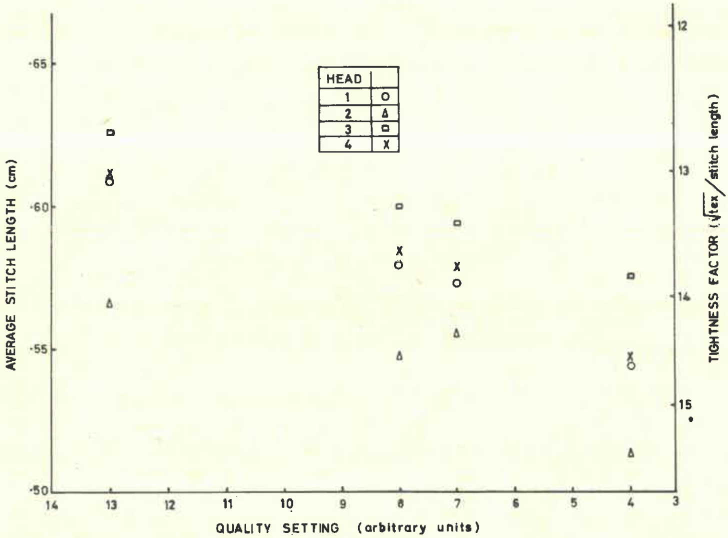

FIGURE 6
Relationship between average stitch length and quality setting.

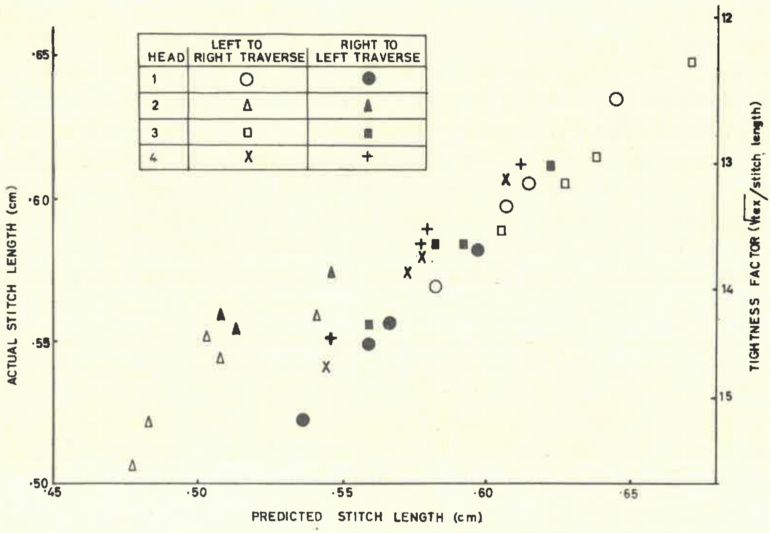

FIGURE 7
Relationship between actual stitch length and predicted stitch length.

clear that stitch length is almost solely dependent upon the distance, D, between needle stems and the throats of the first three sinkers fully forward.

After this adjustment the differences in stitch length between the three heads were eliminated almost entirely. The differences in stitch length within a head, on alternate traverses still existed but can be explained in terms of the distance D. This difference can only be eliminated by replacing the slur cams and ensuring that they are clamped parallel to the slur bar. It is felt that, had the slur cams and needle bars been in better condition on this machine, even the small remaining differences in stitch length between the heads would have been eliminated.

It is interesting to note that the actual stitch lengths are always larger, by approximately 5%, than the predicted stitch lengths. This is contrary to what occurs on machines with individually movable needles, where the actual stitch length is always smaller than the predicted stitch length due to the phenomenon of "robbing back" referred to previously. This discounts the possibility that at the input tension used, "robbing back" occurred. The reason that "robbing back" does not occur is that the slur cam width covers approximately 13 sinkers and these sinkers are therefore all kept in the loop measuring (i.e. completely forward) position. Consequently, yarn which is to be robbed from previously measured loops has to be drawn over approximately 13 sinkers and 13 needles. This is well nigh impossible due to the

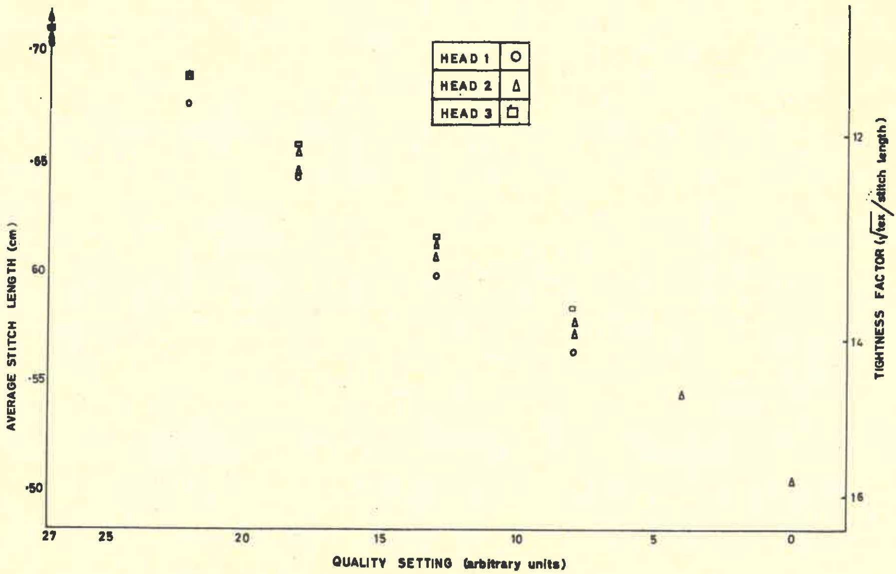

FIGURE 8
Relationship between average stitch length and quality setting after machine adjustment.

many very sharp angled yarn/needle and yarn/sinker contact points. The frictional forces so imposed would be so great that, in the case of a wool worsted yarn, the tension in the yarn would reach the breaking strength of the yarn long before robbing back could occur in this manner. The differences in stitch length obtained during alternate traverses tend to support this theory. During his study on the cam forces in weft knitting Henshaw[4] found that little or no robbing back occurred if a flat-bottom cam extending over 10 needle spaces was used on his experimental circular hose machine. This is in agreement with the conclusions arrived at here.

The reason for the measured stitch length being actually greater than the predicted stitch length is difficult to suggest with any degree of certainty but this could possibly be explained as follows: when the slur cam has cammed the sinkers completely forward (see Fig. 4) the jack springs exert a small force on the sinkers via the striking jacks. This force is intended to prevent the tension in the yarn from forcing the sinkers back, once the slur cam has passed and prevents trouble arising during knitting. If, however, the force exerted by the retaining springs during loop measuring, exceeded the force exerted by the yarn on the sinkers, due to a very low

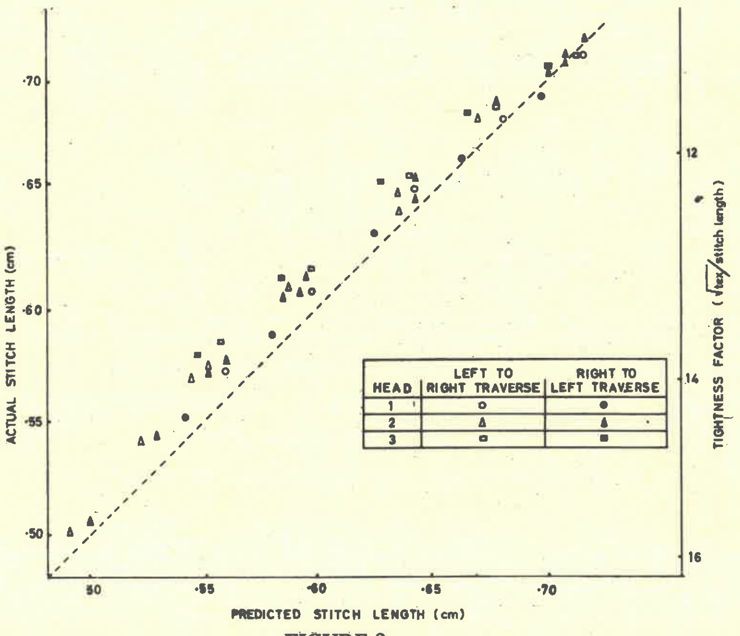

FIGURE 9
Relationship between actual stitch length and predicted stitch length after machine adjustment.

input tension being used, the retaining springs would advance the sinkers further than would have been the case had the slur cam alone been responsible for the movement of the sinkers. Consequently a longer loop would be measured off than was predicted from the distance D, measured with the sinkers held firmly against the slur cam. If this reasoning is correct then the difference between predicted and actual stitch length should decrease with increasing stitch length due to the higher tensions developed in the yarn. This appears to be the case (see Fig. 9). It may be mentioned that the inertia (throw) of the sinkers and striking jacks could also play a rôle in determining the stitch length.

Influence of take-up tension

In Fig. 10 the stitch lengths obtained at different fabric take-up tension values have been plotted against the take-up setting. Unfortunately the fabric take-up tension could not be measured directly and consequently the position of the take-up tension control knob had to be taken as a measure of the tension exerted on the fabric. From Fig. 10 it can be seen that stitch length generally decreases with increased take-up tension, although, on the whole, the differences in stitch length are small. The slight increase in stitch length at the extreme right of the graph is difficult to explain. Possibly the tensions exerted at the extreme positions of the control knob were slightly lower than those at the preceding positions. The take-up tension is supplied by a slipping clutch mechanism. The fact that an **increase** in fabric take-up tension caused a **decrease** in stitch length could only be due to the increased tension

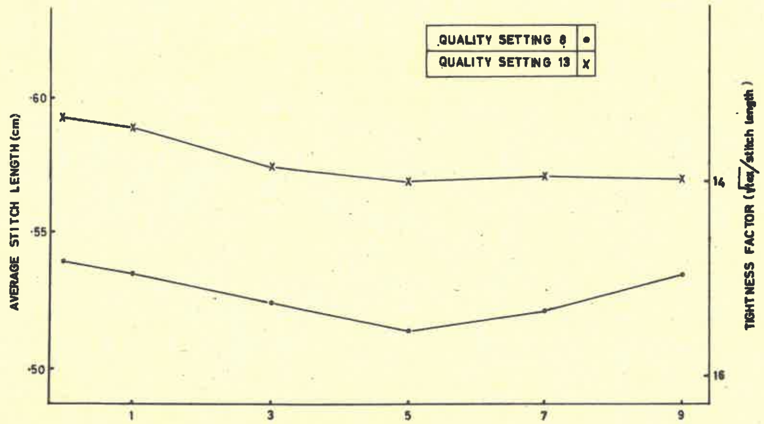

FIGURE 10
Relationship between average stitch length and fabric take-up tension.

on the fabric having caused the bearded spring needles to deflect from the sinkers during loop measuring. Thus the effective distance between the sinker throats and needle stems was reduced.

If this were not the case, increased fabric take-up tension would have resulted in an increase in stitch length since the increased tension on the fabric would decrease the amount of robbing back (from the previous course) which could occur at the selvedges. It is felt that on this type of machine the only robbing back which could possibly occur is at the beginning of a traverse (i.e. at the selvedges) when the first few advancing sinkers can either take yarn from the package or from the previous course depending on the relative values of the yarn input tension and the fabric take-up tension. This form of robbing back, if present, would however only be possible for the first 3 sinkers or so within the knitting width and generally the effect on stitch length will therefore be insignificant.

Influence of yarn input tension

The values obtained for stitch length at different settings of the pre-tensioning device have been plotted against the setting of the pre-tensioning device in Fig. 11. Once again, unfortunately, the input tension could not be measured directly and the setting of the pre-tensioning device had to be taken as a measure of the yarn input tension. It is evident that the yarn input tension has a considerable effect on the stitch length although it may be mentioned that the differences in the yarn input tension were very large and far exceeded that which would normally be found in practice.

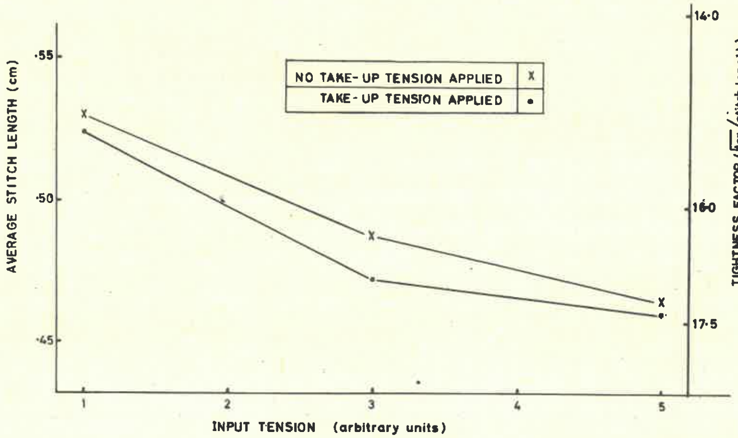

FIGURE 11
Relationship between average stitch length and yarn input tension (quality setting 13).

It was noticed that as the yarn input tension increased, the needle deflection (bending) during loop measuring increased as well. Thus the high tension in the yarn was to a certain extent being compensated for by the bending of the spring needles away from the sinkers thus easing the strain on the yarn. Thus any undue variations in yarn tension due to variation in yarn friction, slubs, knots, etc. are minimised by the ability of the spring needles to flex and this is probably one important reason why the needles are not clamped more rigidly or why more rigid needles are not used. The flexing of the needles caused by increasing the yarn input tension and consequent decrease in the distance D, between needle stems and sinker throats is considered to be the main cause of the decrease in stitch length. At high yarn input tension values yarn stretching (extension) may play a rôle in determining the stitch length as well. Once again the stitch length values obtained with tension applied to the fabric are slightly lower than those obtained without fabric take-up tension.

In practice it is not very difficult to adjust both yarn input tension and fabric take-up tension so as to be the same for the different heads of a machine, and, therefore, provided sufficient care is taken, these two parameters should not be the source of any between head variations in stitch length. The effect of yarn friction would be similar to that of input tension and it is therefore essential that this should not vary unduly either.

SUMMARY AND CONCLUSIONS

The factors affecting stitch length and therefore fabric dimensions on a 24 gauge fully fashioned plain machine have been investigated. It was found that the distance between sinker throat and needle stem, at the instant of loop measuring, critically affects the stitch length. It was suggested that it is variations in this distance which are largely responsible for the between head variations in garment size commonly found in practice. Furthermore, it was found that the stitch length is determined by the average distance between the needle stems and approximately the first **three** sinkers fully forward at the leading end of the slur cam. Therefore, if a slur cam has worn unevenly or is not exactly parallel to the needle bar, large differences in stitch length can be obtained on the same head between a left to right and a right to left traverse of the slur cam.

An instrument was designed which could be used to measure, quickly and accurately, the distance, D, referred to earlier.

The influence of yarn input tension and fabric take-up tension on stitch length was also investigated and it was found that an increase in fabric take-up tension decreased the stitch length slightly. This was thought to be due to the fact that the increase in take-up tension increased the deflection (bending) of the needles in a direction away from the sinkers which effectively reduced the distance between sinker throat and needle stems.

Yarn input tension affected stitch length considerably, an increase in input tension causing a decrease in stitch length. Again, it was felt that this decrease in stitch length was largely due to the needles bending away from the sinkers in order to compensate for the high yarn tension. It is, however, not difficult in practice to adjust both yarn input tension and fabric take-up tension so as to be the same for the different heads of a machine and these two parameters should therefore not contribute significantly towards the between head variation in stitch length. Robbing back was not considered to play a significant rôle in determining stitch length on this type of machine.

It was also found that the predicted stitch length calculated from the distance, D, machine gauge, etc. agreed very well with the actual stitch length. The difference between the average predicted and actual stitch lengths seldom exceeded 5% on the 3 heads used, after the heads were adjusted. After the heads were adjusted, by means of the instrument designed for this purpose, the difference in average stitch length between the heads never exceeded 4% and it is felt that in practice this could be reduced even further.

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