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An Introductory Study on the Effect of Certain Sewing Conditions on Fabric Resistance to Needle Piercing

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AN INTRODUCTORY STUDY ON THE EFFECT OF CERTAIN SEWING CONDITIONS ON FABRIC RESISTANCE TO NEEDLE PIERCING

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ABSTRACT

The effect of stitch length, pressure of presser foot, fabric structure and needle diameter on Fabric Resistance to Needle Piercing (FRNP) during the sewing operation, both with and without sewing thread, was investigated. It was found that the effect of stitch length and pressure of the presser foot depended upon a variety of factors such as fabric, needle size and stitch length. An increase in needle diameter always led to an increase in FRNP, the latter also increased with the product of fabric tightness and fabric mass. The trends were largely independent of whether sewing thread was used or not. The presence of a sewing thread, however, significantly changed the magnitude of FRNP.

INTRODUCTION

In stitching or sewing, the sewing needle has to penetrate through one or more fabric layers, then retract pulling the thread up (during needle withdrawal) so that a stitch loop can be formed. During this operation the needle has to overcome some opposing forces produced by the fabric.

The forces opposing needle penetration generate heat[1–8] causing an increase in needle temperature, but the increase depends on many factors, generally referred to as sewing conditions. The effect of these conditions on needle temperature and needle penetration force has been the subject of many investigations. It was found that such factors as sewing speed[6–13], needle geometry and finish[6–9, 13–22], number of fabric layers[7,9,12,16], fabric structure and fibre composition[1,6 9,13,18], fabric finish[1,4,6,11,19,21–24,26] and presence of needle thread[9–13, 15, 21, 26], have an important effect on either the needle temperature or needle penetration force. Generally, the findings can be summarised as follows:

- an increase in needle penetration force leads to an increase in the needle temperature;
- an increase in sewing speed produces an increase in needle temperature and needle penetration force;
- an increase in needle size results in an increase in needle temperature and needle penetration force;
- fabric structure, finish and composition have a significant effect on the needle temperature and needle penetration force;

— the presence of sewing thread reduces the needle temperature.

The forces acting against the needle during its penetration of the fabric are referred to as "needle penetration force". This term refers to the needle, and not to the fabric. For the purposes of this report two terms are defined, namely: "Fabric Resistance to Needle Piercing (FRNP)" (the first maximum force peak as the needle penetrates the fabric), and "Forces Opposing Needle Penetration (FONP)". The first stage of needle penetration is the piercing of the fabric, thus FRNP is a component of FONP.

Sewing conditions also include such factors as pressure of the presser foot (PPF), stitch length and stitch balance. The effects of these factors, together with the product of fabric tightness and mass, and needle diameter on fabric resistance to needle piercing (FRNP) are discussed here for all-wool woven worsted fabrics.

EXPERIMENTAL PROCEDURE

Method

The sewing process was conducted on an industrial single needle lock-stitch machine. Magnitudes of the following parameters were recorded:

- — fabric resistance to needle piercing (FRNP),
- — pressure of the presser foot (PPF),
- — needle thread peak tension (the highest tension of needle thread during the sewing cycle),
- — stitch length,
- — needle diameter,
- — sewing speed,
- — type of sewing thread and fabric,
- — stitch balance (balanced stitch was maintained throughout).

The magnitudes of the pressure of the presser foot and fabric resistance to needle piercing were measured with the use of a semi-conductor strain-gauge which was placed on the throat plate (Fig. 1a) and connected to an appropriate electrical circuit[22,27]. By this arrangement, a signal was obtained from which the magnitudes of forces opposing the needle penetration (FONP), and the magnitude of the pressure of the presser foot (PPF) could be determined (Fig. 2).

Three distinctive peaks (indicated as 1, 2 and 3 in fig. 2) were observed in the signal. The first peak indicates the magnitude of fabric resistance to needle

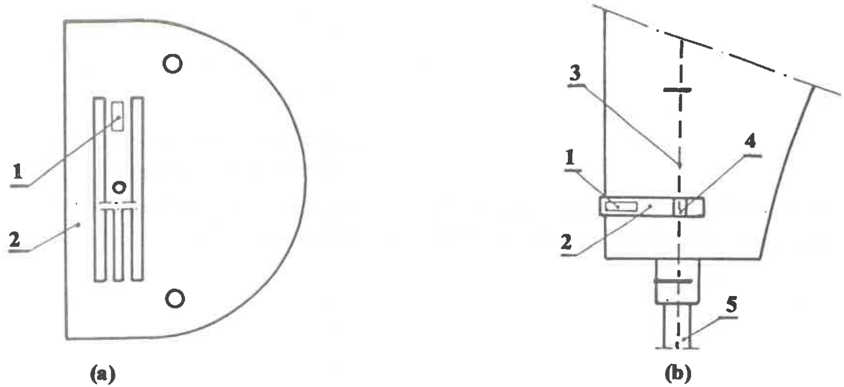

Fig. 1: (a) Position of a semi-conductor strain-gauge on the throat plate to measure forces opposing needle penetration:

1 – semi-conductor strain-gauge
2 – throat plate

Fig. 1: (b) Position of the cantilever on sewing machine to measure needle thread tension:

1 – semi-conductor strain-gauge
2 – cantilever
3 – needle thread
4 – needle thread guid on the cantilever
5 – needle bar

Fig. 3: Examples of signals of needle thread tension;
(a) fine needle
(b) thick needle and fabric

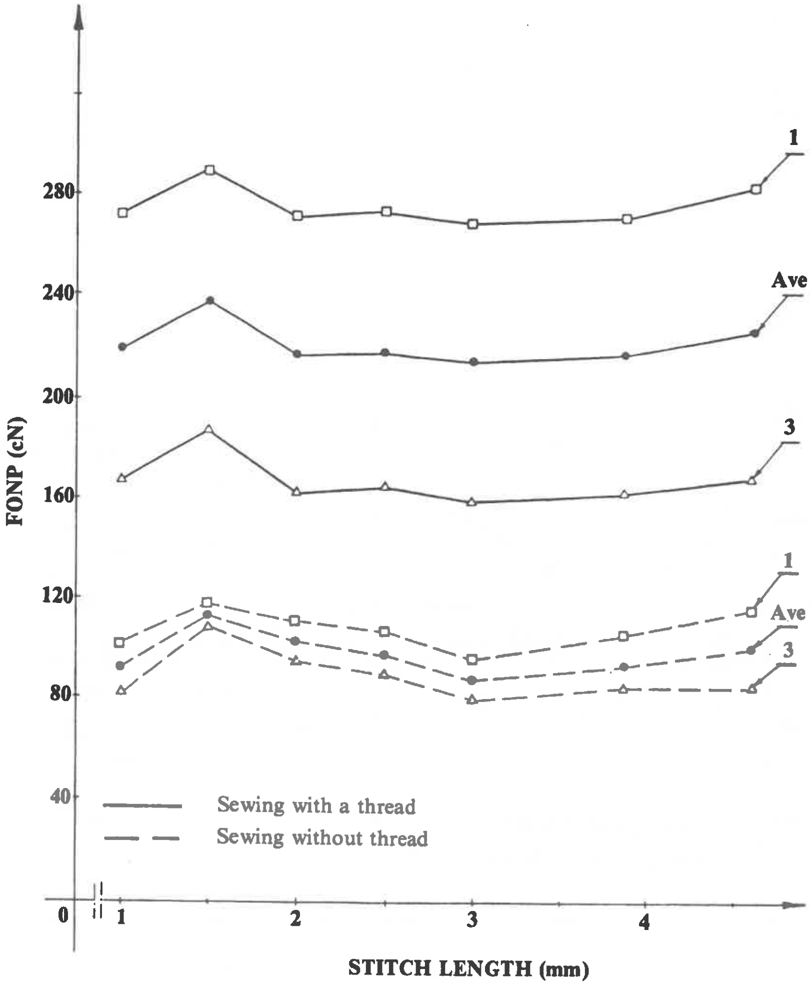

Fig. 4: Effect of stitch length on FONP; fabric 2, needle diameter – 0,60 mm;
1 – first peak of the signal (FRNP),
3 – third peak of the signal,
Ave – average of both.

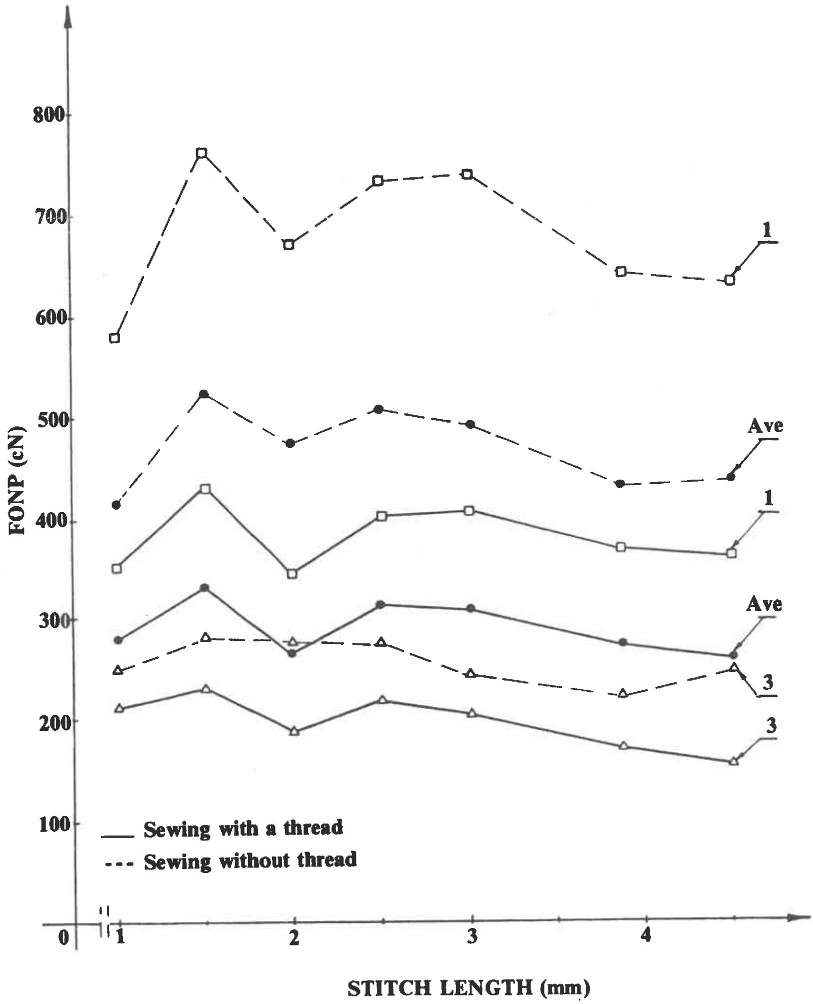

Fig. 5: Effect of stitch length on FONP; fabric 2, needle diameter – 1,00 mm;
1 – first peak of the signal (FRNP),
3 – third peak of the signal,
Ave – average of both.

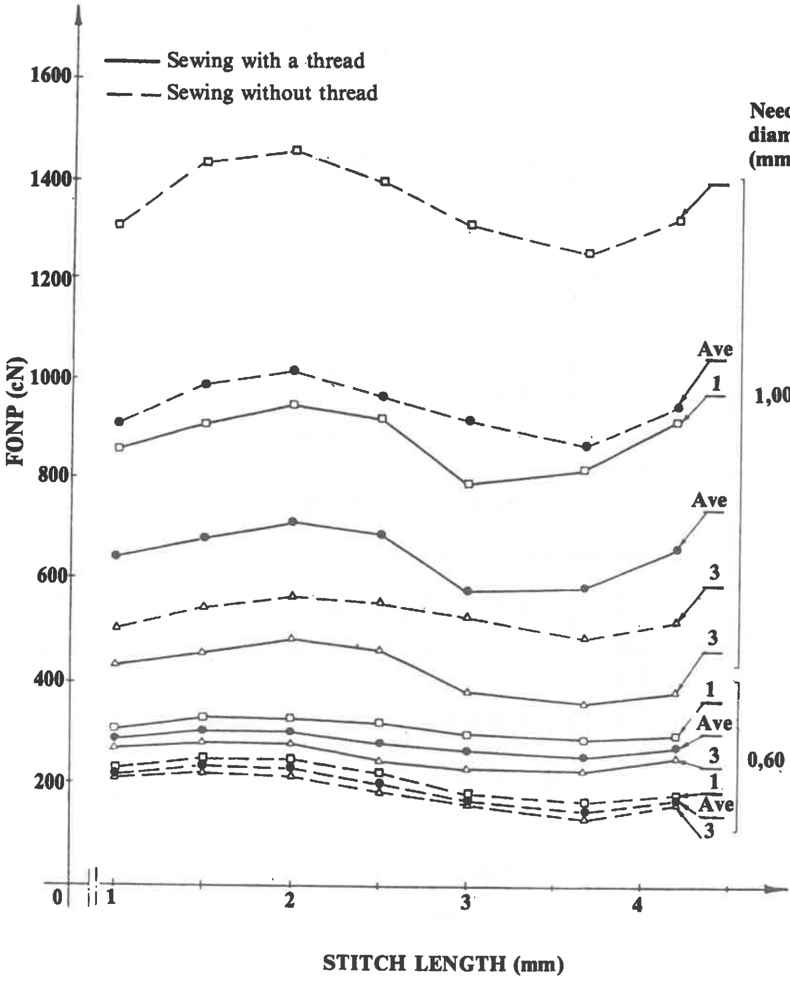

Fig. 6: Effect of stitch length on FONP, fabric 10
1 – first peak of the signal,
3 – third peak of the signal,
Ave – average of both.

TABLE 1

FABRIC SPECIFICATION

Fabric	Weave	Fabric Sett (threads/10 cm)		Resultant Yarn Count (R tex/2)		Fabric Tightness[28]	Fabric Mass (g/m²)	Tightness x Mass
		Warp	Weft	Warp	Weft			
1	Plain	206	198	40,0	40,0	0,94	172	161,7
2	Plain	206	184	40,0	40,0	0,90	165	148,5
3	Plain	204	112	40,0	40,0	0,67	138	92,5
4	2/2 twill	218	207	40,0	40,0	0,75	185	138,7
5	2/2 twill	213	114	40,0	40,0	0,52	144	74,9
6	2/2 warp faced rib	223	187	40,0	40,0	0,81	166	134,4
7	2/2 twill	378	213	47,3	47,3	1,04	316	328,6
8	2/2 twill	394	240	50,5	50,5	1,18	380	448,4
9	2/2 twill	346	283	38,4	38,4	1,07	266	284,6
10	2/2 twill	387	244	49,0	49,7	1,00	266	266,0

peak tension — 340 cN, pressure of presser foot — 2 cN/mm², sewing speed — 1740 stitches/minute, needle diameter — 0,90 mm, stitch length — 1,5 mm, sewing thread — R32 tex/2 (dyed, spun polyester), direction of sewing — warp direction using two fabric layers (for fabric 8 only one layer was used).

RESULTS AND DISCUSSION

Effect of stitch length

Theoretical analyses[1–8] of needle temperature or forces opposing needle penetration have shown no correlation with the stitch length. The experimental findings presented here (Figs 4-7), however, show that FRNP depended on stitch length. The effect varied with needle diameter and pressure of the presser foot. They also show that a change in FRNP with an increase in stitch length had a fluctuating characteristic and it was negligible when a fine needle was used.

Such a trend could be expected since an alteration in stitch length, for a defined fabric and number of stitches, produces a variation in the number of cases where successive stitches overlap with the axes of one or both yarn systems in the fabric. An onverlap produces a high value of FONP (so FRNP). Therefore, the greater the number of overlapping cases, the greater the average value. Analysis of the number of FRNP magnitudes greater than the average for all stitches showed that the character of change in the number in terms of stitch length was the same as in Fig. 6. The results (expressed in %) were: sewing with stitch length of 1,00 mm gave 25% of cases where the magnitude of FRNP was greater than the average; 1,50 mm stitch produced 41% cases; 2,0 mm stitch — 43%; 2,50 mm stitch — 35%; 3,00 mm stitch — 34%; 3,50 mm stitch — 28% and 4,25 mm stitch — 33%.

Introduction of a sewing thread did not alter the trends, but it caused significant changes in the magnitudes of FRNP compared with those where sewing thread was not used.

Effect of fabric structure

It is known that fabric structure, fibre composition and finish affect the magnitude of forces opposing needle penetration and consequently also the fabric resistance to needle piercing. However, no correlation between fabric structure and FRNP was found.

The results presented here (Fig. 8) show that there was a definite correlation between FRNP and the product of fabric tightness, t[28], and its mass, m, for sewing with or without thread. An increase in the product always led to an increase in FRNP.

Based upon Fig. 8 and assuming that in the extreme case where the fabric tightness equals zero, (i.e. no interlacing between warp and weft threads) FRNP would be so small that it could be neglected, the relation between FRNP and $t \times m$ can be described as:

For sewing without thread:

$$FRNP_1 = K (t \times m)^{K_1} \qquad (1)$$

For sewing with a thread:

$$FRNP_2 = K_2 (t \times m)^{K_3} \qquad (2)$$

where

K, K_1 - constants, depending on sewing speed, needle, fabric composition and finish and others.

K_2, K_3 - constants, depending on the same factor as K, K_1 as well as sewing thread.

The results obtained (Fig. 8) also indicate that there was some variation in the magnitude of FRNP due to the change in direction of sewing (warp, weft or bias). However, these differences were not significant and in most cases they were within the error of reading.

Effect of pressure of presser foot

According to theoretical analyses[2–6,8] of needle temperature and forces opposing needle penetration, they also depend on contact area between the needle and a fabric, and on the fabric pressure against the needle during its penetration. An increase in contact area, fabric pressure or both, leads to an increase in FONP.

A change in the pressure of the presser foot (PPF) produces some changes in both contact area (fabric thickness) and fabric pressure against the needle and needle-sewing thread assembly. Therefore, some changes in FRNP due to change in the PPF could be expected and the final effect would be resultant of the above two factors. The results obtained (Figs 9 — 11) confirm this. They show that changes in the magnitude of PPF produced some changes in FRNP and the degree of change depended on needle diameter, stitch length, fabric tightness and mass, and the presence of a sewing thread.

The trends obtained, although not consistent, show that there was a tendency for FRNP to decrease and then to increase with an increase in PPF.

Effect of needle diameter

Previous investigations[6–9,13–22,26] have shown that an increase in needle diameter causes an increase in forces opposing needle penetration. The results obtained here (Figs 12 - 13) showed a similar trend. Moreover, they indicated that the increase in FRNP was proportional to the product of fabric tightness

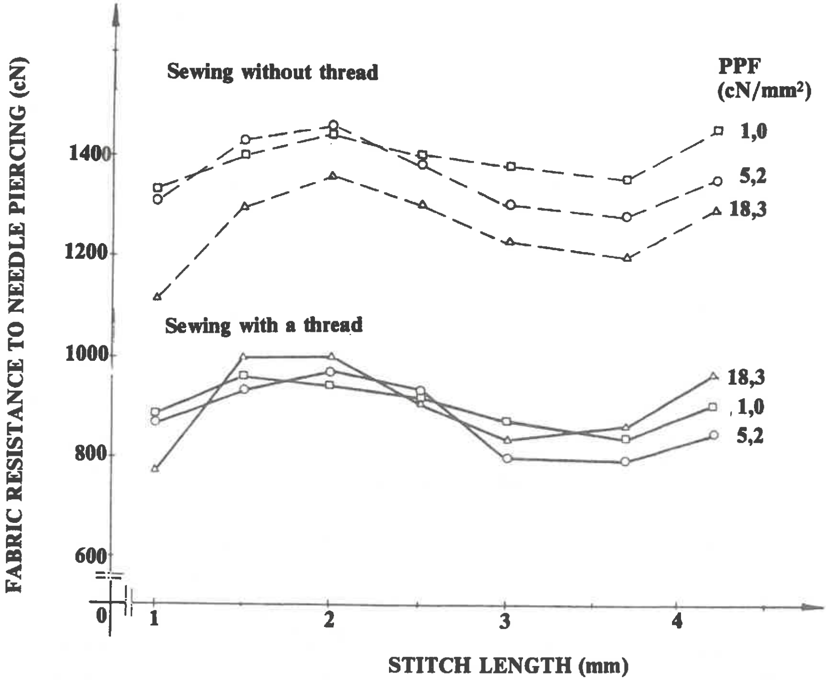

Fig. 7: Effect of stitch length and pressure of presser foot (PPF) on FRNP, fabric 10

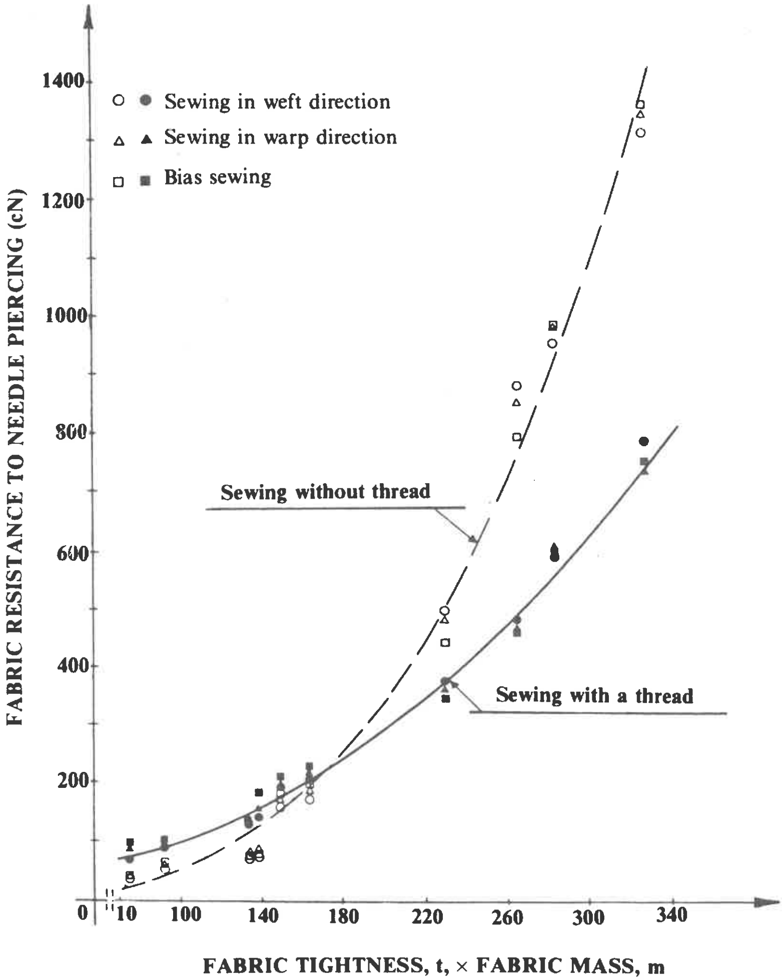

Fig. 8: Effect of the product of fabric tightness and mass (g/m^2) on fabric resistance to needle piercing.

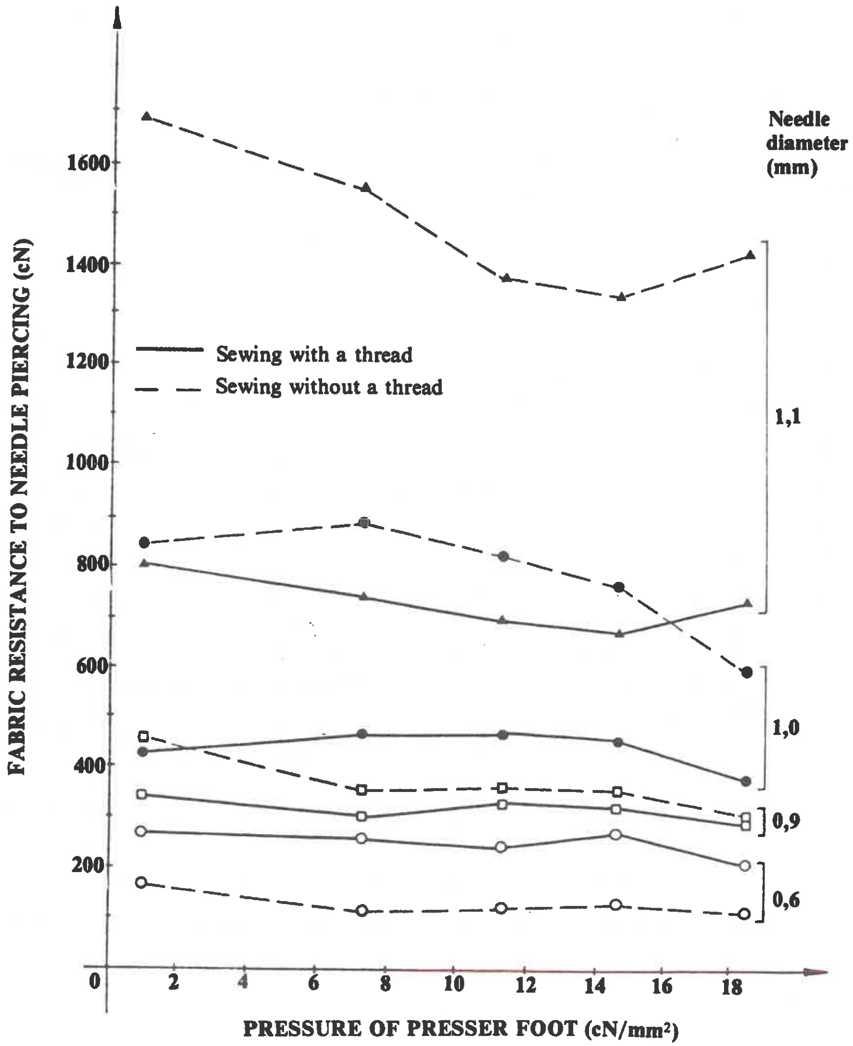

Fig. 9: Effect of pressure of presser foot and needle diameter on FRNP. Fabric 2.

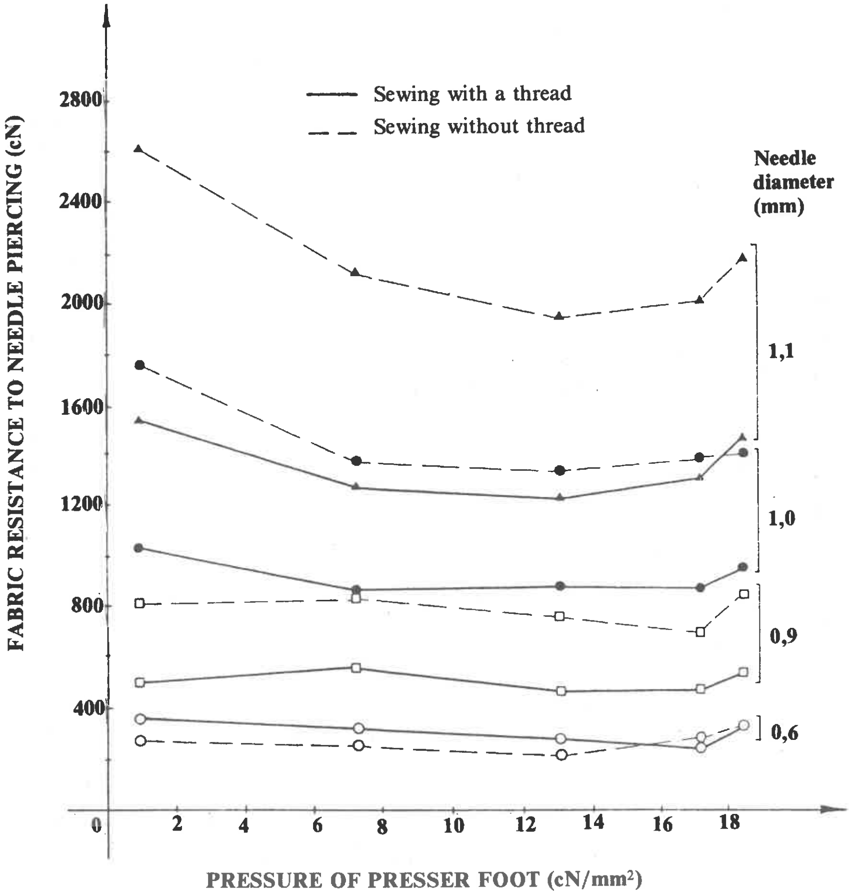

Fig. 10: Effect of pressure of presser foot and needle diameter on FRNP. Fabric 10.

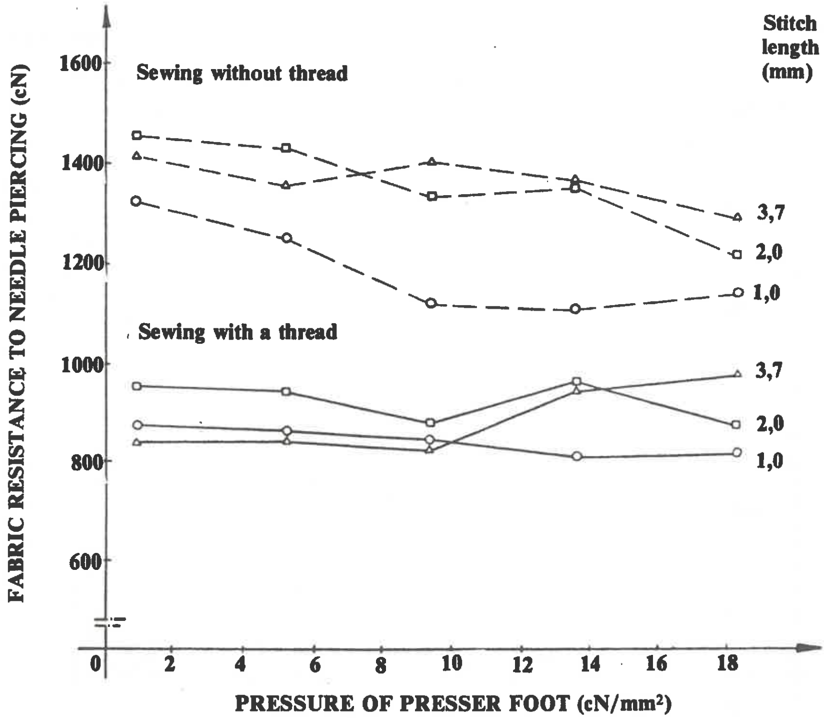

Fig. 11: Effect of pressure of presser foot and stitch length on FRNP. Fabric 10.

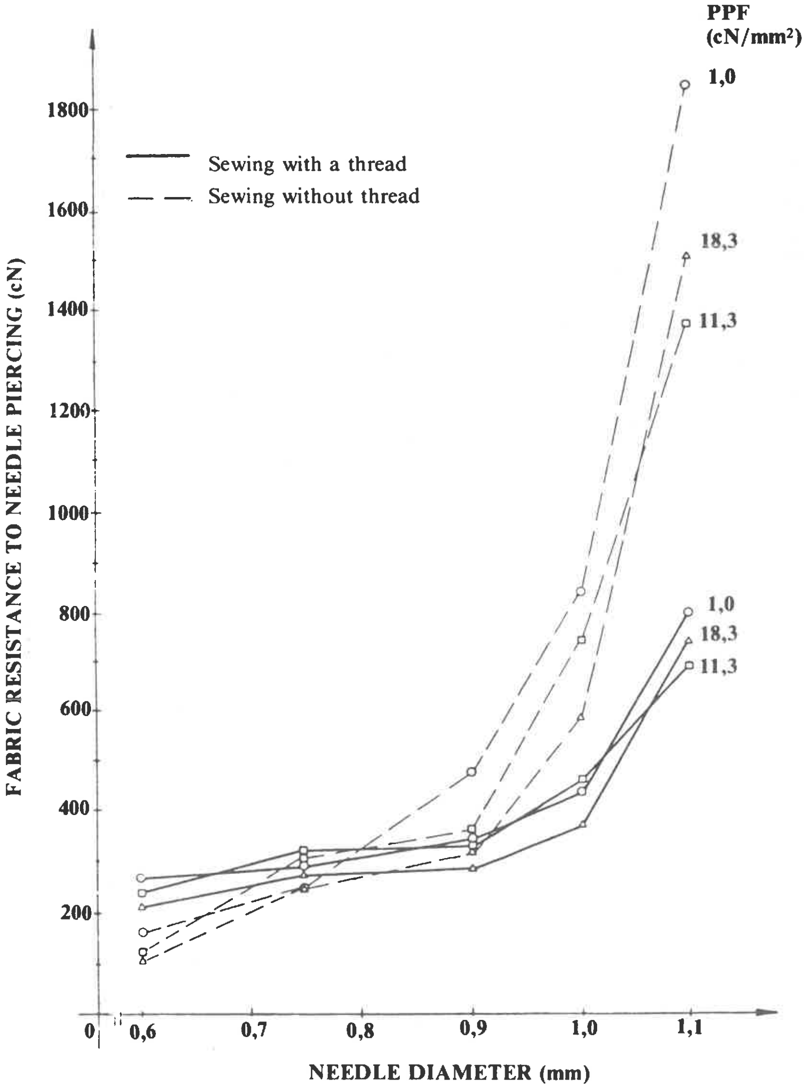

Fig. 12: Effect on needle diameter on FRNP. Fabric 2

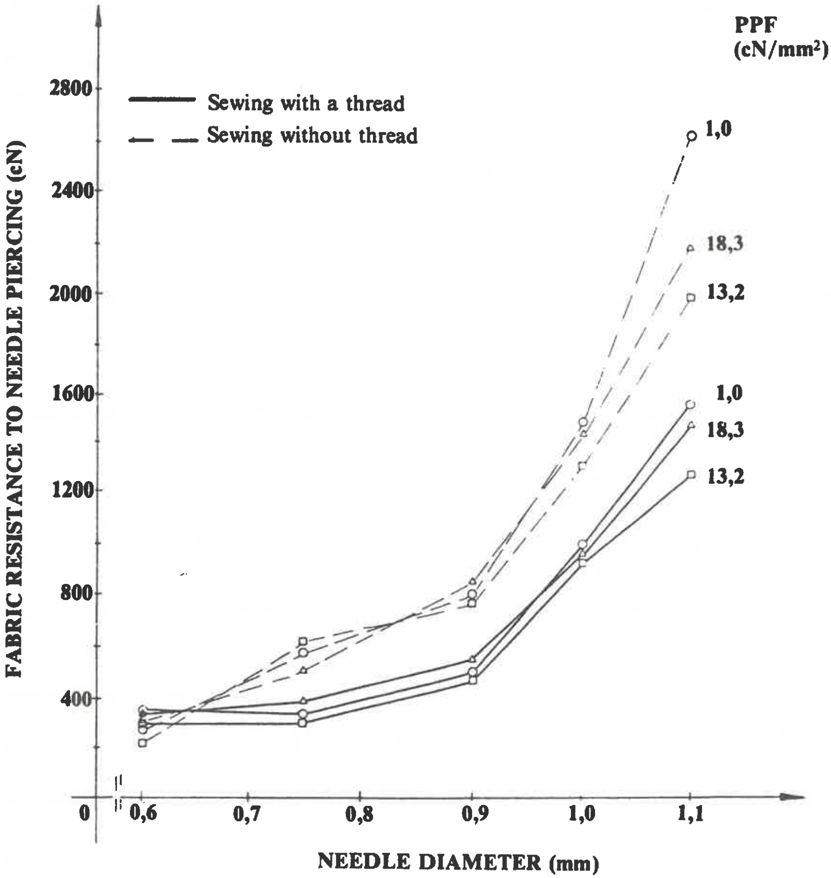

Fig. 13: Effect of needle diameter on FRNP. Fabric 10

and mass and varied with needle diameter. It was also different whether or not sewing thread was employed.

The presence of sewing thread (Figs 12-13) slightly altered the trends, showing two regions in terms of needle diameter. First, for diameters between 0,60-0,90 mm, a change in the diameter did not produce significant changes in FRNP. Second, for diameters greater than 0,90 mm, a small change in the diameter produced significant changes in FRNP. The latter also applies when "sewing" without a thread.

A comparison of values of FRNP obtained for sewing with an without thread shows that for fine needles the value of FRNP for sewing with a thread was greater than that when sewing without thread. As the diameter increased the difference between these two decreased and a further increase in the needle diameter resulted in a reversal of this trend. The point of the reversal depended on fabric tightness and mass.

The change in pressure of presser foot had no effect on the above trends.

Effect of stitch balance and needle thread tension

Whether a stitch is in or out of balance depends on proportion between the needle and bobbin thread tensions. The following three extreme cases can be distinguished when dealing with stitch balances:

(1) — an unbalanced stitch where the bobbin thread does not form a loop,

(2) — a balanced stitch, both threads form loops of similar geometry,

(3) — an unbalanced stitch where the needle thread does not form a loop.

These three cases were investigated under low and high needle thread peak tension, and the results obtained (Table 2) show that the change in stitch balance had a small effect on FRNP. Significant changes were observed, however, in the magnitudes of peaks 2 and 3 which showed the highest values for a balanced stitch with high needle thread peak tension. Generally, the high needle thread peak tension produced greater values of peaks 2 and 3 compared with the low peak tension.

SUMMARY AND CONCLUSIONS

The fabric resistance to needle piercing (FRNP) of all-wool woven worsted fabrics was investigated in terms of stitch length, fabric tightness and mass, pressure of presser foot, stitch balance and needle diameter. The research was carried out on an industrial single needle lock-stitch machine, and the results obtained indicate that:

— the presence of a sewing thread created a significant change in the

TABLE 2

EFFECT OF STITCH BALANCE ON FORCES OPPOSING NEEDLE PENETRATION INDICATED BY MAGNITUDES OF PEAKS AND AVERAGE (FABRIC 10)

Bobbin Tension	Kind of Stitch	FONP (cN)							
		Low needle thread peak tension				High needle thread peak tension			
		Peaks				Peaks			
		1	2	3	Average	1	2	3	Average
Low	Balanced	552	169	235	319	—	—	—	—
	Unbalanced (needle thread does not form a loop)	—	—	—	—	533	265	246	348
High	Balanced	—	—	—	—	547	307	310	388
	Unbalanced (bobbin thread does not form a loop)	568	136	232	312	—	—	—	—

magnitude of FRNP.

— a high correlation was found between the product of fabric tightness and mass and fabric resistance to needle piercing, FRNP increased with an increase in the product,

— neither the pressure of the presser foot nor the stitch length had a consistent effect on FRNP,

— an increase in the needle diameter led to an increase in FRNP,

— a change in the needle thread peak tension or the stitch balance had a small effect on FRNP.

Further work is required to correlate FRNP with fabric tightness and mass for various factors, e.g. fibre composition, fabric finish, sewing speed, needle diameter and sewing thread. Eventually, the results obtained would allow compilation of composite graphs for industrial use, from which optimum sewing conditions for a defined fabric could be predicted.

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USE OF PROPRIETARY NAMES

The names of proprietary products where they appear in this report are mentioned for information only. This does not imploy that SAWTRI recommends the to the exclusion of other similar products.

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