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Effect of Certain Factors on Yarn to Yarn Frictional Force

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EFFECT OF CERTAIN FACTORS ON YARN TO YARN FRICTIONAL FORCE

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ABSTRACT

A new method, allowing to simulate the yarn assembly in a woven fabric for measuring yarn to yarn frictional force, is described. The yarn to yarn frictional force was examined in terms of: yarn tension, contact angle, speed, crimp and linear density. It was found that this force increased with tension, contact angle, crimp and linear density, whereas the yarn speed had a fluctuating effect.

INTRODUCTION

Yarn to yarn friction plays an important role in fabric resistance to seam slippage, sewability and as the frictional component of the weaving resistance. Seam slippage is the movement of one yarn system (in a fabric) against the other where each contact between the yarns of opposite systems creates some frictional force. The greater the frictional force the greater the fabric resistance to seam slippage.

Needle penetration during the sewing operation may make the yarn threads move sideways, causing the yarn threads of one system to move against the other system and in doing so overcoming some frictional forces. These forces may have an important effect on fabric resistance to needle penetration.

In weaving, in order to locate the newly beaten-up weft thread the beat-up force also has to overcome the frictional component of the weaving resistance. The latter is produced by the weft thread movement against the warp. The greater the frictional force, the greater the weaving resistance.

The magnitude of the frictional force depends on the coefficient of friction and a number of other factors. The effect of the coefficient is well known — an increase in the coefficient leads to an increase in the frictional force, and it is common practice to alter the value of the coefficient through application of lubricants or anti-slip agents.

Previous investigations[1–7] concerned with the friction of yarns and fibres against a guide, showed that the value of the frictional force also depends on such factors as: yarn tension, contact angle, yarn speed, diameter of yarn and the guide and the raw material. In the case of yarn to yarn or fibre to fibre friction the information is rather limited. It was found[8,9] that yarn to yarn friction depends on load and contact area for an assembly of two surfaces covered with yarn and moving against each other with the angle between the yarn axes at 90° Other work[10] showed that the yarn to fibre frictional force also depends on yarn speed.

Taking into account the importance of yarn to yarn friction and the limited information available, it was decided to undertake an empirical study of the effect of certain factors on the formation of the yarn to yarn frictional force. Bearing in mind the wide ranges of values possible for the relevant parameters in practice, an attempt was made to vary the range of the relative parameters as widely as was possible.

EXPERIMENTAL

Materials and Apparatus

A number of commercial yarns were used, including wool, polyester, cotton and blends as listed below:

100% Wool Yarns

(a) — 27 tex
(b) — 32 tex
(c) — 37 tex
(d) — 50 tex
(e) — R36 tex/2
(f) — R44 tex/2
(g) — R50 tex/2
(h) — R52 tex/2
(i) — R56 tex/2
(j) — 500 tex

100% Cotton Yarns

(k) — 30 tex (Rotor)
(l) — R56 tex/2

Textured Polyester

(m) — 77 dtex
(n) — 167 dtex

Blends

(o) — R40 tex/2, wool/polyester (45/55)
(p) — R50 tex/2, polyester/cotton (70/30), (sewing thread)
(r) — 100 tex, polyester/cotton (70/30)

The letters a — r are used to denote the yarns in the respective figures.

The experiment was carried out on an Instron Tester with a special device (Fig. 1) attached. The device allowed the simulation of the yarn assembly in a woven fabric i.e. to obtain an angle of 90° between two yarn axes, vary the contact angle between the yarns, and alter the tension of the moving yarn. The change in yarn speed was obtained through variation in jaws speed or application of a positive nip roller device for speeds over 100 cm/min .

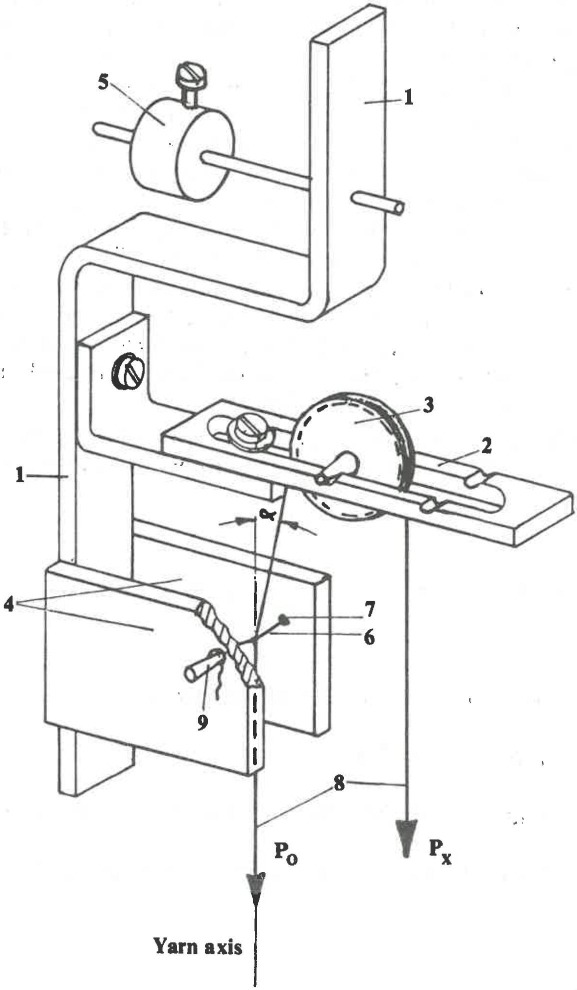

Fig. 1 – The device attached to the Instron Tester.

The device, Fig. 1, consists of an aluminium frame (1), adjustable beam (2), grooved pully (3), stationary yarn holder (4) and a balance weight system (5). It is fastened to the upper jaws of the Instron Tester. The stationary yarn (6) is threaded through the eyelets (7) of the transparent yarn holder, where it is secured with plastic plugs (9). The moving yarn (8) is threaded over the stationary one (6) and the pulley (3) to the lower jaws or positive take-up device. A specified load, P_o, giving the required yarn tension, is applied to the other end of the yarn. The vertical position of the upper jaws is set by using the balance weight. The required contact angle, α, between the moving yarn and stationary one is obtained by alteration of the position of the moving part of the beam. The distance between upper and lower jaws is increased by 5 cm and the upper jaws are again brought to the vertical axis by repositioning the weight along its guide. Then, again, the distance between the jaws is increased by a further 5 cm and the contact angle checked and, if necessary, altered to the required value. When the geometry of the system is set, the load P_o is removed to release the tension in the yarn so that the zero position of the recorder could be set and calibration effected (the upper jaws are set in the vertical position).

The vertical movement of the jaws produces a movement of the moving yarn against the stationary one and thus the upper jaws are under tension T_x:

$T_x = P_o + P_x$ ....(1)

where $P_x = P_o + F_g + F_p$ ....(2)

and

F_g — the frictional force of yarn against the yarn;

F_p — the resistance of the pulley;

P_x — the tension in the yarn between the pulley and lower jaws.

Running the test with no yarn to yarn contact produces a new tension T_{xo} in upper jaws:

$T_{xo} = P_o + P_{xo}$ ....(3)

where

$P_{xo} = P_o + F_p$ ....(4)

P_{xo} — the tension in the yarn between the pulley and lower jaws.

From equations 1 — 4 the frictional force, Fg, is given by

$F_g = T_x - T_{xo}$ ....(5)

Similarly, for the start of yarn movement

$F_s = T_{xs} - T_{xos}$ ....(6)

The forces (tensions) T_x and T_{xo} are recorded so the value of F_g are found from the recording chart[11].

Yarn tension

Three yarns and one sewing thread were used to examine the effect of yarn tension on the yarn to yarn frictional force. The tension was changed within the range 49-1176 mN, keeping all other parameters constant.

Contact angle

The effect of contact angle between yarns on the frictional force was investigated for a few commercial yarns and sewing thread. The yarn tension and speed were kept constant and the angle was changed within the range 15-70°.

Yarn speed

The effect of yarn speed on the frictional forces was examined for three different yarns. The speed was changed within the range 5,0 - 972,2 cm/min .

Yarn crimp

Yarns from five different fabrics were chosen to examine the effect of yarn crimp on the yarn to yarn frictional force. Yarn of zero crimp value was obtained by straightening and setting the yarn without allowing for shrinkage.

RESULTS AND DISCUSSION

The aim of the analysis of the results obtained was to determine how the value of frictional force had been affected by the parameters involved.

Effect of yarn tension

The results obtained, Fig. 2, show that the value of the frictional force increases with applied tension. The degree of increase also depends on the

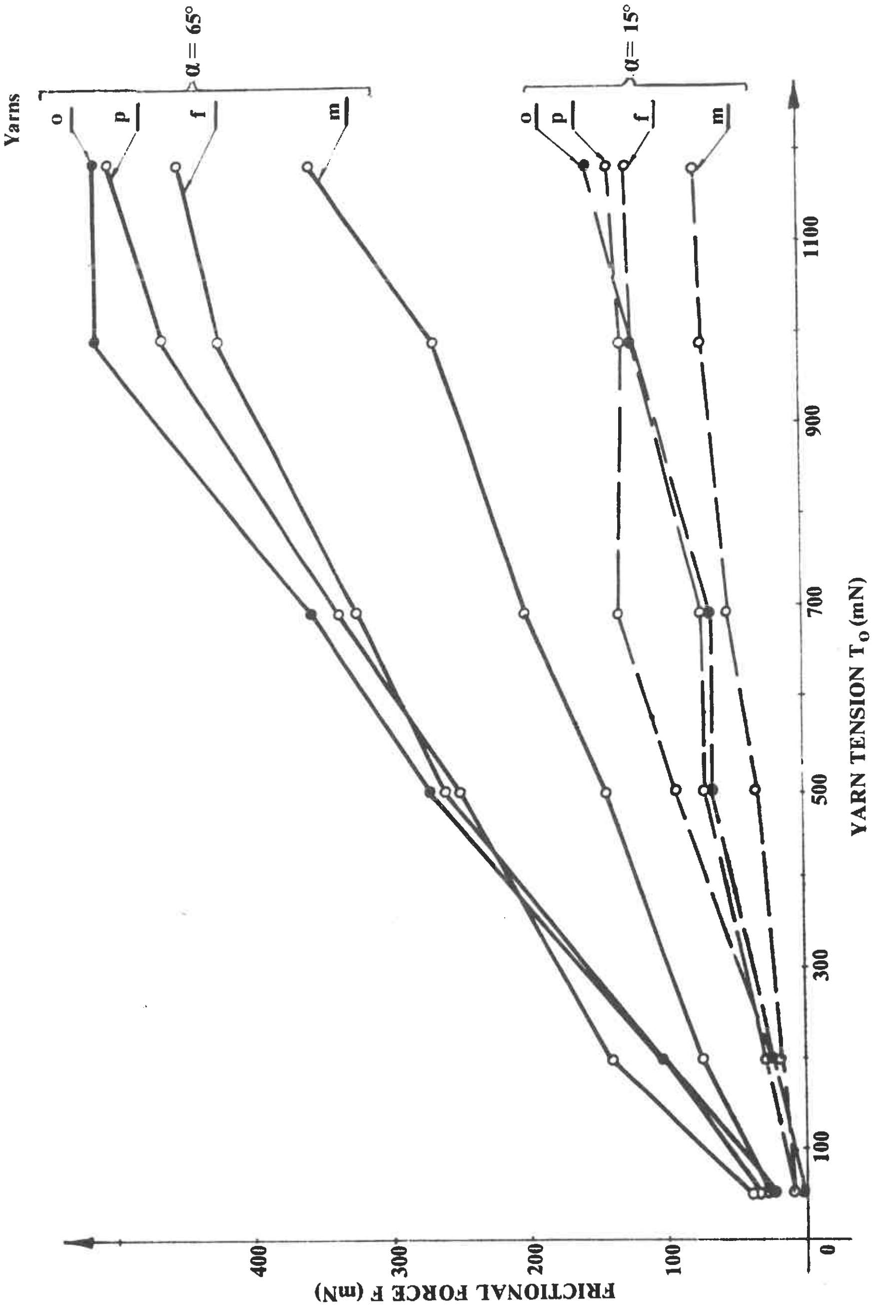

Fig. 2 – Effect of yarn tension on frictional force (V_y = 50 cm/min).

contact angle between the yarns — the greater the angle, the greater the frictional force.

The trends obtained are in agreement with those obtained for yarn, or fibre against a guide[3,5,7], and for yarn against a yarn[8,9].

Effect of contact angle

According to the capstan equation, $T_1 = T_0 e^{\mu\alpha}$, the value of the frictional force should increase with contact angle. The results obtained, Figs 3 and 4, show that the value of the frictional force increased with an increase in the value of contact angle between the moving and stationary yarns and that the magnitude of the increase depended on yarn tension. When the tension was low an increase in the contact angle had a small effect, but as the tension increased the effect of contact angle was much greater.

These trends obtained agree with those found for yarn, or fibre, against a guide[3-7].

Effect of yarn linear density

The results presented so far and those in Fig. 5 (where both yarns, i.e. moving and stationary, were the same) indicate that the value of frictional force varies with yarn linear density.

Use of different yarns as moving and stationary, Fig. 6, showed that the change in yarn position (from moving to stationary and vice versa) may produce significant differences in the magnitude of frictional forces. However, it did not create a clear trend in terms of yarn linear density. Application of the analysis in terms of yarn specific tension (mN/tex) and specific frictional force (mN/tex) also did not reveal definite trends.

Effect of yarn speed

The results obtained, Figs 7-8, show that the value of frictional force depends on yarn speed. All yarns produced some fluctuations in values of frictional force in terms of speed, Fig. 7. However, there is a significant difference in general trends within the applied yarn speed. The 30 tex cotton (Rotor) yarn produces the general trend which is typical for a yarn against a guide[2,3,7] whereas the others show general increases with the yarn speed.

The fluctuation characteristics of the curves suggest that there is more than one change from boundary to hydrodynamic lubrication[2,3].

Examination of values of the frictional force F_s, at the start of yarn movement, Fig. 8, shows that as the yarn speed exceeds about 100 cm/min the yarn movement starts under greater tension than that during the movement. The value of the frictional force at the start of yarn movement is not only greater than that during the movement, but its value increases with the yarn speed, Fig. 8.

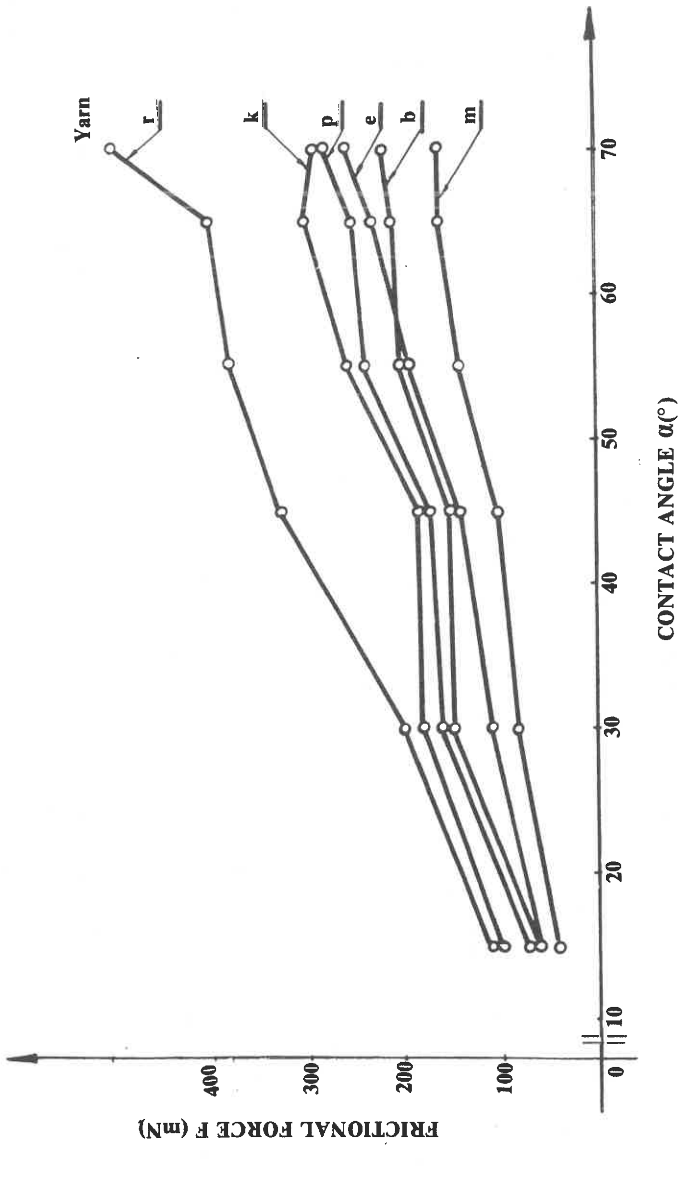

Fig. 3 – Effect of contact angle on frictional force (T_o = 490 mN; V_y = 50 cm/min).

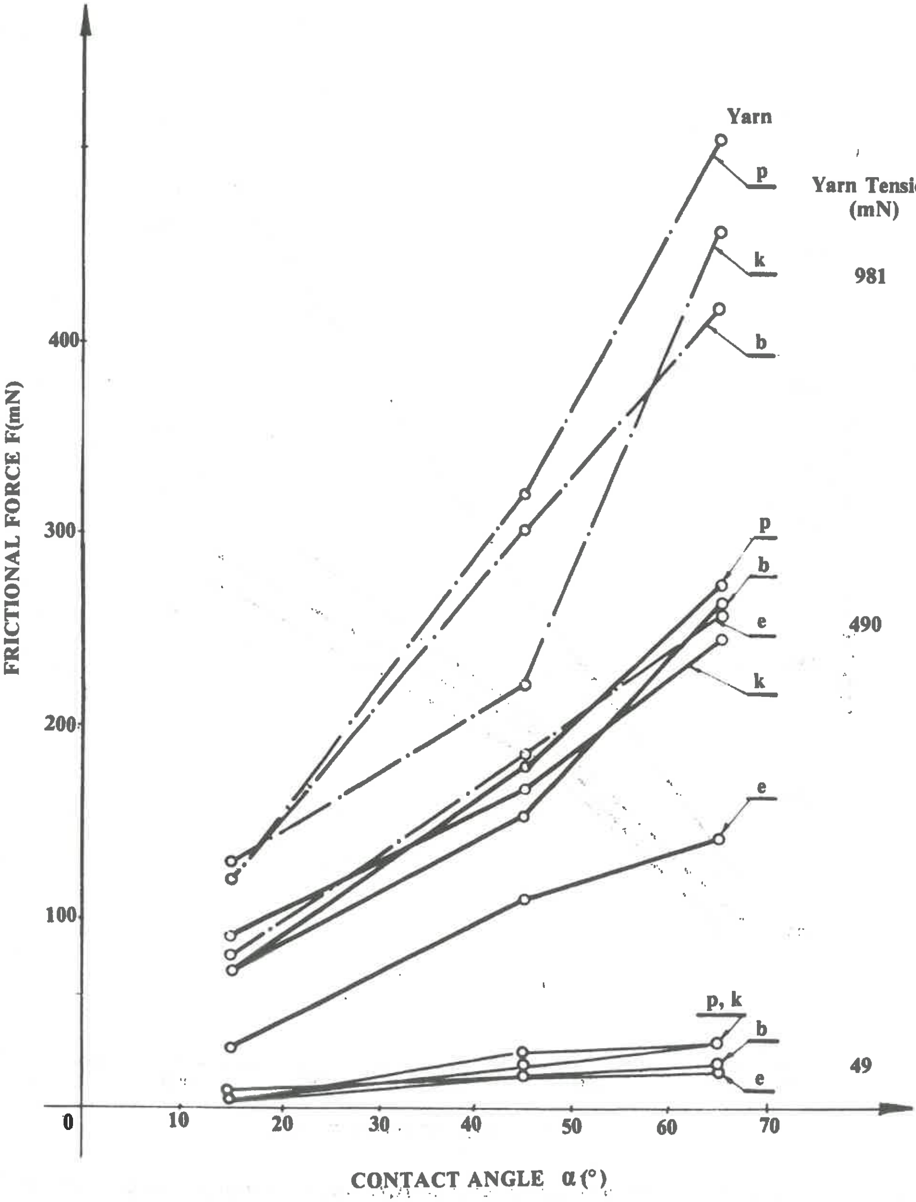

Fig. 4 – Effect of contact angle and yarn tension on frictional force (V_y = 50 cm/min).

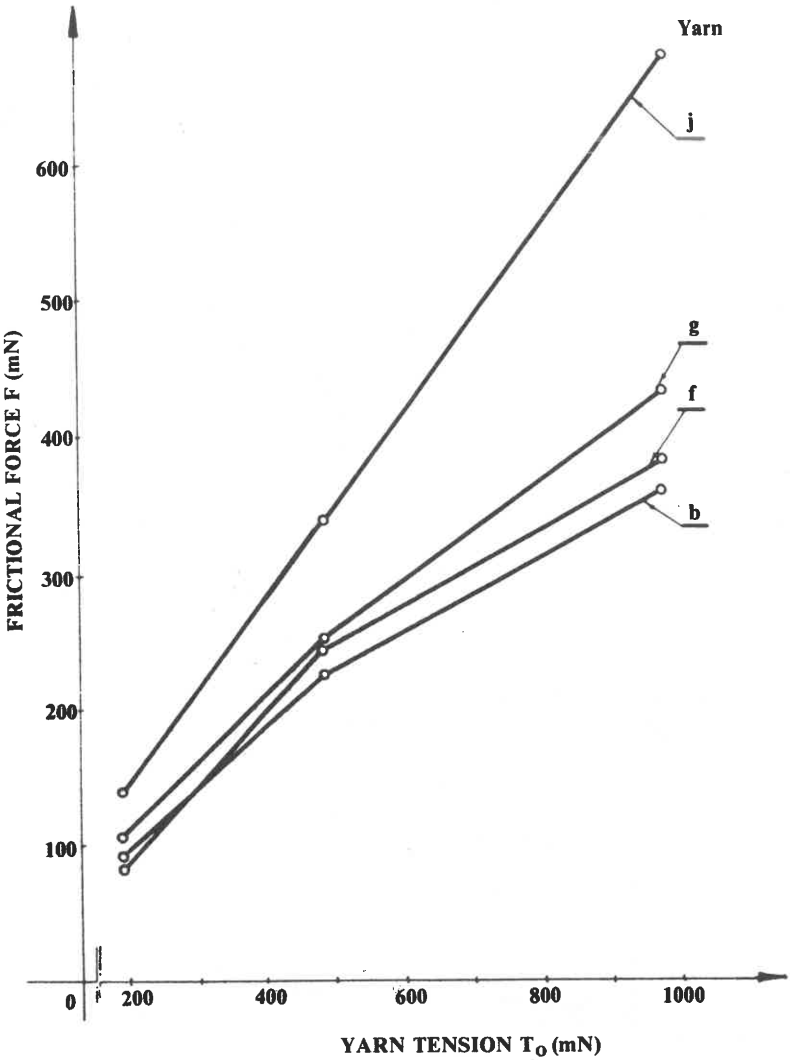

Fig. 5 – Effect of yarn tension and linear density on frictional force ($\alpha = 60°$, $V_y = 50$ cm/min).

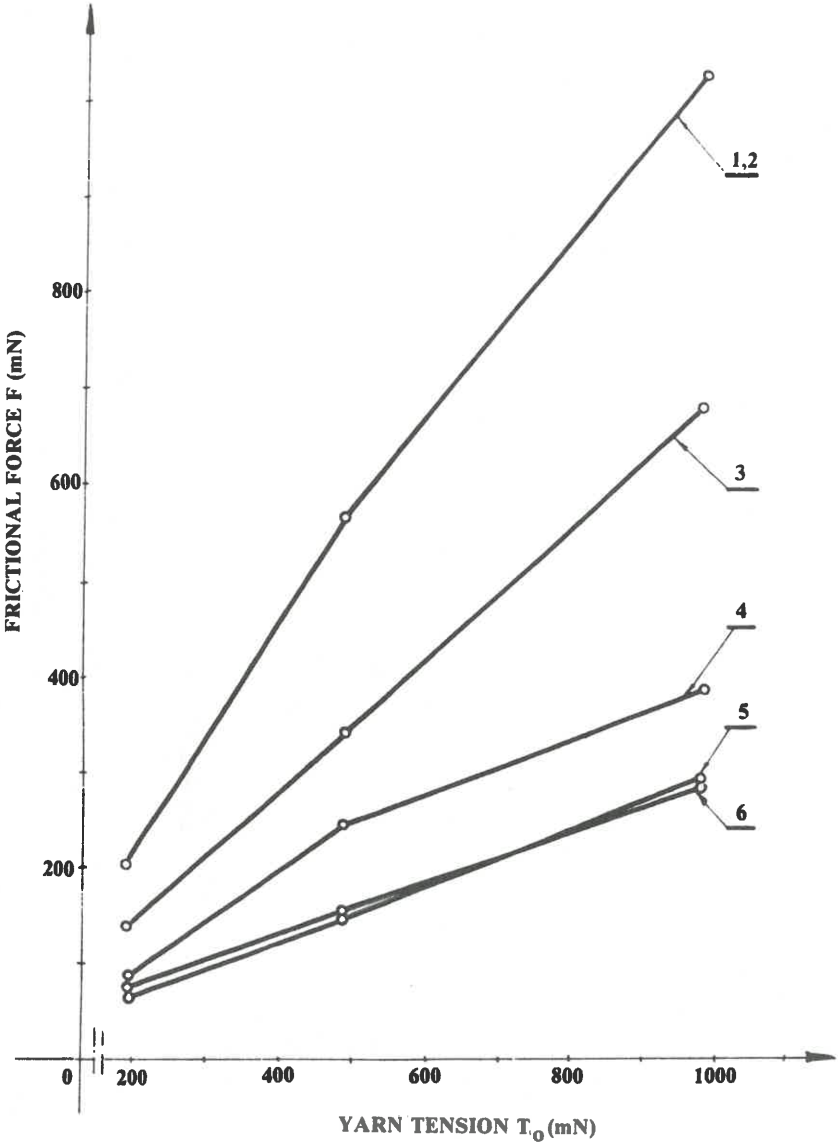

Fig. 6 – Effect of yarn tension and linear density on frictional force ($\alpha = 60°$, $V_y = 50$ cm/min): 1,2 - b vs j and f vs j; 3 - j vs j; 4 - f vs f; 5 - j vs f; 6 - j vs b; b, f, j - different yarns.

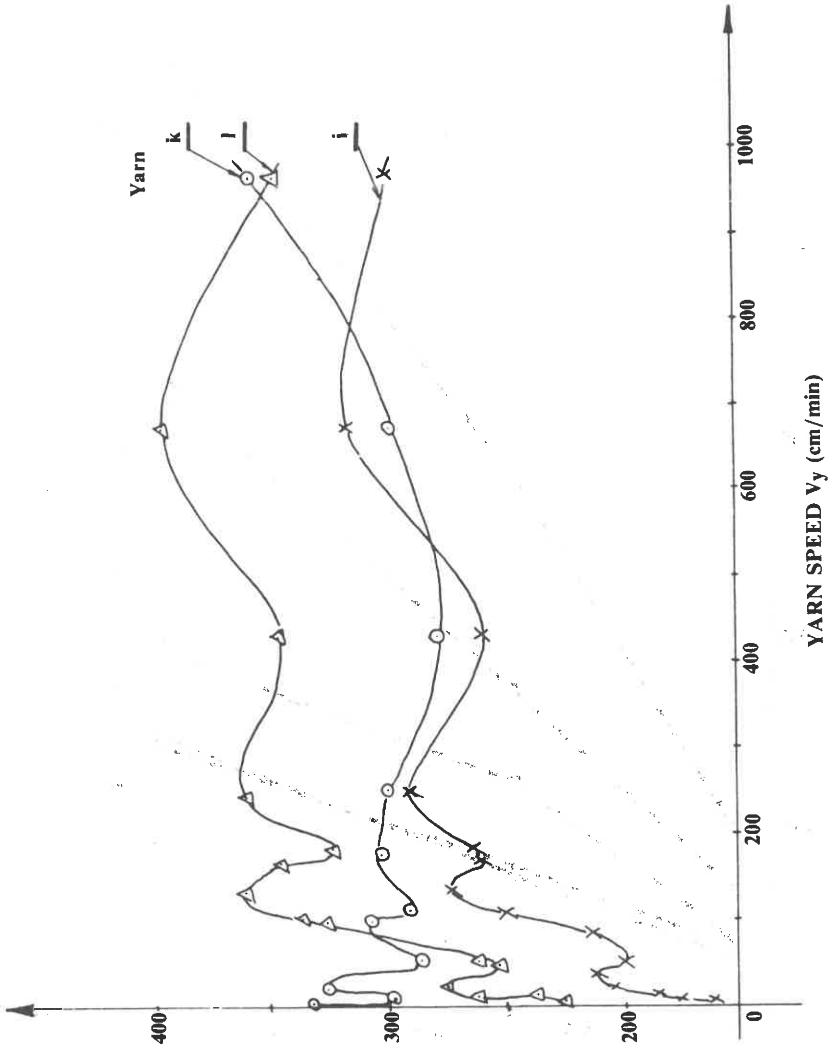

Fig. 7 – Effect of yarn speed on frictional force (T_o = 400 mN; α = 65°).

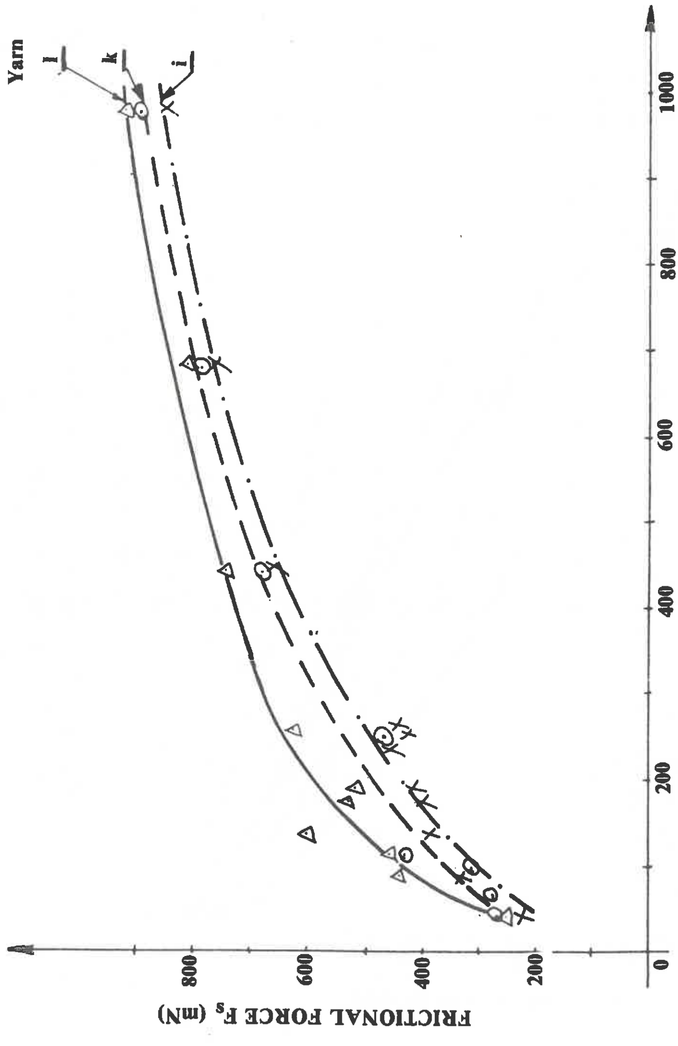

Fig. 8 – Effect of yarn speed on frictional force, F_s, at the start of the yarn movement.

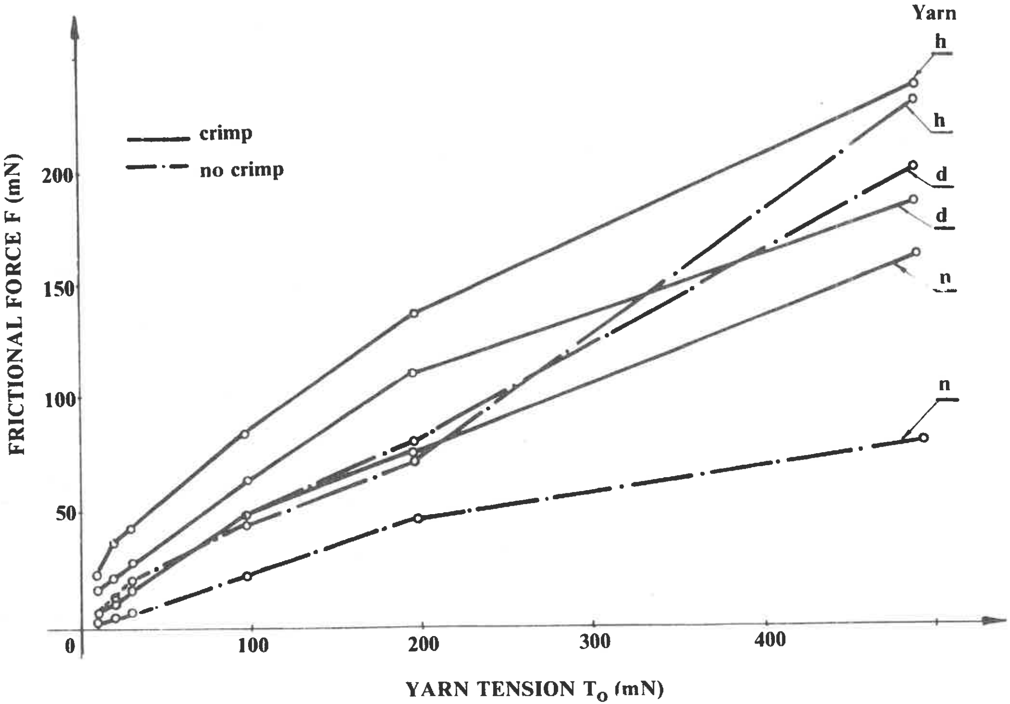

Fig. 9 – Effect of yarn tension and crimp on frictional force (α=65°; V_y = 50 cm/min). Yarn crimp; d - 7,6%, h - 23,5%, n - 3,0%.

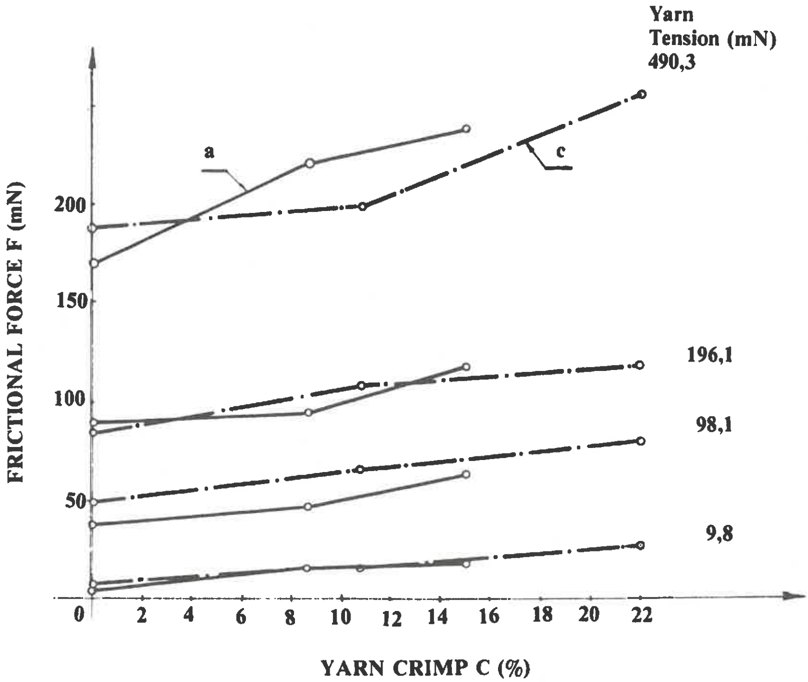

Fig. 10 – Effect of yarn crimp on frictional force (V_Y = 50 cm/min; α = 60°): a, c - different yarns.

Similar trends were obtained when dealing with yarn movement against a guide[7].

Effect of crimp in the moving yarn

To produce a yarn movement in a woven fabric the pulling force has to overcome some resistance caused by crimp removal. The effect of crimp comprises two elements, namely alteration (fluctuation) of the contact angle between the yarns, and straightening of the yarn (removal of the crimp). The magnitude of this effect may also depend on yarn tension and yarn properties.

The results obtained, Figs. 9 and 10, where only the moving yarn possessed crimp, show that the existence of crimp in the yarn produces an increase in the frictional force.

SUMMARY AND CONCLUSIONS

Because of the importance of the yarn to yarn friction in determining fabric sewability, seam slippage and weaving resistance, it was decided to investigate the effect of various factors such as yarn tension, speed, contact angle and crimp on frictional force using a newly developed method. The method allowed simulation of yarn assembly in woven fabric.

The results obtained show that the value of yarn to yarn frictional force produced during yarn movement, with a right angle between the yarn axes, also depends on:

— yarn tension

— contact angle between the yarns

— yarn crimp and

— yarn speed.

An increase in value of the first three of the above parameters led to an increase in the frictional force. An increase in yarn speed produced some fluctuations in values of the frictional force indicating that there are some changes from boundary to semi-boundary and vice versa, regions.

ACKNOWLEDGEMENTS

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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 imply that SAWTRI recommends them to the exclusion of other similar products.

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