EFFECTS OF FIBRE CONTENT, YARN MECHANICAL PROPERTIES AND FINISHING TREATMENTS ON FABRIC HANDLE

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DIGITI

D E D I C A T I O N

This research project is dedicated to my

Mum, Dad and my Wife Rukkayya.

KASHIM IBRAHIM LI
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CERTIFICATION

This dissertation entitled "EFFECTS OF FIBRE CONTENT, YARN MECHANICAL PROPERTIES AND FINISHING TREATMENTS ON THE FABRIC HANDLE" by Darma, Mohammed Umar meets the regulations governing the award of the degree of Master of Science in Textile Science and Technology of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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A C K N O W L E D G E M E N T

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A B S T R A C T

Three groups of materials were employed in this investigation The first consisted of plain were fabrics of different fibre contents. The second group consisted of five weft pile fabrics (corduroys). The third group consists of plain were cotton fabrics subjected to finishing treatments of scouring and mercerization. They were tested both mechanically and subjectively for the three main fabric handle properties, namely, extension/stretchiness, flexion/stiffness and friction/Smoothness. Effect of sled speed on fabric friction was also investigated.

From the results obtained it is clear that fabric handle depends on the fibre content, yarn and fabric construction and finishing treatments. It is shown that an increase in sled speed gives a smoother feel. Also, the closer or the shallower the cords, the smoother will be the feel for the weft-pile fabrics. Initial Young's modulus was found to be most closely related to the subjective stretchiness. Scouring caused decrease in elongation and increase in warp crimp of a plain were Cotton fabric due to consolidation. It however, stabilized after the sixth wash. Finally, increase in caustic soda concentration produced hard and rough surfaces.

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CHAPTER 1

Introduction and Review of literature

1.1 Introduction :-

Fabric handle is the stimuli perceived when the fabric surface is rubbed either mechanically by an instrument or tactually by a human subject.

Generally, there are two approaches to the measurement of fabric handle. One approach entails the summation of sensations and summation of relevant mechanical properties. This approach is referred to as the Kawabata method. The second approach considered individual sensations and individual mechanical properties, for example smoothness with friction, softness with compression, stretchiness with tension, stiffness with flexural rigidity or drapeability. This later approach may be simply carried out using a conventional tensile tester. This approach is reasonably versatile.

Fibre content, yarn and fabric construction, and finish are the major components that influence sensory and physical properties of a fabric (3). The person handling the cloth attempts to describe his sensations in words such as stiff, limp, lively, dead, papery, soft, full, smooth, harsh, etc. Great difficulties often arise because different observers may use different words to describe the same sensation, and because they have different ideas about the type of handle that is desirable in a particular class of fabric. Overabundance of expressions may contribute to misunderstanding.

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1.2 Review of Literature

The handle of a fabric is one of the major characteristics on which its quality and its suitability for a particular end-use may be assessed.

Hoffman and Bestle (1) defined fabric handle as the impressions which arise when fabrics are touched, squeezed, rubbed or otherwise subjected. This implies the ability of the fingers to make a sensitive and discriminatory assessment, and of the mind to integrate and express the results in a single-valued judgement. It is therefore important for the mind and hand to work syncroniously together in order to express the feel of the material.

In judging the feel or handle of a material, use is made of such sensations as smoothness or roughness, softness or hardness, stretchiness or rigidity and stiffness or limpness (2). If a fabric possesses a high coefficient of friction as well as high frictional resistance the material may be regarded as rough, otherwise it is smooth. For a fabric that compresses easily and has a low modulus of compression is likely that the material may be described as soft (3). If a fabric stretches easily and recovers completely, the material is likely to be described as stretchy or resilient and such material would have a high elongation and low tensile modulus. Any fabric that bends easily and posseses a low modulus of flexion and high flexion is likely to be described as limp (3).

Kim and Vaughn (3), Elder et-al (21), Ukponmwan (4), Syed (6) and Ajayi (33) are the workers who found that fibre content, yarn and fabric construction, and finishing, treatment are the major factors that influence sensory and physical properties of fabrics.

Generally there are two approaches namely; objective measurement of mechanical properties likely to correspond to tactile measurements and the subjective assessment of quality features. Correlation of these with relevant mechanical properties.

1.3 Objective and subjective Assessments of Fabric Handle :

Many authors (18-22, 24, 25, 26-29) have sought to relate objective measurements and subjective assessment of fabric handle. What is obvious is the amount of interest.

In an earlier publication which is commonly regarded as the foundation, frictional, compressional and flexural properties of fabrics were considered (2). Tensile stiffness and changes in stiffness with increasing load were related to the impression of limpness, harshness and compliancy (23). The properties of smoothness, weight, thickness and changes in thickness (compression) were related to subjective assessment by multiple factor analysis, with some successful correlations (24,25).

Consideration of results obtained by a large number of researchers suggests that a measure of standardisation can be obtained by expressing the fabric mechanical property measurements in terms of sixteen parameters as shown in Table 1

Table 1 : The Sixteen Parameters Describing fabric Physical Properties

Properties	Code	Description
Tensile	LT	Linearity of load-extension curve
	WT	Tensile energy
	RT	Tensile resilience
Shear	G	Shear regidity
	2HG	Hysteresis of shear force at 0.5 degrees (shearangle)
	2HG5	Hysteresis of shear force at 5 degrees
Bending	B	Bending rigidity
	2HB	Hysteresis of bending moment
Lateral compression	LC	Linearity of compression-thickness curve
	WC	Compression energy
	RC	Compressional resilience
Surface characteristics	Mlu	Coefficient of friction
	MMD	Mean deviation of Mlu
	SMD	Geometrical roughness
Fabric Construction	W	Fabric weight per unit area
	To	Fabric thickness

Reference to Table 1 will show that in the case of tensile and compression properties, three parameters are quoted namely, the linearity of the load-deformation curve, the energy lost during a complete deformation-recovery cycle and the tensile or compression resilience. For shear and bending properties, the rigidity is quoted together with a single value for the hysteresis of bending moment. This is calculated as the mean value of the hysteresis width in the range of curvature 0.5 - 1.5 cm in the case of bending. A similar curvature had also been by Owen (17) in the studies of the bending properties of woven fabrics. Whereas in the case of shear there are two values of the hysteresis of shear force one at a very small shear angle of 0.5° and the second at a moderately large shear angle of 5°. Three parameters are used for the evaluation of fabric surface characteristics, two of which are related to the surface friction and a third related to the geometrical roughness of the surface. Two fabric constructional parameters are also included, viz, the fabric weight per unit area and the fabric thickness.

In an extensive study of objective measurements of wool, cotton and textured nylon fabrics (5), use was made of information theory involving the transformation of human stimuli for the establishment of a numerical scale of hand values and formula to relate physical properties (7). Stiffness and liveliness may be determined from bending hysteresis measurements (8,9). The same applies to the measurement of fabric smoothness, which in an evaluation of cotton calendering (10) was graded on a seven point scale (0.2 smooth - 0.8 not smooth) on the basis of fabric friction.

Kim and Vaughn (3) found that Kinetic friction coefficients were more closely associated with sensory hand qualities than static friction coefficients in woven fabrics. Despite the volume of work, problems remain due, partly to differences in experimental technique and materials, partly to the continued uncertainty about the degrees of correlation which should be expected. Stretching, bending, compression and shear resistance, deformation and recovery do not necessarily relate with each other. For example compresibility may not correlate with stretching recovery or bending recovery. A decrease in a coefficient of friction may relate with an increase in tensile recovery, but not with bending compression or torsional recovery. This may be because of the interplay of material, finish and constructional variable. Fabric rigidity is mainly a function of fabre flexural rigidity (16) and provided interfibre and interyarn frictional forces do not change, and assuming complete freedom of fibre movement, fabric flexural rigidity will be a function of fibre linear density (17). For rayon, Owen (17) found a linear increase in low-curvature elastic flexural rigidity, Go, with increase in fibre linear density. The coercive couple, Co, was independent of fibre linear density.

Dreby (18, 19) also reported three physical parameters namely; flexibility, compressibility and surface friction to be the most important factors contributing to the handle of soft finished fabrics. In order to obtain some overall effects of physical parameters on handle, rank of desirability of dress goods were compared with measured data. It was found that dress goods having "planoflex" value greater than 6.0, coefficient of friction greater than 0.48 and compression greater than 0.057mm had a good handle.

Howorth and Oliver (24) employed factor analysis to study the relationship among subjective assessment of smoothness, softness, coarseness, thickness, weight, flexural rigidity, bending modulus and cover factor, for twenty seven worsted type suiting fabrics. A three factor solution was obtained which represented the relationships between objective tests and subjective rankings. It was concluded that stiffness, smoothness and thickness gave a complete description of the handling qualities of worsted fabrics.

Similar investigations were pursued by Kobayashi (17-29) in which an examination was made of the relation between sensory and physical values. The range of fabrics included silk, wool, cotton, nylon and polyester. By the use of multiple factor analysis, good correlations were reported between subjective smoothness and compressional properties. He, also compared softness with the compression modulus, fluffiness with compressional properties and liveliness with crease resistance modulus with some good correlations.

In a more recent paper, Elder et al (22) have successfully correlated the results of subjective finger pressure and fabric softness. These authors also stated that the pressure applied on a fabric during a subjective assessment was light i.e 20 cm^2. It was also asserted that the degree of compression will vary just as the amount of pressure will vary. However, if two fabrics matched each other in these respects, then their handles will be similar.

A transmission of information caused by stimuli to human response (27,28) and the establishment of a numerical scale of fabric handle is useful.

Using a translation equation, Elder et al (22) have established a scale for the interconvertion between objective data such as drape coefficient and subjective ratings (stiffs).

A similar approach was suggested for fabric friction (64). The later approach was not so successful because of the multiplicity of factors that affect fabric friction (74).

The conflicting reports in the literature as to whether or not this quantity (coefficient of friction) described the stimuli of smoothness or roughness appeared to hinder progress. There are also some conflicting results in the literature as to what constitute stiffness. In engineering technology (75) stiffness is deemed to mean a material with low elongation and relatively light strength. The sense in which this is used in this work has been described in section 1.2. Harshness which appears to be widely used by many authors (76,33) have some multiplicity of meanings and are very difficult to perceive. It has been used to conote roughness (40), and stiffness (40) and also surface topograph (3).

1.3.1. Compression and softness:-

Hamburger (30) believed that the quality of "softness" and the ability to recover from large deflections are important time factors in elasticity and resilience. Compressional resilience which is the ability of fabrics to recover from compressional deformation either in use or during processing is an important parameter for evaluating blankets, wearing apparel where crushing, and warmth are factors. There is also a need for permanency of pile in carpets, and for bulk fibre utilization in mattresses, custions,and the likes. Schiefer (31) defined compressibility as the ratio of decrease in thickness with pressure at a pressure of one pascal, to the standard thickness; He also defined compressional resilience as the work recovered by the specimen when the pressure is decreased from 13.8×10^3 pa, expressed as a percentage of the work done on the specimen when the pressure is increased from 0.69×10^3 pa. The reason he suggested " Compressibility" as well as "Compressional resilience" is that, the former term denotes deformation while the later depicts percent energy recovered. Rees (32) defined compressibility as the percent reduction in volume of the fibre mass resulting from a specified increased in the applied pressure. Rees (32) compared various fibres in various states of aggregation and comments on resilience as:

"The results for cottons showed that, there is no significant difference in resilience between any of the cottons studied. The wool specimen had the highest resilience of all the fibres studied and the hollow viscose staple fibre the lowest. Nylon waste, silk and milk weed fibre had resilience values approaching that for the wool specimen. The kapok and the cellulose acetate staple fibre specimen had greater resilience than the cottons, but lower resilience than milkweed fibre". Rees (33) reported that wool exhibits the highest resilience as well as the highest softness (compressibility) of any fibre tested. Other fibres, viz. nylon waste, silk and milkweed, are almost as good in resilience but have much less compressibility. Addition of cotton or viscose rayon to wool depresses its compressibility values.

The problems of applying compression tests to finished fabrics are the difficulties of measuring small changes in deformations. There is also the attendant uncertainty about the significance of the compressibility and the load range in the materials. Elder et al. (21) have recently reported a sensitive method of measuring compression and compressibility of fabrics and this has been successfully correlated with the subjective impression of softness (21), While it is possible to measure changes in the thickness of some fabrics e.g double knitwear with a Shirely thickness tester, the use of an instrument such as the Instron would seem profitable because of the capabilities thatexist for expending the load and compression scales. This serves to improve the sensitivity and accuracy of measurement. Load capabilities improves from a few grams to kilogrammes, and deformation scale magnifications up to one thousand times permit the measurement of a wide variety of

fabrics and for more sensitive measurements to be made. The uncompressed thickness, the change in thickness on compression and decompression (recovery, resilience) can be determined for a range of pressure and times. Thickness (2) and softness (21) of a fabric depend on the pressure applied to it, and the relation between these quantities is a measure of the hardness of the material, since it is appreciated in handling the material. Kawabata (59) discussed the ability of groups of people to evaluate fabrics prepared in different ways. The subjects were asked to grade the various ranges of cloth, he cautioned them that by touch alone or softness of handle' great care has to be taken to avoid even a casual glance at the cloths. Blind-folding i.e. the use of pillory box was criticised by the same author as being unnatural and likely to disturb the normal judgement. Furthermore this does not correspond to the norma assessment by the people.

Kawabata (59) recorded subjective handle measurement by a team of experts in the United States in assessing 145 fabrics that the properties of softness and fullness for men's suits were found to be related in many fabrics that had a smoothness desirable for winter suiting. A similar positive relation between softness and smoothness was also found recently (33).

Winakor et al (60) found physical roughness to be associated with soft / hard, which was intended to described fabric compressional characteristics. This continum of soft/hard may describe fabric surface characteristics, in knitted fabrics, whereas in woven fabrics it seems to describe fabric stiffness.

However, this is not the sense in which it is used in this work.

1.3.2. Extension and stretchiness :---

The resistance to extension of a cloth is a property that affects the judgement of stretchiness. The extensibility is expressed by the initial Young's modulus. Initial Young's modulus is the part of the stress-strain curve at the initial linear portion starting at zero stress and strain, indicating a linear relationship between the stress and the strain. It gives a measure of the force required to produce a small extension. A high modulus indicates inextensibility and a low modulus great extensibility.

The conversion of load-elongation curve to a stress - strain curve enables more direct comparisons tobe made between different types of materials and structures. The stress-strain curves of fibre structures such as fabrics and yarns will reflect the characteristics of the fibre or fibres from which they have been made modified according to methods used in their construction, e.g. twist, weave, physical and chemical finish. Smith (35) showed (Table 2) that wool has a very low tenacity, followed bythe acetate, whereas cotton and viscose have relatively higher tenacity.

Table 2 : Tenacities of Textile Fibres (35)

Fibres	Tenacity (g/~~tex~~)	Tensile Strength (parcel x 10^6
Acetate	1.2 - 1.5	151.7 - 193.0
Acetate (High Impact)	1.3	
Cotton	2.0 - 5.0	303.3 - 751.4
Flax	2.4 - 7.0	344.7 - 1,034.1
Nylon (regular)	4.5	-
Nylon (strong)	4.0 - 6.3	379.2 - 703.2
Saponified Acetate	4.5 -6.3	668.7 - 937.6
Silk (Boiled off)	2.2 - 4.6	289.5 - 606.7
Silk (Tussah)	3.8	-
Viscose	1.8 - 4.5	268.9 - 668.7
Viscose - G	4.5	-
Viscose HT	3.0	-
Viscose MT	2.4	-
Wool	1.1 - 1.5	144.8 - 193.0

It is likely that the handle of this material will equally vary. Sherman and Sherman (36) ranked the strength of fabrics on the basis of decreasing tenacity as follows: nylon, saponified acetate, ramie, and glass. It is noteworthy that the two fibres at the top of the league are synthetics rather than natural. Wool is far down on the list for tenacity, but has many other desirable properties which accounts for its widespread use.

Some of the breaking elongation data quoted by Sherman and Sherman (36) and Newell (37) are shown in Table 3. This shows that wool extends most before breakage than all other fibres studied, followed by acetate, silk, nylon, viscose, Fortisan and lastly cotton. The area under the load-extension diagram is the product of force and distance, this will represent the work done during the deformation of the material. Meredith (38) listed work of rupture, or energy absorption, or toughness of the various fibres as shown in Table 4.

Table 3: Percent elongation to repture

Fibres	From Sherman (36)		From Newell (37)	
	Dry (%)	Wet(%)	Dry (%)	Wet (%)
Acetate	23-30	30-38	23-30	30-40
Acrilan	-	-	16	16
Cotton	3-7	-	3.7	-
Cuprammonium	-		10.17	17-33
Dacron	-		20-30	20-30
Nylon (regular tenacity)	12.20	13.26	-	-
Orlon (type 81)	-		15-17	15.17
Dynel	-		1	3 1
Fortisan	6-6.5 -	6-6.5	6-6.5	.
Silk	13.20 -	-	-	-
Viscose(regular tenacity)	-		15-30	20-25
Viscose(medium tenacity)	9.20	14.35	12.20	17-30
Viscose(High tenacity)	-		9-17	17 - 20
Wool	30-50	30-60	25-35	25-50

Table 4 : Work of rupture of fibres (38)

Fibres	Work x 10 -3 (J)	Work factor *
Cotton	0.99	0.47
Flax	0.81	0.50
Hemp	0.63	0.49
Jute	0.27	0.50
ramie	1.08	0.17
Viscose	2.34	0.62
Stretched Viscose	1.53	0.51
Acetate	2.25	0.70
Silk	7.38	0.63
Nylon	7.74	0.61
Wool	3.24	0.68
Casein	2.34	0.86

* The "Work factor" is defined as the ratio of the measured work of rupture to the product of load at break and extention at break.

Glass, flax, the "hard" fibres and "Fortisan", inspite of their high strengths, have low damping energy because of their low extensibilities, i.e., they are brittle. Undrawn nylon, high-impact acetate, and the old" Vinyon" E, inspite of their low strengths, have high damping energy because of their very high extensibilities. However, most of this extensibilities is non-recoverable, and is not continuously available in repeated stressing. Fabrics made from such filaments have poor dimensional stability.

Nylon has outstanding high energy-absorption capacity because of its high tenacity and high extensibility. It maintains such properties in cyclic loading.

In the case of wool, its nominally high energy absorption is attributable to its high extension and not because of its high strength. Wool's ability to deform under low loads, and return to its original dimension upon load removal are some of the reasons for its excellent wear resistance.

The resistance to extension of a cloth is property that affects the personal judgement of handle (2). When one is asked to judge the stretchiness of some fabrics, one pull its ends along its axis and the one that extends more will then be most extensible, though this property depends on the applied force which is bond to differ subjectively having no basis for its measurement. Subjective assessment of stretchiness also depends on the dimension of the sample, the shorter the fabric the less extensible it may feel. Subjective assessment of stretchiness however, may not necessarily justify its strength. Personal experience has also shown that natural cellulosics do not stretch easily and also have little recovery. Wool and other man-made fibres that stretch easily, also recover easily and completely and this give the characteristic springness in the handle of these materials.

1.3.3. Flexion and stiffness:-

Peirce (2) in his paper "The handle of cloth as a measurable quantity", concluded that fabric stiffness was a key factor in the study of handle and drape. He also pointed out that the bending modulus may be used to compare stiffness of the material in fabrics of different thicknesses.

Flexural rigidity (39) is a measure of the resistance offered by the specimen to bending. This differs from drape in that the weight of the materials influences a deformation at some angle to the line of action. Drape on the otherhand is the ability of a fabric to assume a graceful appearance in use.

The way in which a fabric drapes or hangs depends largely on its stiffness, i.e its resistance to bending, and on its weight. The bending length is the cube root of the ratio, resistance to bending divided by the weight or unit area, it therefore follows that while the bending length is the measure of stiffness that determines the draping qualities of the fabric, the flexural rigidity # is a measure of the stiffness as appreciated by the fingers. The flexural rigidity measures the actual forces produced in bending the material; thus two fabrics may bend to the same extent under their own weight, but the heavier of the two will exert more resistance to bending say, by the fingers, and so feels stiffer.

The bending and twisting of fibres influence the behaviour of bulked-yarn filaments, drape and handle of fabrics; recovery from bending is a factor in creasing (40). Flexibility of a fibre depends on its shape, its tensile modulus, its density and , most of all, its thickness. All these factors are inter-related and further complicate the subject. Smith (35) demonstrated that the stiffness of an ideal cylindrical rod is proportional to the linear density. Since the linear density in return, is proportional to the diameter, it is evident that stiffness increases as the fourth power of the filament diameter. Finlayson (41) demonstrated that the flexibility of filament is directly proportional to its flatness, as measured by the ratio of major to minor axis of the elliptical cross-section, and is inversely propotional to its modulus of elasticity and the fourth power of its width or diameter.

He also found that to obtain a required level of drape and handle, much finer filament deniers have had to be used in viscose than in cellulose acetate, also to attain the flexibility of silk, Fortisan must have a denier of 0.63 and glass 0.44.

It was also discussed that (35) silk is several times stiffer than wool, and that cotton is several times stiffer than silk, while glass, at the top of the stiffness scale is some seventy-five times stiffer than wool. Acetate is about as pliable as wool, viscose is comparable to silk. Some of the strongest fibres (glass, flax, ramie) are very stiff, but very low on the toughness scale. This combination spells brittleness. The combination of low toughness and low strength means excessive softness and makes a poor fibre. Some fibres, such as wool and acetate rayon, are approximately - equal in strength but differ in toughness. The personalities of the four material fibres are: "Wool: very pliant, weak, but tough. Silk: pliant, moderately strong, very tough. Cotton: Moderately stiff, Moderately strong, moderately tough. Flax: very stiff, very strong, but very brittle".

The fibres can therefore be arranged in order of decreasing stiffness as: Glass, flax, cotton, silk/viscose and wool/Acetate.

Flexural rigidity was an approximation function of diameter (11,13), it alone explaining 93% of the variation in the bending length, 90% of the variation in the flexural rigidity and 80% of variation in drape of the twill fabrics. It also explained 60% of the variation in drape and 50% of the variation in bending length in the case of the Punto-di-Roma fabric. For the twill fabrics, an increase in staple crimp or resistance to compression increased flexural rigidity and drape marginally.

There was also a marginal effect of coefficient of variation of fabric diameter, both bending length and drape increasing slightly with an increased in coefficient of variation of diameter. For the knitted fabrics, bending length also increased slightly with increases in the coefficient of variations of fabric diameter and length.

Elder (42) reported on the effect of temperature and humidity on the bending modulus of some synthetic-fibre monofilaments. For example, at 65% r.h; the bending modulus of nylon 6 falls from 3 KN/mm^2 at 15°c to 1.3 KN/mm^2 at 40 °c but then changes less, whereas Terylene polyester fibre is close to 13 KN/mm^2 between 20 and 40°c but falls to 10.3 KN/mm^2 at 80%c. A change in relative humidity of from 30 to 85% at 20°c causes the bending modulus of nylon to fall from 5.5 to 1.5 KN/mm^2.

Peirce (2) also commented that other things being equal, the flexural rigidity varies with the third power of the thickness, but if any cloth is calendered or otherwise compressed, the relation is reversed owing to the rise in specific stiffness. The presence of lubrieating or cementing matter such as wax and starch on the hairs has evidently a big effect (2). Thus the removal of wax in bleaching increases the stiffness. The absence of wax is also responsible for the excessive harshness caused by mercerising after a scour. Starch, used as filling, has a great stiffness effect, more by cementing the hairs than by virtue of its own rigidity. Dyeing seems to have the opposite effect, the diminution of stiffness being particularly noticeable in the Schreinered satins; heavy printing has an appreciable stiffening effect.

Meredith (43) reported some flexural properties of some fibres as in Table 5. The relative flexibility of the fabrics have been discussed. Also Finlayon (41) gave some typical values of flexural rigidity of some fibres as shown in Table 6.

The flexural rigidity is a measure of the stiffness as appreciated by the fingers.. (77). This is the pair of forces acting in opposite directions that would be appreciated as a pressure on the skin if such a bent strip were held between the finger and thumb (2). The flexural rigidity measures the actual forces produced in bending the material; thus two fabrics may bend to the same extent under their own weight, but the heavier of the two will exert more resistance to bending., say, by the fingers and so feel stiffer.

Hamburger et al (61) used ten fabrics, and seven judges for subjective evaluation. The subjects were requested to :- rank the fabrics in order of increasing stiffness by visual and tactile examination, and (2) rank the fabrics in decreasing order of gracefulness of folds or pleats (drape.), by visual observation of hanging samples.

It was found that for both stiffness and gracefulness most people are able to correctly rank a series of fabrics. It was noted that peoples' ability to rank stiffness (tactile and visual) was better than their ability to rank gracefulness (visual; draped).

Table 5: Flexural properties of fibres, 65% r.h, 2°c (43).

Fibres	Specific flexural rigidity ($mmN/mm^2/tex^2$)	Modulus (KN/mm^2)	
		bending	tension
Cotton	0.53	-	7.3
Viscose rayon : Fibro	0.35	10	8.7
Vincel	0.69	20	-
Secondary acetate	0.25	-	4.2
Triacetate	0.25	-	3.8
Wool	0.24	3.9	5.2
Silk	0.60	-	14
Casein: Fibrolane	0.18	-	2.3
Nylon 6.6. (3 types)	0.15- 0.22	2.5-3.6	1.9 - 3.8
Polyester fibre; Terylene	0.30	7.7	6.2
Acrylic fibre (3 types)	0.33 - 0.48	6.0 - 8.1	4.9 - 7.0
Polypropylene	0.51	5.2	2.4

Table 6: Flexural rigidity (41).

Fibre	Shape Factor (η)	Specific Flexural rigidity Rf ($mNmm^2/tex^2$)
Viscose	0.74	0.19
Fotisan	0.83	0.44
Acetate	0.67	0.08
Wool	0.80	0.20
Silk	0.59	0.19
Nylon	0.91	0.14
Glass	1.0	0.89

1.3.4. Friction and Smoothness :-

The friction of a fabric on itself or on another fabric has a significant effect on fabric performance and comfort (44). Interfibre friction determines the behaviour of drafting assemblies, the strength of yarns, the wear of guides in textile machinery, the tensions developed in fibre and yarn handling equipment, the possibility of felting and shrinkage, and even the feel or handle of the finished fabric (45).

Fuller and Johnson (46) defined friction as the resistance to motion developed when one body slides, or tends to slide, over the surface of another. This force always acts in opposite direction to that of motion. It depends on the nature and condition of the surface in contact. Static friction is that which opposes a tendency to move due to the force acting on a body at rest, and its limiting value occurs when the body is at the point of transition from rest to motion. Kinetic friction is that which continually opposes the motion. When a fabric is dragged on itself, the motion involved is almost a reciprocating motion In analysing the results obtained , Dreby(47)found that when a fabric was repeatedly dragged on another fabric in the same direction, a reduction in the frictional force occur This could be as a results of polishing, flattening and directional alignment of surface fuzz. Backer (48) propounded three mechanisms of friction - namely the surface roughness, the adhession and the plowing hypothesis.

The first suggests that surface roughness and the mechanical interlocking of surface protuberances are considered to cause frictional resistance. The second mechan ism proposes that when two bodies are rubbed together, the atoms of the protuberances of upper and lower surface are removed into each other's electrostatic field of attraction and this form minute welds or adhessions. Continued movement of the surfaces requires additional force to rupture these adhesions. The third mechanism involves the ploughing of a soft surface by a hard one. Backer (48) suggested that all the three mechanisms probably contributed to the total force of friction.

Although fibres do not have a true, constant coefficient (μ) of friction, because this value of μ varies with many experimental conditions (load, speed, area and geometry of contact, humidity etc). It is so dependent on the exact state of the surface that only typical values found in particular experiment can be quoted. Some examples are given in Table 7. They cannot be expected to have validity.

Table 7 : Typical values of μ in all circumstances.

(a) Between fibres

Fibres	Crossed fibres(49)	Parallel fibres (50)
Nylon	0.14 - 0.6	0.47
Silk	0.26	0.52
Viscose rayon	0.19	0.43
Acetate	0.29	0.56
Cotton	0.29, 0.57	0.22
Glass	0.13	-
Jute	-	0.46
Casein	-	0.46
Saran	-	0 .55
Terylene Polyester fibre	-	0.58
Wool, with scales	0.20 - 0.25	0. 11
Wool, against scale	0.38 - 0.49	0.14

In general, values of μ for fibres and plastics range between 0.1 and 0.8, although, under extremely clean conditions, much higher values of fibre friction are found. Another exception is polytetrafluroethylene which has an extremely low coefficient of friction, often less than 0.05.

(b) For yarns passing over guides (51)

Fibres	Hard Steel	Porcelain	Fibre Pulley	Ceramic
Viscose rayon	0.39	0.43	0.36	0.30
Acetate, bright	0.38	0.38	0.19	0.20
Acetate, dull	0.30	0.29	0.20	0.22
Grey Cotton	0.29	0.32	0.23	0.24
Nylon	0.32	0.43	0.20	0.19
Linen	0.27	0.29	0.19	-

The value of kinetic friction is usually less than the static friction. Some typical examples are given in Table 8. The difference affects the feel of the materials. If this difference is large.

TABLE 8 : STATIC AND KINETIC FRICTION (50)

	Static (μs)	Kinetic (μk)
Rayon on rayon	0.35	0.26
Nylon on nylon	0.47	0.40
Wool on wool: with scale	0.13	0.11
Against scales	0.61	0.38
fibres in the same direction	0.21	0.15
Wool on rayon: with scales	0.11	0.09
against scales	0.39	0.35
Wool on nylon: with scales	0.26	0.21
against scale	0.43	0.35

The material is'scroopy', that is, it will have a coarse, crunchy feel and will give a fabric that rustles like silk, owing to the marked 'stick-slip' motion. This tendency will be reduced by any finish or lubricant that reduces the differences between μ_s and μ_k. Ajayi (33) had recently proved that this phanomenon is experimentally valid.

Market (52) found that the coefficient of friction of single cotton fibres against cotton-covered cylinders increased steadily with speed. Under a certain load, the coefficient of friction was 0.23 at 3.6 cm/min, but it increased to 0.25 at 200 cm/min and to 0.39 at 4500 cm/min. One consequences of this is that the slippage of cotton, in the deformation of needled fabrics, occurs more smoothly without the stick-slip effect characteristics of other fibres Roder (79) noted a further drop in the friction, at much higher speeds other workers have found that the friction increased as the speed increase . The variation of friction with speed will have a considerable influence on the behaviour of fibres in drafting. Cotton is exceptional in that even at low speeds the coefficient of friction increases with the speed of sliding.

The frictional force is changed if the surface is lubricated either naturally, for example, by waxes in cotton, or artificially or has been contaminated by dirt or impurities. For acetate yarn (54) with more than 1% of oil applied, the frictional force increases both as the oil content is increased and as the viscosity of the oil increases. However, fibres from which all traces of lubricant have been removed show high values of friction; thus, in one experiment (55), raw cotton on steel gave $\mu=0.25$, μ=coefficeint of friction whereas scoured cotton on steel gave $\mu=6.7$, and

lubricated scoured cotton on steel gave values of μ ranging from 0.14 to 0.35.

Bradbury and Reicher (56) have found that extremely high values of friction are obtained between flat continuous filament yarns and glass if excessive precautions are taken to ensure the cleanliness of both surfaces. A similar effect was observed by King (57) who found a reduction in the friction of wool fibres on various materials when the surface was roughened. The frictional force usually increases as the regain of the fibres is raised (57). Nalgaard (58) observed that the coefficient of friction decreased with increased pressure for fabric over fabric, but the result was not related to the tactile sensation of smoothness or roughness.

The tactile impressions obtained by stroking the fabric surface with fingers or by rubbing it between the fore-fingers and thumb is referred to as smoothness or roughness. Subjective judgment of fabric smoothness is influenced by sensations caused when minute identations are felt as the skin is pressed (62) .

Morrow (63) found that whilst such descriptions as smooth, harsh, etc, may be applied as a result of handling a fabric, observers were very uncertain and divergent in judgement based on softly stroking a fabric laid flat on a table, that is, when nothing but sliding friction could be appreciated.

Hoffman and Bestle (23) selected a series of five twill fabrics and ten observers were asked to rate them from low to high in smoothness, assigning the numbers 1 to 5, respectively. These subjective ratings agreed fairly well with the static coefficients of friction as shown in Table 9.

Table 9 : Coefficients of friction (Fabric Vs leather (23)

Materials	Subjective rating of smoothness	Static coefficient of friction (μs)
Nylon 6.6	2.1 ± 0.8 (4)	0.62 ± 0.03 (1)
Viscose Rayon	1.8 ± 0.7 (5)	0.60 (2)
Experimental fibre	3.7 ± 0.4 (2)	0.46 (4)
Polyeshylene	5 0 ± 0 (1)	0.35 (5)
Acetate rayon	2.2 ± 1.0 (3)	0.59 (3)

(Value is parenthesis refer to rank order)

In another experiments (23), two pieces were cut from a tropical worsted and a nap was raised on one piece by means of a hand card. Everyone who examined these fabrics described the piece with the nap as being softer than the other. The coefficient of friction were measured under a 10 - gram load (0.95 g/cm^2) with the result that the napped piece gave a higher value than the other (0.67 and 0.63 respectively). Finally, a value of coefficient of friction of 1.31 was obtained on a piece of velvet under the 10 - gram load. Most people would describe the surface feel of velvet as being very soft or smooth.

1.4. Influence of Fibre content and Fabric structure on Handle:-

Fibre content and fabric construction are among the important variables that affect handle. Although the end-use requirements may demand that certain fibre content be used, the resultant handle of different materials is still of importance. For example, the softness of a blanket is a requisite for good hand-in a blanket, the stiffness of an organdie is a requisite for good hand-in this fabrics.

A fibre property which is an assest in one instance can be a liabiii_y in another. For example, the scaliness of wool is an assest in promoting inter-fibre cohesion and strength, but quite undersirable as this is the primary cause of felting shrinkage (78) and so many directional frictional effect (78). Subjective factors are involved, but that in order to compare the relative ability of fibres to produce specific fabrics the catologing of fabric properties would be required, after which notations could be made as to the ability of the various fibres to meet the necessary demands.

Peice (2) stated that handle encompasses stiffness, hardness, and smoothness (and their antonyms) Some consideration may be made of the ability of the various fibres to produce requisite hands for specific usages.

The low tensional and bending modulus, high elastic recovery, and exceilent compressional resilience properties of wool and accounts for the soft, lofty, flexural characteristics of such woolen goods as Sweater, blankets and flannels. Nylon and Dacron fit the same category except that these fibres according to Cassie (65) are most prone to pack down to give "lean, cold yarns." Various types of wool will, of course, have different bending moduli depending upon fibre diameter and denier. The fact that synthetic filaments can be made in a range of diameters give the synthetic filament-maker opportunity to produce, within limits, desirable bending modulus. This, coupled with proper yarn and fabric engineering, enables the attainment of a range of fabric flexibilities.

Similarly, it is illogical to attempt to rank the frictional characteristics of fibres as they might influence hand. The wool fibres, as pointed out by Gralen and Olofson (66), is a smooth fibre, but so many fabric geometry effects can become of greater importance and significance that friction coefficient, as it affects fabric property, may become of secondary consideration. Subjective evaluation also deminish its importance because people cannot, or at least are not willing to seperate it from, flexibility, compressional resilience, warmish etc.

Another correlation borne out by Schiefer's work (67), 68) showed that viscose, acetate, and cotton lower the compressional resilience of wool; that viscose is less compresible than wool, and acetate is better than wool.

Effects of fibre content and fabric construction on responses to sensory hand qualities were examined using a paired "t" test (69). The differences between means of paired samples were compared (69). Use was made of the cells as in Table 10 except that two cells in the design were missing: Modacrylic terry loop-pile knit and cordelan brushed knit.

Table 10 : Description of test fabrics and design of experience to test the effects of fibre content and fabric construction type on sensory hand qualities. (80).

Fibre Construction type	Fibre Content		
	Polyester	Modacrylic	Cordelan
Plain yersey Knit	Fabric A	Fabric C	Fabric E
Terry Loop-pile Knit	fabric A	-	fabre F
Brush Knit	fabric Ga	Fabric Db	-

a Tricot warp Knit

b Jersey Knit of 65/35 % modacrylic/Polyester.

All others are weft-Knit fabrics of spun-yarn.

There were 38 female judges all of which were University Students enrolled in an intermediate textile course. Six different comparisons of means were tested; results are shown in Table 11.

Table 11: Results of paired t tests for differences in means for the nine polar pairs (60)

Polar adjective Pairs	Paired Comparison					
	(A + G) VS (C + D	(A + C) VS (D+G)	Interaction between columns 1 & 2	(A+E) VS (E+F)	(A+E) + (B+F)	Interation between columns 4 & 5
Compact/loose	0.76	3.73[a]	0.63	2.51[b]	1.25	1.41
Rough/Smooth	1.44	3.03[a]	0.10	2.79[a]	10.13[a]	0.28
Soft/hard	0.27	0.76	2.70[b]	4.05[a]	4.16[a]	0.98
Flimsy / firm	2.75[a]	13.15[a]	0.10	3.43[a]	6.92[a]	0.37
Bulky/not bulky	2.05[b]	15.23[a]	4.75[a]	2.64[b]	689 [a]	0.40
Flat/Textured	0.95	10.31[a]	5.83[a]	1.28	9.67[a]	0.74
Thick/Thin	4.02 [a]	17.71[a]	5.08[a]	0.97[a]	11.15[a]	1.43
Harsh / gentle	0.27	3.83[a]	3.80[a]	2.91[a]	6.55[a]	2.39[b]
Wafm /Cool	2.00	7.42[a]	2.96[a]	0.84	1.71	0.94

a 0.01 level of significance; df = 37

b 0.05 level of significance; df = 37

Fabric code (see Table 10)

The responses of polyester and modacrylic to thick/thin, flymsy/ firm and bulky/not bulky differed significantly in the two fibre content for plain Jersey and brushed Knit construction (A + G versus C+D). In the three adjective pairs, modacrylic fabrics were judged thicker, firmer and bulkier than the polyester fabrics. This would be expected from the differences in fibre properties : Modacrylic is a weaker fibre and thus more fibres are used in thick firm and bulky yarn and fabric construction.

The t values (Table 11) for polyester and cordelan fibres in plain Jerssey Knit and tery loop-pile Knit (A+B versus E + F) were generally higher than those for polyester versus modacfylic (A+G versus C+D), indicating that judges could discern differences in hand between the polyester and cordelan fabrics more clearly than between the polyester and modacrylic fabrics. Responses to soft/hard, flimsy/firm, hard/gentle, rough/smooth, bulky/not bulky, and compact/loose differed significantly between the polyester and cordelan fibre contents.

Sensory responses to the nine polar adjective pairs for the two fabric construction types differred significantly except for soft/hard (Table 11). This demonstrated that judges could clearly discern differences in hand by fabric construction types; however, judges did not discern significant differences in hand with respect to soft/hard characteristics for the two Knit fabrics.

In the case of plain jersey knit versus loop-pile knit, sensory responses to all polar adjectives pairs except compact/loose and warm/cool differed significantly for the two fabric construction types (A+E versus B+E). The t values (Table 11) for plain yersey versus tery loop-pile Knits

(A+E versus B+F were generally much higher than those for polyester versus cordelan fibres (A+B versus E+F). This shows that, judges were more influenced by fabric construction than by fabric content in assessing sensary hand qualities of these sleepwear fabrics.

The interactions between polyester and modacryiic fibres, and plain jersey and brushed Knit constructions were significant ($P<0.01$) : modacrylic brush Knit (D) is more textured, thicker, gentler, and warmer than polyester brushed Knit (G), whereas modacrylic plain jersey (C) is flatter, thinner, less gentle, and less warm than polyester jersey (A). However, the interactions between polyester and cordelan fibres and plain jersey and terry pile Knit constructions were not significant at $P<0.01$ level.

1.5 Influence of Finishing treatments on Handle:-

Finishing treatments are applied to textile substrates for several reasons. This may be to improve some quality features such as handle, i.e., Smoothness, softness, stiffness and stretchnines, or to enhance performance features such as crease resistance, demensional stability and strength (70).

Cotton fibres, yarn, and fabrics subjected to chemical treatments may involve different phases of finishing, and may affect either the internal structure of the fibre, the surface of the fibre, or both (71). Purification is one process that substantially involves the surface and deserves some attention.

In the preparation of cotton for textile finishing, the purification process generally includes scouring, i.e boiling in an alkali, followed by an oxidation bleaching (71). Relaxation of stresses imposed on fibres, yarns and fabrics may also occur during scouring and other wet treatments. This along with mechanical agitation may cause structural consolidation i/e shrinkage, which might in turn be expected to cause changes in the frictative resistance to motion (70). This hypothesis would be tested in this investigation.

Another commercial use of internal and surface modification to enhance fabric handle is the mercerization process. Mercerisation also increase dyeability and luster of cotton materials. It consists of immersion of the fabric in 18 to 25% Sodium hydroxide at ambient conditions. The cellulose is so modified that the absorption properties are greatly improved.

Chemical modification of the internal structure (i.e, crease recovery through chemical linking of cellulose chains) would appear to be of minor importance to surface modification, unless the addition of new groups in the inner region of the fibres cause physical enlargenment of the cross section of the fibre. Such additions of groups would cause changes in the folds (ridge-and-groove system) on the fibre surface. Damage to the primary wall may even result, as is evident with certain formaldehyde treatments (71). On the other-hand, acetylation, partial cyanoethylation, and partial carboxymethylation result in a smoother surface than does either scouring or mercerization of fabrics. In the first three processes the frequency and height of the ridge system is reduced. Wrinkle-resistence treatments with polymerization chemicals such as urea-formaldehyde and methylol melamine cause surface modifications also.

Objective evaluation of Apparel fabrics (72,73), the initial implementation stages of fabric objective evaluation through the measurement of basic fabric mechanical properties were reviewed. Two bending hysteresis curves were studied, one for an unfinished wool worsted suiting material and the other for the same fabric in the finished state. The curves showed that the remarkable effect of finishing on fabric mechanical properties can be expressed quantitatively by carrying out, for example, a bending deformation recovery cycle and by measuring the fabric bending rigidity and more importantly, the bending hysteresis or energy loss. These parameters are greatly reduced by finishing and therefore may be used directly for production and quality control purposes.

1.6 Conclusion :

From the details perused from literature, it is evident that a sizeable amount of work had been carried out in the area of fabric stifness (2,11,13,35,39,43,61,77), compression (2,21,30,33,59 - 60) and extention (35 - 38). The one on extention is not usually related to fabric handle. Also, studies on fabric smoothness have been exclusively restricted to coefficient of friction. In view of the fact that polymeric materials such as textile assemblies do not obey the classical laws on which such coefficient are based and the fact that fabric surfaces are so diverse, other frictional parameters are needed to describe the surface feel of fabrics. This is one of the objectives of this work.

1.7. Scope of Investigation :-

The present work entails the correlation of mechanical and subjective properties of fabrics handle . Flexion was measured variously by drape meter, bending length tester and correlated with stiffness assessed subjectively. Similarly, extention of fabrics was measured and evaluated as secant modulus. The latter parameter is the initial — resistance of fabric to stretching deformation. This was then correlated with subjective assessment of stretchness. Friction was measured and expressed as frictional resistance, amplitude of the stick-slip trace, number of peaks, pitch in addition to the conventional coefficient of friction. These parameters were correlated with subjectively assessed smoothness. The influence of systematically varied parameters such as speed, load was also examined.

CHAPTER 2

Materials and Methods

2.1 Materials :-

Three groups of materials were employed in this investigation. The first consisted of plain weave fabrics of different fibre contents, details of these may be found in Table 12. The second group consists of five weft pile fabrics (corduroys). The weight range between 220-369.9 g/m^2, the thickness range between 0.0158-0.0264 mm, Cord width was in the range of 0.1-0.6 cm, number of cords per 5.5cm range between 8.25-35, yarn count 26-60 tex, yarn crimp 1.2 -24.5 per cent and ⟷ pick spacing (sett) 12-36 threads per centimeter. Further details may be found in Table 13.

The third group consisted of plain weave cotton fabrics, of which some were scoured with domestic detergent, ranging from one to ten washes, whereas others were mercerized with caustic soda at concentration strength of the range of 10-25%. Details of these fabrics may be found under cotton in Table 12.

Table 12 : Details of plain weave fabrics.

Fibre Contents / Parameters		Cotton (c) *	Viscose rayon (V)	Triacetate (T)	Wool (W)
Yarn count (tex)	P	38.5	21.5	63	-
	T	41	29.5	63	-
Sett(Tread/cm)	P	21	31	20	-
	T	18	24	15	-
Crimp (%)	P	7.3	10	10.2	-
	T	23.6	14.6	15.1	-
** Thickness(mm) x 0.01		0.5455	0.5330	0.5495	1.5394
Weight (g/m^2)		162.3	136.2	209.0	298.2

* fabric code shown in parenthesis

P Warp

T Weft

** Baty gauge pressure of 20.0/g/cm ^{2}

Table 13 : Details of weft pile fabrics.

Fabrics Code / Parameters		A	B	C	D	E
Yarn count (tex)	P	31	40	26	51.5	33.5
	T	60	56	36	58.9	60
Sett(Thread/cm)	P	30	24	36	13	28
	T	16	20	30	12	15
Crimp (%)	P	9.8	18.3	3.5	6.3	7.1
	T	16.3	1.2	24.5	13.1	16
Thickness(mm)x 0,01	**	1.58	2.64	1.68	1.76	1.60
Weight (g/m^2)		339.5	369.9	220.0	294.4	369.2
Cord width (cm)		0.6	0.3	0.1	0.4	0.35
Number Cords/5.5 cm		8.25	17.5	35	12	13.5
fibre Content:	Base	Polypropylene	Cotton	Acrylic	Cotton	Cotton
	pile	Secondary acetate	Polypro- pylene	Orlon (Acrylic)	Polypropy- lene	Cotton

* Pile gummed with latex

** Baty gauge pressure of 20.0 g/cm^2

P - Warp

T - Weft

2.2 Experimentals :_

2.2.1 Tensile Testing:_

Instron model 1026 was used. Its operation guide is as shown in Fig. 1. Five samples of gauge length 5 cm and width 1 cm were cut from the plain woven fabrics of Table 12 and also the scoured and the mercerized samples. The edges of the fabrics samples were frayed before test. The settings on the instron was as follows, unless otherwise stated:

Crosshead Speed = 50 mm/min.

Chart; Crosshead Speed = 4:1

Full scale deflection = 20 kg

A sample was then clamped between the upper and lower jaws, and the instrument was actuated, the material was extended to breakage before stopping the instron. A record chart plotting the load-elongation behaviour of the material was obtained. in the autographic unit. Five samples were tested and the mean of these reported.

2.2.2 Friction:-

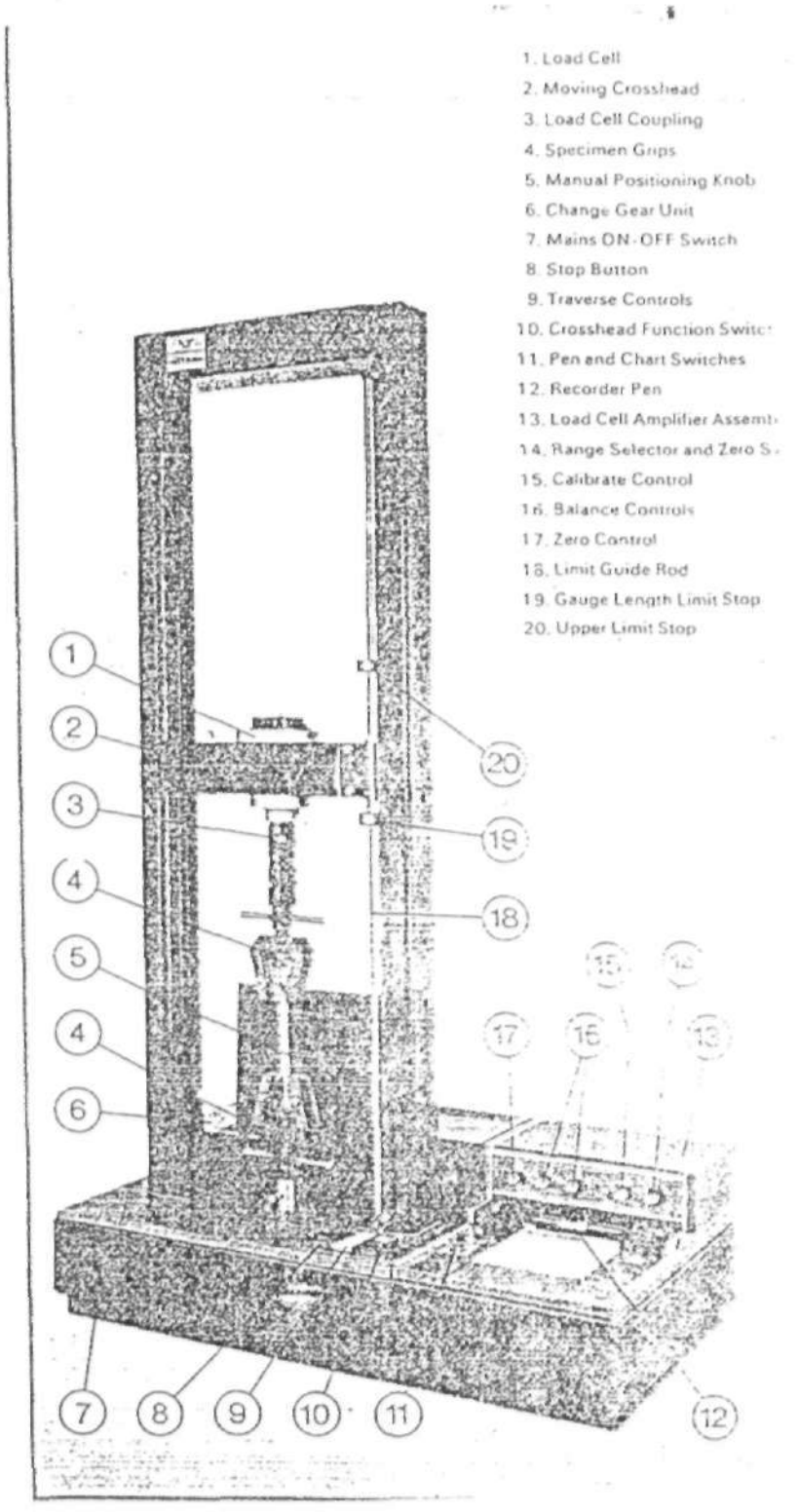


Fig. 1

Instron model 1026

Instron tensile tester model 1026 (fig 1) was suitably adapted for friction measurement as shown in figure 2a and the sketch diagram in figure 2b. The assembly consisted of a flat wooden plate wrapped with the cloth undertest held with a clamp. This was placed in contact with the Instrons lower jaw. A pulley enables the sled to be freely driven over the test surface

The sledwas made of a peice of wooden material suitably loaded and having a string-cord fixed to one of its sides. The string was led over the pulley guide and clamped to the upper jaw. The instron settings was as follows, unless otherwise stated:

Length of Traverse	=	5.5 cm
Cross-head Speed	=	50 mm/min
Chart : Cross-head Speed	=	4:1
Weight of Sledge	=	233.68 g (15.57 g/m) *
Full scale deflection	=	500 g

All the corduroys and the finished fabrics were tested, one after the other.

* give the pressure of the sled.



Fig. 2_a

Modified Instron

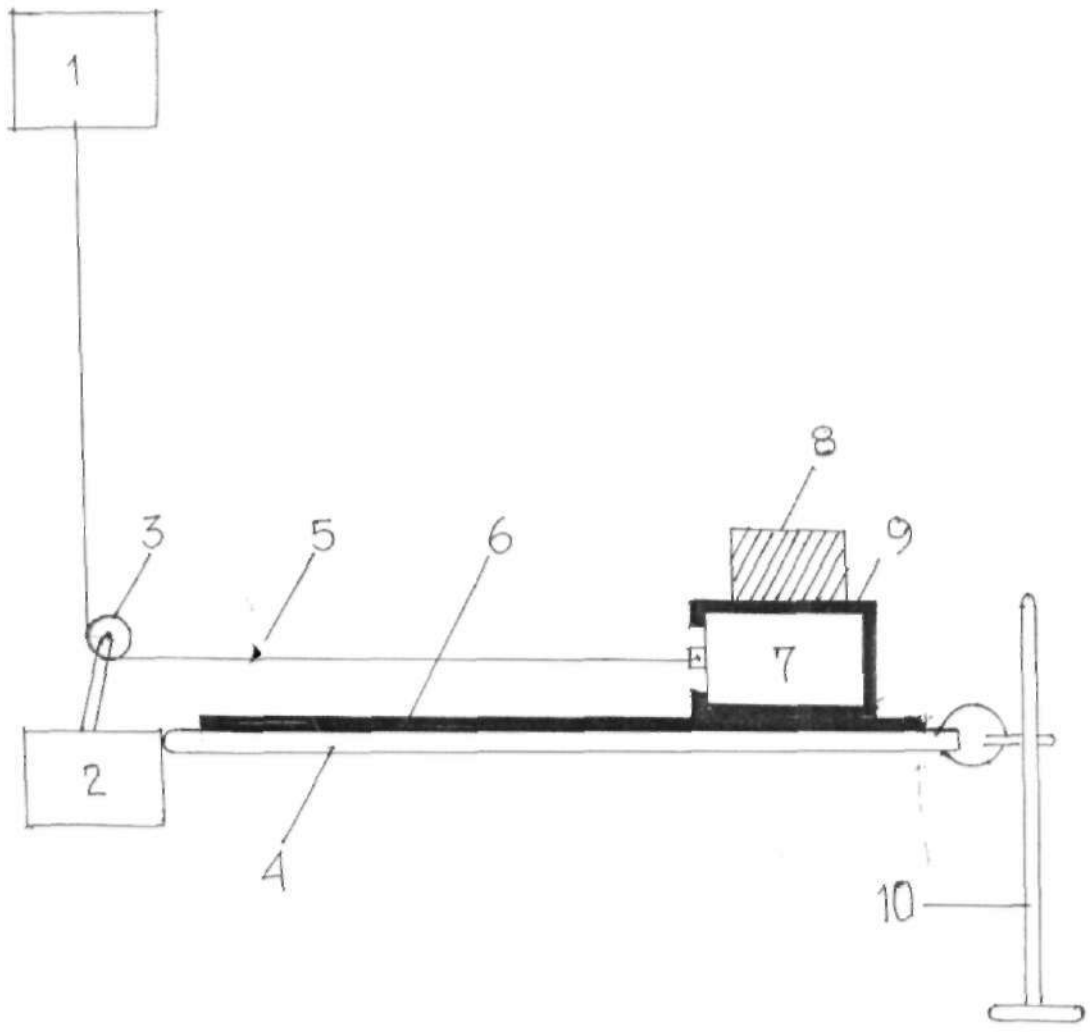


Fig. 2_b: Sketch diagram of the modified Instron Trester.

1, 2 - Upper and lower jaws of the Instron

3 - Pulley

4 - Flat wooden plate

5 - string filament

6 - lower fabric

7 - sled

8 - suitable load

9, - fabric sample

10. - Clamp

2.2.3 Flexion :-

2.2.3.1 Drape Coefficient:-

The instrument used was a Cusic drape meter. The essential features of this drape tester are shown in fig. 3. This consists of the following parts:

i) Two horizontal dises of diameter 18 cm between which the two specimen is held, the lower disc having a central locating pin.

ii) A point source of light positioned centrally beneath the dises and at the focus of a concave parabolic mirror which reflects parallel light vertically upwards and so casts-off a shadow of the drape annular ring of fabrics unto a similar ring of paper placed centrally above the dises as the lid of the instrument.

iii) A central plate on the lid to locate the paper ring,

iv) Circular Templates: A - 24 cm, B - 32 cm, c - 38 cm.

v) Annular rings of transluscent paper - 18 c.m diameter,

vi) Balance or weighing machine

Atmosphere for conditioning and testing:

Relative humindity	65 ° 2%
Temperature	27 ° 2° c.

With the help of 32 cm diameter template, a pin to mark the centre, pen for marking and scissors to cut, three samples each were cut from all the example in Tables 12 and 13, except wool which was very small to meet the requirement.

A specimen was place on the lower horixontal disc of the apparatus, so that the pin passes through the centre of the specimen, then the top disc was positioned. The lid of the apparatus was lowered. An annular ring was placed to the test specimen on the lid. The light was switched on and the shadow cast on the papers was marked. The paper ring was removed, folded and weighed, (M_1) The paper ring around the periphery of the shadow was cut and the area of the paper ring not shaded was discarded. The mass of the residual portion of the paper ring was then determined (M_2). The drape coefficient is then determined as the ratio of the two masses M_2/M_1 expressed as percentage. The higher the numerical value of drape coefficient, the stiffer the material. A lower value of drape coefficient implies a material that is less stiff.

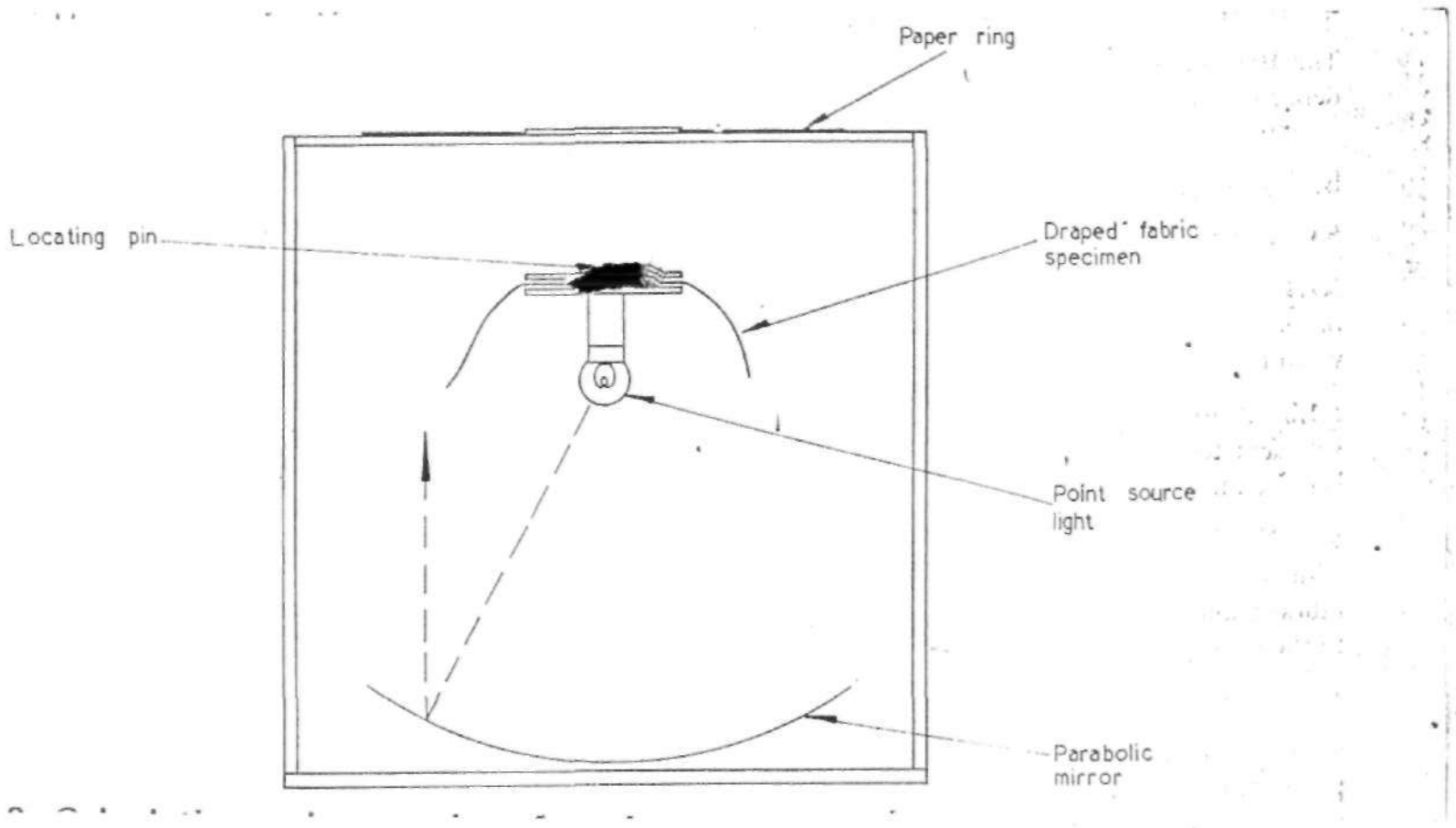


Fig. 3

Section through the Drape tester.

2.2.3.2 Bending length Testing :-

The test was carried out in accordance with the B.S. specification (79). The equipment used was the fixed angle flexometer. The essential features of the fixed-angle flexometer are shown in Figure 4. On the horizontal platform P rests a slide S graduated on its upper surface with a scale which indicates bending length directly in units and tenths of a unit. For the angle of inclination of 41.5° unit graduations of the scale on the slide are uniformly spaced 2 cm apart. When the front edge of the slide coincides with the front edge of P, the zero of the scale on S coincides with a datum line D on the instrument . Two sighting lines L_1 and L_2 passing through the upper forward edge of P and inclined at an angle of 41.5° below the horizontal, are inscribed on the transparent side pieces of the instrument. The under surface of S is covered with a layer of high friction material such as sheet rubber and the upper surface of P is polished so that, when S is moved, it will carry forward a specimen placed between the slide and the surface P. The width of the slide S should be 2.5cm and its mass should be 10 ± 2 g/cm.

The range of the instrument is governed by its size. It is convenient to be able to determine bending lengths of about 8cm to 10 cm in which case the overhanging length of the specimen is 16 cm to 20 cm.

Three specimens each measuring 2.5 cm wide and 20 cm long from both the warp and the weft threads of all the samples in Table 12 and 13 were cut. They were then exposed to the atmosphere for testing (relative humidity 65 ± 2 %, temperature 20±2°c) for 24 hours.

The instrument was placed on a level table. A specimen was then placed on the platform P with one of its end coinciding with the front edge of the platform and a slide S was also placed on the specimen and the zero of the scale in line with the mark D. The slide was pushed forward to project the specimen over the edge of P to bends over with its own mass. The slide was then moved forward until the end of the specimen comes into line with the two lines L_1 and L_2. After intervals of seven seconds, the bending length of the specimen was read. This operation was repeated with the other face of the specimen up, and again at the other end of the specimen, first with the original face up and then with the specimen turned over.

The flexometer was placed in such away that the zero of the scale lies towards the observer, which enables the scale on S read with comfort.

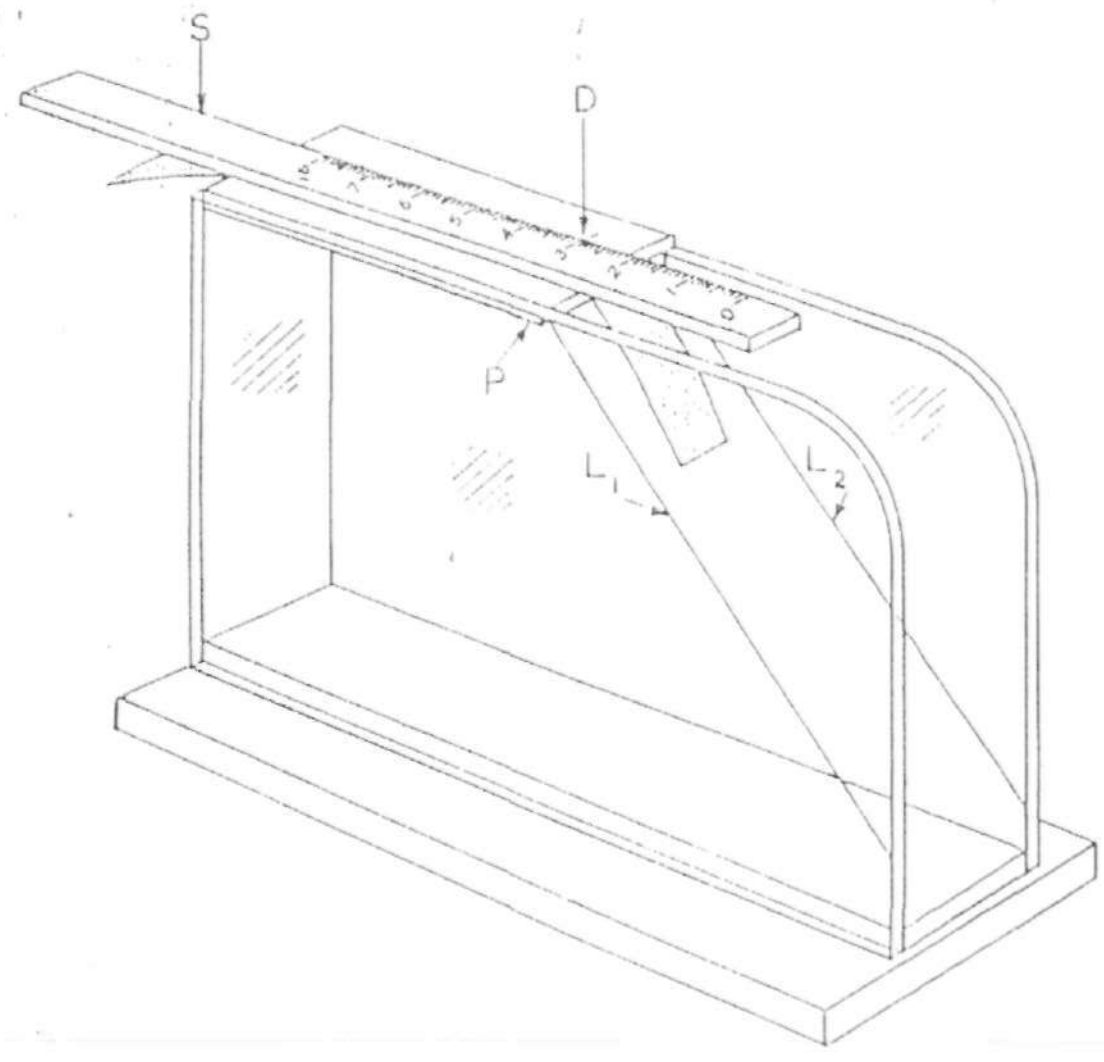
From these lengths obtained from the flexometer and the fabric weights of the samples as shown in Tables 12 and 13, the flexural rigidity 'G' of the fabrics are calculated using the formula :

Flexural rigidity 'G' $= \frac{WL^3}{10}$, where L = Bending length (cm)
W = weight of fabric (g/m^2).

The lower the numerical value of bending length, the less rigid the material. A high value of bending length implies that the material is rigid.

2.2.4 Finishing Treatments :-

A plain woven cotton fabric 10 meter squared was subjected to a mild hand washing using domestic detergent (Imperial leather). The conditions of washing are as contained in 1.S.O. 1 wash fastness test , i.e. in 5 g/l Soap flakes at 40°c for 30 minutes.



S = Slide

D = Datum line

P. Horizontal platform

L_1 & L_2 = Sighting lines

Fig. 4

Fixed - angle flexometer

The sample was then left to dry. Washing procedure was repeated ten times, taking notes of the initial dimensions before each wash and the final dimensions of the dried sample after each wash. Samples were cut after the first, third, sixth, eight and the tenth washings.

2.2.4.2. Mercerization :-

A solution of the required concentration of caustic soda was prepared. Samples of plain cotton fabrics of known dimensions were immersed. The materials were mercerized at ambient temperature i.e 25°c for 1 minute each, the materials were neutralised and conditioned. The final dimensions were also measured.

2.2.5. Subjective Assessment :-

2.2.5.1 Paired comparison:-

This is a subjective method of inspection in which two fabrics are presented to the judge who assesses which of the pair in his opinion has the better property. This method is discussed in detailed in appendix 1. The assessors were eleven (11) female undergraduate students of Ahmadu Bello University, Zaria. The established questions were:

i) Which fabric stretches more ?

ii) Which fabric is Smoother

iii) Which fabric is stiffer ?

iv) Which fabric is more hairy ?

The dimensions of fabrics were 5cm x 5cm for subjective assessments of smoothness, stiffness and softness, whereas it was 10cm x 2cm for the assessment of extensibility and stretchness.

2.2.5.2. Magnitude estimation:-

10cm x 10 cm specimens of all the five weft-pile fabrics listed in Table 13 were used. Corduroy B taken as the reference sample, all other corduroys were seperately presented along with reference B to each of the eleven female assessors. They were asked to comment on the fabrics ridgeness when compared with B, and that if B was rated- 10. They were asked to rate other corduroys. A rating of 10 was chosen primarily because it enable assessors toevaluate and compare materials on base 10, and considerably ease calculations. Less ridged were rated lower than 10, and higher ridged were rated more. The assessors were also asked to rate the corduroys on the basis of wideness of ridges with reference to corduoroy B rated 10.

Lastly, they were asked to rate the corduroys on the basis of shallowness of the ridges with references to corduroy B rated 10.

2.2.6 Miscellaneous Tests:-

2.2.6.1 Thickness measurement :-

The instrument used was a Gusick thickness tester. The essential features of this tester are shown in Figure 5.

The procedure consisted of cleaning the anvil and the foot. The instrument was then adjusted to give the pressure of 20g /cm^2 and the gauge was set to read zero. The parallel plates were seperated and uncreased part of the sample of conditioned fabric or yarn placed in contact with the anvil without tension. The distance between the anvil and the presser foot of the gauge was reduced at a rate of 0.05 mm/s until contact with the fabric was made. The reading of the gauge was immediately noted, this was repeated using other parts of the specimen ten times, the average of which is taken as the thickness of the fabric.

This was repeated for all other samples under test.

2.2.6.2 Yarn Linear density and fabric weight :-

These were determined in accordance with the British standard specification (77).

2.2.6.3 Fabric Shrinkage:-

The dimensions of all the plain woven cotton fabrics intended to be finished, in both warp and weft ways were measured. The difference in dimensions before and after each treatment expressed as a percentage of dimension before the treatment was taken as the percentage shrinkage.

2.2.6.4 Crimp Determination:

The crimp tester was employed in this test . Its principle involved straightening out a known length of thread by application of tension which is varied according to the nature and linear density of the yarn.

The difference between the straightening length of the thread and the distance between the ends while in fabric expressed as a percentage of the later.

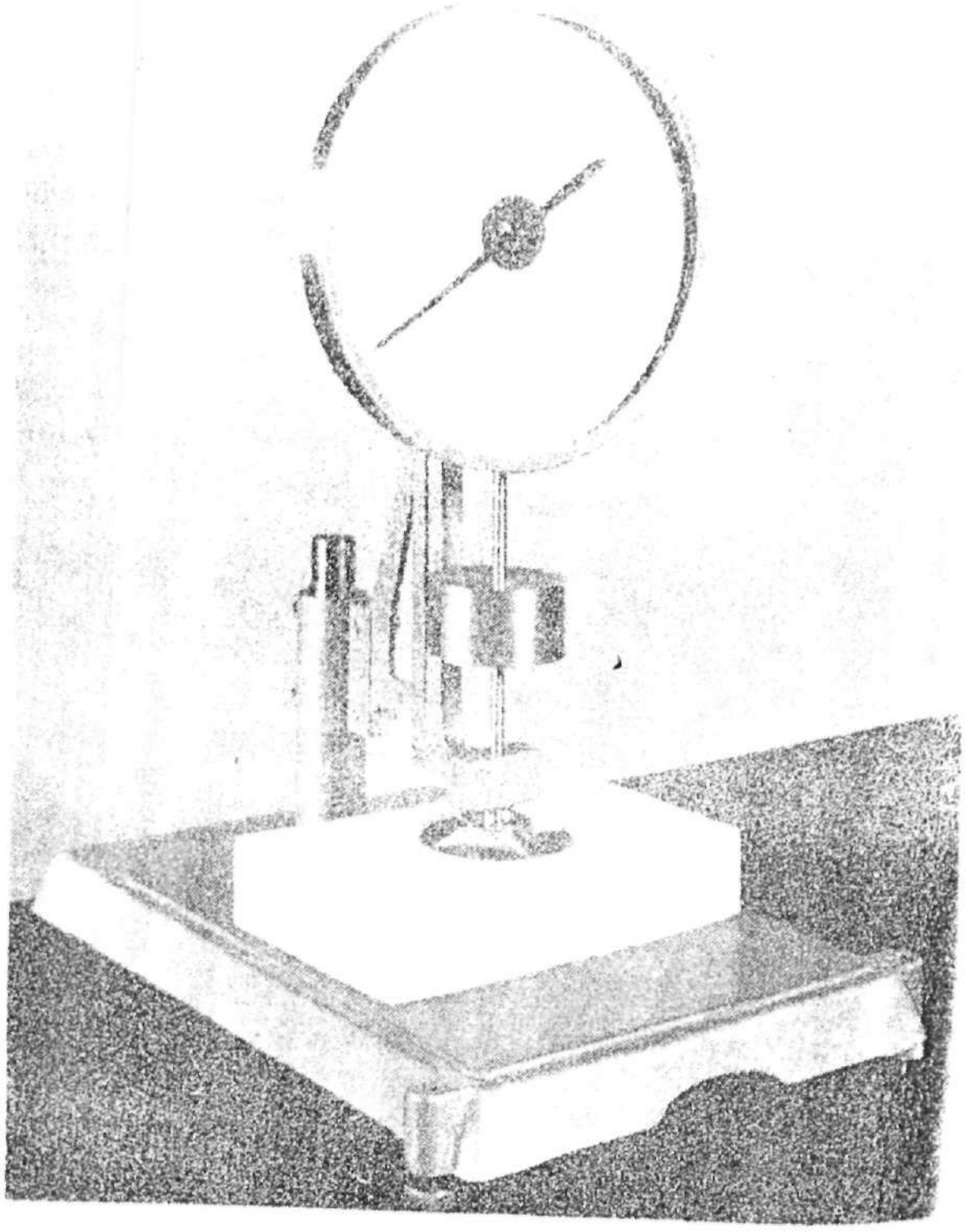


Fig. 5

Shirley thickness tester.

CHAPTER 3

Results and Discussion.

3.1 Objective Specification of Fabric handle :-

3.1.1. Effects of fibre content on fabric strength and stretchiness:-

From the tensile results of the plain woven fabrics in Table 12, the informations in Table 14 - 17 were obtained for various fabrics. The tensile property parameters of these fabrics were then compared as shown in Table 18.

In this work interest is mainly on the resistance to stretching deformation. Therefore the complimentary load needed to produce a given extension is taken. Generally, the load needed to produce an extension of 10% (74) is used as a standard. The higher the load the more difficult it is to stretch the materials. The advantage of this is the direct relationship between the values and the subjective evaluation of stretchniness.

Table 14: Load-elongation and stress-strain result for cotton.

Load (N)	Elongation (mm)	Strain (%)	Stress $(N/m^2)\times10^6$
0	1.25	2.5	0
0.12	2.50	5.0	2 . 2
0.22	3.75	7.5	4. 0
0.18	5.00	10.00	5. 1
0.40	6.25	12.5	9. 2
0.89	7/50	15.0	16.3
1.67	8.75	17.5	30.6
2.88	10.00	20.0	52.8
4.70	11.25	22.5	86.8
6.96	12.50	25.0	127.6
9.32	13.75	27.5	171.0
11.48	15.00	30.0	210.6

Table 15: Load-elongation and stress-strain results for viscose rayon.

Load (N)	Elongation (mm)	Strain (%)	Stress $(N/M^2) \times 10^6$
0	1.25	2.5	0
0	2.50	5.0	0
0.18	3.75	7.5	1.5
0.20	5.00	10.00	3.8
0.45	6.25	12.5	8.4
0.98	7.50	15.0	18.4
2.16	8.75	17.5	40.5
3.92	10.00	20.0	73.5
5.80	11.25	22.5	108.8
7.32	12.50	25.0	137.3
8.50	13.75	27.5	159.5
9.43	15.00	30.0	177.1

Table 16 : Load-elongation and stress-strain results for Triacetate

Load (N)	Elongation (mm)	Strain (%)	Stress $(N/M^2) \times 10^6$
0	1.25	2.5	0
0.07	2.50	5.0	1.3
0.27	3.75	7.5	4.9
0.91	5.00.	10.0	16.6
0.42	6.25	12.5	44.1
4.86	7.50	15.0	88.5
6.28	8.75	17.5	114.4
7.92	10.00	10.0	144.2
8.73	11.25	22.5	158.9
9,70	12.50	25.0	176.6

Table 17 : Load-elongation and stress-strain results for Wool.

Load (N)	Elongation (mm)	Strain (%)	Stress $(N/m^2)\times10^6$
0	1.25	2.5	0
0.2	2.50	5.0	1.3
0.63	3.75	7.5	4.1
1.62	5.06	10.0	10.5
2.49	6.26	12.5	16.2
4.11	7.50	15.0	26.7
5.25	8.75	17.5	34.1
6.18	10.00	20.0	40.1
6.95	11.25	22.5	45.1
7.63	12.50	25.0	49.6
8.17	13.75	27.5	53.1
8.59	15.00	30.0	55.8
8.83	16.25	32.5	57.5

Table 18: Effects of fibre content on fabric mechanical properties:

Fabrics	Breaking -Load (Kg)	Breaking Elongation (cm)	Working Rupture $(N/M^2\times10$	Young Modulus $(N/m^2)\times10^6$	Load at 10 % elongation (N) Secant Modulus
Cotton	11.48 (4)	1.5 (2)	15.25 (2)	30.5 (4)	0.28)2)
Viscose rayon	9.43 (2)	1.5 (2)	15.6 (3)	20 (3)	0.20 (1)
Triacetate	9.7 (3)	1.28 (1)	16 (4)	14 (2)	0.91 (3)
Wool	8.85 (1)	±.625 (4)	8.935)1)	5 (1)	6.62 (4)

Values in parenthesis represent rank order.

Breaking-load, breaking-elongation and work of rupture were obtained from stress- strain curves. The Young's Modulus was determined by Coplan method (40). From table 18, wool has the lowest tenacity and cotton has the highest, this is in agreement with Smith's (35) findings. Wool also extends most before breakage, according to Sherman and Sherman (36) and Newell's work (37) but other fibres do not agree with their rankings.

The work of rupture believed to be associated with strength showed that wool has the least, followed by Cotton, Viscose rayon, while triacetate was rated highest. This is in contradiction with Meredith's (38) work.

Young modulus which was not compared by previous workers showed wool having the least, followed by triacetate, Viscose rayon and lastly cotton. The values obtained for the secant modulus showed almost opposite results to the Young's Modulus, the load required for ten percent elongation showed viscose rayon as having the least, then cotton, triacetate and lastly wool.

The differences in the tensile parameter values is largely atributed to the differences in their fibre content.

3.1.2 Effects of fabric structure on strength :

The effect of fabric structure on mechanical properties such as strength is well documented (36-38). Many models have been proposed to explain experimental results for this reason the fabric structure was kept constant i.e plain weave fabrics were used.

3.1.3 Effects of scouring treatment on fabric stretchiness :-

The tensile data of fabrics subjeted to ten cycles of washing treatments are shown in Table 19.

Table 19 : Load-elongation results for the scoured samples,

No of washes / Elongation (mm)	Load (N)				
	1	3	6	8	10
1.25	0	0	0.03	0.03	0.07
2.50	0.09	0.15	0.28	0.21	0.35
3.75	0.35	0.46	0.82	0.55	0.80
5.00	0.83	1.13	2.00	1.20	1.66
6.25	1.82	2.34	3.84	2.27	3.06
7.50	3.10	4.01	6.06	3.80	5.00
8.75	4.78	6.00	-	-	7.00

Elongation at some load values (5 kg_f and 2 kg_f) were obtained by a plot of the elongation versus number of washes as shown in Figure 6. From the curve, it could be observed that there is a general decrease in elongation as the number of washes increases. This shows that as the number of yarns per cross-section increase, the fabric consolidation also increases. As a result, the interstices between yarns diminishes, thus the initial resistance of the material to stretching force deminishes. This is to be expected because according to Peice (2), Grosberg (8), and several other workers (70,71) the initial modulus increases as the yarn in the cross-section increase. The shrinkage and the crimp also increase the yarn per cross-section, and a similar behaviour might be expected in this case.

Fig. 7 shows that as the number of wash increases, there is an increase in the percentage crimp in the warp yarns, and decrease in the weft. This is due to the consolidation of the the warp yarns, thereby decreasing in length.

There is also decrease in crimp in the weft as it has to get longer so as to go round a more consolidated warp.

3.1.4 Effects of Mercerization on fabric stretchines :-

Similarly, from the mercerized samples at different concentrations of caustic soda, the following data of Table 20 were obtained.

Table 20: Loadelongation results for the Mercerized Samples

% Caustic Soda / Elongation (mm)	Load (kgf)			
	10%	15%	20%	25%
1.25	0.08	0.03	0.03	0.06
2.50	0.41	0.33	0.27	0.27
3.75	1.02	0.96	0.75	0.54
5.00	2.68	2.32	1.83	1.20
6.25	4.88	4.42	3.44	2.44
7.50	7.16	6.86	5.64	4.24
8.75	-	-	7.41	6.60
10.00	-	-	-	8.89

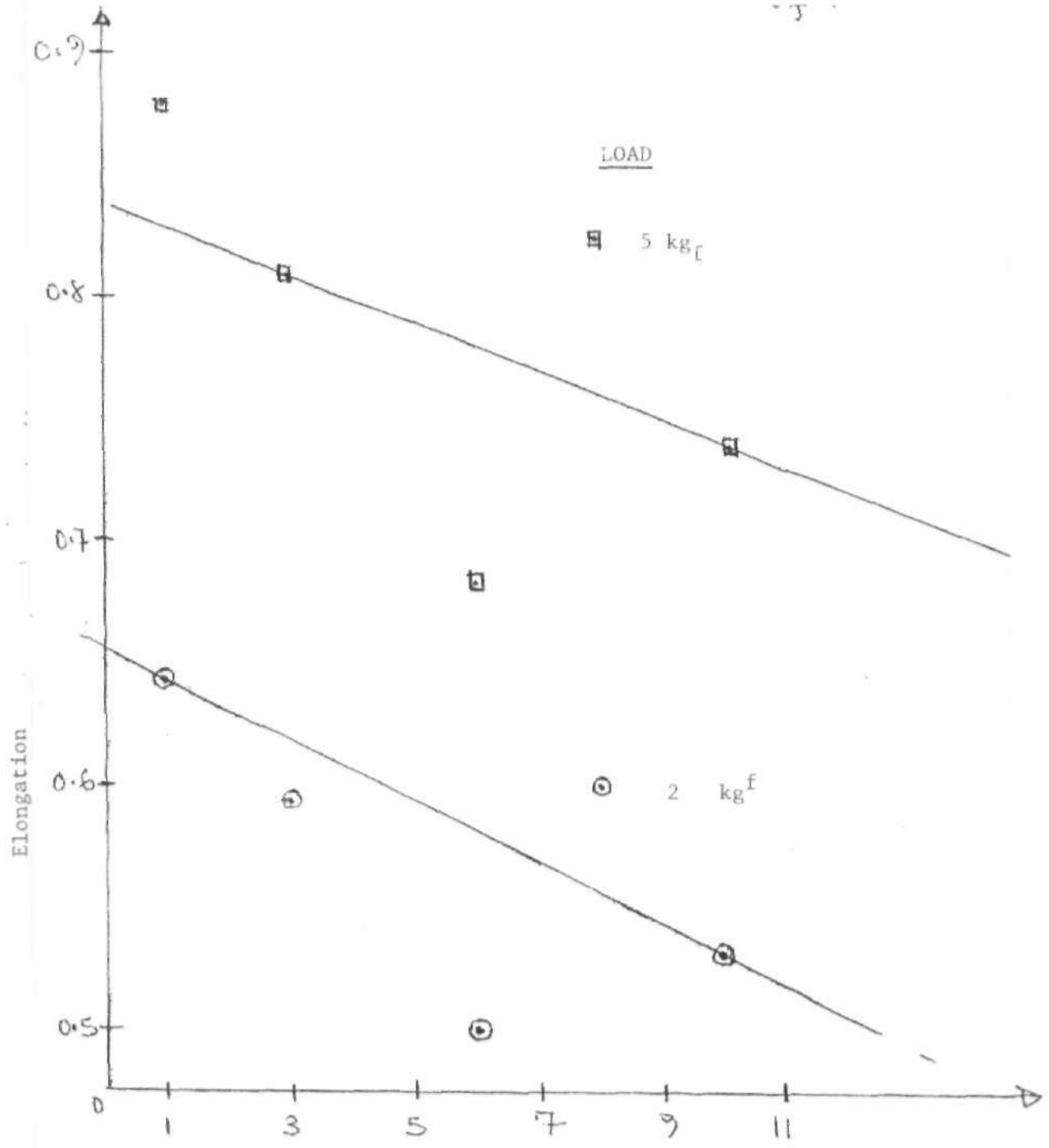


Fig 6

Effects of washing treatments on fabric stretchiness.

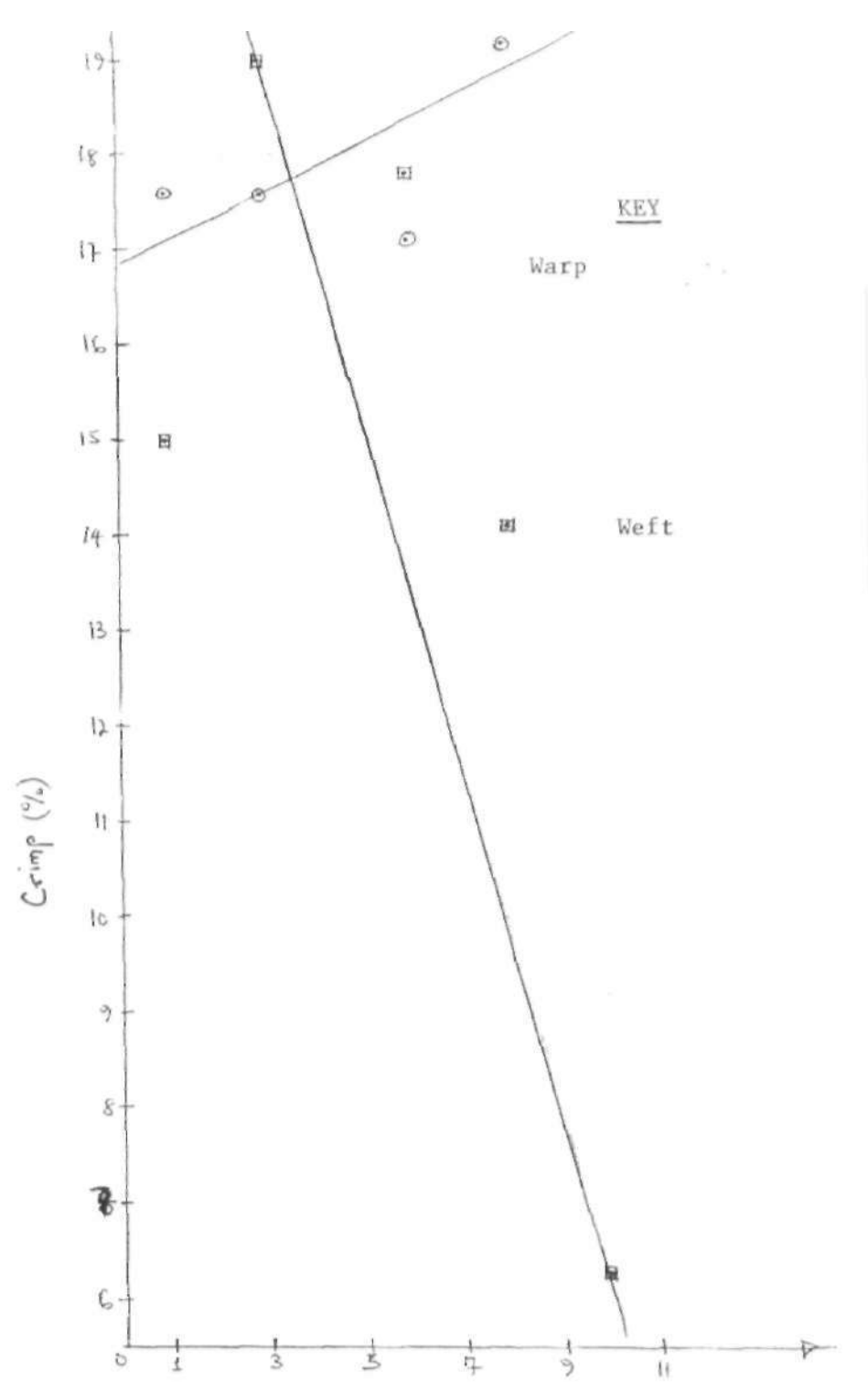


Fig 7

Effects of Scouring on the crimp percentage.

The percentage shrinkage and crimp for all the mercerized samples were determined. A plot of percentage shrinkage against caustic soda concentration give a linear relationship as shown in figure 8. The higher the caustic soda concentration, the higher the shinkage, and warp yarns shrunk more than the weft yarns. This is to be expected considering the fact that the weft yarn is considerably tensioned during processing.

Similarly, plot of percentage crimp against caustic Soda concentration showed an increase in crimp with the increase in caustic soda concentration as seen in figure 9. These, might be due to the increase in the yarn diameter as a result of swelling because yarns have to coil more over the other set of yarns. The difference between the warp and weft might be due to increase in consolidation as a result of mercerization.

The crown height was further analysed in accordance with appendix 2. The result obtained plotted against the caustic soda concentration give figure 10. From Fig. 10 there was an increase in the crown height with the increase in caustic soda concentration, this is due to the reason earlier stated, that the yarns have to coil more as to go round a swollen yarn. The consideration being in the warp direction. The negative values of crown height implied that the crown of the weft yarns is higher than those of the warp.

The increased swollen, hence crown height with increased caustic soda concentration is in agreement with an earlier findings by Duckett (71). This might also be expected to produce a rougher surface.

3.1.5 Effects of fabric structure on frictional properties:-

The charts obtained on the modified Instron give the frictional behaviour of the corduroys. The frictional behaviour of dragging wood over fabric for all the five fabrics are as compared in Fig. 11. Similarly, that of a fabric over fabric for the corduroys A,B,C,D and E are shown in figures 12, 13, 14, 15 and 16 respectively. The frictional parameters for these figures were evaluated and are as shown in Table 21.

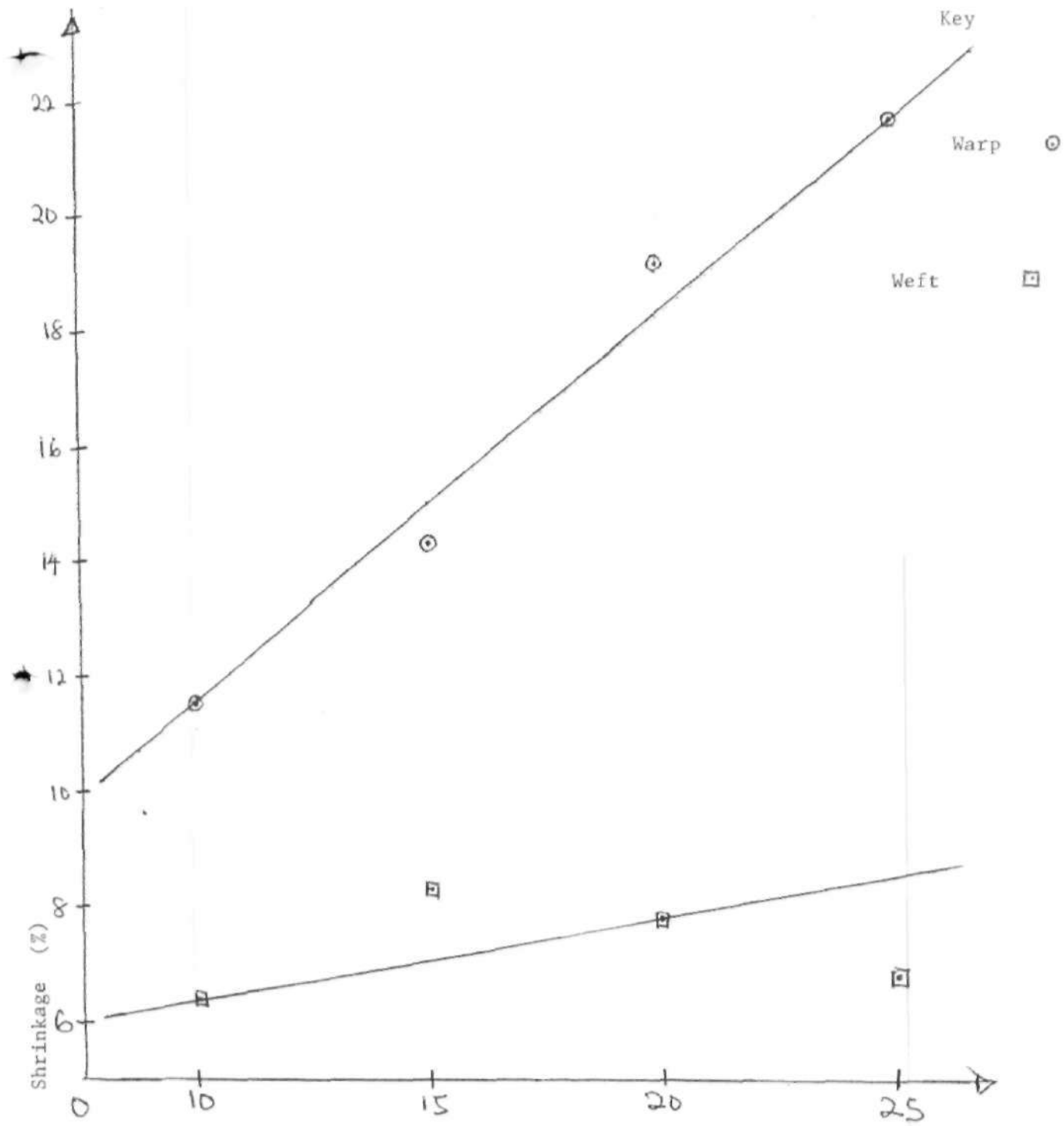


Fig 8

Effects of increasing the strength of mercerising solution on fabric Shrinkage.

Key

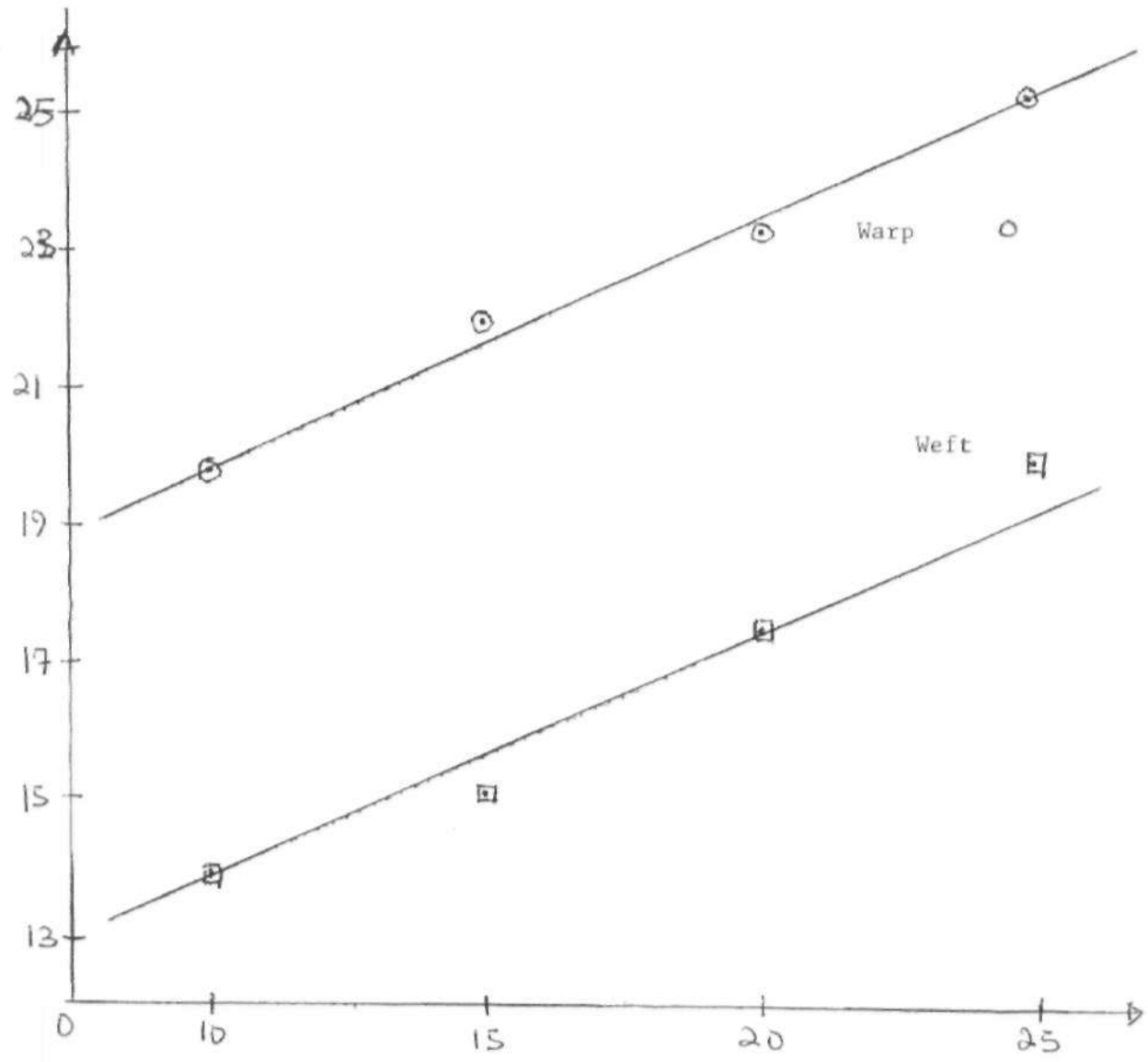


Fig 9

Effects of increasing the strength of mercerizing solution on the the yarn crimp

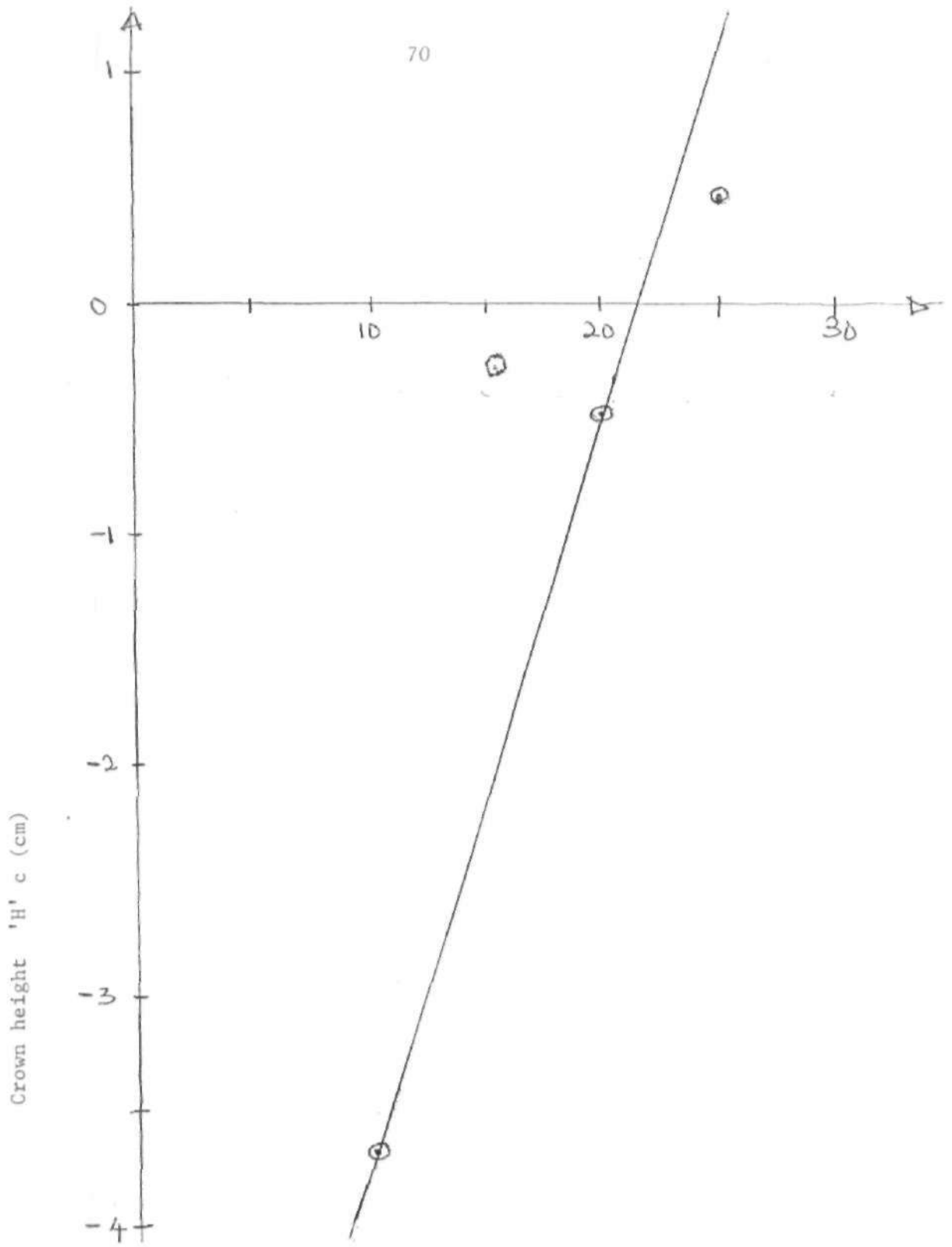


Fig. 10

Effect of mercerization on Crown height of plain weave fabric.

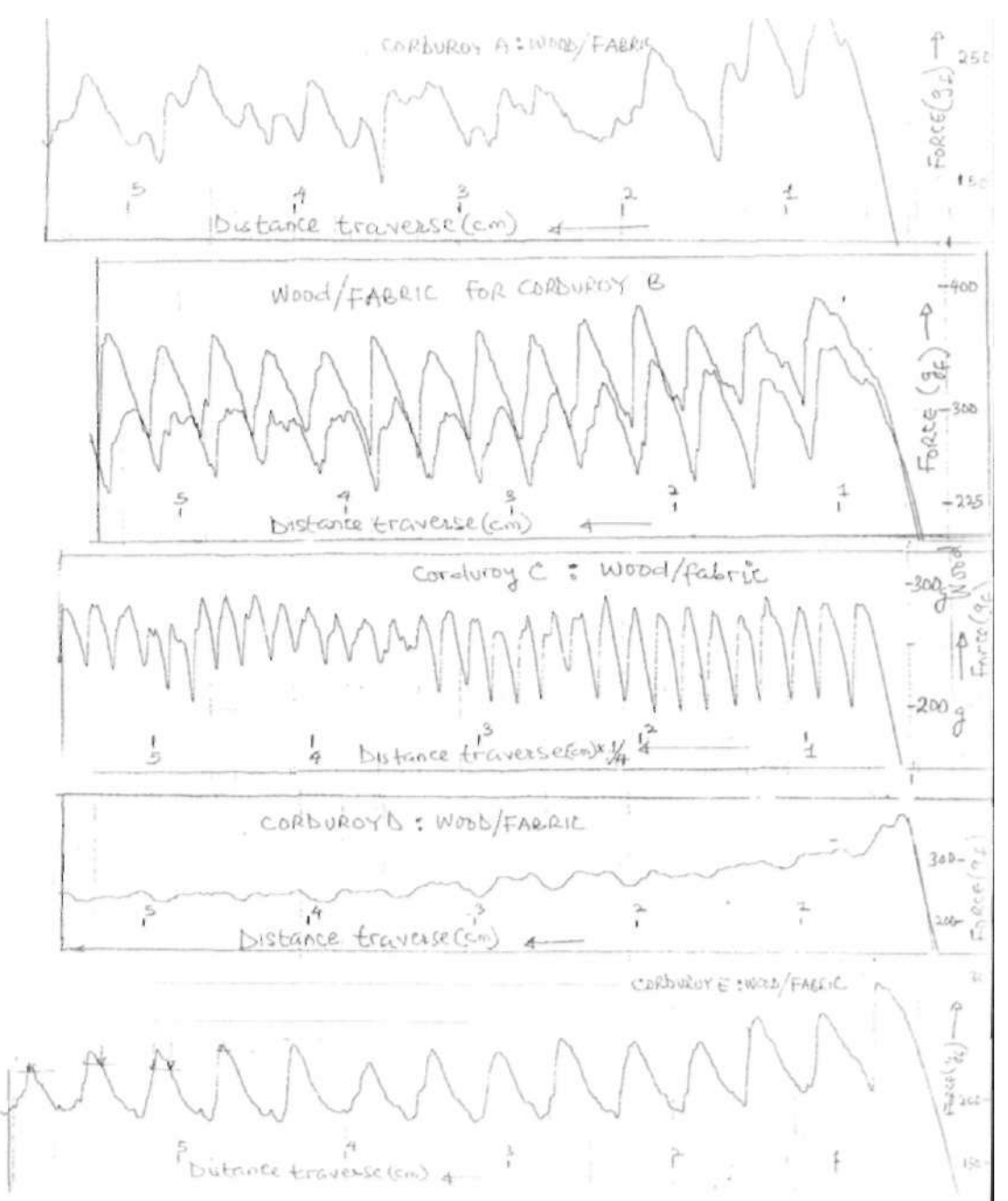


Fig 11

Frictional traces of wood over fabric for corduroys A, B, C, D and E Respectively.

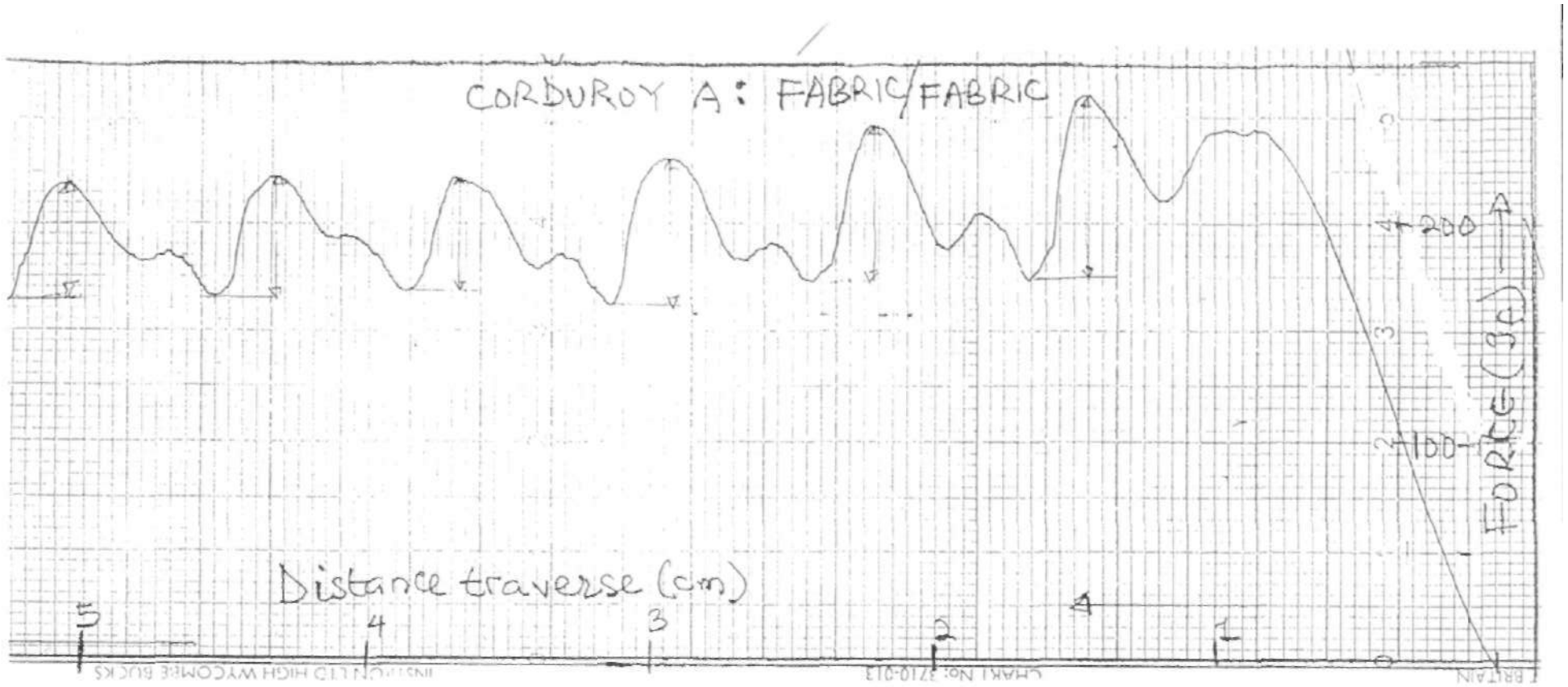


Fig. 12

Frictional trace of Corduroy A

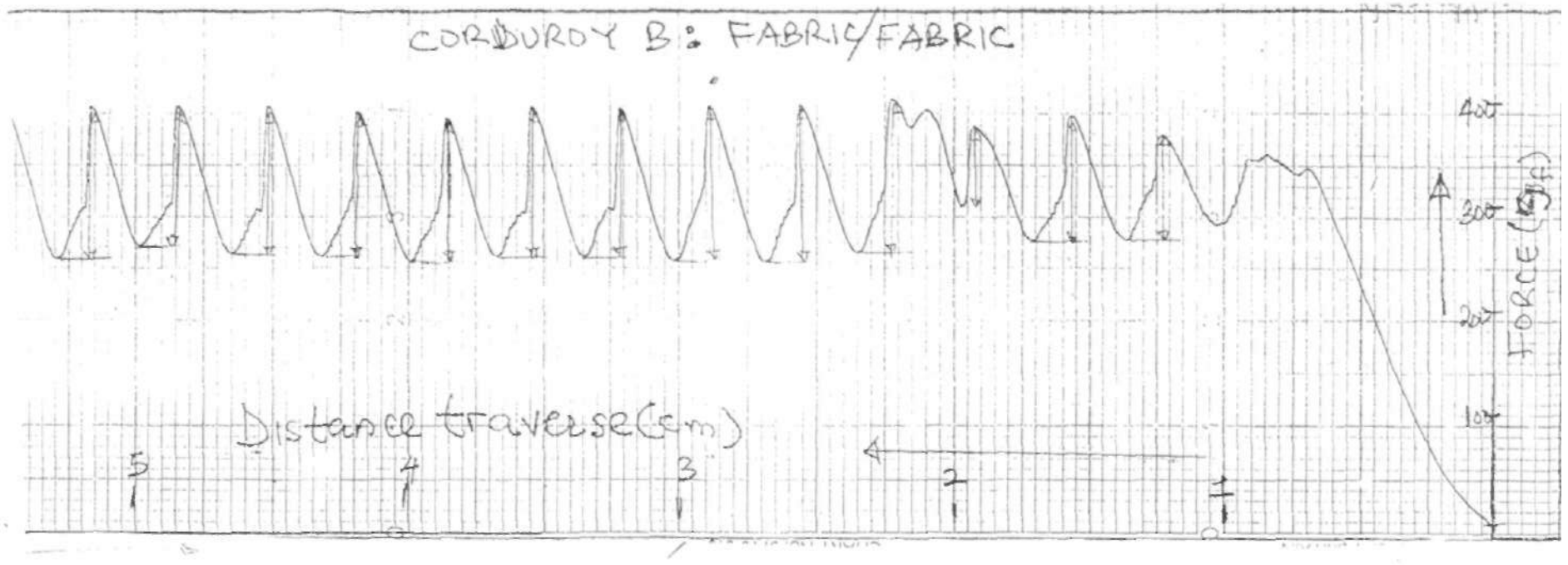


Fig. 13

Frictional trace of Corduroy B

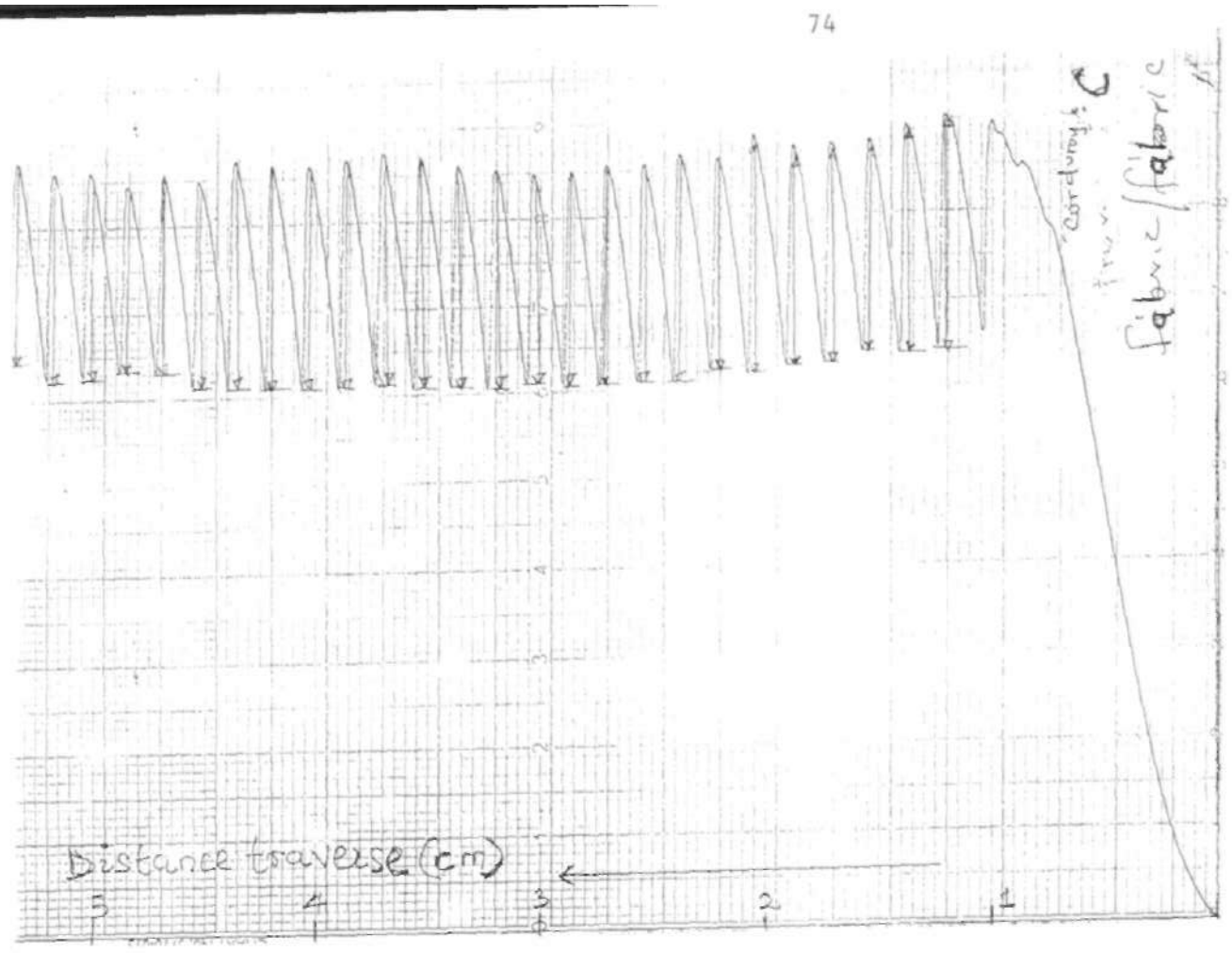


FIG . 14

Frictional trace of Corduroy C

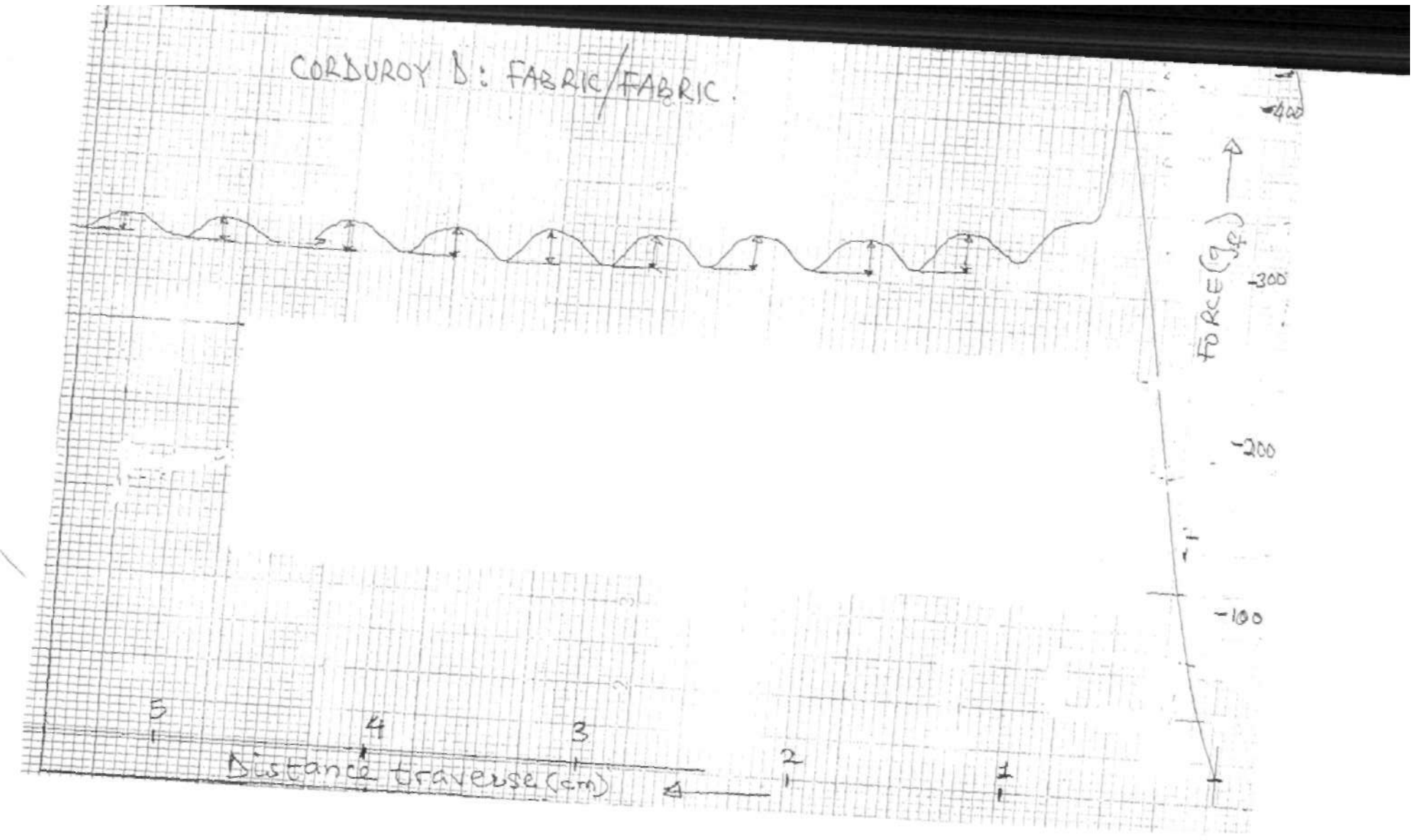


Fig. 15

Frictioonal behaviour of Corduroy D

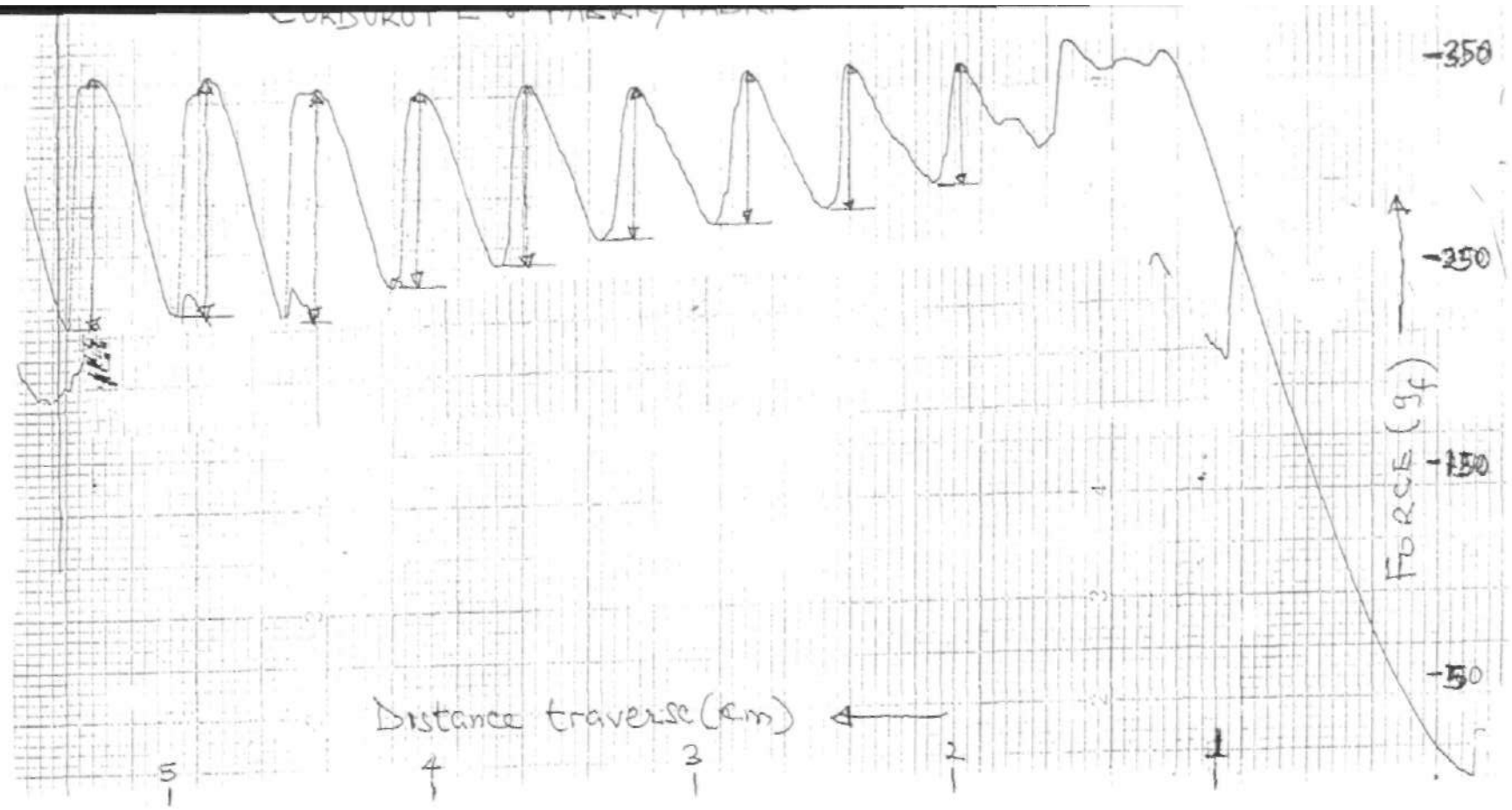


Fig. 16

Frictional trace of Corduroy E

Table 21: Frictional parameter of corduroys A - E

Fabrics / Parameters	A	B	C	D	E
Fs (g_f)	252.5 (1)	360.0 (2)	449.5 (5)	410 (4)	365 (3)
Fk (g_f)	203.4 (1)	339.8 (4)	370.8 (8)	296.8 (2)	308.3 (3)
Fa (g_f)	65.0 (2)	135.0 (5)	119.4 (4)	18.3 (1)	91.3 (3)
Fn	6 (1)	14.0 (4)	27 (5)	9 (2)	9 (2)
Fp (cm)	0.92 (5)	0.39 (2)	0.20 (1)	0.61 (3)	0.61 (3)
Fs - Fk (gf)	49.1 (2)	20.2 (1)	78.7 (4)	112.3 (5)	57.22 (3)

Values in parenthesis represent rank order.

Fs = Static friction is the force which opposes a tendancy to move due to the forces acting on a body at rest. It is the highest peak at the commencement of motion.

Fk = Kinetic friction is the force which continually apposes the motion. It is the mean of all peaks and thoughs excluding the first peak.

Fa = Frictional amplitude, is the height from the peak to the trough.

Fn = Number of peaks per unit length

Fp = Frictional pitch which is the ratio of distance traverse to number of peaks.

Generallv, the higher the values of frictional resistance, the higher the resistance they offer to motion, and the rougher it will feel.

Reference to table 21 the materials could therefore be ranked on this basis in order of decrease smoothness as C,D /B,E, and A.

These frictional resistance values are higher than when dragging just wood over fabric, because of the small increase in weight, as explained by Malgaard (58). Because of the increased pressure of the upper fabric on the base fabric, there is a corresponding increase in resistance. The frictional resistance also dictates the nature of the cloth surface, the longer the cords, and the wider they are apart, the more the resistance they offered to motion. All the static frictional values are lower than the kinetic in accordance to Ölofsson and Glallen's (50) work.

The smaller the difference between the static and the kinetic frictional resistance, the smoother the material. This is due to the smaller resistance to motion after overcoming initial resistance. In this respect the results of the corduroys could be arranged in order of decreasing smoothness as B,A,E,C and D. This result corroborate with recent findings by Ajayi and Elder (70).

The higher the frictional amplitude, the higher the surface asperities, and the rougher the surface of the material. The results therefore dictates the corduroys order of decreased smoothness as D,A,E,C and B.

The corduroys could also be arranged in the decreasing number of peaks as C,B, D/E and A. The higher the number of peaks the smoother the surface of the material. A plot of the number of peaks versus number of cords in Fig. 17 gave a linear relationship with the corduroys' arranged in the order shown above. This shows the ability of the frcitional experiment to detect all the cords (asperities).

As such the corduroys are getting rougher in the order shown. This results would greatly aid surface characteriszation of fabrics.

The frictional pitch result is almost reciprocal of that of the peak number. The corduroys could be arranged in decreasing order of their pitch as A, D/E, B and C. A plot of frictional pitch against cord width shown in Fig. 18 give a linear relationship with the corduroys' arranged in this order. The wider the cord, the more the ability to detect difference between the cords and the higher its frictional pitch, implying a rougher feel. On the other hand when frictional pitch is low, by rubbing finger accross the cords, the hand cannot go in between the ridges to detect the differences between the cords, and the smoother the feel because of the 'bedding effect'. This also shows that the frictional experiment is useful in the evaluation of the width of the cords or the diameter of the yarn. In this respect the corduroys could be arranged in the order of decreased smoothness as C,B,D/E and A.

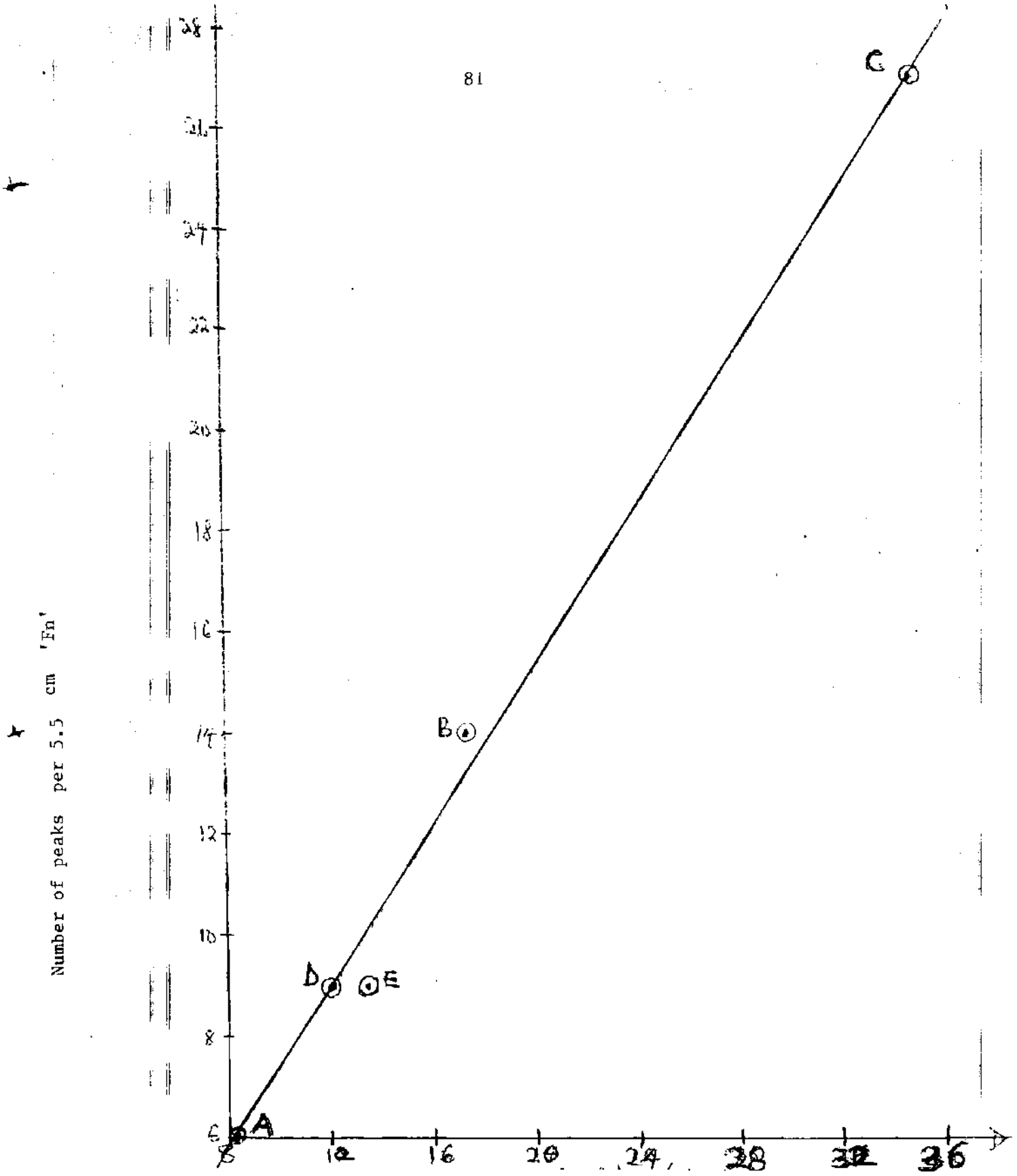


Fig. 17 Number of peaks 'F'n Vs number of Cords per distance treaversed.

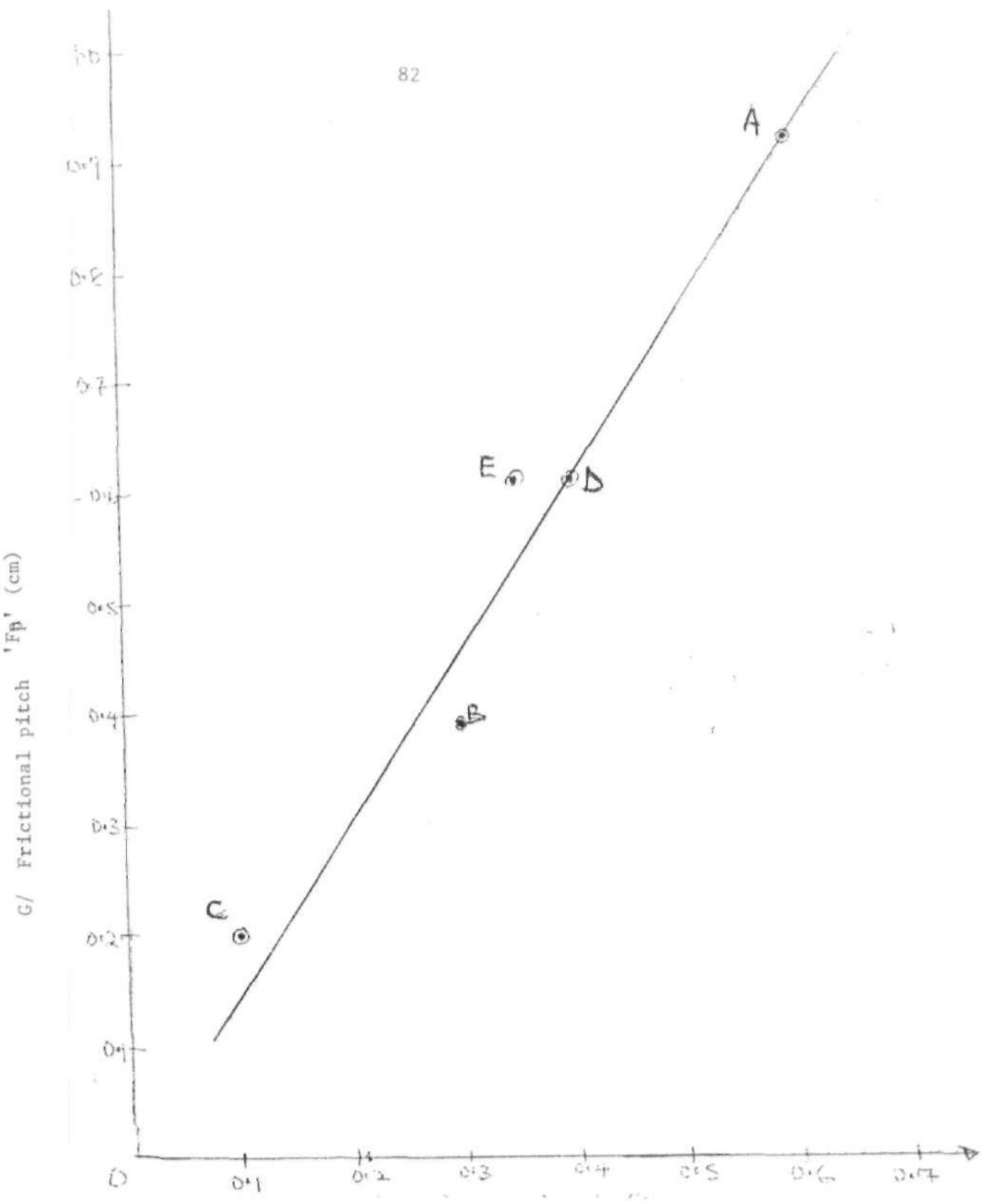


Fig. 18.

Frictional pitch Vs Cord width for the Corduroys.

3.1.6 Effects of Scouring treatment on fabric frictional properties:-

The trace obtained on the modified instron for warp over warp of the first washed and tenth washed samples are shown in Figure 19 a and b respectively. Similarly, for weft over weft are shown in Figure 20, analyses of these traces give following data (Table 22).

Table 22: Frictional parameters of Scouring samples.

Number of wash	Warp over Warp		Weft over Weft	
Parameters	1	10	1	10
Fs (g)	240 (1)	265 (2)	170 (1)	240 (2)
Fk (gf)	155	155	120 (1)	155 (2)
F_A (gf)	10 (2)	9 (1)	15 (2)	13 (1)

Values in parenthesis represent rank order.

Except the kinetic frictional resistance of warp over warp which ramain constant, all other frictional resistances showed an increase with increasing number of wash. This shows that the material was getting smoother, as the number of washes increases. According to Bradbury and Reicher (56) and King (57) who found extremely high values of friction as the surface is very smooth. The changes in the frictive resistance to motion (70) is caused by the increase in crown height as a consequence of the relaxation of stressess imposed on fibres, yarns and fabrics during scouring. This along with mechanical agitation might have caused structure consolidation, i.e., shrinkage removes oil, fat and waxes, and according to Moss (55), fabres from which all traces of lubricant have been removed show high values of frictional resistance. This is in agreement with this work.

The frictional amplitude decreased with increased number of washes this lowered the surface asperities, and the surface was getting smoother with increased number of wash.

3.1.7. Effects of Mercerization on fabric frictional properties:-

The charts obtained on the modified Instron for warp over warp of fabrics mercerized at difference caustic soda concentrations is as shown in Figure 21. Similarly, for weft over weft is as shown in Figure 22. Analyses of these traces give the results shown in Table 23.

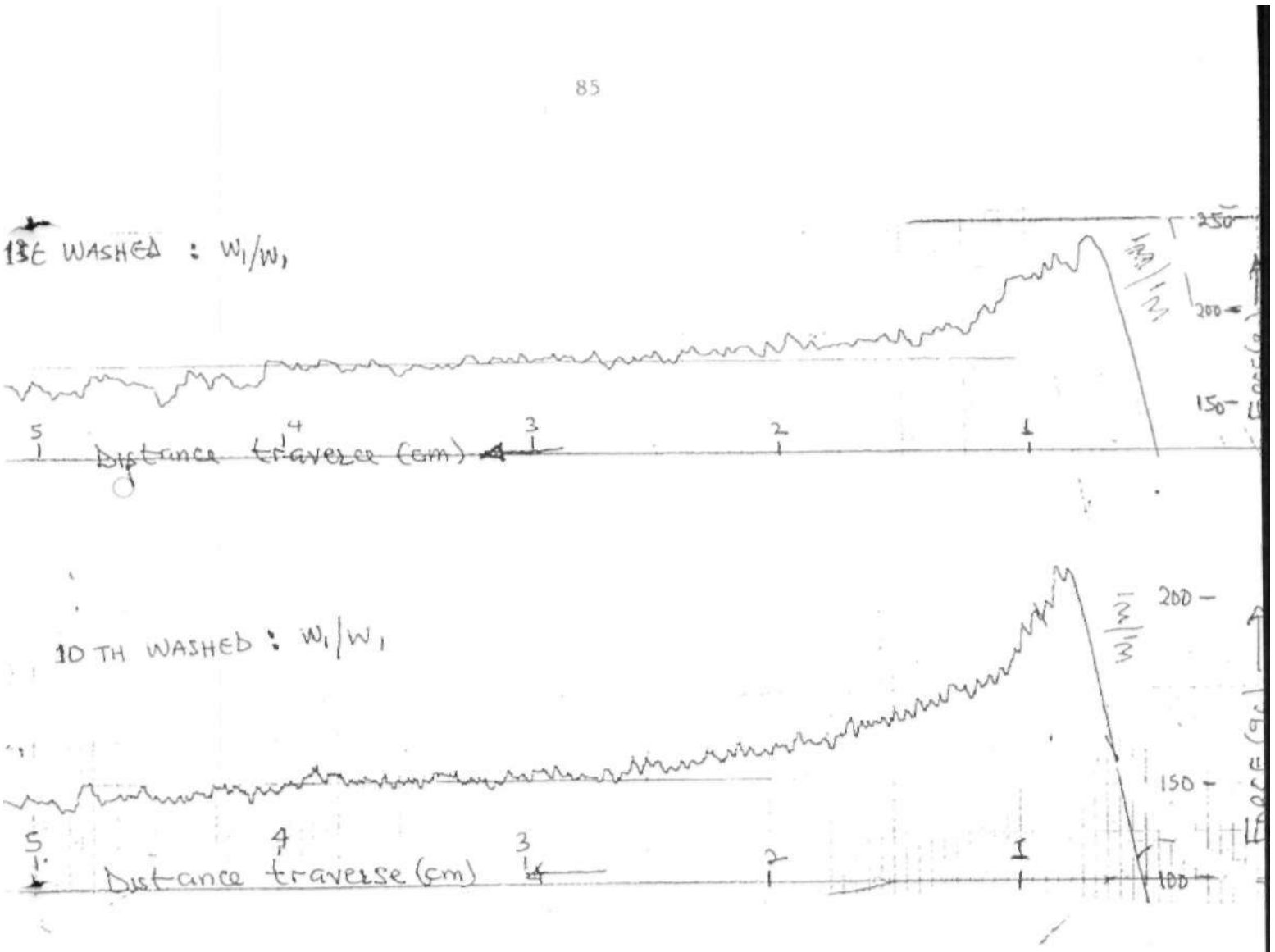


Fig. 19

Frictional parameters of warp over warp for the Scoured samples.

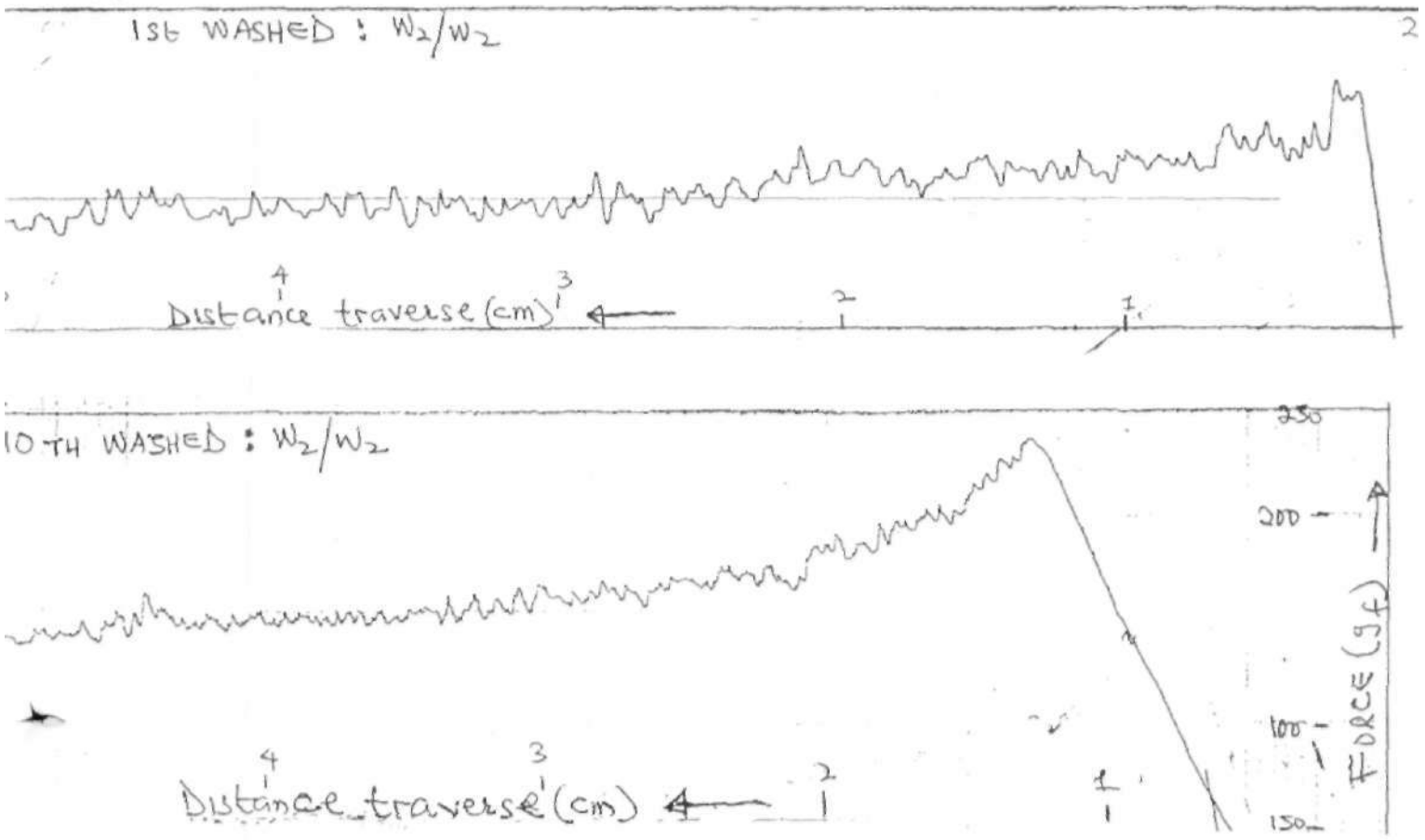


Fig. 20

Frictional parameters of weft over weft for the Scoured samples.

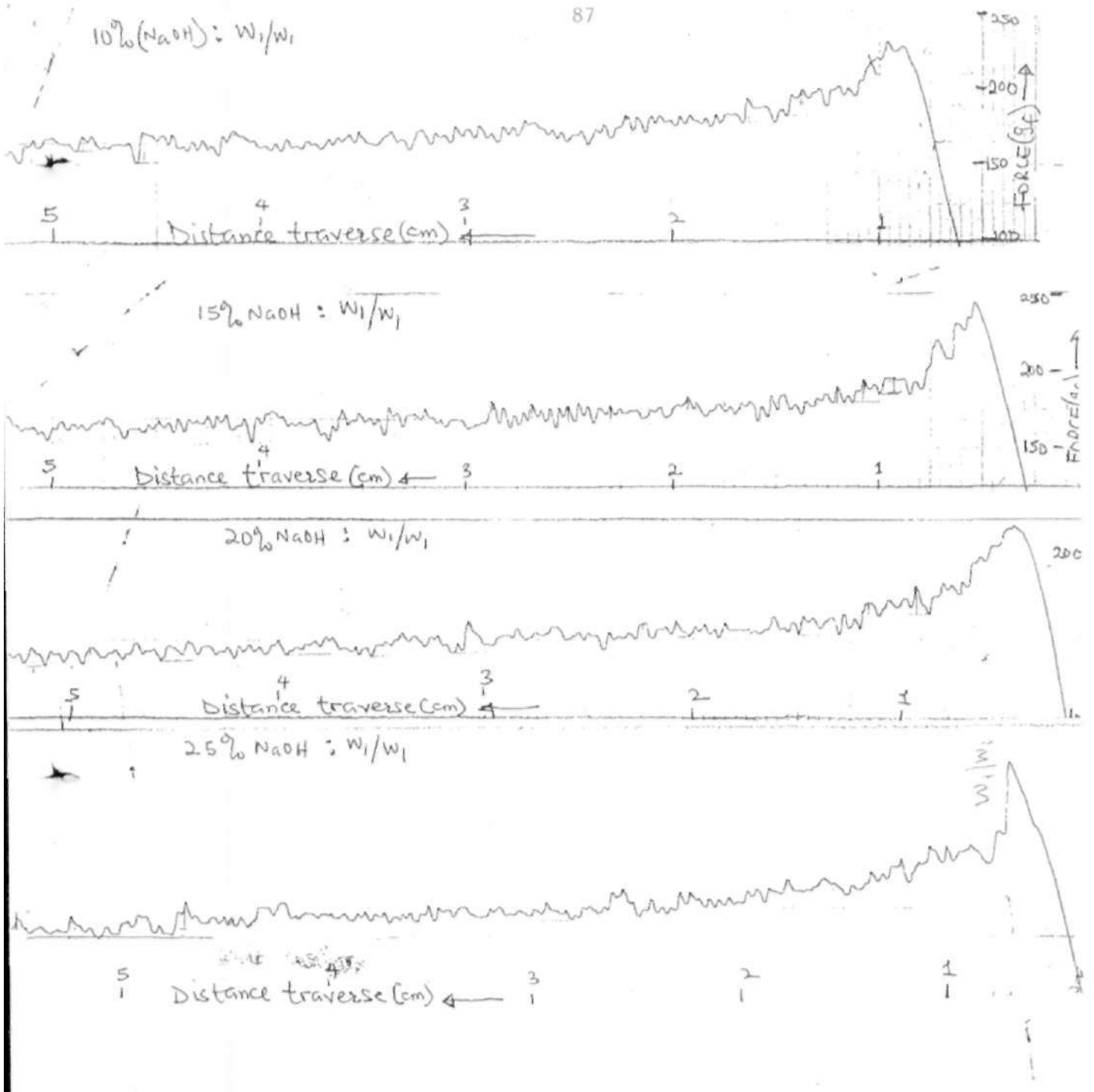


Fig. 21

Frictional parameters of warp over warp

for the mercerized samples.

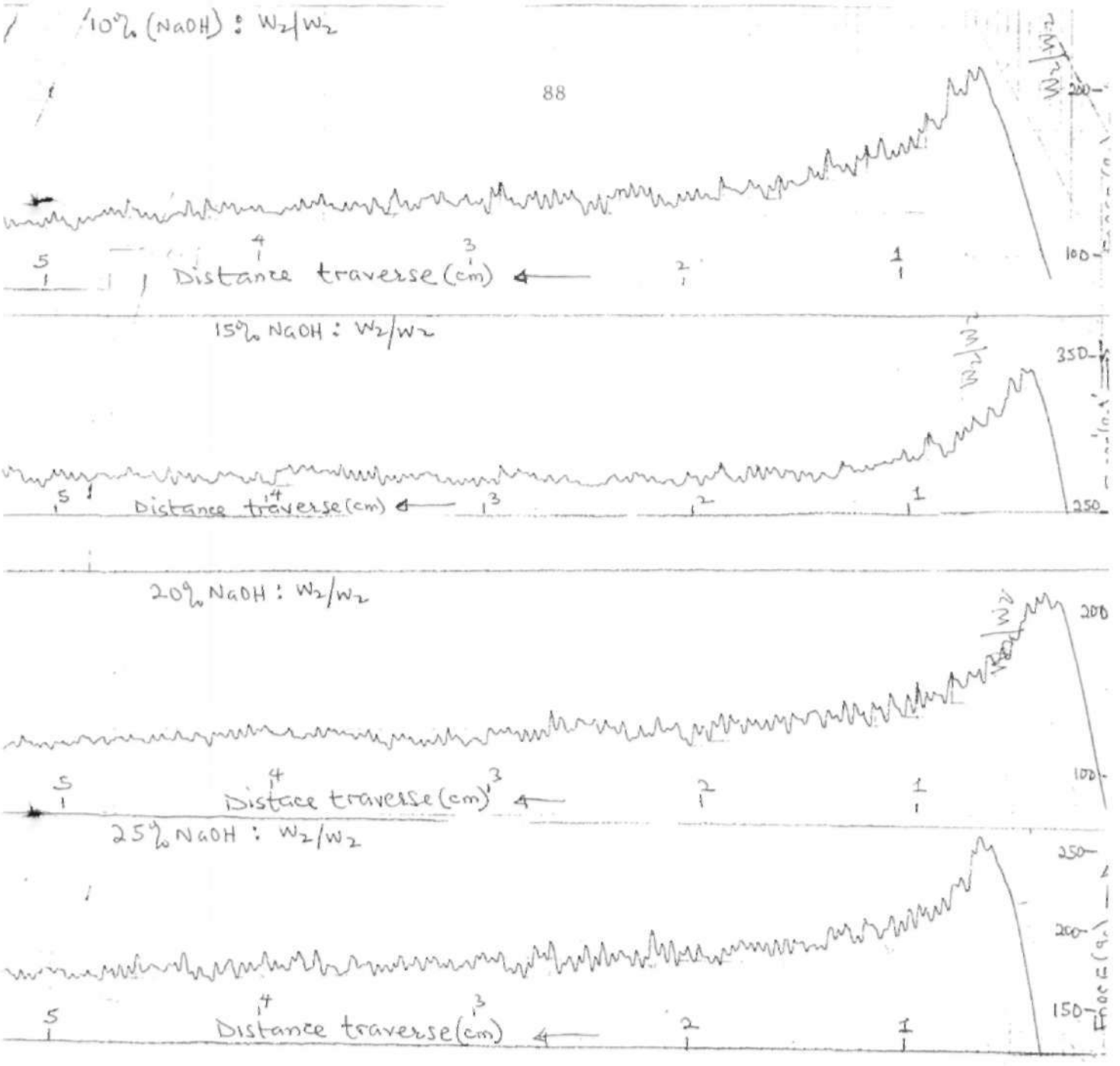


Fig. 22

Frictional parameters of weft over weft for the mercerized fabrics.

Table 23: Frictrional parameters of mercerized samples:

Caustic Soda concentration(%)	Warp over Warp				Weft Over Weft			
Parameters	10	15	20	25	10	15	20	25
Fs (gf)	220(1)	225(2)	245(3)	270(4)	205(1)	220(2)	230(3)	250(4)
Fk (gf)	250(1)	165(2)	170(3)	170(4)	125.5(1)	130(2)	165(3)	180(4)
F_A (gf)	13(1)	13(1)	14(3)	16(4)	12(1)	15(2)	16(3)	19(4)
FN	59(1)	75(4)	65(2)	65(2)	83(3)	83(1)	87(3)	90(4)

Values in parenthesis represent rank order.

Both static and kinetic frictional resistance increased with increasing caustic soda concentration. This implied increase in smoothness as stated by Bradbury and Reicher (56) and Kin (57). The swollen fibres might have caused more waviness of the fibres of the other series, hence offering more resistance to motion, thereby raising the frictional resistance values.

The frictional amplitude showed an increase with the increased austic soda concentration. This suggested higher surface asperities, meaning that the surface was getting rougher with increased caustic soda concentration. This is to be expected because of the increase in crown height, but the result was in contradiction with its frictional resistance values.

The number of peaks did not show any consistent trend. Bearing in mind that going along warp (weft) direction, the barrier is created by the weft (warp), the number of peaks in the warp (weft) direction was plotted against the weft (warp) thread sett. These plots did not show any consistant relationship and are therefore not included in this work.

3.1.8 Effects of sled speed on fabric friction:-

The results obtained by testing various corduroys fabric at different speeds are depicted in figures 23 - 27. Speeds ranging between 50 - 200 mm/min were employed. The result is evaluated and shown in Table 23.

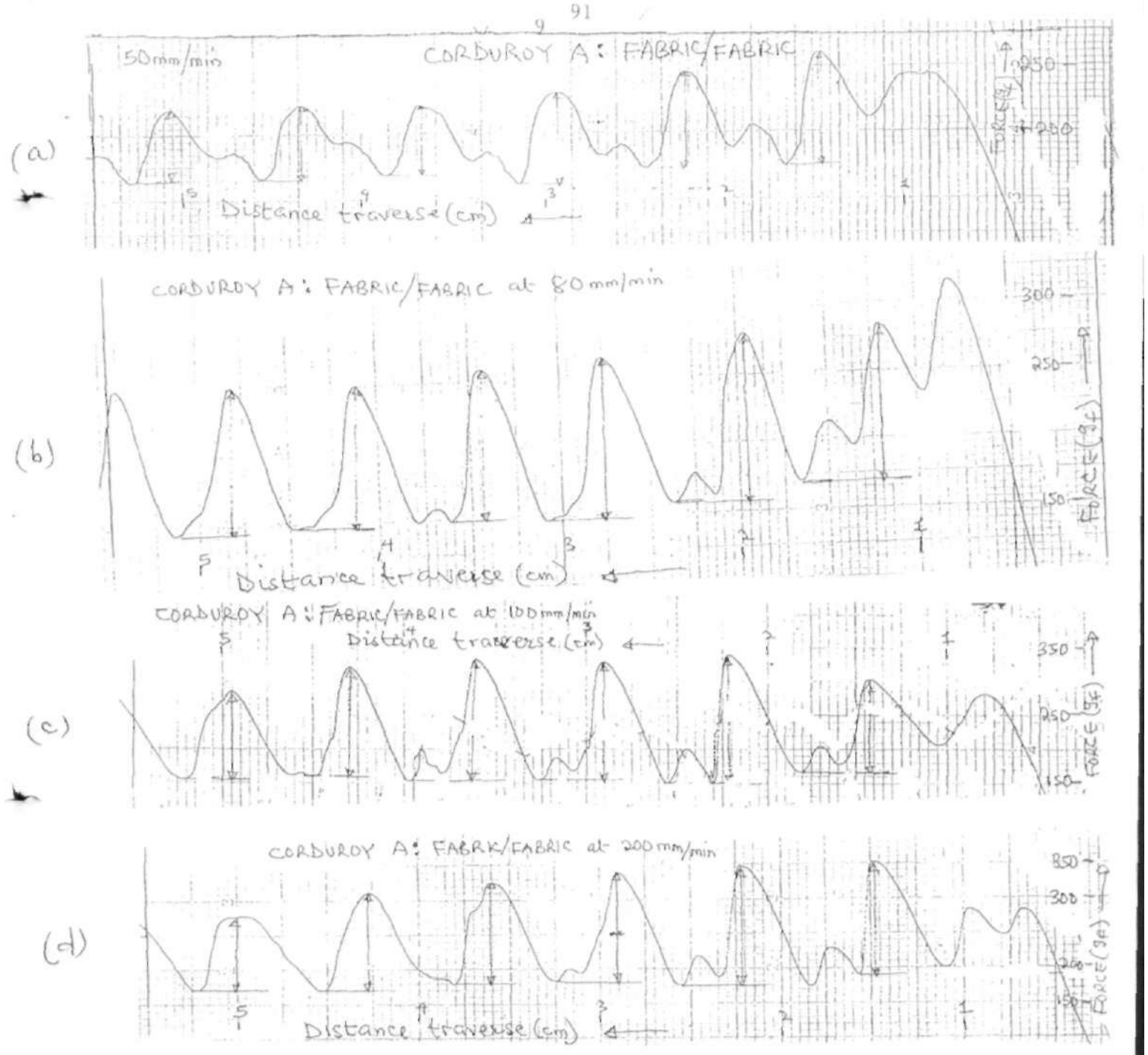


Fig. 23

Effect of speed on frictional properties of corduroys A

(a) at 50 mm/min
(b) at 80 mm/min
(c) at 200 mm/min
(d) at 200 mm/min

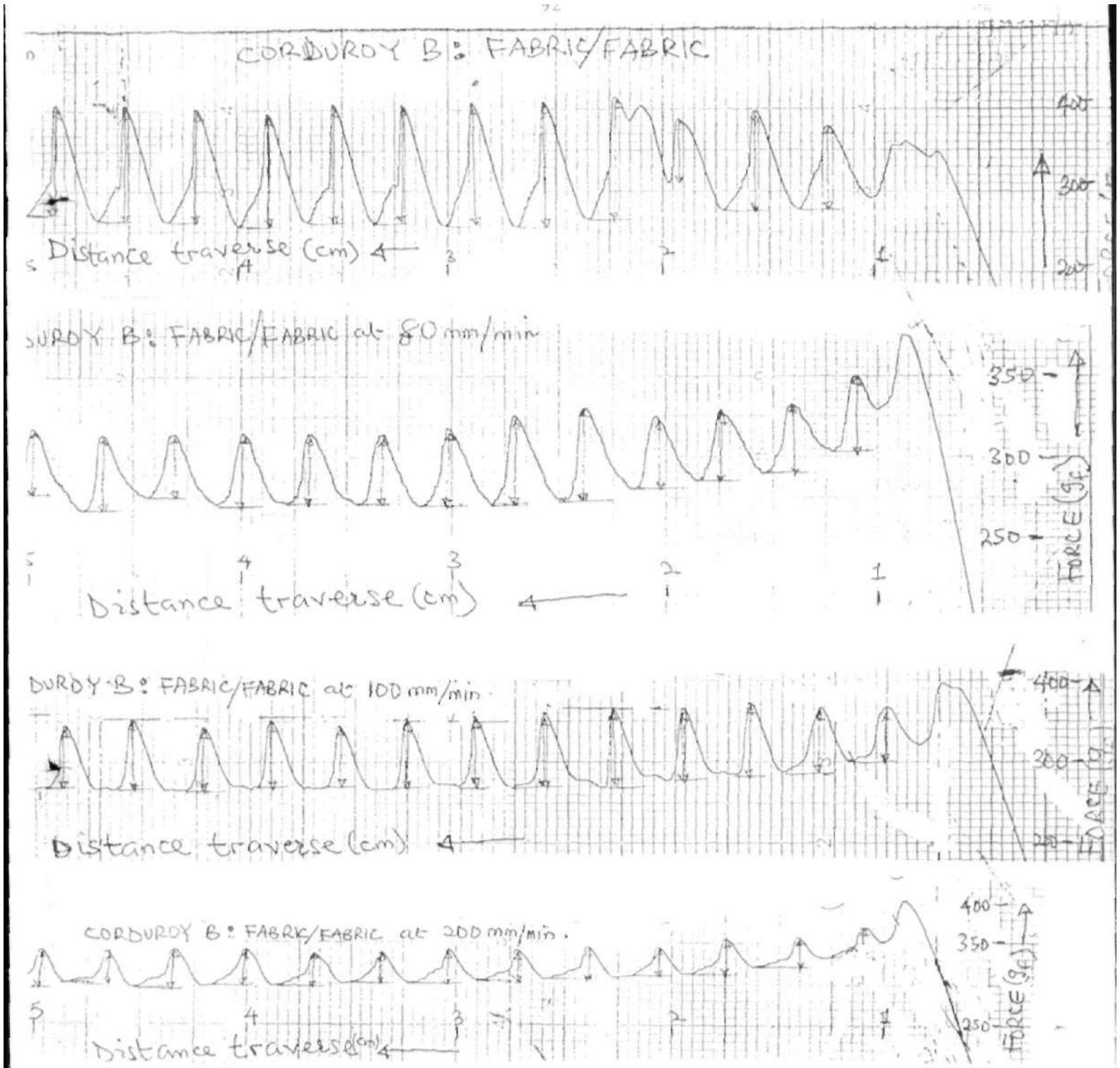


Fig. 24

Effects of speed on frictional properties of Corduroy B

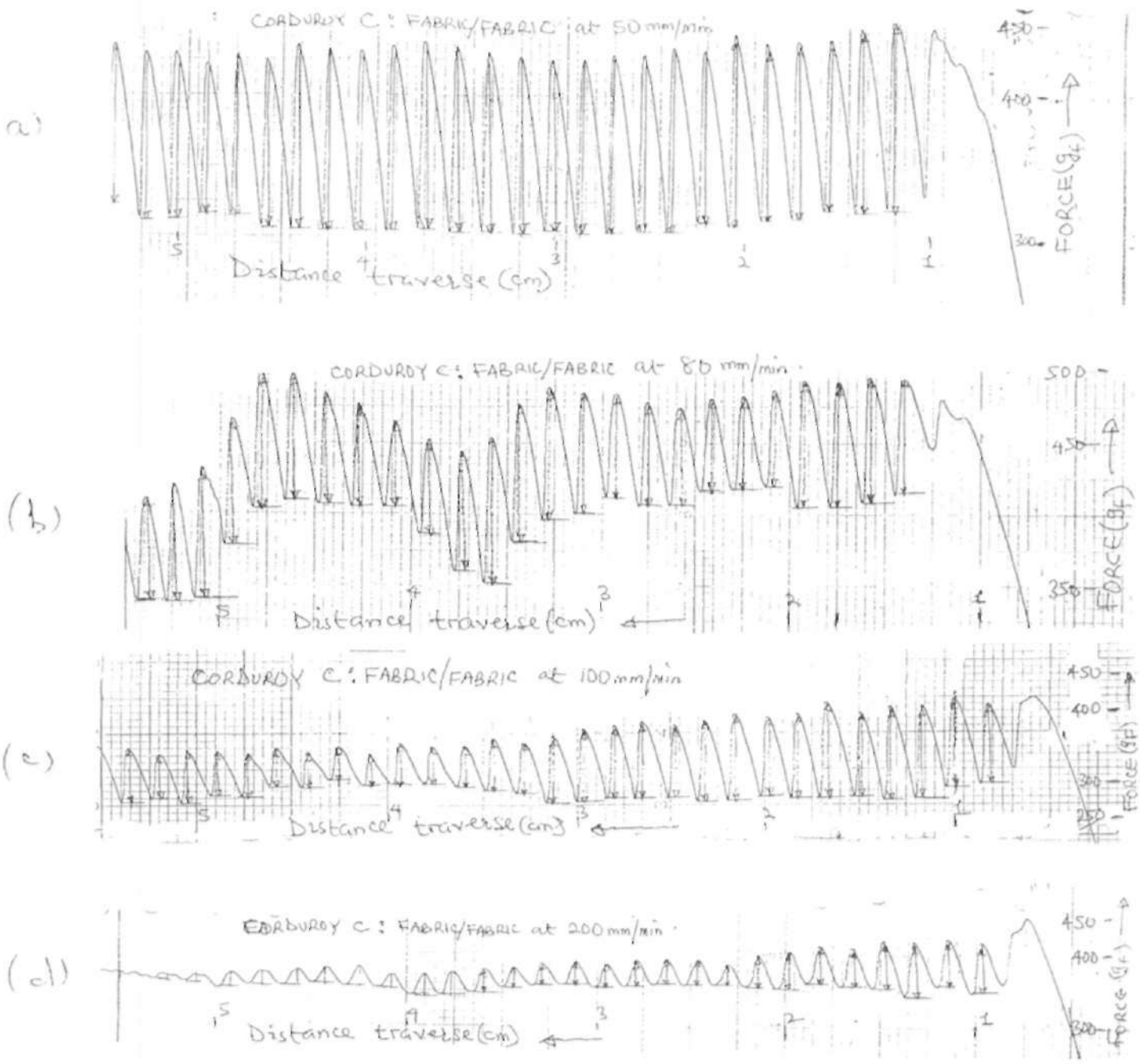


Fig. 25

Effect of Speed on frictional properties of Corduroy C

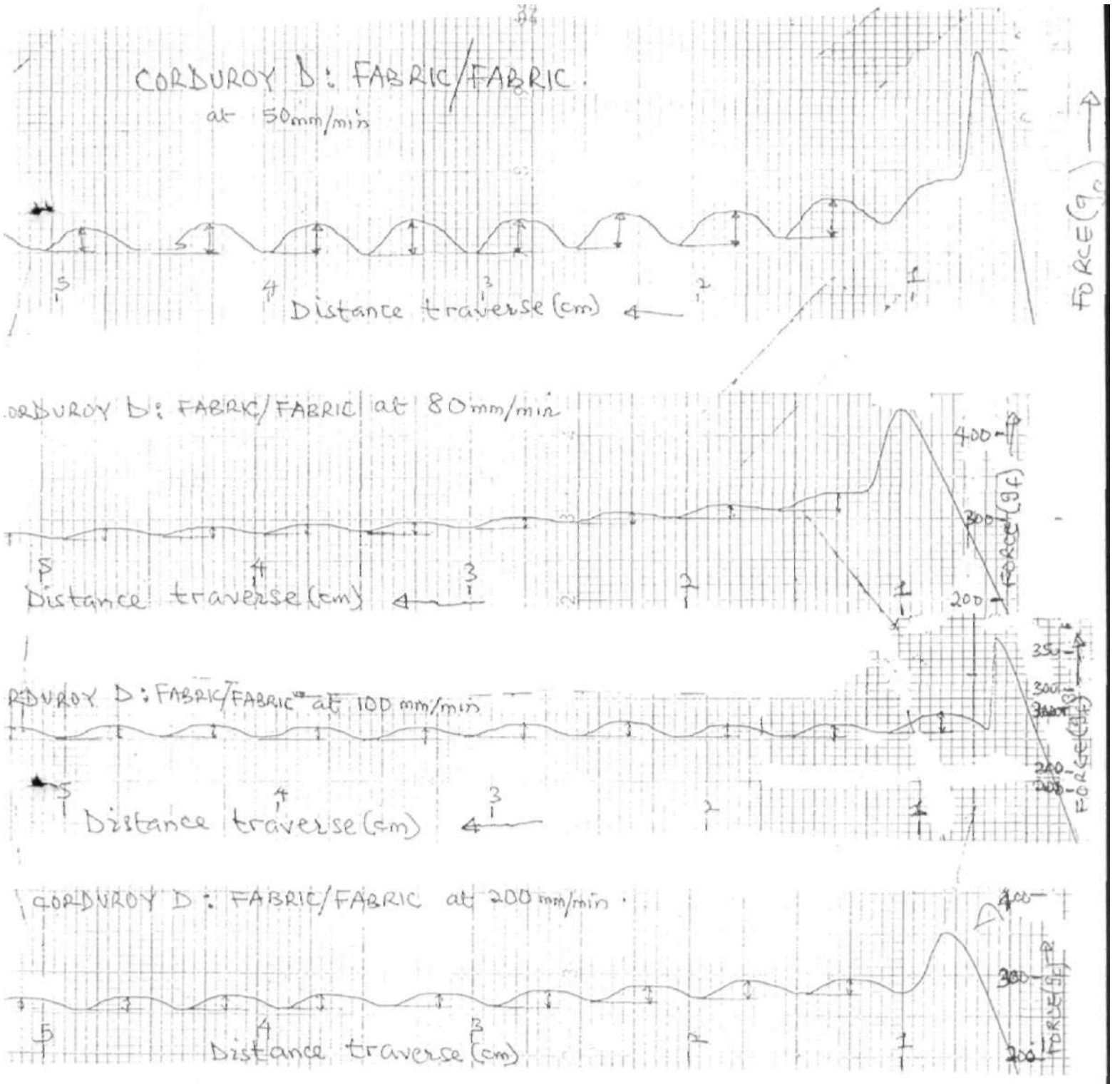


Fig. 26

Effect of speed on frictional properties of corduroy D

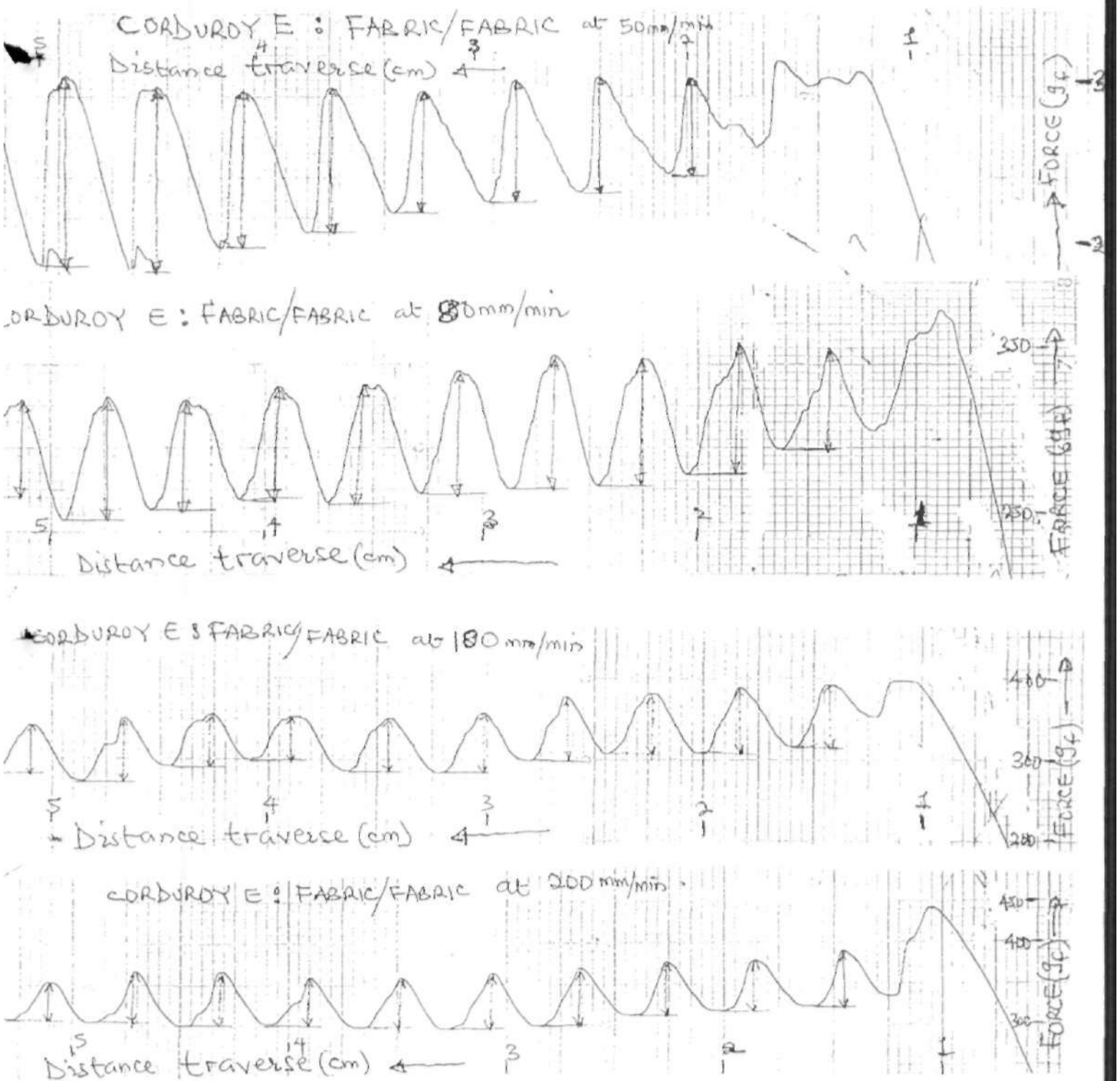


Fig. 27

Effect of speed on frictional properties of corduroy E.

Table 23 : Effects of sled Speed on frictional properties of Corduroys.

Frictional Parameters	Speed (mm/min.)	Corduroys A	B	C	D	E
Fs (g_f)	50	245 (1)	350 (1)	447.5 (3)	407 (3)	360 (1)
	80	315 (4)	375 (2)	467.5 (4)	430 (4)	372.5 (2)
	100	280 (2)	390 (3)	420 (1)	365 (2)	395 (3)
	200	280 (2)	405 (4)	450 (2)	350 (1)	440 (4)
Fk (g_f)	50	200 (1)	340 (4)	370.8 (4)	296.8 (4)	305 (2)
	80	205 (2)	300 (1)	327.7 (2)	290.0 (3)	295 (1)
	100	230 (3)	310 (2)	327.0 (1)	252.5 (5)	325 (3)
	200	250 (4)	325 (3)	370.0 (3)	270.0 (2)	335 (4)
$F_A(g_f)$	50	65 (1)	135 (4)	119.4 (4)	18.3 (3)	91.3 (4)
	80	110 (2)	45 (2)	80 (2)	12.5 (2)	70 (2)
	100	160 (4)	80 (3)	80 (2)	7.5)1)	70.5 (3)
	200	150)3)	40 (1)	35 (1)	20.0 (4)	62.5 (1)
F_N	50	6 (1)	14	27 (2)	9 (1)	10 (1)
	80	7 (4)	14 (	25 (1)	9 (1)	10 (1)
	100	6 (1)	14	29 (3)	10 (3)	11 (3)
	200	6 (1)	14	29 (3)	10 (3)	11 (3)

Theoretically, the resistance to motion would be expected to increase with the time of contact (74, 75). Thus any increase in speed will be expected to reduce the frictional parameter. This trend could b observed with the static frictional resistance of coduroys A and D, kinetic frictional resistance of corduroys C and D, and frictional amplitude of all except corduroy A. This means that, at higher speeds the cords are hardly detected or discriminated because of the 'bedding effect', hence the reduction in amplitude. A comprehensive mechanism responsible for this has recently been worked out by Ajayi and Darma (80).

Roder (53), however found an increase in friction with speed at much higher speeds. This could be the case as with the static frictional resistance of corduroys A and E, kinetic frictional reistance of corduroys A,B and E, and frictional amplitude of corduroys A. This suggested that at high speed there is shorter loading time, and at lower speed there is longer loading time hence higher bedding effect and increased frictional resistance.

Static frictional resistance of corduroy C did not show any consistent trend.

In most cases, the number of peaks remained fairly constant. This confirmed the ability of frictional experiment to detect all the cords at different speeds.

3.1.9 Effects of fibre content on fabric drape coefficient:-

The result of the drape tester for all the plain woven fabrics are shown in Table 24.

Table 24: Drape coefficient of some plain woven fabrics.

Fabrics	Drape Coefficient (%)
Cotton	58.92 (3)
Viscose rayon	27.13 (1)
Triacetate	28.97 (2)
Wool	-

Values in parenthesis represent rank order.

The results showed that the fabrics can be arranged in order of increasing drape coefficient as viscose rayon, triaectate and cotton. This is to be expected because they are made up of different fibres. Livesey and Owen (16) stated that the fabric flexural rigidity is a function of the fibre flexural rigidity. Except for viscose rayon, the results agreed with Smith's (35) ranking.

3.1.10 Effects of fibre content/fabric bending length:-

The results obtained from the bending length tester for all the plain woven fabrics were used to calculate their flexural rigidities using the fomula given in chapter 2. The flexural rigidities are shown in Table 25.

The result in Table 25 shows that the fabrics can be arranged in order of increasing the bending lengths and flexural rigidities as viscose rayon, cotton, triacetate and wool. This result agreed perfectly with the comment made by Peice (2) that other things being equal, the flexural rigidity increased with fabrics thickness.

Table 25 : Bending lengths and flexural rigidities of some fabrics

Fabrics	Bending length 'L' (cm)		Fabric Weight 'W'	Flexural rigidity 'G' (mg/cm)	
	Warp	Weft	(g/m^2)	Warp	Weft
Cotton	1.8 (2)	1.7(2)	162.3	94.7 (2)	79.7 (2)
Viscose rayon	1.7 (1)	1.6 (1)	136.2	66.9 (1)	55.8 (1)
Triacetate	1.9 (3)	1.8 (3)	209.0	143.4 (3)	121.9 (3)
Wool	2.8 (4)	2.8 (4)	298.2	654.6 (4)	654.6 (4)

3.1.11 Effect of fabric structure on drape coefficient δ^-

The result of the drape tester for all the corduroys are shown in Table 26.

Results of Table 26, show that the corduroys could be arranged in order of increased drape coefficient as B, A, E, C and D. It should be noted that the higher the drape coefficient, the stiffer the fabric. The difference in the values could therefore be attributed to the fabric structure.

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Table 26 : Drape coefficient for some corduroys

Corduroys	Drape coefficient (%)
A	67.8 (2)
B	46.0 (1)
C	78.9 (4)
D	80.2 (5)
E	77.2 (3)

Values in parenthesis represent rank order.

3.1.12 Effect of fabric structure on bending length:-

The results obtained from the bending length tester for all the corduroys were used to calculate their flexural rigidities using the formula given in chapter 2, these are shown in Table 27.

Table 27 : Bending lengths and flexural rigidities of some corduroys.

Corduroys	Bending length 'L' (cm)		Farbric weight 'w'	Flexural rigidity 'G' (mg/cm)	
	Warp	Weft	(g/m^2)	Warp	Weft
A	1.6 (1)	1.2 (1)	339.5	139.1 (1)	58.7 (1)
B	2.3 (2)	1.8 (2)	369.9	450. (3)	215.7 (3)
C	2.6 (4)	2.1 (4)	222.0	390.2 (2)	205.6 (2)
D	2.8 (5)	2.3 (5)	294.4	646.3 (5)	658.2 (5)
E	2.5 (3)	1.9 (3)	369.2	576.9 (4)	253.2 (4)

Values in parenthesis represent rank order.

On the basis of increased bending length, the corduroys are arranged as A,B,E,C and D. Though, corduroy A remains most limp and D stiffest, others differ because flexural rigidity takes weight into account. The fabric could therefore be arranged in order of increasing stiffness as A, C, B, E and D. The result further confirmed the differences in rigidities due to structure. This could be due to the differences in linear densities (17,35), diameter (35), fibre content (16) or fabric thickness (2).

3.2 Subjective assessment of fabric handle:

3.2.1 Paired comparison method:-

This is subjective method of inspection where two fabrics are presented to the judges who assess which of the pair in their opinion has the better property. Mathematical techniques assist the interpretation of results. The success of this method depends upon the ability of the judge to discriminate differences consistently. Details of this method and the mathematical techniques for interpretation of the results are as given in Appendix 1. Only one table will be shown for the calculation of coefficient of rank correlation and that of Kendall coefficient of concordance. All others were calculated in a similar way.

3.2.1.1 Effects of fabric content on the subjective assessment of stretchiness:-

The plain woven fabrics were presented at random to each of the eleven female assessors to judge their stretchiness. The result is given in Table 28.

Table 28: Stretchines ranking of plain woven fabrics.

Assessors	Fabrics and Ranks			
	Cotton	Viscose rayon	Triacetate	Wool
1	3	2	1	4
2	4	2	3	1
3	4	3	2	1
4	3	4	2	1
5	3	1	2	3
6	3	4	1	2
7	3	2	4	1
8	4	1	3	2
9	4	3	1	2
10	4	2	3	1
11	4	3	2	1
Rj (Sum of ranks)	39	27	24	19
$Rj - \frac{\sum Rj}{N}$ (sum of ranks-mean)	11.75	- 0.25	- 3.25	- 8.25
$(Rj - \frac{\sum Rj}{N})^2$	138.06	0.0625	10.56	67.76

$\sum Rj = 109$ (sum of Rj)

$\frac{\sum Rj}{N} = 27.25$ (mean of Rj)

The results showed that the fabrics could be subjectively ranked in the order of increased stretchniness as, wool, triacetate, viscose rayon and cotton. This result when compared to the result of Table 18 showed perfect agreement with the Young modulus. The more stretchy the material is,the higher its Young's modulus.

However, the Spearman coefficient of rank correlation showed agreement with only two assessors as given in appendix 1 a . This indicates the difficulty associated with correlating the objective elongation with the subjective stretchiness.

From the Kendall coefficient of concordance value calculated in appendix 1 b showed perfect agreement among the judges at level of significance p (0.01), this means that there is less than 1 % probability that the results were obtained by chance. As such the subjective ranking perfectly holds.

3.1.1.2 Effects of scouring on the subjective assessment of stretchine

The scoured samples were presented at random to each of the assessors to judge their stretchiness, the results is given in Table 29.

Table 29 : Stretchines ranking of Scoured fabrics

Number of wash / Assessors	Fabrics and ranks				
	1	3	6	8	10
1	5	1	2	2	2
2	5	4	1	2	3
3	5	4	3	1	2
4	2	2	2	5	1
5	4	2	1	2	4
6	3	3	2	3	1
7	5	3	3	1	1
8	5	4	3	2	1
9	5	1	4	2	2
10	2	2	2	1	5
11	5	4	1	3	2
Rj	46	30	24	24	24
$Rj-\frac{\sum Rj}{N}$	16.4	0.4	- 5.6	- 5.6	- 5.6
$(Rj - <Rj)^2$	268.96	0.16	31.36	31.36	31.36

$\sum Rj = 148$ $\sum Rj/N = 29.6$

From the Rj values, there is an increase in stretchiness between the first and the sixth washes, but thereafter remain constant upto the tenth wash. This may suggest that maximum consolidation was established after six washes. However, Figure 6, suggest a decrease in elongation with increased number of washes. These results were compared as given in appendix 1 c. The degree of agreement between the judges was also calculated as in appendix 1d. The Spearman rank correlation coefficient calculated in appendixl c showed that only one judge agreed with the objective ranking at level of significance p (0.01). Two at level of significance P(0.05), all other judgements were negatively correlated with the objective ranking. This further confirms the difficulty associated with correlation of extension with subjective stretchiness. It may therefore be concluded at this stage that the modulus is a better parameter for the objective specification of fabric stretchiness.

From the Kendall coeefficient of concordance calculated in appendix 1 d, there was a perfect agreement among the judges at level of significance P(0.01). This means that there is less than 1% probability that the results were obtained by chance. As such the subjective rankings mentioned in section hold perfectly.

3.2.1.3 Effects of Mercerization on the subjective assessment of stretchiness:-

The mercerized samples were presented at random to each of the assessors to judge their stretchiness, the result is given in Table 30.

Table 30: Stretchiness ranking of Mercerized fabrics

Caustic soda concentration (%) / Assessors	Fabrics and ranks			
	10	15	20	25
1	1	2	4	3
2	1	3	3	2
3	1	3	1	3
4	1	3	1	3
5	1	3	4	2
6	1	1	3	3
7	1	4	2	3
8	2	3	1	4
9	1	2	3	4
10	1	3	4	2
11	1	2	3	4
Rj	12	29	29	33
$Rj - \sum Rj/N$	-13.75	3.25	3.25	7.25
$(Rj - \sum Rj/N)^2$	189.06	10.56	10.56	52.56

$\sum Rj = 103$ $\sum Rj/N = 25.75$

From the Rj values, there is an increased stretchiness from 10% to 15% caustic soda concentration, it then remained constant up to 20%, thereafter it increased again to 25% concentration. This generally showed an increased in stretchiness with concentration. Figures 8 and 9 also showed increased in both shrinkage and crimp with caustic soda concentration respectively. These samples are subjectively compared as given in appendix 1 (e). The degree of agreement between the judges is calculated and shown in appendix 1 (f).

The Spearmans rank correlation coefficient showed that only two judges agreed with the objective ranking at the level of significance P (0.01), all others yielded negative correlations. This also confirmed difficulty associated with correlating shrinkage or crimp with stretchiness.

From the Kendall coefficient of concordance given . in appendix 1 f, there was a perfect agreement among the judges at level of significance P(0.01). This means that there is less than 1% probability that the results were obtained by chance. As such subjective rankings mentioned here perfectly holds.

3.2.1.4 Effects of fabric structure on the subjective assessment of smoothness:-

The corduroys were presented at random to each of the assessors to judge their smoothness. The results is given in Table 31.

From the Rj values, the corduroys could be arranged in the order of increased smoothness, as , B,C,E,A and D. This was compared with the kinetic frictional force given in Table 21 as in appendix 1 (g). According to Kim and Vaughn (3) kinetic friction coefficients are more closely associated with sensory hand qualities than static friction coefficients in woven fabrics. The degree of agreement between the judges is calculated as in appendix 1 h .

From the Spearman's rank corelation coefficient, no agreement existed among the judges and the objective rankings.

Table 31 : Smoothness rankings of the corduroys.

Assessors	Fabrics and ranks				
	A	B	C	D	E
1	5	2	1	4	3
2	5	1	2	3	3
3	4	2	1	4	3
4	4	1	1	5	3
5	4	1	2	4	3
6	4	2	1	5	3
7	4	2	1	5	3
8	4	1	1	5	3
9	4	1	1	5	1
10	2	1	4	5	2
11	3	1	3	5	1
Rj	43	15	18	50	28
$Rj - \Sigma Rj/N$	12.2	-15.8	-12.8	19.2	-2.8
$(Rj-\Sigma Rj/N)^2$	148.84	259.64	163.84	368.64	7.84

$\Sigma Rj = 154$ $\Sigma Rj/N = 30.8$

This is in agreement with Kaswell's (64) findings that correlating friction coefficient with subjective smoothness is always negative. This is because of the multiplicity of factors that affect fabric friction (74), and the fact that this parameter may be insufficient for surface characterization.

However, Kendall coefficient of concordance showed agreement at level of significance P (0.01). This means that the agreement among the assessors is less than 1% that their results were obtained by chance.

3.2.1.5 Effects of Scouring on the subjective assessment of smoothness:-

The scoured samples were presented at random to each of the assessors to judge their smoothness. The results is given in Table 32.

From the Rj values, there was a decrease in smoothness with washings upto the sixth wash; it thereafter remained constant upto the tenth washing. However, it was not compared with the objective frictional parameters because only the first and the tenth wash samples were tested objectively. The result agreed with an earlier hypothesis that the increase crown height might have been adjudged to mean roughness.

The degree of agreeement between the judges was calculated as in appendix 1 (i).

Kendall coefficient of concordance showed agreement at level of significance (P. =.01). This means that the agreement among the assessors is less than 1 % that their results were obtained by chance.

Table 32: Smoothness ranking of the Scoured samples

Number of wash / Assessors	Fabrics and ranks				
	1	3	6	8	10
1	5	1	2	2	2
2	5	4	1	2	3
3	5	4	3	1	2
4	2	2	2	5	1
5	4	2	1	2	4
6	3	3	2	3	1
7	5	3	3	1	1
8	5	4	3	2	1
9	5	1	4	2	2
10	2	2	2	1	5
11	5	4	1	3	2
Rj	46	30	24	24	24
$Rj - \sum Rj/N$	16.4	0.4	-5.6	-5.6	-5.6
$(Rj - \sum Rj/N)^2$	268.96	0.16	31.36	31.36	31.36

$\sum Rj = 148$ $\qquad \frac{\sum Rj}{N} = 29.6$

3.2.1.6 Effects of Mercerization on the subjective assessment of smoothness:-

The mercerised samples were presented at random to each of the assessors to judge their smoothness. The results is given in Table 33.

From the Rj values, there was no consistent trend in smoothness ranking with increased caustic soda concentration. This was compared with the kinetic frictional resistance of Table 23 for the same reason given by Kim and Vaughnn (3), as calculated in appendix 1 (j). The degree of agreement among judges was also calculated as in appendix 1 (k).

Both Spearmans rank correlation coefficient and Kendall coefficient of concordance showed negative results. This means that neither the judges agreed with the objective ranks non among themselves. This further confirmed Kaswell (64) findings that friction results are difficult to correlate with subjectively assessed smoothness.

Table 33: Smoothness rankings of the mercerized samples

Caustic Soda Concentration (%) / Assessors	Fabrics and ranks			
	10	15	20	25
1	1	3	1	4
2	1	4	1	1
3	1	3	1	3
4	1	1	3	3
5	4	3	1	2
6	4	2	1	3
7	2	2	1	2
8	1	2	4	3
9	2	2	1	2
10	1	4	1	1
11	1	4	3	2
Rj	19	30	18	26
$Rj - \zeta Rj/N)$	- 4.25	6.75	- 5.25	2.75
$(Rj - \zeta Rj/N)^2$	17.96	45.56	27.56	7.56

$\zeta Rj = 93$ $\zeta Rj/N = 23.25$

3.2.1.7 Effects of fibre content and fabfic structure on the subjective assessment of stiffness:-

Both the plain woven fabrics and the corduroys were presented at random to each of the assessors to judge their stiffness. The results is given in Table 34.

This result was compared with combined flexural rigidities of Tables 25 and 27. The comparison was as given in appendix 1 (l). The degree of agreement among judges is given in appendix 1 (m).

The spearmans rank correlation coefficient showed that all the judges agreed with the objective ranks at level of significance P(0.05). Seven out of the eleven assessors also agreed with the objective ranks at level of significance P(0.01). This shows that judges were able to correlate the objective stiffness with their subjective rankings. This correlated well with an earlier work by Elder et-al (22) Ukponwan (4) and Syed (6).

Kendall coefficient of concordance showed agreement at level of significance P(0.01). This means that the agreement among the assessors is less than 1% that their results were obtained by chance .

Table 34: Stiffness ranking of the plain woven fabrics and the corduroys

Assessors	Fabrics and ranks								
	Cotton	Viscose rayon	Triacetate	Wool	Cord A	Cord. B	Cord. C	Cord. D	Cord. E
1	2	1	3	8	4	7	4	9	4
2	7	1	5	8	1	6	4	8	3
3	4	1	3	9	2	6	4	6	8
4	2	1	2	9	4	7	5	6	7
5	3	1	2	8	5	8	4	6	6
6	3	2	4	7	1	7	5	7	6
7	1	1	3	9	4	7	3	6	7
8	3	1	2	9	4	8	5	6	6
9	4	1	3	9	2	8	5	7	6
10	5	1	3	6	4	8	1	8	7
11	4	1	3	9	2	6	4	8	6
Rj	38	12	33	91	33	78	46	77	66
$Rj-\frac{\sum Rj}{N}$	-14.67	-40.67	-19.67	38.33	-19.67	25.33	-6.67	24.33	±3.33
$\left(Rj-\frac{\sum Rj}{N}\right)^2$	215.2	1654.0	386.9	1469.2	386.9	641.6	44.5	591.9	177.7

$\sum Rj = 474$ $\qquad \frac{\sum Rj}{N} = 52.67$

3.2.1.8 Effects of scouring on the subjective assessment of hairiness:-

Scouring or domestic washing frequently produces an increase in the surface fuzziness of fabrics. It was therefore thought that an assessment of this would provide some useful information. The scoured fabrics were presented at random to each assessor to judge their surface hariness by tactile feeling only. The result is given in Table 35.

From the Rj values, there is decreased hairiness with increased number of washes. This could be as result of wet abrasion and mechanical agitation during washing (74), the surface fuzziness might be expected to increase giving an apparent high softness as hypothesized by Elder et-al (22).

The results are by no means consistent because of the interplay between compression and hairiness.

Kendall coefficient of concordance showed agreement at level of significance P (0.01). This means that the agreement among the assessors is less than 1% that their results were obtained by chance.

Table 35: Hairiness ranking of the scoured cotton fabrics

Number of wash / Assessors	Fabrics and ranks				
	1	3	6	8	9
1	5	4	1	1	1
2	4	4	3	2	1
3	5	3	1	3	1
4	5	2	3	4	1
5	5	4	3	2	1
6	2	4	4	2	1
7	4	5	2	3	1
8	3	3	2	3	1
9	5	4	3	2	1
10	3	3	2	3	1
11	5	3	3	1	1
Rj	46	39	27	26	11
$Rj - \sum Rj/N$	16.2	9.2	-2.8	-3.8	-18,8
$(Rj - \sum Rj/N$	262.44	84.64	7.84	14.44	353.44

$\sum Rj$ = 149 $\sum Rj$ = 29.8

3.2.1.9 Effects of mercerization on the subjective assessment of softness:-

The mercerized fabrics were presented at random to each of the assessors to judge their softness. The result given in Table 36.

From the Rj values, there is decreased softness with increased caustic Soda concentration. This confirmed an earlier statement that the material mercerized at 25% caustic soda produced a bare hard surface (74)

Kendall coefficient of concordance showed agreement at level of significance P(0,05). This means that the agreement among the assessors is less than 5% that their result were obtained by chance.

3.2.2.2 Magnitude estimation:-

3.2.2.1 Effects of fabric structure on the magnitude estimation of Ridginess:-

Ridginess is an important attribute of corduroys. It affects the surface feel, durability as well as the aesthetic effects. A quantitative subjective method of assessing this was thought useful. The assessors were presented with the corduroys to comment about their feel of ridginess with reference to corduroy B rated 10. This value of 10 is choosen for easy calculations.

Table 36: Softness ranking of the mercerised fabrics.

Caustic Soda concentration (%) / Assessors	Fabrics and ranks			
	10	15	20	25
1	2	3	4	1
2	4	2	3	1
3	1	2	2	2
4	1	4	3	2
5	4	3	2	1
6	4	2	3	1
7	3	3	1	1
8	3	4	1	2
9	3	4	2	1
10	4	1	3	2
11	4	3	1	2
Rj	33	32	25	16
$Rj - \sum Rj/N$	6.5	5.5	- 1.5	- 10.5
$(Rj - \sum Rj/N)^2$	42.25	30.23	2.25	110.25

$\sum Rj = 106$ $\sum Rj/N = 265.$

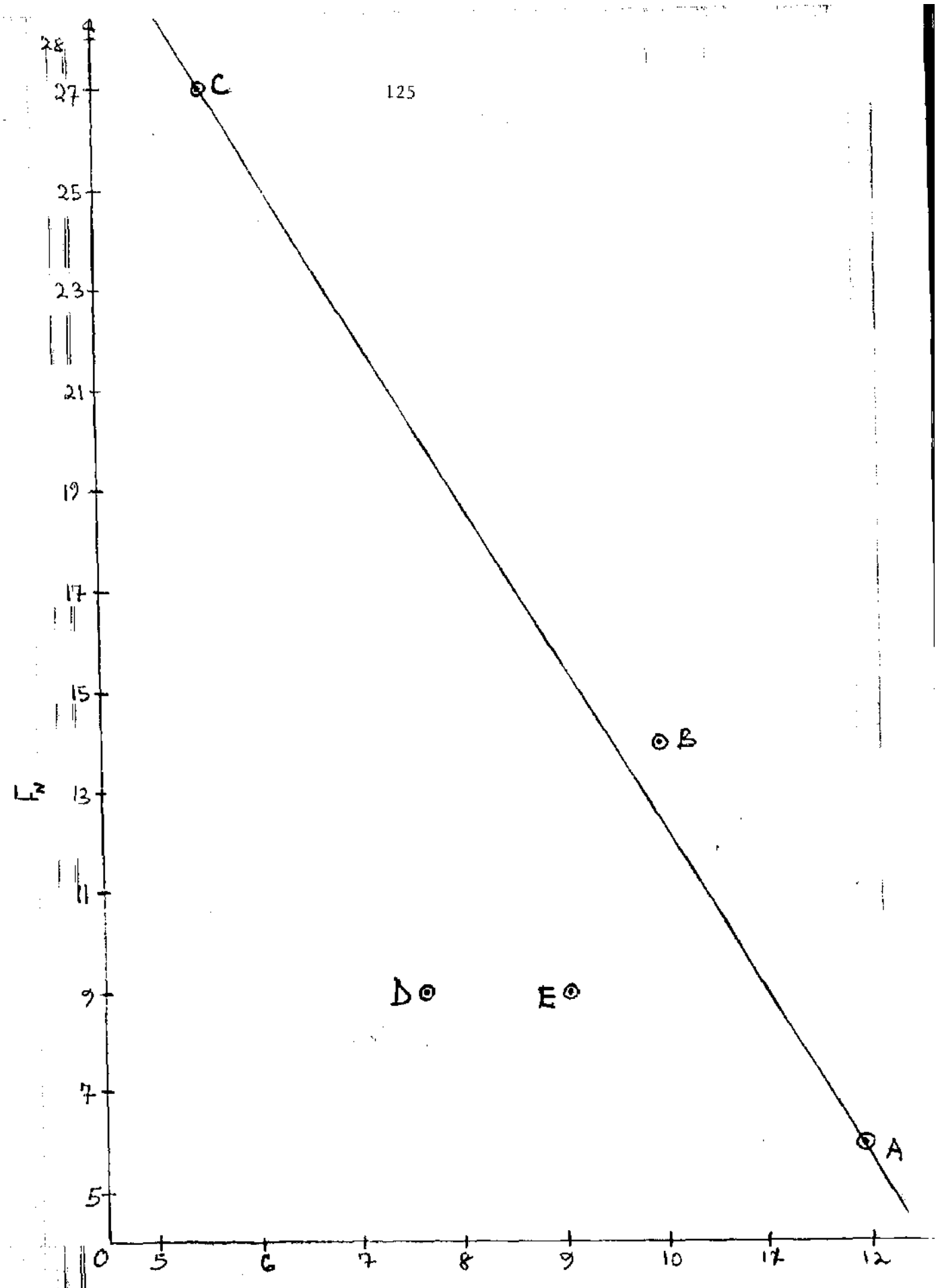
The result is given in Table 37. Geometric mean values rather than arithmetic mean, was calculated because of the ratio nature of the comparis A detail method of calculation is shown in appendix 3 a.

The number of peaks as given in Table 21 when plotted with the geometric mean for the ridginess of cords give an inverse linear relationship as shown in figure 28. This curve showed that the more the number of peaks the less ridged the material subjectively. This is because when cofds are close to each other the fingers cannot discriminate accurately between the ridges of the cords. Based on this the corduroys can be arranged on the basis of increased ridginess as C,B,D/E and A, a tie rank being produced between Fabrics D and E.

From another plot to justify Steven's law (70) frictional resistance against ridginess estimation also gave an inverse linear relationship as shown in figure 29. This curve showed that the more the ridginess, the less the frictional resistance. Generally, the lower the numerical values of frictional resistance , the rougher the material. On this basis the corduroys may be arranged in order of increased roughness as C,D,E,B and A. This further confirmed the earlier ranking as under 3.1.5.

Table 37: Ridginess rating of corduroys.

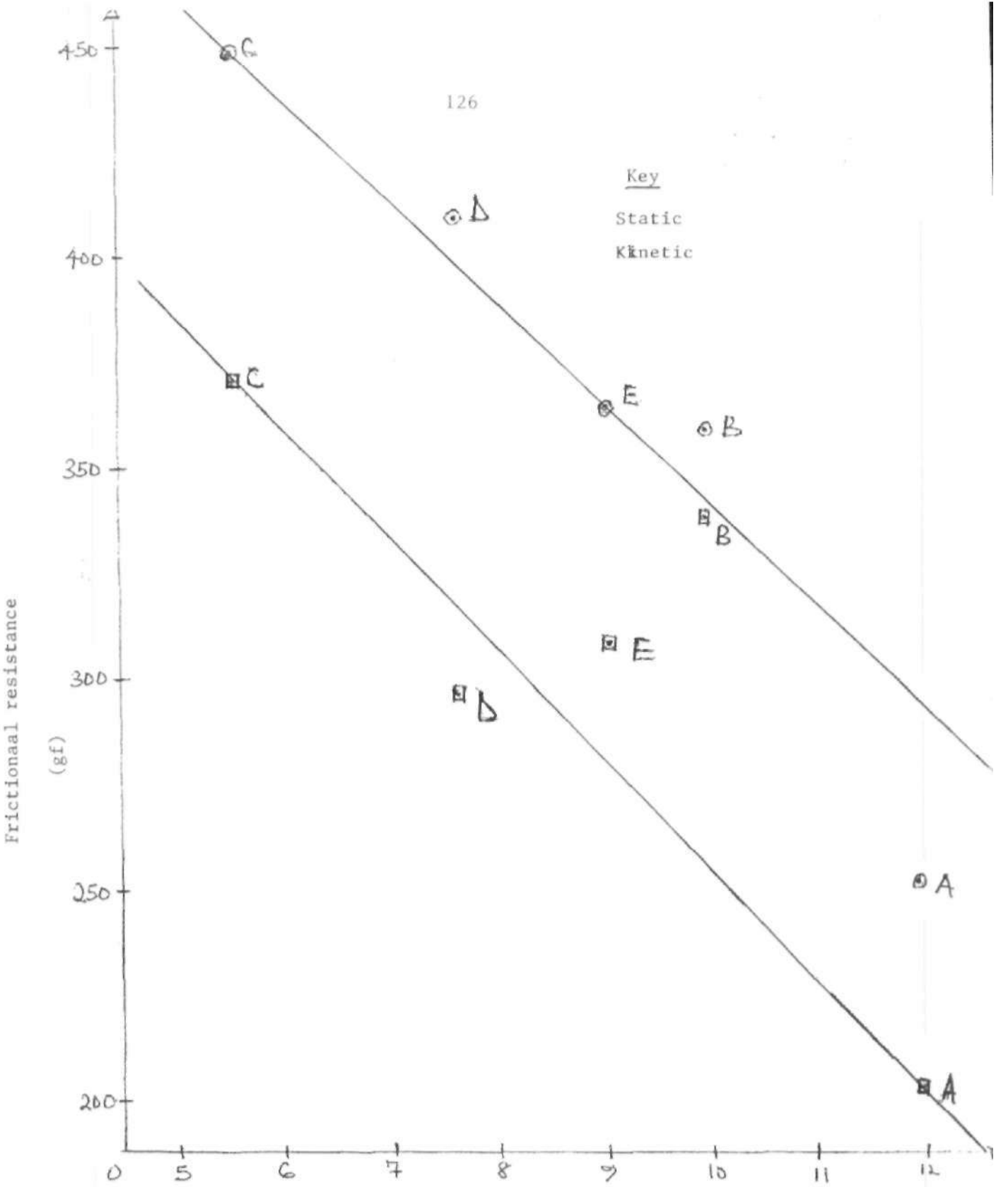
Assessors	Corduroys and rating				
	A	B	C	D	E
1	13	10	6	12	8
2	7	10	7	12	8
3	8	10	5	8	12
4	7	10	5	4	7
5	17	10	6	6	6.5
6	20	10	5	20	10
7	15	10	5	13	13
8	13	10	8	8	15
9	14	10	7	8	8
10	30	10	4	3	8
11	5	10	4	4	8
Product	7.095×10^{11}	10×10^{10}	1.411×10^{8}	5.521×10^{9}	3.489×10^{10}
Geometric mean ($\sqrt[n]{\text{product}}$)	11.95	10	5.51	7.68	9.09



Ridginess estimation for the corduroys

Fig. 28

Ridginess estimation Vs number of peaks of the corduroys.



Ridginess estimation for the corduroys

Fig. 29

Steven's law (frictional resistance Vs Ridginess estimation).

3.2.2.2 Magnitude estimation of cord width:-

The assessors were presented with the corduroys to comment on the wideness of ridges with reference to corduroys B rated 10. The result is given in Table 38. Geometric mean values were again calculated as in 3.2.2.1 A plot of the frictional pitch given in Table 21 versus geometric mean of cord width gave a direct linear relationship as in Figure 30. This curve showed that frictional pitch increases directly with the width of the ridges. This suggests that the frictional results agreed with the width of the cord. If we assume that thelarger the numerical value or the frictional pitch the rougher the material, the corduroys could be arranged in order of increased roughness as C, B, D/E and A. This further confirmed corduroys C as the smoothest and A as the roughest .

Table 38: Ridges wideness rating of corduroys

Assessors	Corduroys and rating				
	A	B	C	D	E
1	20	10	3	12	12
2	12	10	7	9	12
3	30	10	3	15	12
4	15	10	6	13	13
5	17	10	5	13	13
6	20	10	5	20	20
7	20	10	5	13	13
8	20	10	6	15	13
9	22	10	4	15	12
10	20	10	5	13	12
11	20	10	5	18	12
Product	1.293×10^{14}	10×10^{10}	2.835×10^{7}	3.748×10^{12}	1.706×10^{12}
Geometric mean values	19.18	10	4.76	13.90	12.94

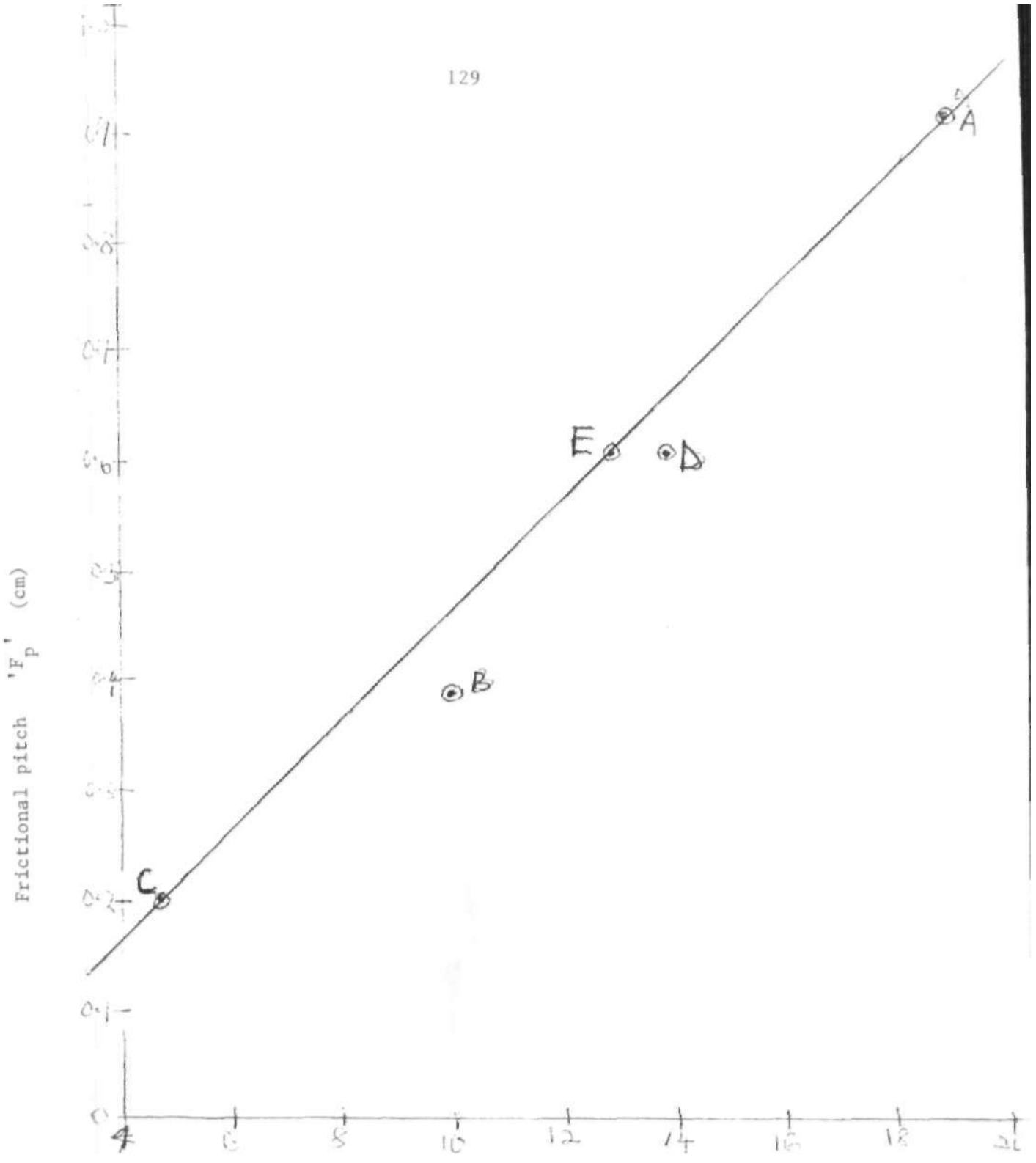


Fig. 30.

Frictional pitch $'F'_p$ (cm) Vs magnitude estimation of cord width.

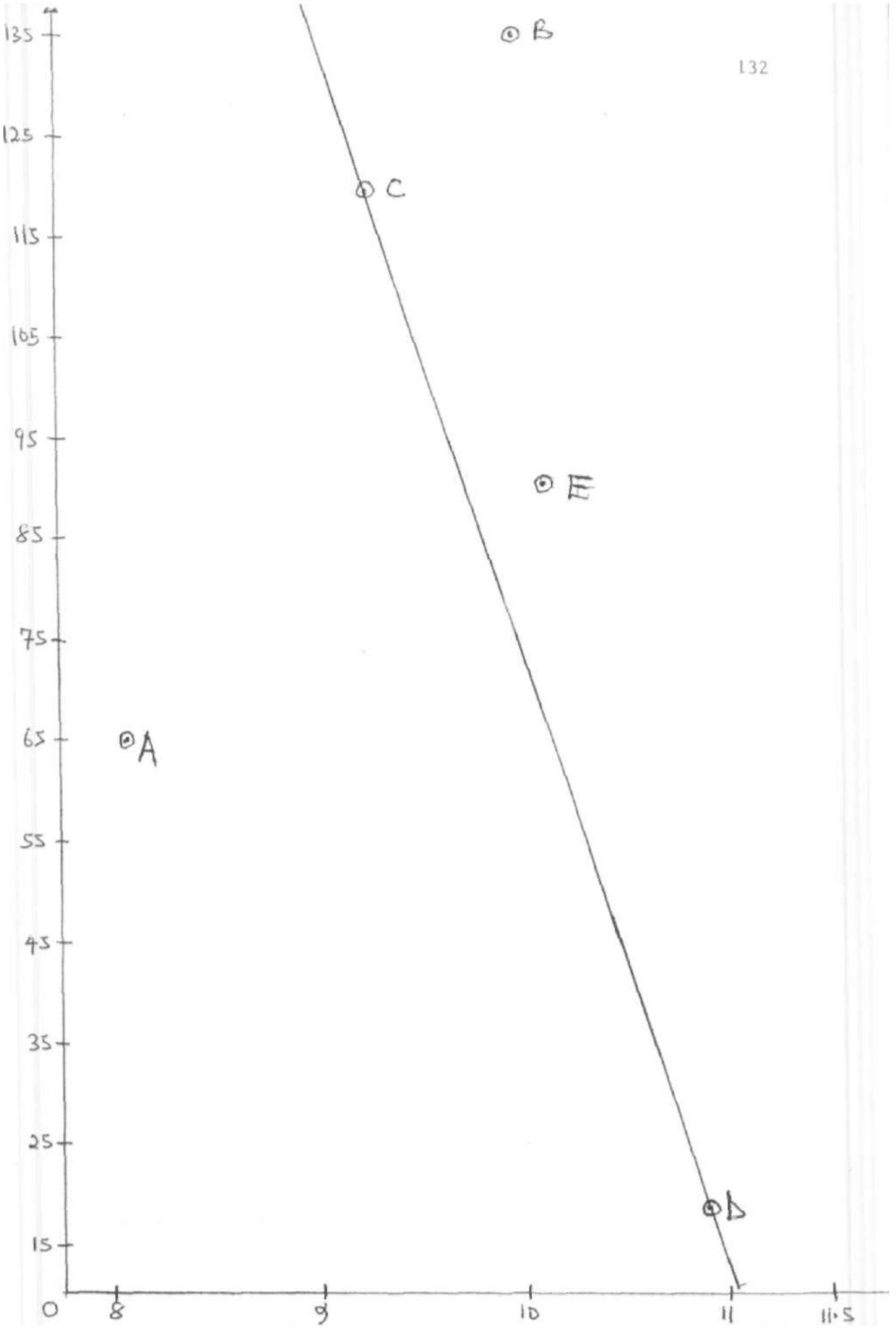
3.2.2.3 Magnitude estimation of shallowness of ridges:-

The assessors were presented with the corduroys to comment on the shalloweness of the ridges with reference to corduroys B rated 10. The result is given in Table 39. Geometric mean values were calculated as in 3.2.2.1 .

A plot of frictional amplitude given in Table 21 against the shalloweness estimation of ridges gave the relationship shown in Figure 31. Though the points are scattered, the best line suggested an inverse relationship. This means that the shallower the ridges the lower the frictional amplitude. This could be atributed to the difficulty in detecting the cords when they are shallow especially at high speed. Generally, the higher the frictional amplitude, the higher the surface asperities, and the rougher the feel. The curve therefore dictates that the corduroys could be arranged in order of increased roughness as D, A,E,C and B. This result by far deviate from other rankings and may be due to the confusion in separating the flatness of ridges from the shallowness of the fibre tufts that makes the pile.

Table 39: Shallowness of ridges rat ing of corduroys.

Assessors	and Corduroys/ratings				
	A	B	C	D	E
1	15	10	5	8	8
2	8	10	12	8	12
3	15	10	5	9	12
4	6	10	4	14	14
5	8	10	4	14	13
6	5	10	20	20	5
7	7	10	20	7	8
8	5	10	15	13	13
9	7	10	15	7	8
10	5	10	20	12	11
11	18	10	5	15	12
Product	9.526×10^9	10×10^{10}	4.32×10^{10}	2.589×10^{11}	1.151×10^{11}
Geometric mean value	8.08	10	9.29	10.90	10.13



Magnitude estimation of shallowness of ridges

Fig_ 31

Frictional amplitude Vs shallowness estimation of ridges.

CHAPTER 4

Conclusion.

From the result in this investigation, the following conclusions may be ventured:

(1) The smaller the differences between the static and the kinetic frictional resistance the smoother the material, this rated corduroy D as the roughest and B the smoothest. On the basis of amplitude, corduroy D was the smoothest, because the higher the amplitude, the rougher the surface. Similarly, the higher the pitch the rougher the surface, this however, rated corduroy A as the roughest and C the smoothest.

The number of peaks increases with the smoothness of the surface, this featured corduroy A as the roughest and C the smoothness

These multiple parameters mislead one on what actually represent surface smoothness, especially when rated subjectively (64, 74).

(2) At higher sled speeds the cords are hardly discriminated because of the bedding effect, this makes the fabric feel smoother.

(3) The weft pile fabrics feel smoother when the cords are closer or when they are shallower.

(4) Among the plain woven fabrics studied, cotton needed heaviest load before breakage whereas wool needed lightest. However, wool extended most before breakage and triacetate, least. Triaectate on the otherhand required highest evergy to rupture, and wool required least. There was a fair ranking based on tenacity and breaking elongation that agreed with earlier findings (35 - 37).

5. Young's modulus was found to be more closely related to the subjective stretchiness than all other tensile parameters.

(5) Among the plain woven fabrics studied, their flexural rigidities showed that wool was stiffest, followed by cotton, then triacetate whereas viscose rayon was most limp. This was also in agreement with their subjective rankings as suggested by earlier findings (22,64).

(7) There was decrease in elongation as the number of wash increases due to fabric consolidation. This agreed with earlier findings (2,8). Scouring, also increased the crimp percentage in the warp yarns due to consolidation, and decreased it in the weft as yarns have to coil more over the warp.

(8) Increased caustic soda concentration increased the shrinkage, crimp and the crown height, this was interpreted subjectively as hard and rough surfaces.

(9) Increased caustic soda concentration decreased subjective softness. This supported earlier finding that 25% caustic soda produced bare surface (74).

(10) Magnitude estimation of cord ridginess decrease as the number of peaks increases. Whereas Magnitude estimation of cord width increased with frictional pitch. Similarly, Magnitude estimation of ridges shallowness increased with frictional amplitude.

(11) From the first to sixth wash, there was increased stretchiness and decreased smoothness subjectively, thereafter they remained constant. This was due to consolidation and it also suggested that fabric stabilizes after the sixth wash.

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APPENDIX 1

PAIRED COMPARISONS OF FABRICS

SCOPE

To rank various fabrics for subjective properties, such as handle, dye regularity, colour differences etc., by the paired comparison technique. Comparisons of more than 6 fabrics are not recommended, because of increasing fatique of operator and assessors. This technique can be used to obtain a one-dimensional ranking only.

DEFINITION

Paired comparison technique: A ranking technique by which each specimen is compared with each other specimen separately and in isolation. It is prefereable to a simple ranking in that (i) it can be carried out 'blindfold'; (ii) it affords the possibility of checking the consistency of each assessor in his decisions, the agreement between assessors, and the significance of differences between rankings.

PRINCIPLE

Each fabric is compared in turn with each other fabric and at each comparison the assessor is asked to answer a partinent question. The assumed results from a series of assessors are analysed in order to rank the fabrics in order for the relevant property. Assessment of the significance of the ranking can be made, where necessary, using a computer programme.

APPARATUS

Pillory box (where necessary). This is a screen, with armholes, which prevents the assessor seeing the fabrics he is judging by touch.

CONDITIONING AND TESTING ATMOSPHERE

No special conditions are necessary unless fabrics being assessed are likely to be affected by ambient conditions In the latter case all specimens are conditioned and all assessments carried out in the standard atmosphere for testing, i.e. a relative humidity of 65 + 2% and a temperature of 20 ± 2°c.

TEST SPECIMENS AND ASSESSORS

Specimens need not be in any special form, but should be uniform. The larger the number of assessors, the more representative will be the final ranking of general opinion. A minimum of 6 assessors is realistic. Each assessor will be required to make ½ k (k-1) paired comparisons, where k is the number of specimens to be ranked. Each assessor should complete his "set" of assessments; any uncompleted set should be discarded, not finished by another assessor.

PROCEDURE

Establish with the job author the question to be asked to each assessor. Example of useful questions are:::::: -

Which fabric is softer ?

Which fabric is bulkier ?

Which is the least synthetic ?

Which appears most irregular ?

The question should relate as far as possible to only one aspect of the fabric.

Questions such as :-

Which fabric do you prefer ?

Which fabric has the best handle?

involve judgements of several aspects, which different assessors may rank differently. Such questions should preferably be avoided, but if necessary to give a general impression, should be asked of a large number of assessors (5-29) so that individual idiosyncracies will not unduly affect the impression gained.

Give the specimens alphabetical references and mark these along the sides of a standard chart (see Figure 1). Mark the chart with the assessors' name.

Seat the assessor at the pillory box.

Select two of the specimens at random and present them to the assessor. Ask the agreed question, and record the answer in the upper triangle on the chart. If, for example, specimens B and D are being compared, and D is chosen as best answering the requirements of the question, record a '1' in the box in column D, row B. If B is chosen, record a '0' in this box. If no choice is given, record a '½' in this box (figure 1A gives an example for the specimens).

Repeat for all other pairs of specimens, selecting each pair randomly.

Repeat the same procedure for the remaining assessors.

CALCULATION AND EXPRESSIONS OF RESULTS

Complete the lower triangle of the chart. In the example where D is chosen rather than B, a '1' was recorded in the box in column D, row B, consequently, a '0' should be recorded in the box in column B, row D (see figure 1B).

Sum the (k-1) entries in each column.

Repeat the chart for each assessor.

Sum the totals on the charts for each specimen to give the overall ranking. The specimen with the highest score then ranks as the softest, bulkiest, etc. and that with the lowest score the least soft, least bulky, etc.

	A	B	C	D	E	F	G	H	
A		1	1	½	1	1	1		A
B			0	1	1	1	1		B
C				0	1	1	1		C
D					1	1	1		D
E						0	1		E
F							0		F
G									G
H									H
Total									Total

Figute 1 A

Enter results in upper triangle only

Enter '1' if column ranked higher

Enter '0' if row ranked higher

	A	B	C	D	E	F	G	H	
A		1	1	½	1	1	1		A
B	0		0	1	1	1	1		B
C	0	1		0	1	1	1		C
D	½	0	1		1	1	1		D
E	0	0	0	0		0	1		E
F	0	0	0	0	1		0		F
G	0	0	0	0	0	1			G
H									H
Total	½	2	2	1½	5	5	5		Total

Figure I B

STATISTICS FOR PAIRED COMPARISON RESULTS

From the final ranking of the scores SPEARMAN RANK CORRLATION COEFFICIENT r_S can be used to compare, for example, subjective judgements of handle with and individual objective measurement.

FORMULA: $$r_S = 1 - \frac{6 \Sigma d^2}{N(N^2-1)}$$

where N is the number of fabrics ranked and d is the difference between the two ranks.

METHOD: make a list of the fabrics and under each fabric enter the ranks for the two measurements being compared. Calculate the difference (d) between the two ranks, square each difference (d^2) and add together these squared difference ($<d^2$). Then enter this value and the value order of N (i.e. the number of fabrics) into the fomula and calculate.

EXAMPLE: For a set of seven fabrics subjective ranks have been obtained and these are to be compared with the rank order of an objective measurement of these seven fabrics.

Fabrics	A	B	C	D	E	F	G
Subj. Ranks	2	6	5	1	3	4	7
Obj. Ranks	3	4	2	1	6	5	7
Difference(d)	-1	2	3	0	-3	-1	0
d^2	1	4	9	0	9	1	0

$$r_S = 1 - \frac{6< d^2}{N(N^2 - 1)}$$

$$= 1 - \frac{6(24)}{7(7^2 - 1)}$$

$$= 1 - 0.429$$

$$= 0.571$$

For these 7 fabrics the correlation between the subjective and the objective ranks is $r_S = 0.571$. To test for the SIGNIFICANCE of this result, it is customary to test what is called the NULL HYPOTHESIS. This means that we consider the 2 sets of ranks are NOT associated and that the obtained value of r_S differs from zero only by chance.

To determine this for small samples (N<10) use TABLE A attached. If the calculated value of r_S equal or exceeds the value from the tables then the NULL HYPOTHESIS is rejected and it is accepted that the calculated value is significant at the level indicated, either 0.05 or 0.01. This means that there is a less than 5% or 1% probability that the results were obtained by chance.

EXAMPLE: From the data where N = 7 and $r_S = 0.571$ TABLE A shows that r_S would have to be greater than or equal to (>) 0.714 to be significant and that therefore the NULL HYPOTHESIS is accepted,meaning that the 2 sets ranks are NOT associated. For larger samples N> 10 the null hypothesis may be tested by the formula

$$t = r_S \sqrt{\frac{N-2}{1-r_S}} \quad 2$$

Calculate the 't' value from this formula. Refer to TABLE B, (df = N-2). Again the calculated value for 't' has to be greater than or equal to the tabled value for 't' before the null hypothesis can be rejected and it can be concluded that there is association between the 2 rank orders.

To compare more than 2 sets of ranking KENDALL COEFFICIENT OF CONCORDANCE W, would be appropriate. This is a measure of the relationship between several rankings and therefore may be used to express the degree of association among the rankings of fabrics obtined by several test methods or by several judges.

FORMULA : $$W = \frac{S}{1/12\ k^2\ (N^3 - N)}$$

where N is the number of fabric ranked

k is the number of tests or judges

s is the sum of squares of the difference between the total of the ranks for each fabric and the mean of these totals i.e

$$S = \sum (Rj - \langle Rj/N)\ 2$$

METHOD:

Make a list of the fabrics and under each fabric enter the ranks obtained for the tests or from the judges. Sum the ranks (Rj) for each fabric. Then sum the Rj and divide by N (the number of fabrics) to obtain the mean value of Rj. Substract this mean from the total rank (Rj) for each fabric and square the numbers thus obtained. Add the squared number derived from each fabric. This is the 's' value.

EXAMPLE: A set of six fabrics has been ranked by 3 judges.

JUDGES	F A B R I C S					
	A	B	C	D	E	F
1	1	6	3	2	5	4
2	1	5	6	4	2	3
3 3	6	3	2	5	4	1
Rj (Sum of Ranks)	8	14	11	11	11	8
Rj - $\sum$Rj/N (Sum of Ranks-Mean)	8-10.5 =-2.5	14-10.5 =3.5	11-10.5 =0.5	11-10.5 =0.5	11-10.5 =0.5	8-10.5 =-2.5
(Rj - $\sum$Rj/N) 2	6.25	12.25	0.25	0.25	0.25	6.25

$\sum$Rj = 63 (Sum of Rj)

$\sum$Rj/N=10.5 (Mean of Rj)

$\Sigma(Rj - \Sigma Rj/N)^2 = 25.5$

(Sum of squared deviations from the mean)

i.e $S = 25.5$

$$W = \frac{S}{1/12k^2\ (N^3-N)}$$

$$= \frac{25.5}{7\frac{1}{2}\ (3)^2\ (6^3-6)}$$

$$= 0.16$$

W = 0.16 expresses the degree of agreement among the judges. To test the significance of W consult TABLE C attached. This is applicable for k (number of tests or judges) from 3 to 20 and for N (Number of fabrics from 3 to 7. The tabled result is to be compared with the S value (N.B. - not the W value) and to be significant the S value has to be greater than or equal to the tabled value.

For example where S = 25.5, k = 3, N = 6 TABLE C shows that for the agreement among judges to be significant at the 0.05 level, S would have had to be > 103.9. Therefor e the NULL HYPOTHESIS is accepted . That is, the judges' rankings are NOT associated other than by chance.

To test the significance of larger samples (i.e. when N is more than 7) chi square tables can be used, after converting the data by using the formula

$$\chi^2 = k\ (N-1)W$$

Refer to TABLE D, with df = N-1. For the obtained W to be significant the χ^2 value has to be greater than or equal to the value obtained from the table.

INTERPRETATION OF SIGNIFICANCE OF W

A significant value of W may be interpreted as meaning that the judges are applying essentially the same standard in ranking the N fabrics under study.

COMPUTER PROGRAMME- There is a program on KENDAL COEEFICIENT OF CONCORDAN W on the I.C.L. 1900 which can be accessed from the terminal in the Fibre Science Unit.

TABLE A TABLE OF CRITICAL VALUES OF r_s, THE SPEARMAN RANK CORRELATION COEFFICIENT*

N	Significance level (one-tailed test)	
	.05	.01
4	1.000	
5	.900	1.000
6	.829	.943
7	.714	.893
8	.643	.833
9	.600	.783
10	.564	.746
12	.506	.712
14	.456	.645
16	.425	.601
18	.399	.564
20	.377	.534
22	.359	.508
24	.343	.485
26	.329	.465
28	.317	.448
30	.306	.432

TABLE B TABLE OF CRITICAL VALUES OF t*

df	Level of significance for one-tailed test: .10	.05	.025	.01	.005	.0005
	Level of significance for two-tailed test: .20	.10	.05	.02	.01	.001
1	3.078	6.314	12.706	31.821	63.657	636.619
2	1.886	2.920	4.303	6.965	9.925	31.598
3	1.638	2.353	3.182	4.541	5.841	12.941
4	1.533	2.132	2.776	3.747	4.604	8.610
5	1.476	2.015	2.571	3.365	4.032	6.859
6	1.440	1.943	2.447	3.143	3.707	5.959
7	1.415	1.895	2.365	2.998	3.499	5.405
8	1.397	1.860	2.306	2.896	3.355	5.041
9	1.383	1.833	2.262	2.821	3.250	4.781
10	1.372	1.812	2.228	2.764	3.169	4.587
11	1.363	1.796	2.201	2.718	3.106	4.437
12	1.356	1.782	2.179	2.681	3.055	4.318
13	1.350	1.771	2.160	2.650	3.012	4.221
14	1.345	1.761	2.145	2.624	2.977	4.140
15	1.341	1.753	2.131	2.602	2.947	4.073
16	1.337	1.746	2.120	2.583	2.921	4.015
17	1.333	1.740	2.110	2.567	2.898	3.965
18	1.330	1.734	2.101	2.552	2.878	3.922
19	1.328	1.729	2.093	2.539	2.861	3.883
20	1.325	1.725	2.086	2.528	2.845	3.850
21	1.323	1.721	2.080	2.518	2.831	3.819
22	1.321	1.717	2.074	2.508	2.819	3.792
23	1.319	1.714	2.069	2.500	2.807	3.767
24	1.318	1.711	2.064	2.492	2.797	3.745
25	1.316	1.708	2.060	2.485	2.787	3.725
26	1.315	1.706	2.056	2.479	2.779	3.707
27	1.314	1.703	2.052	2.473	2.771	3.690
28	1.313	1.701	2.048	2.467	2.763	3.674
29	1.311	1.699	2.045	2.462	2.756	3.659
30	1.310	1.697	2.042	2.457	2.750	3.646
40	1.303	1.684	2.021	2.423	2.704	3.551
60	1.296	1.671	2.000	2.390	2.660	3.460
120	1.289	1.658	1.980	2.358	2.617	3.373
∞	1.282	1.645	1.960	2.326	2.576	3.291

TABLE C TABLE OF CRITICAL VALUES OF s IN THE KENDALL COEFFICIENT OF CONCORDANCE*

k	N					Additional values for $N = 3$	
	3†	4	5	6	7	k	s
			Values at the .05 level of significance				
3			64.4	103.9	157.3	9	54.0
4		49.5	88.4	143.3	217.0	12	71.9
5		62.6	112.3	182.4	276.2	14	83.8
6		75.7	136.1	221.4	335.2	16	95.8
8	48.1	101.7	183.7	299.0	453.1	18	107.7
10	60.0	127.8	231.2	376.7	571.0		
15	89.3	192.0	349.8	570.5	864.9		
20	119.7	258.0	468.5	761.4	1,158.7		
			Values at the .01 level of significance				
3			75.6	122.8	185.6	9	75.3
4		61.4	109.3	176.2	265.0	12	103.5
5		80.5	142.8	229.4	343.8	14	121.9
6		99.5	176.1	282.4	422.6	16	140.2
8	66.8	127.4	242.7	388.3	579.9	18	158.6
10	85.1	175.3	309.1	494.0	737.0		
15	131.9	269.8	475.2	758.2	1,129.5		
20	177.0	364.2	641.2	1,022.2	1,521.9		

† For comparison of alternative tests of sig-

Table D Table of Critical Values of Chi Square*

df	Probability under H_0 that $\chi^2 \geq$ chi square													
	.99	.98	.95	.90	.80	.70	.50	.30	.20	.10	.05	.02	.01	.001
1	.000157	.000628	.00393	.0158	.064	.148	.455	1.07	1.64	2.71	3.84	5.41	6.64	10.83
2	.020	.040	.103	.211	.446	.713	1.39	2.41	3.22	4.60	5.99	7.82	9.21	13.82
3	.115	.185	.352	.584	1.00	1.42	2.37	3.66	4.64	6.25	7.82	9.84	11.34	16.27
4	.297	.429	.711	1.06	1.65	2.20	3.36	4.88	5.99	7.78	9.49	11.67	13.28	18.46
5	.554	.752	1.15	1.61	2.34	3.00	4.35	6.06	7.29	9.24	11.07	13.39	15.09	20.52
6	.872	1.13	1.64	2.20	3.07	3.83	5.35	7.23	8.56	10.64	12.59	15.03	16.81	22.46
7	1.24	1.56	2.17	2.83	3.82	4.67	6.35	8.38	9.80	12.02	14.07	16.62	18.48	24.32
8	1.65	2.03	2.73	3.49	4.59	5.53	7.34	9.52	11.03	13.36	15.51	18.17	20.09	26.12
9	2.09	2.53	3.32	4.17	5.38	6.39	8.34	10.66	12.24	14.68	16.92	19.68	21.67	27.88
10	2.56	3.06	3.94	4.86	6.18	7.27	9.34	11.78	13.44	15.99	18.31	21.16	23.21	29.59
11	3.05	3.61	4.58	5.58	6.99	8.15	10.34	12.90	14.63	17.28	19.68	22.62	24.72	31.26
12	3.57	4.18	5.23	6.30	7.81	9.03	11.34	14.01	15.81	18.55	21.03	24.05	26.22	32.91
13	4.11	4.76	5.89	7.04	8.63	9.93	12.34	15.12	16.98	19.81	22.36	25.47	27.69	34.53
14	4.66	5.37	6.57	7.79	9.47	10.82	13.34	16.22	18.15	21.06	23.68	26.87	29.14	36.12
15	5.23	5.98	7.26	8.55	10.31	11.72	14.34	17.32	19.31	22.31	25.00	28.26	30.58	37.70
16	5.81	6.61	7.96	9.31	11.15	12.62	15.34	18.42	20.46	23.54	26.30	29.63	32.00	39.29
17	6.41	7.26	8.67	10.09	12.00	13.53	16.34	19.51	21.62	24.77	27.59	31.00	33.41	40.75
18	7.02	7.91	9.39	10.86	12.86	14.44	17.34	20.60	22.76	25.99	28.87	32.35	34.80	42.31
19	7.63	8.57	10.12	11.65	13.72	15.35	18.34	21.69	23.90	27.20	30.14	33.69	36.19	43.82
20	8.26	9.24	10.85	12.44	14.58	16.27	19.34	22.78	25.04	28.41	31.41	35.02	37.57	45.32
21	8.90	9.92	11.59	13.24	15.44	17.18	20.34	23.86	26.17	29.62	32.67	36.34	38.93	46.80
22	9.54	10.60	12.34	14.04	16.31	18.10	21.34	24.94	27.30	30.81	33.92	37.66	40.29	48.27
23	10.20	11.29	13.09	14.85	17.19	19.02	22.34	26.02	28.43	32.01	35.17	38.97	41.64	49.73
24	10.86	11.99	13.85	15.66	18.06	19.94	23.34	27.10	29.55	33.20	36.42	40.27	42.98	51.18
25	11.52	12.70	14.61	16.47	18.94	20.87	24.34	28.17	30.68	34.28	37.65	41.57	44.31	52.62
26	12.20	13.41	15.38	17.29	19.82	21.79	25.34	29.25	31.80	35.56	38.88	42.86	45.64	54.05
27	12.88	14.12	16.15	18.11	20.70	22.72	26.34	30.32	32.91	36.74	40.11	44.14	46.96	55.48
28	13.56	14.85	16.93	18.94	21.59	23.65	27.34	31.39	34.03	37.92	41.34	45.42	48.28	56.89
29	14.26	15.57	17.71	19.77	22.48	24.58	28.34	32.46	35.14	39.09	42.56	46.69	49.59	58.30
30	14.95	16.31	18.49	20.60	23.36	25.51	29.34	33.53	36.25	40.26	43.77	47.96	50.89	59.70

* Table C is abridged from Table IV of Fisher and Yates: *Statistical tables for biological, agricultural, and medical research*, published by Oliver and Boyd Ltd., Edinburgh, by permission of the authors and publishers.

Appendix 1 (a)

Spearman rank correlation coefficient for plain woven fabrics stretchiness as compared to Young Modulus.

First assessor:-

Fabrics	A	B	C	D
Subjective ranks	3	2	1	4
Objective ranks	4	3	2	1
Difference (d)	1	1	1	3
d^2	1	1	1	9

$\langle d^2 = 12 \quad , \quad N = 4$

$$r_s = 1 - 6 \langle d^2/N(N^2-1) = \frac{6 \times 12}{4/4^2-1)} = 1 - \frac{72}{60} = 1-1.2 = \underline{0.2}$$

From Table A, $r_s = 1.00 >> - 0.2$, meaning that the two sets of rankings are not associated.

All others are caluculated in a similar way.

Second and tenth assessor: $r_s = 1.00 >> 0.8$, rankings not associated

third and eleventh assessor: $r_s = 1.00 = r_s$ calculated, meaning that the rankings are associated.

Fourth assessor: $r_s = 1.00 >> 0.8$, meaning the ranks are not associated.

Fifth assessor: $r_s = 1.00$ 0.1, meaning the ranks are not associated.

sith assessor: r_s 1.00 >> 0.6, meaning the ranks are not associated.

seventh assessor: $r_s = 1.00 >> 0.4$, meaning the ranks are not associated.

Eigth assessor: $r_s = 1.00 >> 0.4$, meaning the ranks are not assessor.

Nineth assessor: $R_s = 1.00 >> 0.8$, meaning the ranks are not associated.

Appendix 1 (b)

Kendall coefficient of concordance 'W' for stretchiness of plain woven fabrics by eleven assessors is calculated as:

from table 28, $\sum (Rj - \frac{\sum Rj}{N})^2 = 216.44 = S$

but, $W = \frac{S}{1/12k^2 (N^3-N)}$, $N = 4$, $k = 11$

$\therefore \quad W = \frac{216.44}{1/12x(11)^2x(4^3-4)} = \frac{216.44}{1/12x121x60} = 0.358$

from Table C, at $k = 11$, $N=4$, $S= 194.2$

Since $S = 216.44 > 194.2$, There is perfect agreement among the judges at level of significance P(0.01)

Appendix 1 (c)

Spearman rank correlation coefficient of scoured cotton as compared to the relationship in fig. 6.

First and 9th assessor ; r_s = 0.900 >> 0.45 meaning that the ranks are not associated .

Second assessor: r_s = 0.900>> 0.6, meaning the ranks are not associated.

Third and Seventh assessors: r_s = 0.900 = r_s calculated, meaning the two sets of ranks are related at level of significance P(0.05).

Fourth assessor: r_s = 0.900>> - 0.15, meaning the ranks are not associated.

Fifth assessor: r_s = 0.900 >> 0.1, meaning the ranks are not associated.

Sixth assessor: r_s = 0.900>> 0.65, meaning the ranks are not associated.

Eigth assessor: R_s = 1.00 = r_s calculated, meaning the two sets of ranks are related at level of significance P(0.01).

Tenth assessor: r_s = 0.900>>,0.55, meaning the ranks are not associated.

Eleventh assessor: r_s = 0.900 >>0.7, meaning the ranks are not associated.

Appendix 1 (d)

Kendall coefficient of concordance 'W' for stretchiness of scoured cotton fabrics by eleven assessors is calculated as:

from table 29, $\leq (Rj, \leq (Rj/N)^2 = 363.2 = S$

but, $W = \frac{S}{1/12k^2(N^3-N)}$, N = 5, k = 11

$$\therefore \quad W = \frac{363.2}{1/12x11^2x(5^3-5)} = \frac{363.2}{1/12x121x120} = \frac{363.2}{1210} = 0.30$$

from Table C, at k= 11, N=5, S= 342.32

since S = 363.2 > 342.32, There is perfect agreement among the judges at level of significance P(0.01)

Appendix 1 (e)

First and Sixth assessors: $r_s = 1.000 > 0.8$, meaning the ranks are not associate.

Second assessor: $r_s = 1.000 > 0.5$, meaning the two ranks are not associated.

Third,fourth, fifth, seventh and tenth assessors: $r_s = 1.000 > 0.4$, meaning the ranks are not associated.

Eight assessor: $r_s = 1.00 > 0.7$, meaning the ranks are not associated.

Nineth and eleventh assessors: $r_s = 1.00 = r_s$ calculated, meaning the two sets of ranks are associated at level of significance P(0.05).

Appendix 1 (f)

Kendall coefficient of concordance 'W' for stretchiness of mercerized cotton fabrics by eleven assessors is calculated as:-

from Table 30, $S = \sum (Rj - \sum Rj/N)^2 = 262.74$, N=4, K= 11

$$\therefore \quad W = \frac{S}{1/12\ k^2\ (N^3-N)} = \frac{262.74}{605} = 0.435$$

from table C, at k = 11, N = 4, S = 194.2

since S = 262.74 > 194.2, There is perfect agreement among the judges at level of significance P (0.05).

Appendix 1 (g)

First assessor: r_s = 0.900>> - 1, meaning the ranks are not associated.

Second assessor: r_s = 0.900>> -0.25, meaning the ranks are not associated.

Third assessor : r_s = 0.900>> -0.65, meaning the ranks are not associated.

Fourth and eight assessors: r_s = 0.900>>-1.15, meaning the ranks are not associated.

Fifth assessor: r_s = 0.900>>-0.55, meaning the ranks are not associated.

Sixth and seventh assessors: r_s0.900>> - 0.6, meaning the ranks are not associated.

Nineth assessor ; r_s = 0.900>>-1.35, meaning the ranks are not associated.

Tenth assessor: r_s = 0.900>>-0.5, meaning the ranks are not associated.

Eleventh assessor: r_s = 0.900>> - 0.05, meaning the ranks are not associated.

Appendix 1 (h)

Kendall coefficient of concordance 'W' for smoothness of corduroys by eleven assessors is calculated as:

from table 31, $S = \sum (Rj - \sum Rj/N)^2 = 938.8$, $N = 5$, $K = 11$

but, $W = \frac{S}{1/12\ k^2(N^3.N)} = \frac{938.8}{1210} = 0.78$

from Table C, at $K = 11$, $N = 5$, $S = 342.32$

Since $S = 938.8 >> 342.32$, There is perfect agreement among the judges at level of significance P (0.01)

Appendix 1 (i)

Kendall coefficient of concordance 'W' for smoothness of the scoured samples by eleven assessors is calculated as:

from table 32, $S = \sum(Rj - \sum Rj/N)^2 = 363.2$, $N=5$, $K=11$

but, $W = \frac{S}{1/12 \times k^2\ (N^3-N)} = \frac{363.2}{1210} = 0.30.$

From Table C, at $K= 11$, $N=S$, $S=342.32$.

Since $S= 363.2 > 342.32$, There is perfect agreement among the judges at level of significance P(0.01)

Appendix 1 (j)

First assessor : r_s = 1.00>> 0.5, meaning the ranks are not associated.

Second and tenth assessors: r_s = 1.00>> -0.7, meaning the ranks are not associated.

Third assessor: R_s =1.00>> 0.4, meaning the ranks are not associated.

Fourth and eighth assessors: R_s =1.00>> 0.8, meaning the ranks are not associated.

Fifth assessor; r_s = 1.00>>-0.8, meaning the ranks are not associated.

Sixth assessor: R_s = 1.00>>-0.4 , meaning the ranks are not associated.

Seventh and nineth assessors: r_s = 1.00 >> 0.1, meaning the ranks are not associated.

Eleventh assessor: r_s = 1.00>> 0.2, meaning the ranks are not associated.

Appendix 1 (k)

Kendall coefficient of concordance 'W' for smoothness of the mercerized samples by eleven assessors is calculated as:

from Table 33, $S = \sum(Rj - \sum Rj/N)^2 = 98.64$, N=4, K=11

but, $W = \frac{S}{1/12\ k^2\ (N^3-N)} = \frac{98.64}{605} = 0.16$

from table C, at K=11, N=4, S = 194.2 at P(0.01) and S= 192.0, atP(0.05).

Since S = 98.64 < 194.2 or 192.0, there is no agreement among the judges at both level of significance P(0.01) and P(0.05) respectively.

Appendix 1 (1)

first assessor : r_s calculated = 0.86, which is greater than 0.6 at P(0.05) and also 0.783 at P(0.01). Meaning the two set of ranking are associated at the two levels of significance.

Second assessor: r_s = 0.6 < 0.7, meaning the ranks are associated at level of significance P(0.05).

Third assessor * r_s calculated = 0.08, which is greater than 0.6 at P(0.05) and also 0.783 at P(0.01). Meaning the two sets of rankings are associated at the two levels of signicance.

Fourth and seventh assessor: r_s calculated = 0.83 Ranks are associated at the two levels of significance as with the 1st assessor.

Fifth assessor * r_s = 0.6 < 0.77, meaning the ranks are associated at level of significance P(0.05).

Sixth assessor: r_s calculated = 0.92. Ranks are associated at the twe levels of significance as with the 1st assessor .

Eight assessor: $r_s$calculated = 0.81. Ranks are associated at the two levels of significance as with the first assessor.

Nineth assessor: r_s calculated = 0.9. Ranks are associated at the two levels of significance as with the first assessor.

Tenth assessor: R_s = 0.6 < 0.72, meaning the ranks are associated at level of significance P(0.05).

Eleventh assessor: R_s calculated = 0.95. Ranks are associated at the two levels of significance as with the first assessor.

Appendix 1 (m)

Kendall coefficient of concordance 'W' for the plain woven fabrics and the corduroys by eleven assessors is calculated as:

from Table 34, $S = \sum (Rj - \sum Rj/N)^2 = 5,567.9$, N=9, K=11

but, $W = \dfrac{S}{1/12k^2 (N^3-N)} = \dfrac{5,567.9}{7,260} = 0.77.$

From Table C, at K = 11, N=9, S= 621.84 at P(0.01).

Since S = 6,567.9 >> 621.84, There is perfect agreement among the judges at level of significance P(0.01).

Appendix 1 (n)

Kendall coefficient of concordance 'W' for hairiness of the scoured Samples by the assessors is calculated as:

from Table 35, $S = \sum (Rj-\sum Rj/N)^2 = 722.8$, N=5, K=11

but, $W = \frac{S}{1/12\ k^2(N^3-N)} = \frac{722.8}{1210} = 0.60$

From Table C, at 0.01 level of significance, when N=5, K=11, S = 342.32

Since S= 722.8> 342.32, there is perfect agreement among the judges at level of significance P(0.01).

Appendix 1 (p)

Kendall coefficient of concordance 'W' for softness of the mercerized samples by the assessors is calculated as:

from Table 36, $S = \sum(Rj - \sum Rj/N)^2 = 185$, N =4, K=11

but, $W = \frac{S}{1/12\ k^2\ (N^3-N)} = \frac{185}{605} = 0.31$

From Table C, when K = 11, N=4, at 0.01 level of significance S=194.2, and at 0.05 level of significance S = 140.82.

Since S= 185> 140.82 but < 194.2, There is perfect agreement among the judges at level of significance P(0.05).

APPENDIX 2

GEOMETRICAL ANALYSIS OF A PLAIN WEAVE FABRIC STRUCTURE

(a) CROWN HEIGHT

The models of fabric-on-fabric (woven) contact for warp-over-warp and weft-over-weft motion are shown in Figure 1 (a) and (b) respectively. A tangent to the weft yarn crown (XX^1) was taken as an arbitrary plane of the fabric. The protrusion of the yarn crown (warp) from the plane of the fabric is depicted by the hatched portion (see Figures 1 (a) and (b).

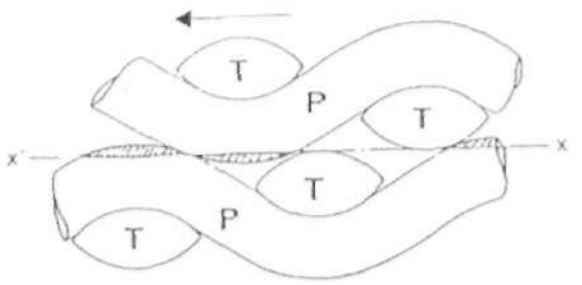
Following a similar procedure by Ohsawa and Namiki [93], Ohsawa et al [94], the relative height of the protrusion of yarn crown is calculable from the geometrical configuration.

According to Pierce [102, 103], the relationship between the yarn crimp (C), spacing (P) (i.e. threads per cm) and the crimp amplitude (h) is given by the following equation:

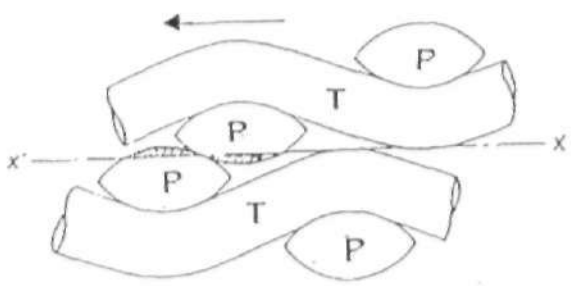
$$\frac{h_p}{P_T} = \frac{4}{3}\sqrt{C_p} \qquad 1$$

where the subscripts P and T refer to warp and weft yarns respectively.

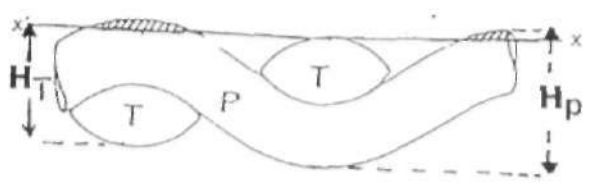
The distances between the planes tangent to the warp and weft yarn crowns (Figure 1 (C) are correspondingly given by:



(a)



(b)



(c)

Figure 1

Model of fabric on fabric contact

(a) warp on warp motion

(b) weft on weft motion

(c) a unit cell of a woven fabric.

XX^1 = arbitrary plane of fabric surface

P = warp yarn, T = weft yarn

arrow indicates the direction of sliding

$$H_P = h_P + b_P \quad (2)$$

$$H_T = h_T + b_T \quad (3)$$

where H = distance between the planes tangent to the yarn crown,

b = minor diameter of the flattened yarns

subscripts P and T refer to warp and weft yarns respectively.

In a balanced yarn system, where the warp and weft sett, and linear density are similar, it is evident that

$$h_P + h_T = b_P + b_T \quad (4)$$

Suppose the linear densities of the component yarns are different, and assuming the ratio of the minor diameter of warp to weft yarns is denoted by (δ), where

$$\delta = \frac{b_P}{b_T} \quad (5)$$

and substitution of this relation into equation 4 yields:

$$h_H + h_T = (1 + \delta)b_T = (b_P + b_T) \quad (6)$$

$$b_P = \frac{\delta}{(1 + \delta)}(h_P + h_T) \quad (7)$$

$$b_T = \frac{\delta}{(1 + \delta)}(h_P + h_T) \quad (8)$$

From equations 2 and 3

$$H_P = h_P + \frac{\delta}{(1 + \delta)}(h_P + h_T) \quad 9$$

$$H_T = h_T + \frac{\delta}{(1 + \delta)}(h_P + h_T) \quad 10$$

Therefore the relative height of yarn crown (H_C) may be written as

$$H_C = \frac{1}{2}(H_P - H_T) \quad 11$$

$$H_C = \frac{1}{2}\{(h_P - h_T) - (h_P + h_T)(\delta - 1/\delta + 1)\} \quad 12$$

The factor of ($\frac{1}{2}$) represents the protrusion of warp yarn crown from the plane of weft yarns on only one side, i.e. face. The magnitude of H_C may be positive or negative. A positive value would indicate a warp projection, otherwise a weft projection is obtained.

Appendix 3

Determination of geometric mean value:

$$\text{Geometric mean} = \sqrt[N]{a \times b \times c \times \ldots\ldots \times X}$$

where N = The number of rankings

a, b, c ..... x = The ranked values

(a) Geometric mean for ridged effect

corduroy A Geometric mean $= \sqrt[11]{13x7x8x7x17x20x15x13x14x30x5}$

$= \sqrt[11]{7.095 \times 10^{11}} \approx \underline{\underline{11.95}}$

All other geometric means were calculated in a similar way.