Mansoura Engineering Journal

Volume 3 | Issue 1 Article 7

6-1-1978

A Study of Dimensional Properties of Carding Fabrics Knitted from Wool and Acrylic Yarns Part I. Full Cardigan.

Mostafa El-Gaiar
Assistant Professor., Textile Engineering Department., Faculty of Engineering., El-Mansoura University., Mansoura., Egypt.

A STUDY OF DIMENSIONAL PROPERTIES OF CARDIGAN FABRICS KNITTED FROM WOOL AND ACRYLIC YARNS

PART I. FULL CARDIGAN

BY

Dr. Mostafa El-Gaiar*

It is shown experimentally that for practical purposes, the geometrical properties of worsted, and acrylic full cardigan fabrics can be described by sets of K-values. In the fully relaxed state the dimensional properties of the Knitted fabric are determined uniquely by the length of yarn in the stitch. The relationships obtained between courses, ribs and stitch density and the loop length, in the fully relaxed states are very simple, and similar to those proposed for plain stitch. It was found that with the use of suitable relaxation treatment, both yarn and machine variables are of very little effect.

Key-Words:-

L-loop length, C/Cm = courses/centimeter, r/cm = ribs/centimeter, S = Stitch density, K_c= courses constant, K_r=ribs constant, K_s=stitch density constant, C.F. = cover factor, K-K=Knit-Knit, t-K = tuck - knit, W-O, T-D = wetting out and tumble dried respectively, D-R= dry relaxed, W-R = wet relaxed, T-D = tumbled directly, c.f. = continuous filament, and C.R. = crimp rigidity.

I.1. INTRODUCTION:

The literature of dimensional properties of weft knitted fabrics show that structures such as plain, and 1x1 rib have recieved considerable attention from the investigators of the field of fabric geometry, while structures such as half and full cardigan did not recieve such extensive studies. This may be due to the belief that these structures are complex and not simple to analysis theoritically as with the case of plain and 1x 1 rib structures.

Full cardigan is a weft knitted structure that based structurally on 1x 1 rib. The repeat occurs over two courses, and in one of these courses half the needlee makes tucking and the others knits normally. This process is reversed in the second course.

---

* Lecturer at Textile Engineering Depart., Faculty of Eng., El-Mansoura University.

Full cardigan fabrics are widely used as outerwear garments, and because of the tucking process that occurs during knitting, the fabric is bulky and has greater thickness than that of plain and 1x 1 rib fabric knitted from the same yarn and at the same cover factor.

In the past majority of cardigan fabrics were usually knitted from wool yarns, but with the creation of acrylic fibres, attention had been directed towards the use of yarns spun from these fibres, not only as a substitute for wool yarns, but also for the unique properties it possesses. For example easy care, hard wearing, non shrinkage when properly proceseed, and finally non felting. However the use of acrylic yarns in knitting did not pass smoothly but gave rise to many problems not only during processing, but also in fabric behaviour when subjectsd to external etrains. Among these problems is the problem of dimensional stability which was and is still considered one of the major problems of the knitting industry, which makes weavers proud with their woven products from that side.

In the present investigation, a comprehensive study of the dimensional properties of full cardigan fabrics knitted from a wide range of counts and relaxed with various methods, has been made, and reported. The examined fabrics were knitted at equal repeating courses.

I.2. Specifications of Yarns Used.

The specifications of yarns used are given in Table 1.

Table (1)

Wool yarns	Acrylic yarns
3 x 379/2 denier	1 x 266/2 denier
2 x 498/2 denier	1 x 532/2 denier
3 x 569/4 denier	2 x 443/2 denier
2 x 664/8 denier	1 x 886/2 denier

I.3. Relaxation Treatments Used for Wool Fabrics.

I.3.1. Dry Relaxed (D-R).

The fabrics after being removed from the knitting machine were left to relax in a standard atmosphere for 24 hr, before the dimensions have been measured.

I.3.2. Wet Relaxed (W-R)

The fabrics were given a static soaking in worm water (40°C) for 24 hr, then left to dry flat in a conditioned atmosphere.

I.3.3. Wet Relaxed and Tumble Dried (W-R, T-D).

The fabrics were given a static soaking in worm water (40°C) containing soap detergent, for 24 hr, after which it was removed and hydro-extracted for 30 seconds, and finally dried in a tumble drying unit at 72°C for 1 hr. Fabric dimensions were measured after being left in a conditioned atmosphere for 24 hr.

I.4. Relaxation Treatments Used for Acrylic Fabrics.

I.4.1 Dry Relaxed (D-R)

Similar to that used for wool fabrics.

I.4.2. Tumbled Directly (T-D)

The fabrics after being removed from the knitting machine were directly tumbled in a tumble drying unit, at 72°C for ½ hr. Dimensions were measured after 24 hr in a standard atmosphere.

I.4.3. Wet Relaxed and Tumble Dried (W-R, T-D).

The fabrics were given a static soaking for ½ hr in hot water (85°C), then hydro-extracted and tumble dried at 72°C for ½ hr. Dimensions were measured after the fabrics had been left for 24 hrs in a standard atmosphere.

I.5. Knitting Machine Used.

The fabrics were knitted on a 7 gauge flat V-bed knitting machine. Dead weights are used in this type of machines to pull the fabric down during knitting. For tight fabrics higher dead weights are required to help in clearing the formed stitch from the head of the needle.
For each cover factor (or loop length) five samples were knitted at 100 needles and 200 rows. Precautions were taken during fabric removal to avoid distorsion, especially for low cover factor (slack) fabrics.

I.6. Loop Length Measurment.

For wool and acrylic fabrics the loop length was determined from the total length of yarn used in the repeating coursee divided by twice the number of needles used. This length was measured under the specified tension recommended for each count.

I.7. Results and Discussion of Results

I.7.1. Effect of Loop length on C/Cm, r/Cm, and S.

The results obtained for courses/Cm for wool and acrylic fabrics[5] show that the relaxation treatmente used led to a remarkable increase in the courses at any loop length. The opposite occurred to the ribs/Cm. This can be explained in the light of the fact, that full cardigan fabrics increases considerably in width after being tumbled at 72°C for ½ and 1 hr. The increase in width is accompanied by decrease in length. The percentage increase in width at any cover factor is higher for acrylic fabrics than for wool fabrics. One may relate this difference to the high frictional restraints at the cross-over points for wool yarns, either because of scale presence or due to increase in internal friction because of partial felting (especially for wet relaxed fabric), which increases yarn diameter.

When the individual values[5] of c/cm, r/cm, and s were plotted against 1/L and $1/L^2$ respectively for each count at the various relaxed states, it was found that linear relationships in the form of; Y = a + bX can be used. The correlation coefficients are very high (r = 0.96 to 0.98) and highly significant at the 5% level. The sign and the value of the intercept (a) varied from count to another and from one relaxation treatment to another. But in general it was found that the higher values of (a) are obtained in the dry relaxed state, and drops in magnitude by the use of the two other relaxation treatments proposed. This is for wool and acrylic fabrics. The best fit lines obtained using the least square method are given in Table 2. Statisticall analysis showed that the intercepts existing in the courses, ribs, and stitch density equations, are of insignificant values and may be ignored to give rise to simple linear relationships passing through the origin. Plotted in Figs. 1 to 6 the values of c/cm and s against 1/L and $1/L^2$ respectively in the fully relaxation treatments used.

Table (2)

Fabric	Best Fit Line	Relaxation Treatment
Wool	$c/cm = \frac{9.04}{L} + 0.59$ $r/cm = \frac{3.84}{L} - 0.202$ $s = \frac{34.2}{L^2} + 1.37$	(W-R, T-D)
Acrylic	$c/cm = \frac{11.1}{L} + 0.43$ $r/cm = \frac{3.82}{L} + 0.16$ $s = \frac{33.9}{L^2} + 0.13$	(T-D)
Acrylic	$c/cm = \frac{8.39}{L} - 0.34$ $r/cm = \frac{3.34}{L} + 0.07$ $s = \frac{32.6}{L^2} - 1.1$	(W-R, T-D)

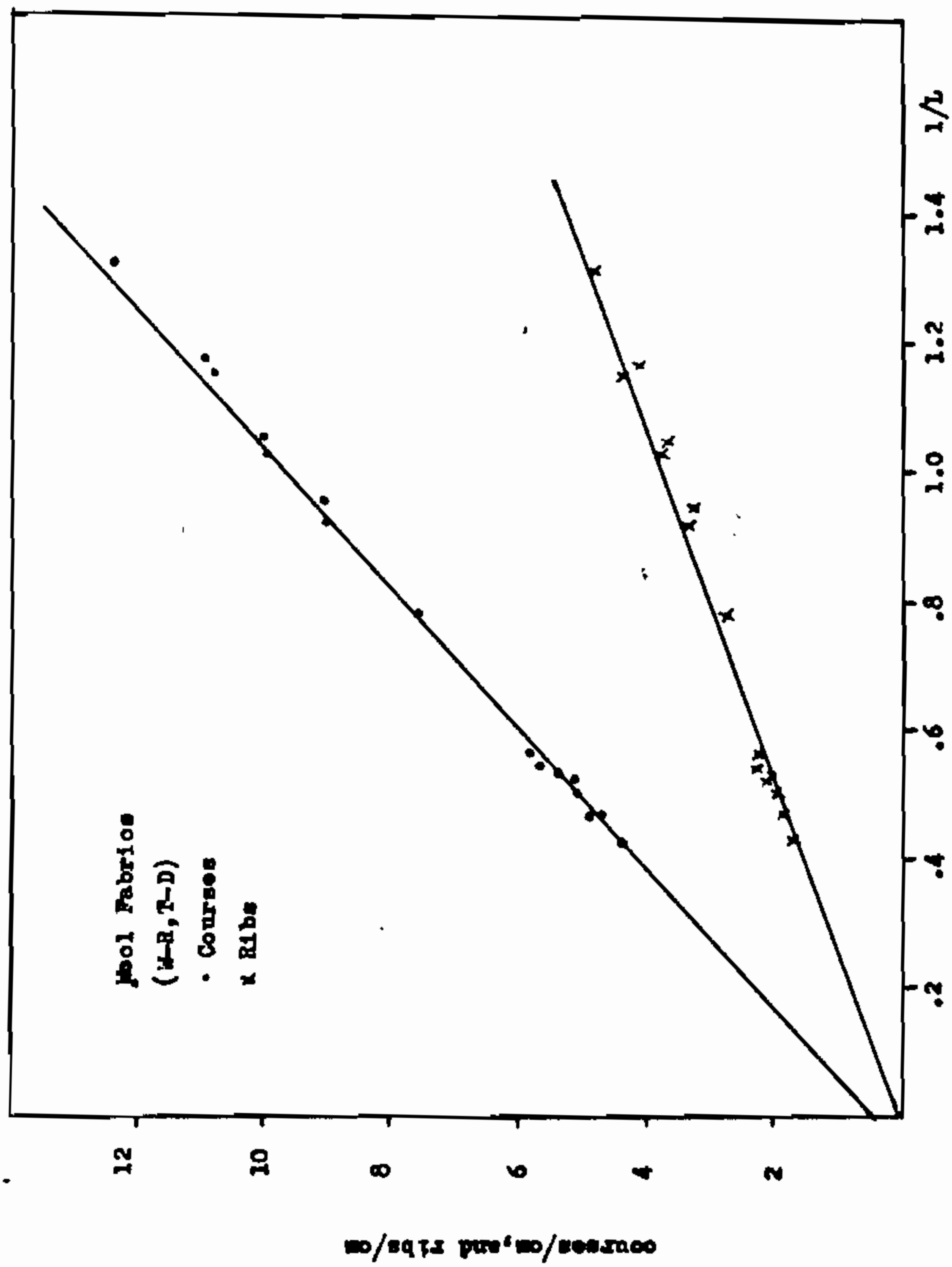
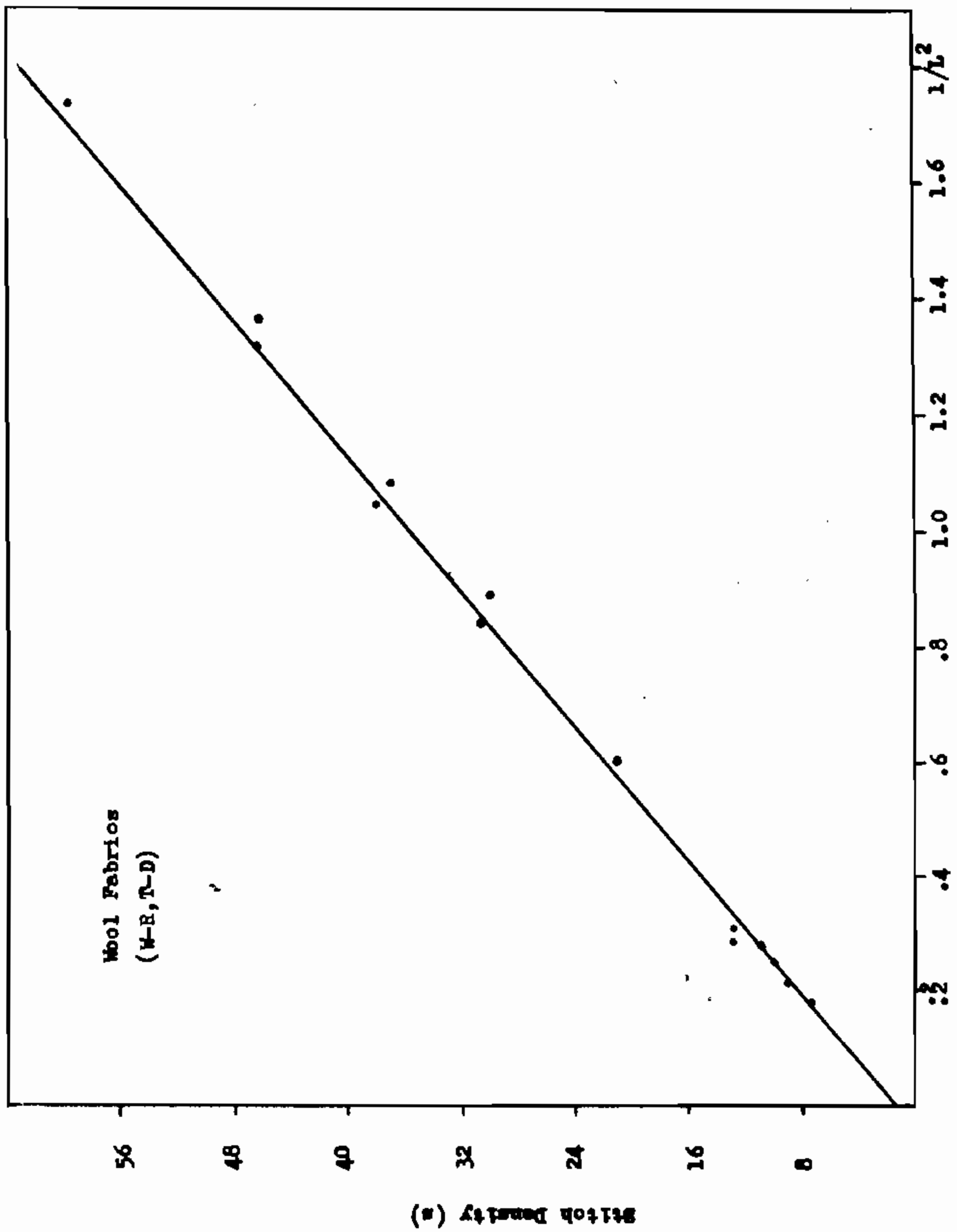
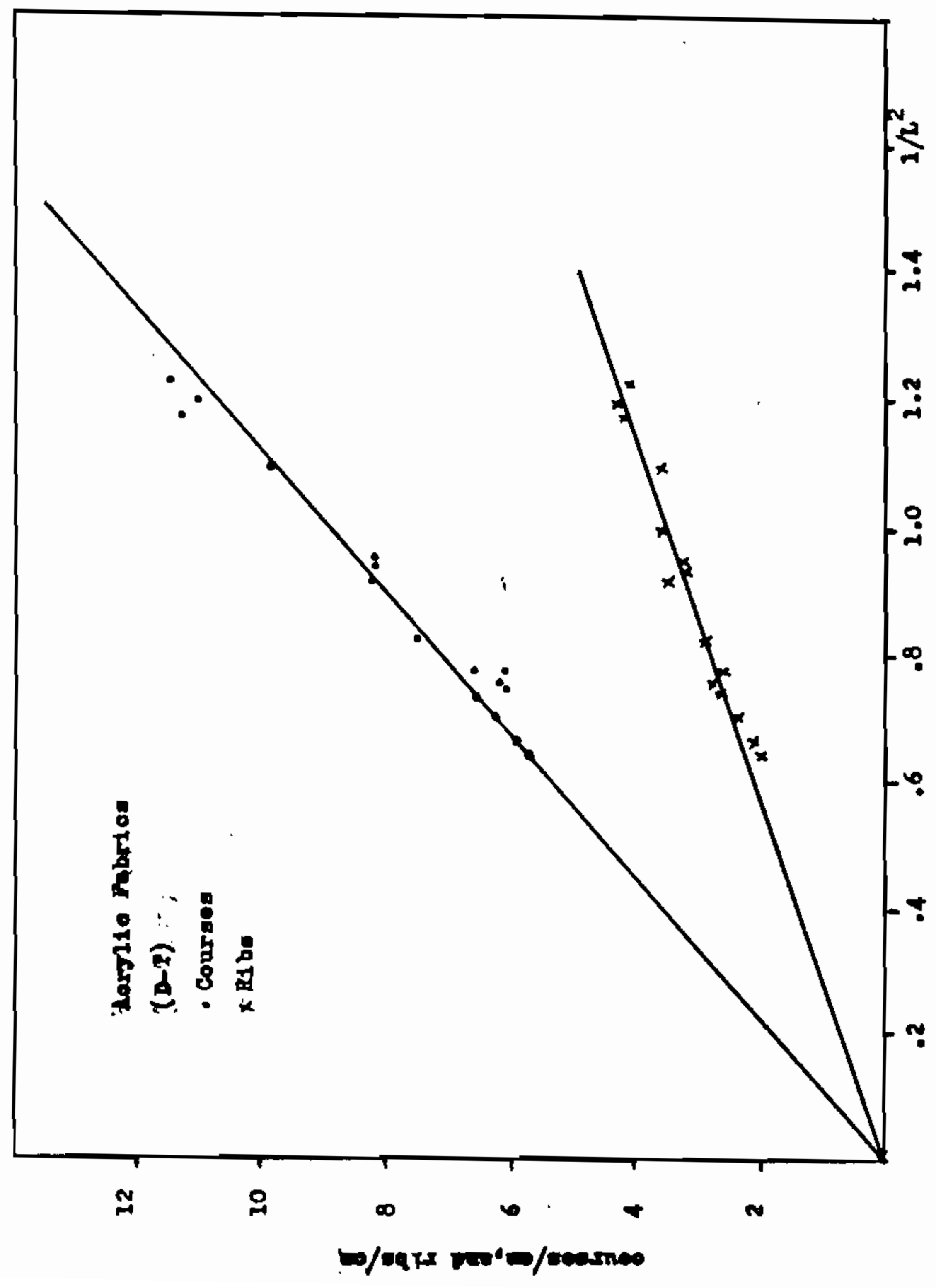

Wool Fabrics
(W-R, T-D)
· Courses
x Ribs
courses/cm, and ribs/cm
1/L
2
4
6
8
10
12
.2
.4
.6
.8
1.0
1.2
1.4

Fig.1



Wool Fabrics
(W-R, T-D)
Stitch Density (s)
1/L²
56
48
40
32
24
16
8
.2
.4
.6
.8
1.0
1.2
1.4
1.6

Fig.2



Acrylic Fabrics
(D-T)
• Courses
x Ribs
courses/cm, and ribs/cm
12
10
8
6
4
2
.2
.4
.6
.8
1.0
1.2
1.4
1/L²

Fig.3

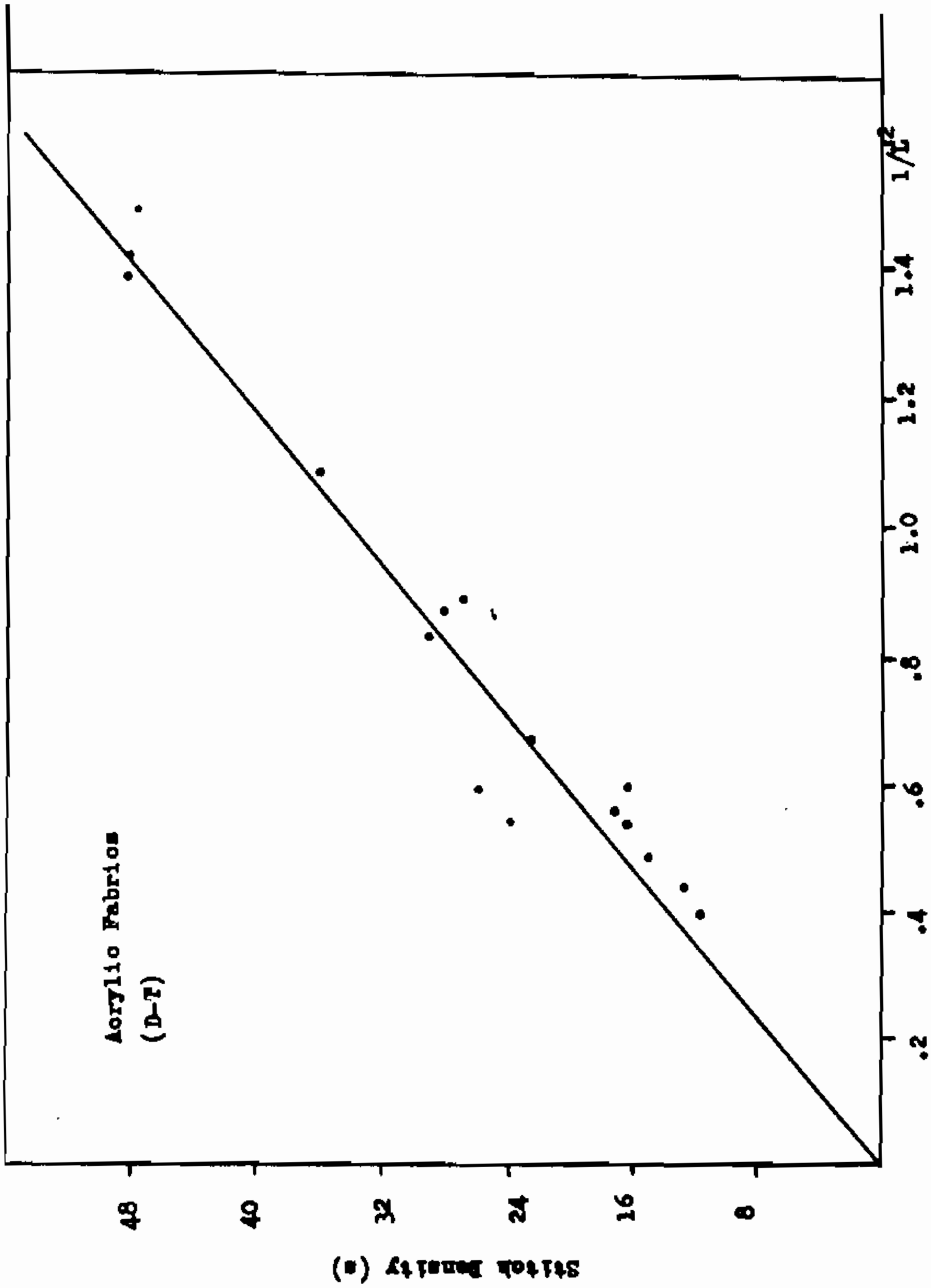

Acrylic Fabrics
(D-F)
Stitch Density (s)
48
40
32
24
16
8
.2
.4
.6
.8
1.0
1.2
1.4
1/L²

Fig.4

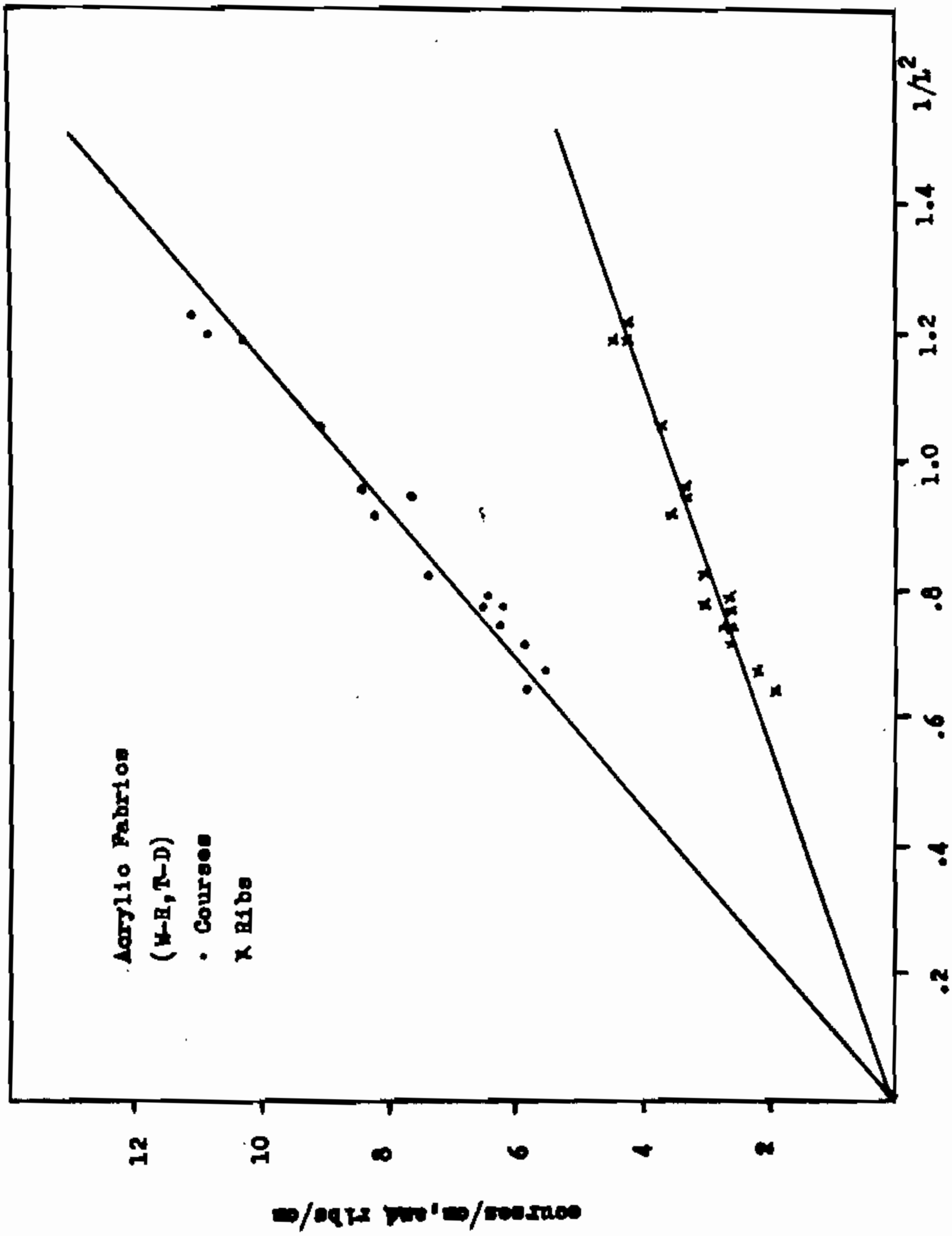

Acrylic Fabrics
(W-R,T-D)
· Courses
x Ribs
courses/cm, and ribs/cm
$1/L^2$
.2
.4
.6
.8
1.0
1.2
1.4
2
4
6
8
10
12

Fig.5

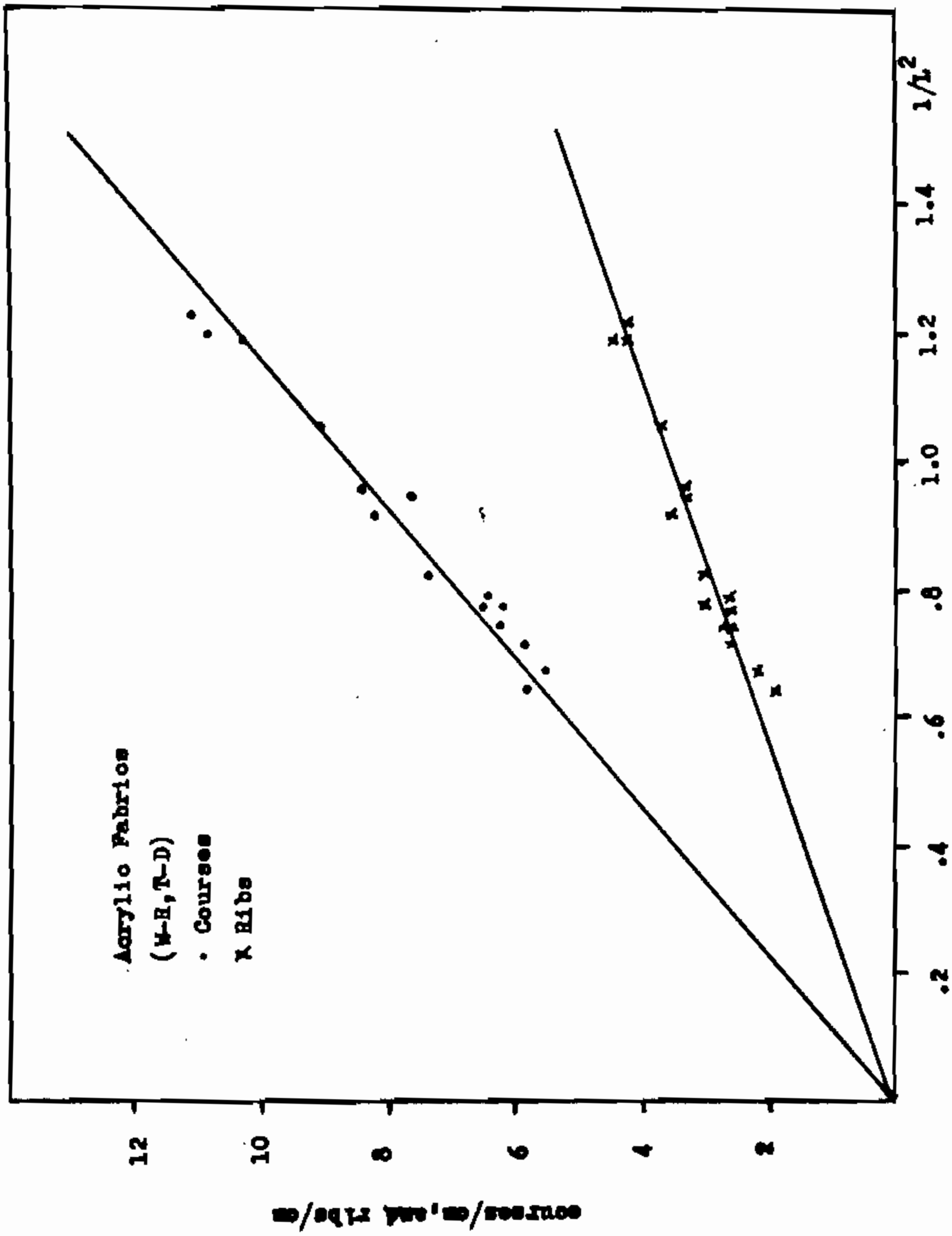

Acrylic Fabrics
(W-H,T-D)
· Courses
x Ribs
courses/cm, and ribs/cm
$1/L^2$

Fig.5

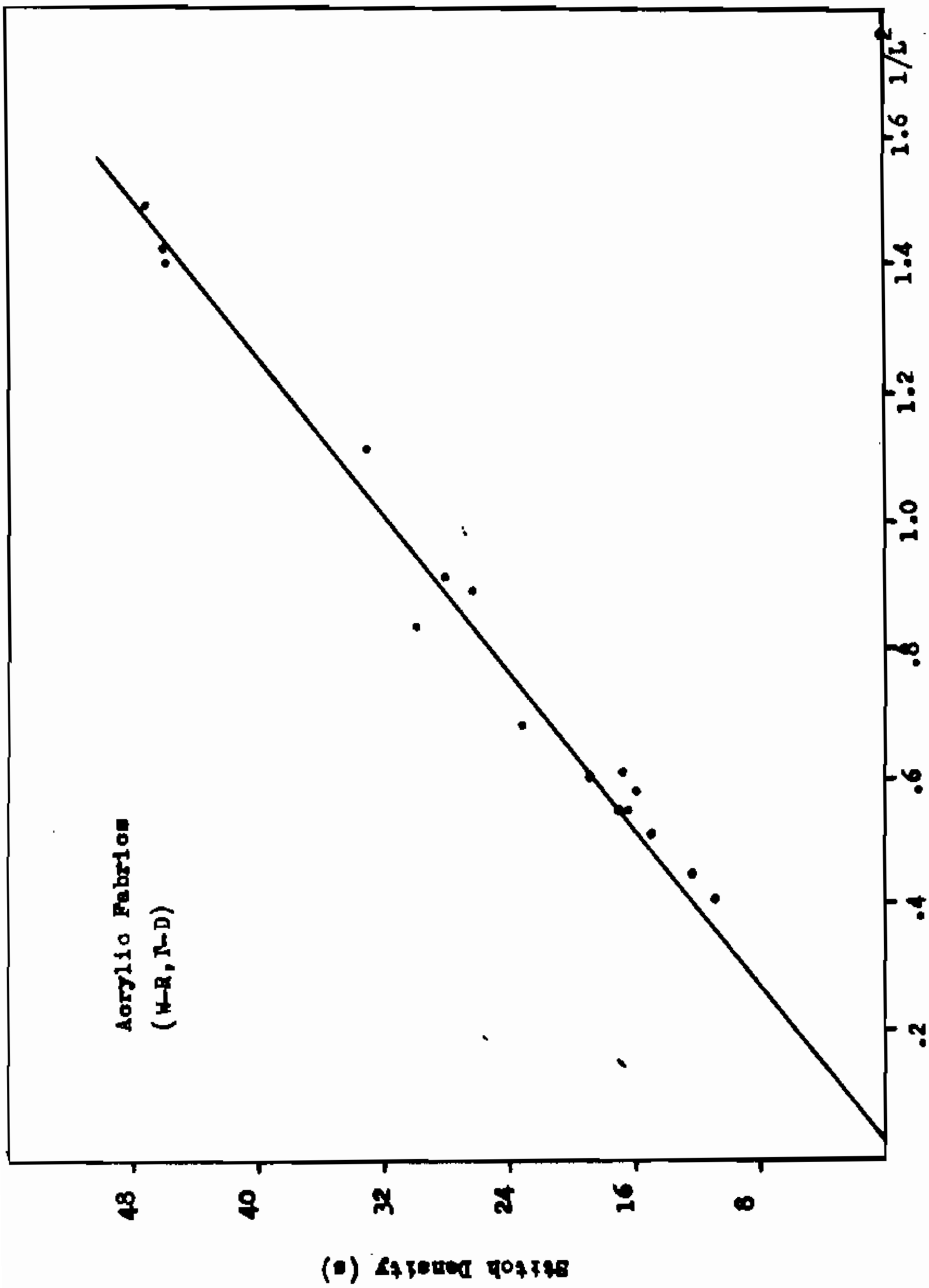

Acrylic Fabrics
(W-R, T-D)
48
40
32
24
16
8
Stitch Density (s)
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1/L²

Fig.6

When it was realized that the relaxation treatments described in I.3.2, I.3.3, I.4.2 and I.4.3 are effective in bringing the fabrice to a state of minimum elastic energy (by obtaining simple straight lines with negligable intercepts), it was decided to find out if all wool and acrylic fabrics relaxed by the methods described in sections I.3.2, I.3.3, I.4.2 and I.4.3. would follow the same trend or not.
Plotted in Figs. 7 and 8 all values obtained for c/cm, r/cm, and s against 1/L and $1/L^2$ respectively, of wool and acrylic fabrics in the founded fully relaxed states. The correlation coefficients are very high and ranging between 0.96 and 0.98 and highly significant at the 5% level. The best fit lines obtained between c/cm, r/cm and s and 1/L and $1/L^2$ respeotively, using the least square method are as follows:-

$$c/cm = \frac{9.49}{L} + 0.13 \qquad \text{.......(1)}$$

$$r/cm = \frac{3.74}{L} \qquad \text{.......(2)}$$

$$s = \frac{33.6}{L^2} + 0.13 \qquad \text{.......(3)}$$

The intercepts existing in equations 1 and 3 are statistically of insignificant valuė and may be ignored to give simple linear relationships between c/cm, r/cm and s and 1/L and $1/L^2$ rsspectively.

From the above equations (1 to 3) it is evident that when the suitable relaxation treatment is used the courses, ribs, and stitch density can be related to the loop length by simple linear relationships passing through the origin in the form of,

$$c/cm = \frac{K_c}{L} \qquad \text{.......(4)}$$

$$r/cm = \frac{K_r}{L} \qquad \text{.......(5)}$$

$$s = \frac{K_s}{L^2} \qquad \text{.......(6)}$$

in which K_c, K_r and K_s are constants for the loop under consideration. These equations are similar to that obtained and proposed for plain[1], and 1x 1 rib[2] fabrics when fully relaxed. Also the equations obtained for full cardigan wool and acrylic fabrice in the various relaxed states (one may say fully relaxed states) points to another important point, and that is yarn diameter. The intercepts obtained in the equatione are very small and that over the range of diameters used no additional terms are required to be added to the equations of courses, ribs and stitch density to account for yarn diameter. The tumbling technique used during drying for the wool and acrylic fabrics proved to be effective in bringing the fabrics to stable dimensions and not to cause distortion as had been found by smirfitt[2] for 1x 1 rib

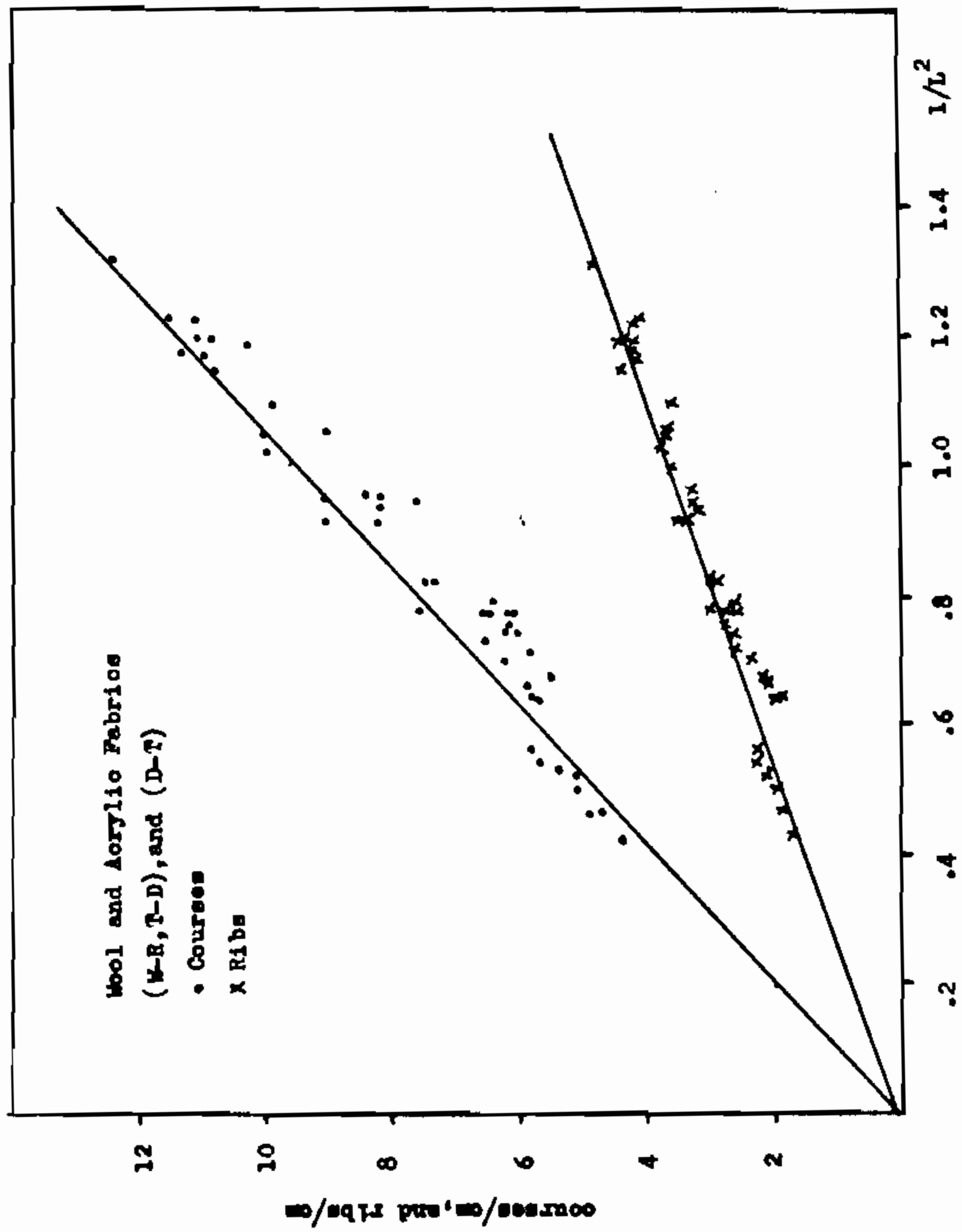

Wool and Acrylic Fabrics
(W-R,T-D),and (D-T)
• Courses
X Ribs
courses/cm,and ribs/cm
12
10
8
6
4
2
.2
.4
.6
.8
1.0
1.2
1.4
1/L²

Fig.7

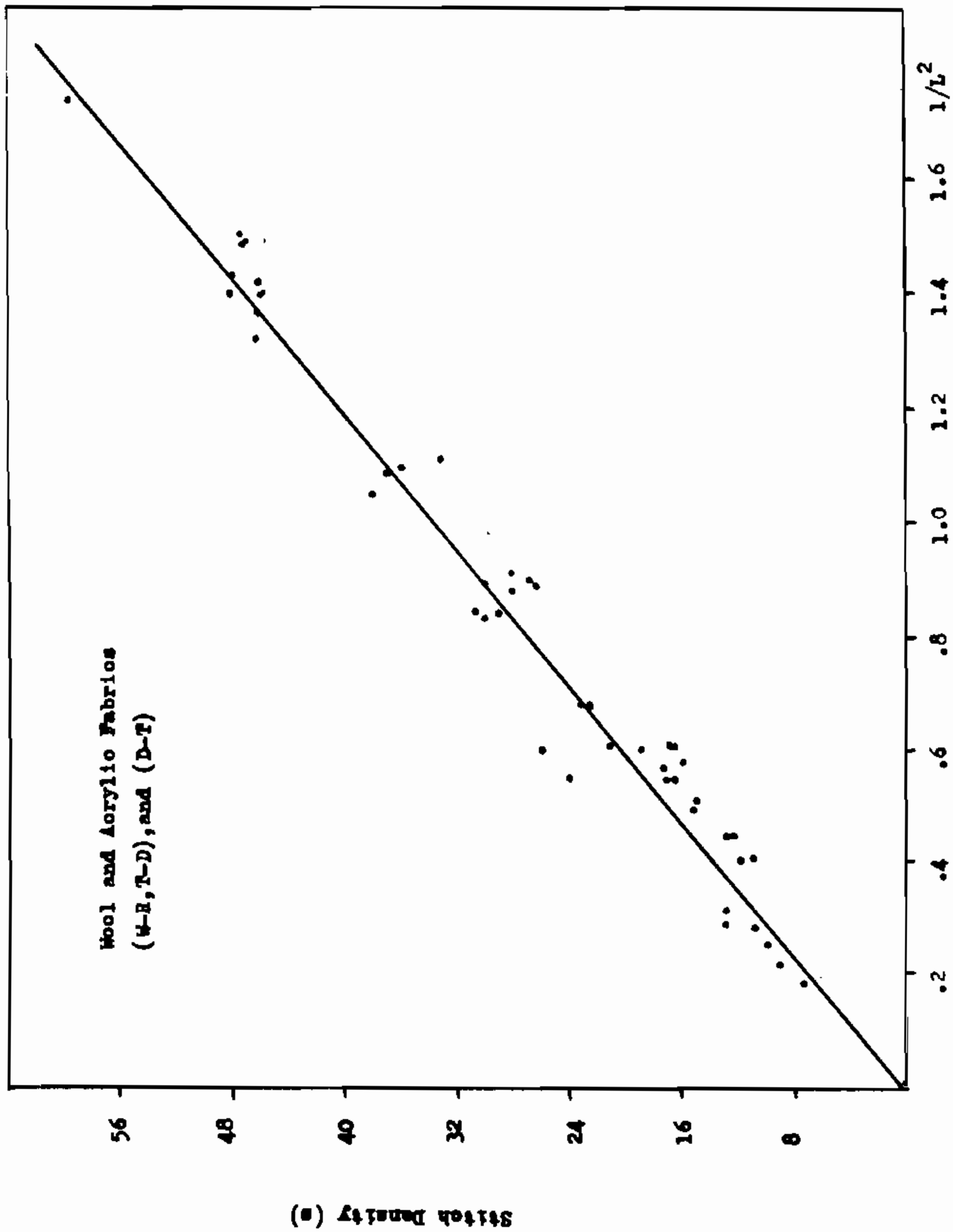

Wool and Acrylic Fabrics
(W-E,T-D),and (D-T)
Stitch Density (s)
56
48
40
32
24
16
8
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1/L²

Fig.8

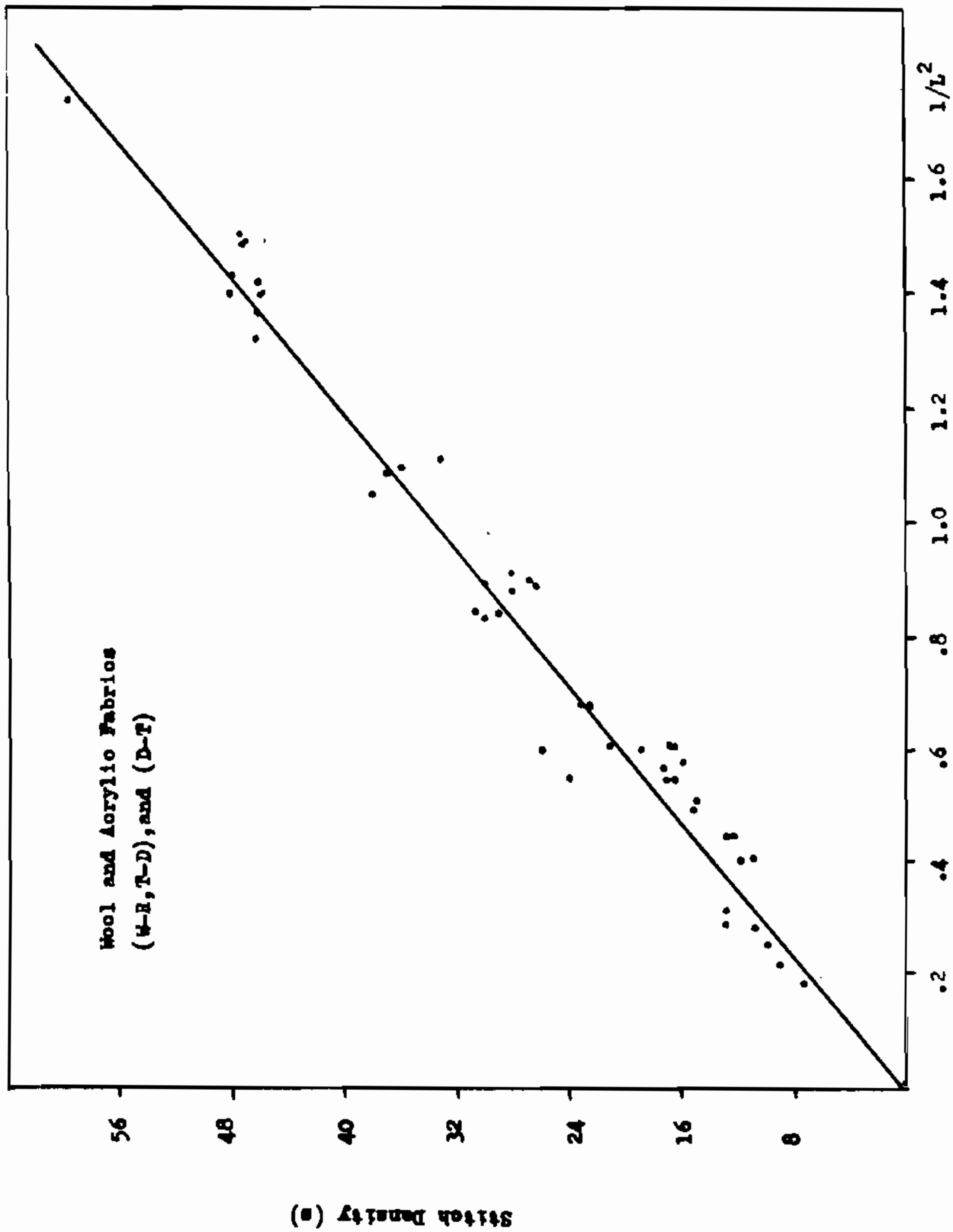

Wool and Acrylic Fabrics
(W-R,T-D),and (D-T)
Stitch Density (s)
56
48
40
32
24
16
8
.2
.4
.6
.8
1.0
1.2
1.4
1.6
$1/L^2$

Fig.8

wool fabrics that tumble dried for 30 min at 50°C. In the present investigation tumbling was carried out for wool and acrylic fabrics at 72°C, and for 1 and ½ hr respectively. For the complex structure, i.e full cardigan it is evident from the results obtained in the dry state, and in the other used relaxed states, that tumbling during drying is essential other wise the loops would not be able to achieve the configuration of minimum elastic energy, which is restricted by the high internal friction between loops at the cross-over points.

The results obtained in the present work, and concerns the intercepts in the courses, ribs, and stitcb density and the loop length equations, strengthen the view of the Centre des Recherches de la Bonneterie (C.R.B)[3], whose report on dry and wet-relaxed plain knitted fabrice, ascribes these intercepts to incomplete relaxation of tightly knitted fabrics and puts forward the view that static immersion in water (for wool fabrics) is not sufficient to relax a plain-knitted fabric. To ensure complete relaxation and thereby reduce the intercepts, the C.R.B. used a more vigorous relaxation procedure, in which the fabrics were first relaxed at 90°C and then tumble-dried in the cold. In Smirfitt's[2] opinion subsequent tumble drying of rib fabrics is to increase, not decrease, the size of these intercepts.

I.7.2. Fabric "K" Values.

Given in Table 3 the "K" values obtained for wool and acrylic fabrics in the fully relaxed states, i.e. W-R, T-D, and W-R, T-D, and T-D respectively. These values were taken from equations given in Table 2 and from equations 1, 2 and 3. Also given in the table the average K-values of full cardigan fabrics knitted from high bulk continuous filament yarns (Nylon 6.6)[4]. The averages were calculated from the individual values obtained by the authors (Fitton and Hopkinson[4]) at each loop length. From Table 3 one may observe that the K-values obtained in the present work are higher than that obtained by Fitton and Hopkinson[4]. Also from the table one may observe that the direct tumbling techniqus used for acrylic fabrics is more effective than the (W-R, T-D) technique. This is reflscted from the high values of K_c and K_r at this treatment.

The differences in K-values for wool and acrylic fabrics and high bulked nylon fabrics may be due to several reasons, such as yarn count, fibre material, number of ends, and relaxation method. In Fitton and Hopkinson'e[4] work fine yarns were used, while in the present work coarser yarns have been used to produce the same structure. Also in their relaxation treatment agitation had been only used during the wet process, which is simply illustrated in immersing the fabrics in water (20°C) containing a detergent. The temprature was gradually raised to 55°C, and after 30 min at this temperature the liquor was allowed to cool at 30°C before the fabrics were removed. After removal from the water, the fabrics were hydro-extracted and

Table (3)

Yarn	K_c	K_r	K_s	K_c/K_r	Author
2 x 2/70 den. false twist C.R. = 25%	6.25	2.95	18.32	2.12	F.&H*
2 x 2/70 den. false twist C.R. = 33%	5.60	3.05	16.75	1.84	"
2 x 2/70 den. Post-treated, false twist, C.R. = 7.5%	5.05	2.20	11.17	2.33	"
2 x 2/70 den. Post-treated, false twist, C.R. = 11%	5.18	2.20	11.40	2.35	"
2 x 2/70 den. Post-treated, false twist, C.R. = 15%	5.40	2.35	12.70	2.29	"
Wool (W-R, T-D).	9.04	3.84	34.2	2.35	Present
Acrylic (W-R, T-D).	11.05	3.82	33.9	2.89	"
Acrylic (D-T).	8.39	3.34	32.6	2.51	"
Wool And Acrylic together	9.49	3.74	33.6	2.52	"

* Fitton and Hopkinson[4].

dried flat without tension on a flat surface. From the results obtained in the present work it seems that tumbling during drying is essential to help the loops to over-come the frictional restraints at the cross-over points, and hence to achieve the configuration of minimum energy. This was possible for wool and acrylic fabrics when tumbled during drying at 72°C for 1 hr, and ½ hr rsspectively. Also it is evident that direct tumbling of acrylic fabrics without static wet relaxation was very effective in bringing the fabrics to stable dimensions, with K-values very close to that of wool fabrics.

I.8. Conclusions.

1) Full cardigan fahrics increases in width and decreases in length when relaxed.
2) The dry relaxed state is not a state of minimum energy and fabric continues to change its dimensione when other relaxation treatments are used, and especially that includes tumbling during the drying cycle.
3) In the fully relaxed state, i.e. with the best and suitable relaxation treatment, c/cm, r/cm and s can be related to $1/L$ and $1/L^2$ respectively by simple straight line relationships passing through the origin.
4) For wool fabrics, wet relaxation followed by hydro-extraction, and finally tumble dried at 72°C for 1 hr is very effective in bringing the fabrics to stable dimensions.
5) For acrylic fabrics both direct tumbling, and wet relaxation followed by tumble drying at 72°C for ½ hr are very effective in relaxing the fabrics.
6) Yarn variables, such as count, number of ends, twist, and fibre material are of little importance when the fabrics are well relaxed.
7) For wool and acrylic full cardigan fabrics in the fully relaxed state, the K_c, K_r and K_s values are 9.49, 3.74 and 33.6 respectively.

Part II. HALF CARDIGAN

II.1. INTRODUCTION

Half cardigan structure is one of the complex weft knitted structures that structurally based upon 1x 1 rib. The repeat is two courses, i.e. knit-knit (1x 1 rib), and tuck-knit. Tucking occurs always on half the number of needles used. The fabric is usually knitted at equal knit-knit and tuck-knit courses, but for the purpose of investigation two series of fabrics of fixed knit-knit and variable tuck-knit courses, and vice-versa, were knitted[5] to find ths effect of ths repeating courses on fabric appearance, handle, and among all fabric dimensions.

dried flat without tension on a flat surface. From the results obtained in the present work it seems that tumbling during drying is essential to help the loops to over-come the frictional restraints at the cross-over points, and hence to achieve the configuration of minimum energy. This was possible for wool and acrylic fabrics when tumbled during drying at 72°C for 1 hr, and ½ hr rsspectively. Also it is evident that direct tumbling of acrylic fabrics without static wet relaxation was very effective in bringing the fabrics to stable dimensions, with K-values very close to that of wool fabrics.

I.8. Conclusions.

1) Full cardigan fahrics increases in width and decreases in length when relaxed.
2) The dry relaxed state is not a state of minimum energy and fabric continues to change its dimensione when other relaxation treatments are used, and especially that includes tumbling during the drying cycle.
3) In the fully relaxed state, i.e. with the best and suitable relaxation treatment, c/cm, r/cm and s can be related to 1/L and $1/L^2$ respectively by simple straight line relationships passing through the origin.
4) For wool fabrics, wet relaxation followed by hydro-extraction, and finally tumble dried at 72°C for 1 hr is very effective in bringing the fabrics to stable dimensions.
5) For acrylic fabrics both direct tumbling, and wet relaxation followed by tumble drying at 72°C for ½ hr are very effective in relaxing the fabrics.
6) Yarn variables, such as count, number of ends, twist, and fibre material are of little importance when the fabrics are well relaxed.
7) For wool and acrylic full cardigan fabrics in the fully relaxed state, the K_c, K_r and K_s values are 9.49, 3.74 and 33.6 respectively.

Part II. HALF CARDIGAN

II.1. INTRODUCTION

Half cardigan structure is one of the complex weft knitted structures that structurally based upon 1x 1 rib. The repeat is two courses, i.e. knit-knit (1x 1 rib), and tuck-knit. Tucking occurs always on half the number of needles used. The fabric is usually knitted at equal knit-knit and tuck-knit courses, but for the purpose of investigation two series of fabrics of fixed knit-knit and variable tuck-knit courses, and vice-versa, were knitted[5] to find ths effect of ths repeating courses on fabric appearance, handle, and among all fabric dimensions.

As with the case of full cardigan fabric, the literature show that little attention has been paid to the study of dimensional properties of half cardigan fabrics, especially those knitted from staple acrylic yarns. Also in the published works on half cardigan no informations concerning the relationship between c/cm, r/cm, and s and 1/L and $1/L^2$ are given, except that work carried out by tomaka on alimited counts (2/28 and 2/24 worsted count). In Tomaka's work (unpublished but mentioned in Ref. 7), dry and wet relaxation treatments were used. The linear relationships between c/cm, r/cm, and s and 1/L and $1/L^2$ respectively in these relaxed states have high intercepts with the courses, ribs and stitch density axises. The intercepts existing in those equations cannot be left out, and hence it indicates that the used relaxation treatments were not effective in relaxing the fabrics.

II.2. Knitting Machine Used.

That mentioned in I.5 for knitting full cardigan fabrics.

II.3. Yarns Used.

The specifications of yarns used are given in Table 1 Part I.2.

II.4. Relaxation Methods.

As the described in I.3. and I.4.

II.5. Loop Length Measurement.

In the case of equal courses fabrics the loop length was determined from dividing the total length of the repeating courses by twice the number of needles used. But in the case of unequal courses fabrics each of the repeating courses (K-K, or t-K) was measured seperatly and divided by the number of needles used to give the k-k or t-k loop length.

II.6. Dimensional Properties of Half Cardigan Fabrics with Equal Knit-Knit and Tuck-Knit Courses.

II.6.1. Effect of Loop Length on c/cm, r/cm, and s.

To examine the effect of loop length on the dimensional properties of half cardigan fabric, a series of fabrics[5] were knitted at equal repeating courses, i.e. equal Knit-Knit and tuck-Knit courses.

For wool and acrylic fabrics it was found[5] that fabrics (at any loog length) tend to increase in width and decrease in length not only in the dry relaxation state, but also after being relaxed with the methods described in I.3 and I.4. This trend was also found as been mentioned in Part I for full cardigan fabrics and seems to be common with fabrics that contains tuck-knit courses. Given in Table 4, the percentage change (increase (+), or decrease (-)) in length and width of wool and acrylic fabrics-in their fully relaxed states (W-R, T-D, and D-T, for the former and the latter respectively) from that of the dry state.

Table (4)

Yarn Count	Wool Fabric		Yarn Count	Acrylic Fabric	
Denier	Length(-)	Width(+)	Denier	Length(-)	Width(+)
2 x 2/498	3-13	13-16	886/2	18-41	9-22
3x 2/379	9-21	14-27	2 x 443/2	18-42	11-22
3x 4/569	0.5-2.5	7-16	3x 266/2	9-24	13-18

When the individual values[5] of the c/cm, r/cm, and s were plotted against 1/L and $1/L^2$ respectively for wool and acrylic fabrics, it was found that linear relationships in the form of; $Y = a_1 + b_1 X$ can be used to relate the c/cm, r/cm, and s against 1/L and $1/L^2$ respectively, where a_1 and b_1 are the intercept; and the slope respectively of these lines. The correlation coefficient is very high and highly significant at the 5% level. The best fit lines for wool and acrylic fabrics are given in Table 5. Plotted in Figs. 9 to 14 the values of c/cm,r/cm and s against 1/L and $1/L^2$ respectively in the fully relaxed states.

Table (5)

Fabric	Best Fit line	Relaxation Method
Wool	$c/cm = \frac{8.45}{L} + 0.49$ $r/cm = \frac{3.77}{L} + 0.28$ $s = \frac{33.9}{L^2} + 1.59$	W-R, T-D
Acrylic	$c/cm = \frac{7.29}{L} + 0.88$ $r/cm = \frac{3.40}{L} + 0.40$ $s = \frac{30.3}{L^2} + 0.34$	D-T

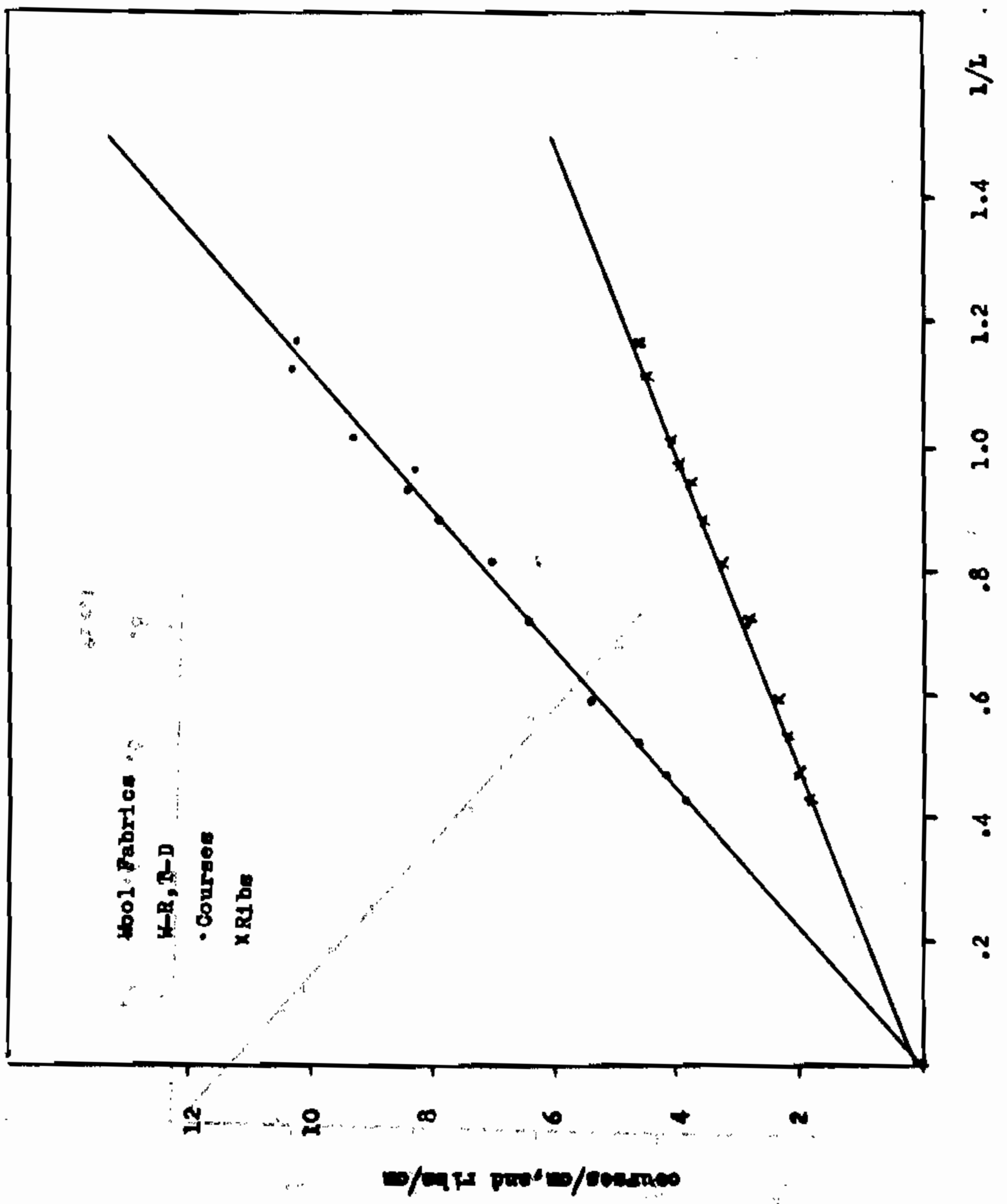

Wool Fabrics
W-R, T-D
• Courses
X Ribs
courses/cm, and ribs/cm
1/L
.2
.4
.6
.8
1.0
1.2
1.4
2
4
6
8
10
12

Fig.9

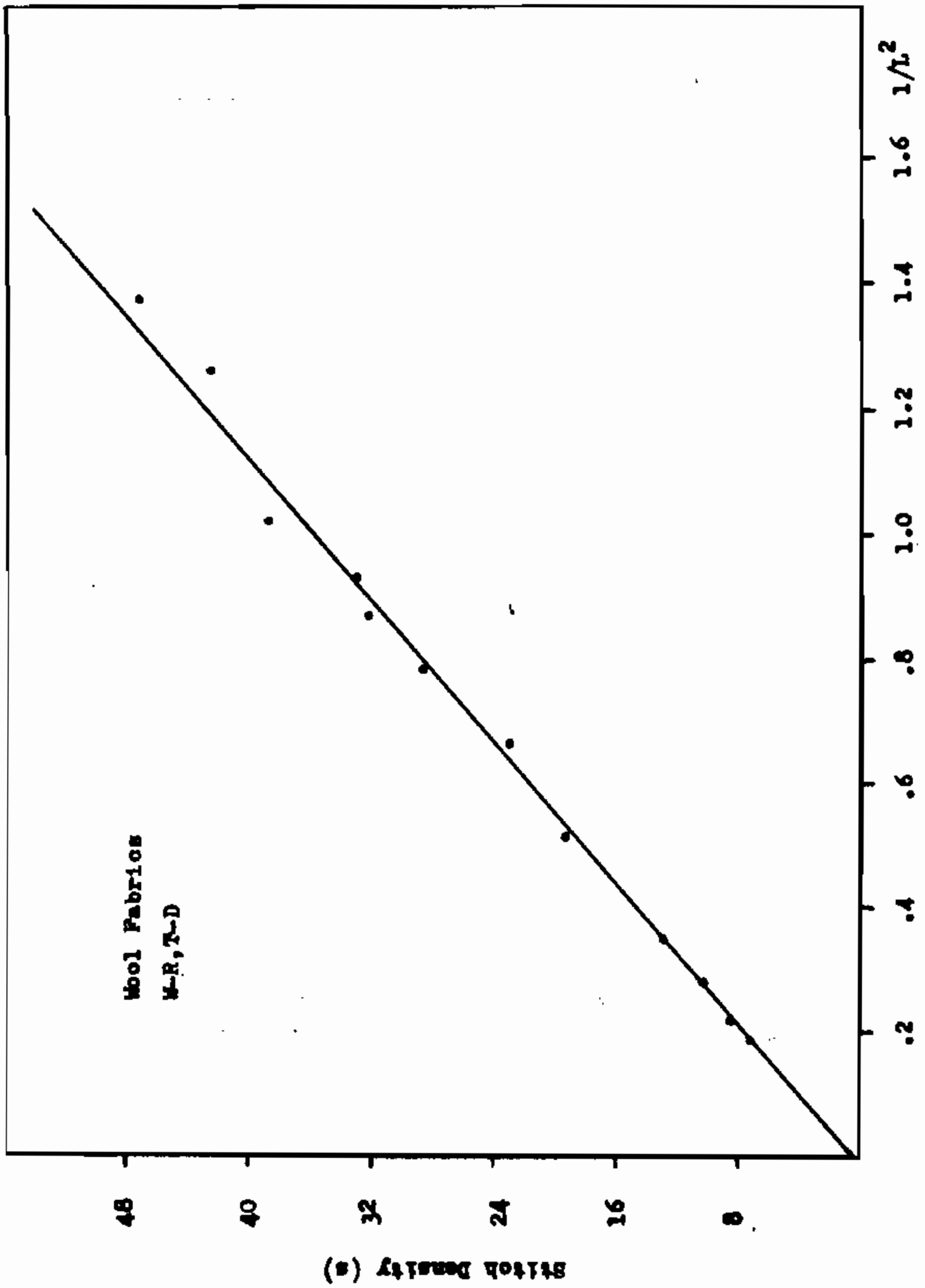

Wool Fabrics
W-R,T-D
$1/L^2$
.2
.4
.6
.8
1.0
1.2
1.4
1.6
8
16
24
32
40
48
Stitch Density (s)

Fig.10

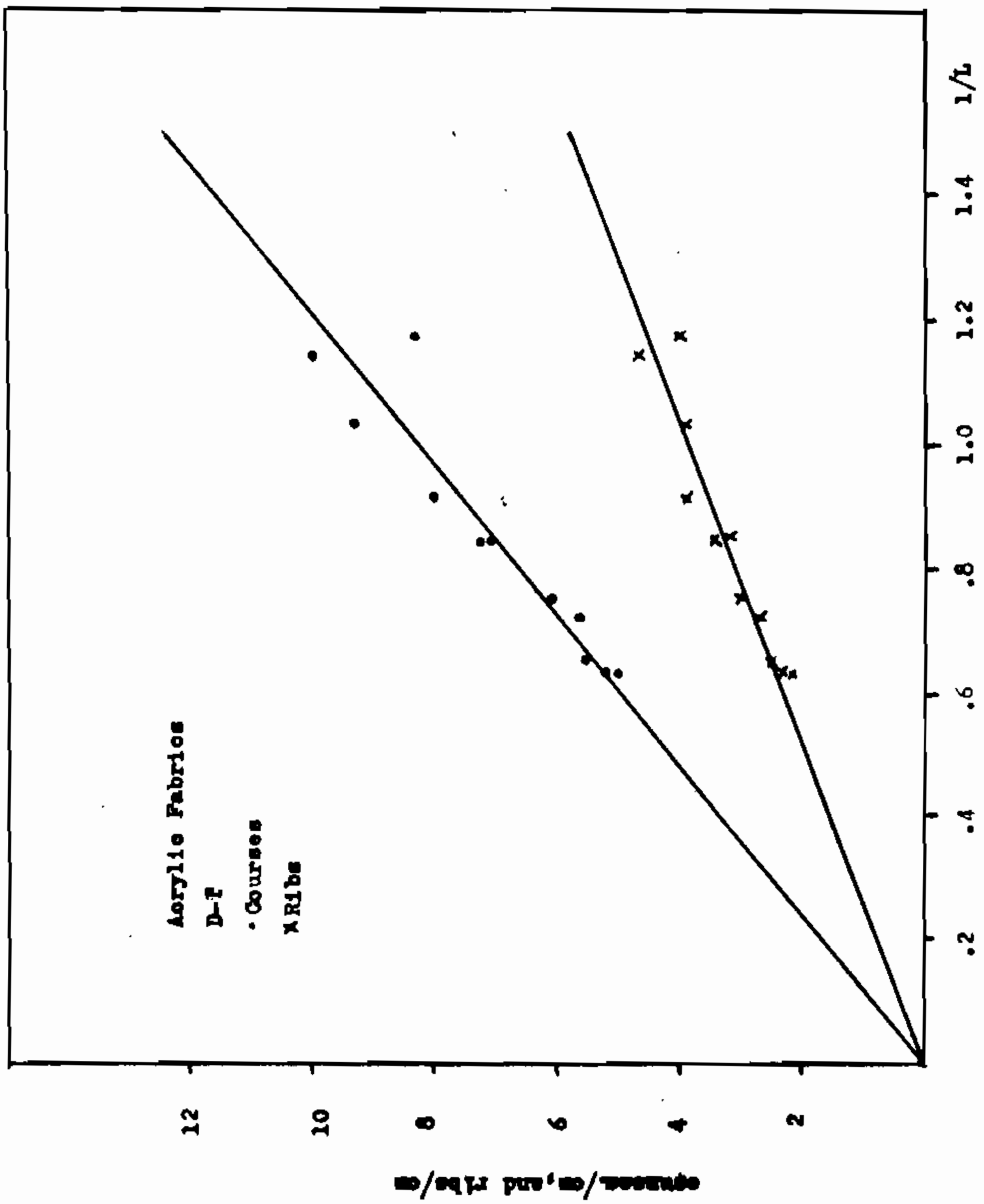

Acrylic Fabrics
D-T
· Courses
x Ribs
1/L
.2
.4
.6
.8
1.0
1.2
1.4
12
10
8
6
4
2
courses/cm,and ribs/cm

Fig.11

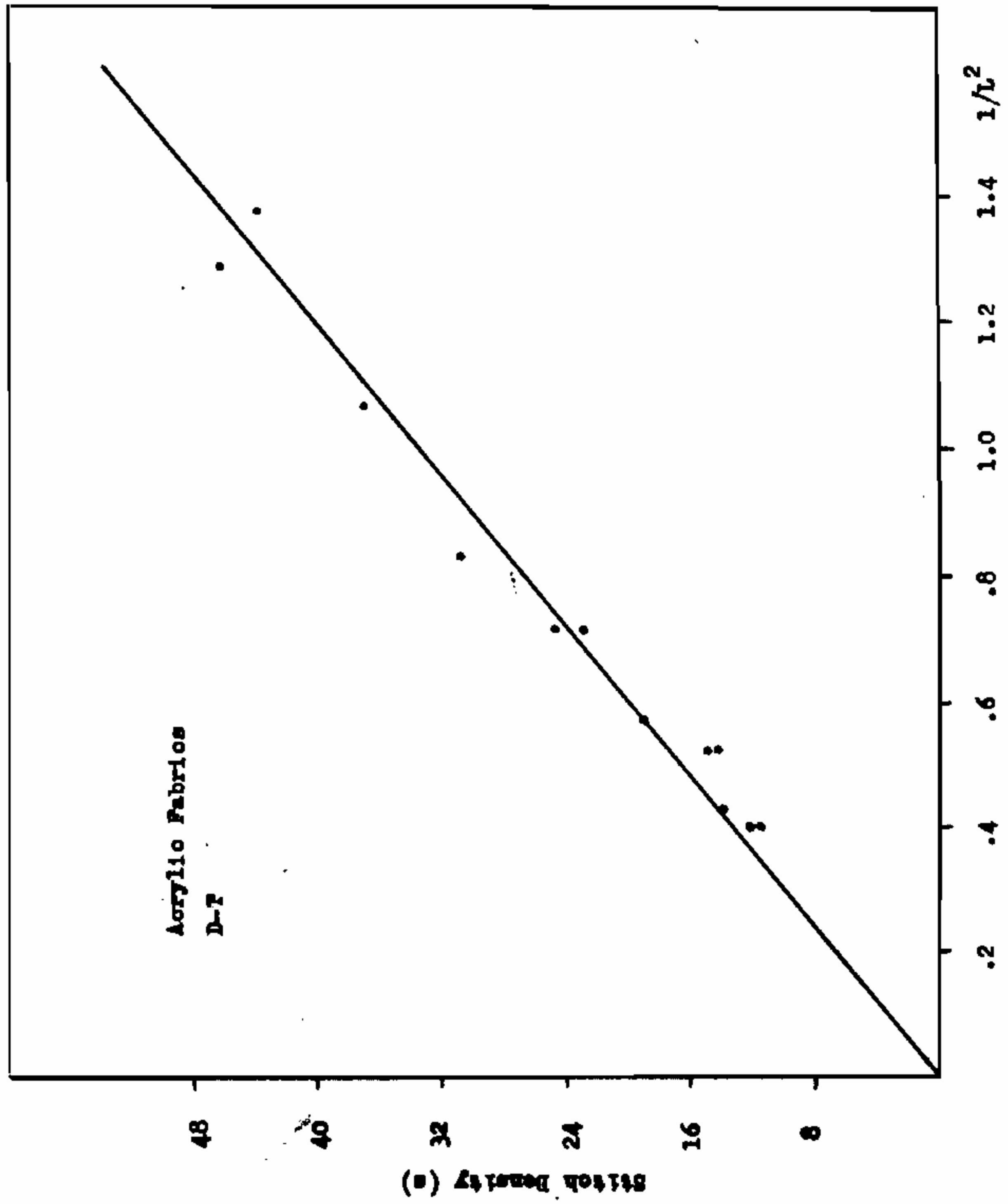

Acrylic Fabrics
Stitch Density (s)
48
40
32
24
16
8
.2
.4
.6
.8
1.0
1.2
1.4
1/L²

Fig.12

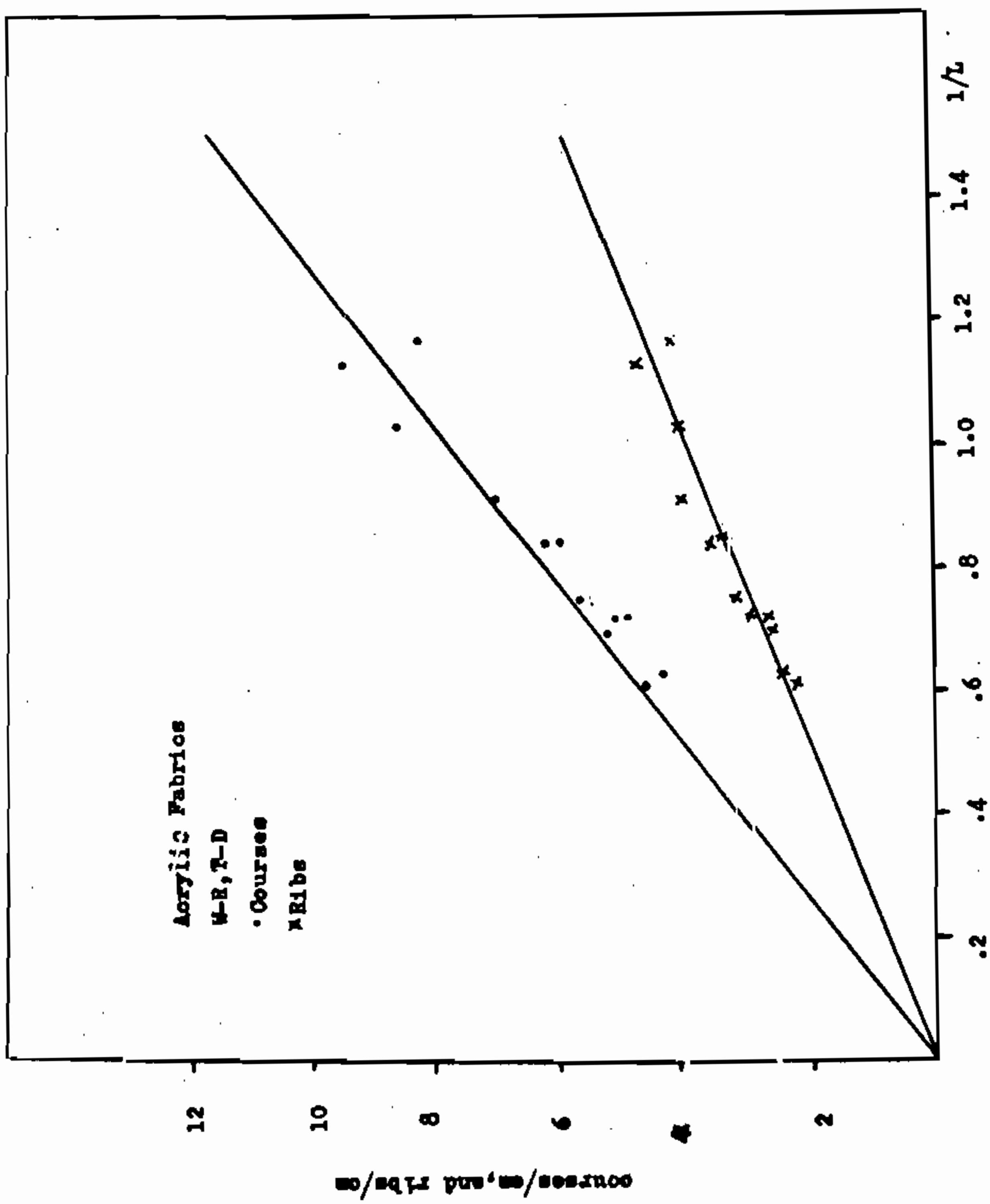

Acrylic Fabrics
W-R,T-D
· Courses
x Ribs
1/L
.2
.4
.6
.8
1.0
1.2
1.4
12
10
8
6
4
2
courses/cm,and ribs/cm

Fig.13

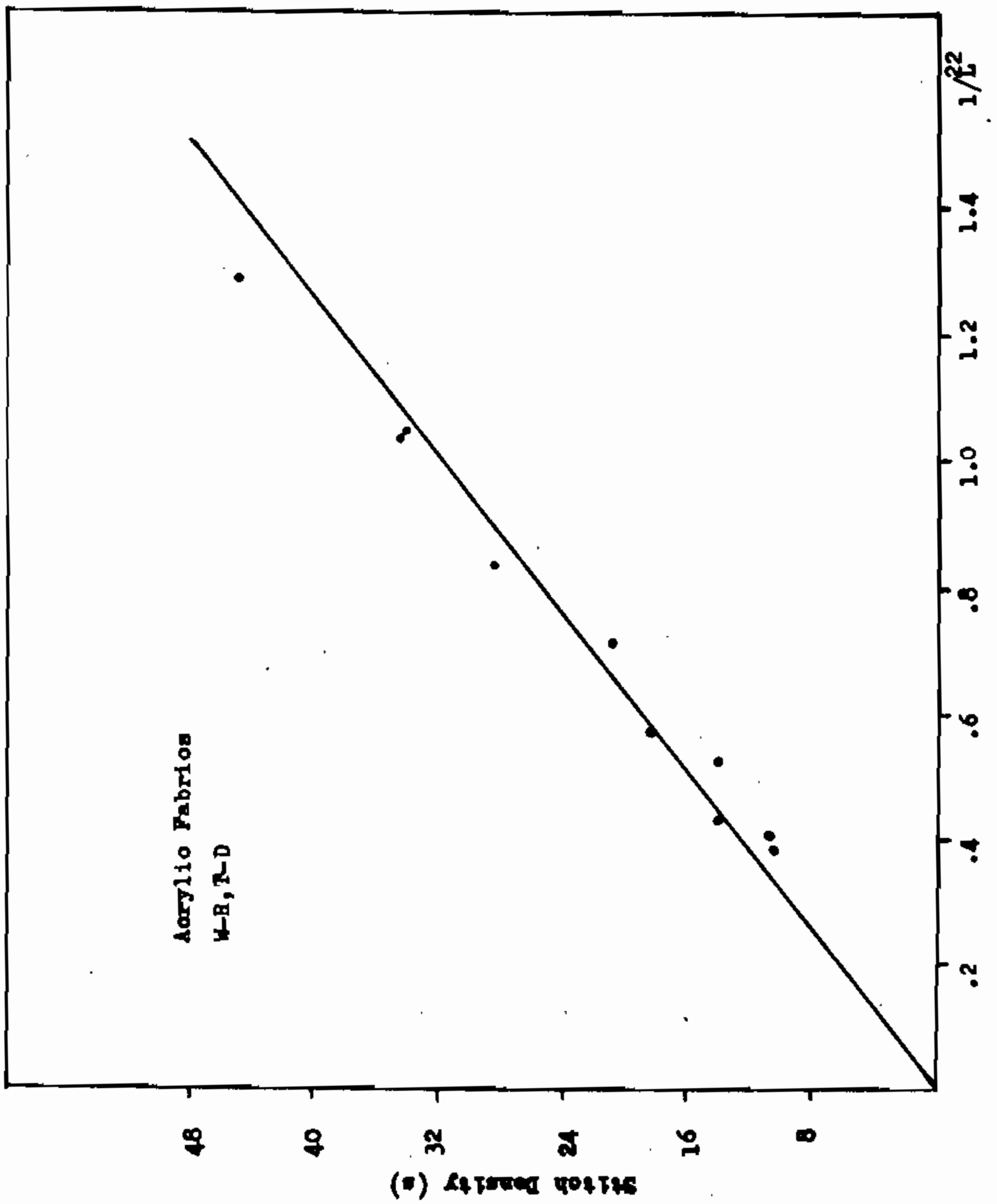

Acrylic Fabrics
W-R,T-D
Stitch Density (s)
48
40
32
24
16
8
.2
.4
.6
.8
1.0
1.2
1.4
1/L²

Fig.14

Table (5)(Continue).

Fabric	Best Fit line	Relaxation Method
Acrylic	$c/cm = \frac{7.60}{L} + 0.21$ $r/cm = \frac{3.34}{L} + 0.04$ $s = \frac{30}{L^2} + 0.27$	W-R, T-D

The intercepts existing in the equations are statistically of insignificant values and the equations can be used with very high confindence, when they are left out. Also it is evident from the table that the two relaxation treatments used to relax the acrylic fabrics led to more or less the same equations for the courses, ribs and stitch density. But in general when the intercepts are left out for wool and acrylic fabrics, simple linear relationships in the form of:-

$$c/cm = \frac{K_c}{L} \qquad ....(7)$$

$$r/cm = \frac{K_r}{L} \qquad ....(8)$$

$$s = \frac{K_s}{L^2} \qquad ....(9)$$

can be used to determine the dimensions of the fabric, where K_c, K_r and K_s are constants that are independent of yarn variables. These equations are similar in form to those obtained for full cardigan fabric (except the K-values are different) and for the simple plain fabric, and the 1 x 1 rib fabric.
The above finding is very important since it proves that even with complex structures that contains more than one type of loops, for example knit and tuck loops, the structure can achieve a state of minimum elastic energy although its repeating elements were exposed during knitting to different strains. This is the case with half cardigan since in the tucking course, the stitch with which tucking occurs extends more than that loop which is cleared always in each row. This state of minimum energy has been achieved for wool by wet relaxation, followed by tumble drying at 72°C for 1 hr, and for acrylic by similar treatment (but different wetting temperature) and by direct tumbling at 72°C for ½ hr.

When the used relaxation treatments were found to be effective in bringing the wool and acrylic fabrics to a state of minimum energy-it has been decided to plot all the results of c/cm, r/cm and s for wool and acrylic fabrics against 1/L and $1/L^2$ respectively in these relaxed states. Figs. 15 and 16 show the relationships obtained. From the plots it is evident that linear relationships can be used to relate the fabric variables to the loop length. The correlation coefficient is very high, ranging between 0.96 and 0.98 and highly significant at the 1% level. The best fit lines using the least square method are in the form of:-

$$c/cm = \frac{7.79}{L} + 0.44 \qquad \text{.......(10)}$$

$$r/cm = \frac{3.59}{L} + 0.33 \qquad \text{.......(11)}$$

$$s = \frac{31.6}{L^2} + 1.08 \qquad \text{.......(12)}$$

Statistically the intercepts of equations 10, 11 and 12 are of insignificant value, and can be ignored for practical purpose to give rise to simple linear relationships passing through the origin. This again indicates that when the relaxation process is suitable and successful there is no need to add any terms to the simple equation, i.e. Y = a X to account for yarn diameter, or fibre denier or material. In such case the general formulae proposed by Munden[1] for the simple plain stitch may also be used to determine the fully relaxed dimensions of complex fabrics, i.e. as in the present case of half cardigan. The obtained equations for courses, ribs and stitch density show that tumbling during drying is very effective and essential, and did not cause distortion as smirfitt[2] found in his case with 1x 1 rib fabrics.

II.7. Dimensional Properties of Half Cardigan Fabrics with Unequal Repeating Courses.

II.7.1. Fabrics with Fixed Tuck-Knit course, and Variable Knit-Knit Course-Effect of Relaxation Treatment on Length and Width.

Given in Table 6, the range of percentage change in length (decrease) and width (increase) over the range of cover factors used, for each of the used relaxed states, and calculated from the dry relaxed values.

Table (6)

Fabric	Decrease in Length %	Increase in Width %	State
Wool	11-25 4-17	14-17 10-15	W-R, T-D W-R
Acrylic	14-22 6-11	29-34 28-30	D-T W-R, T-D

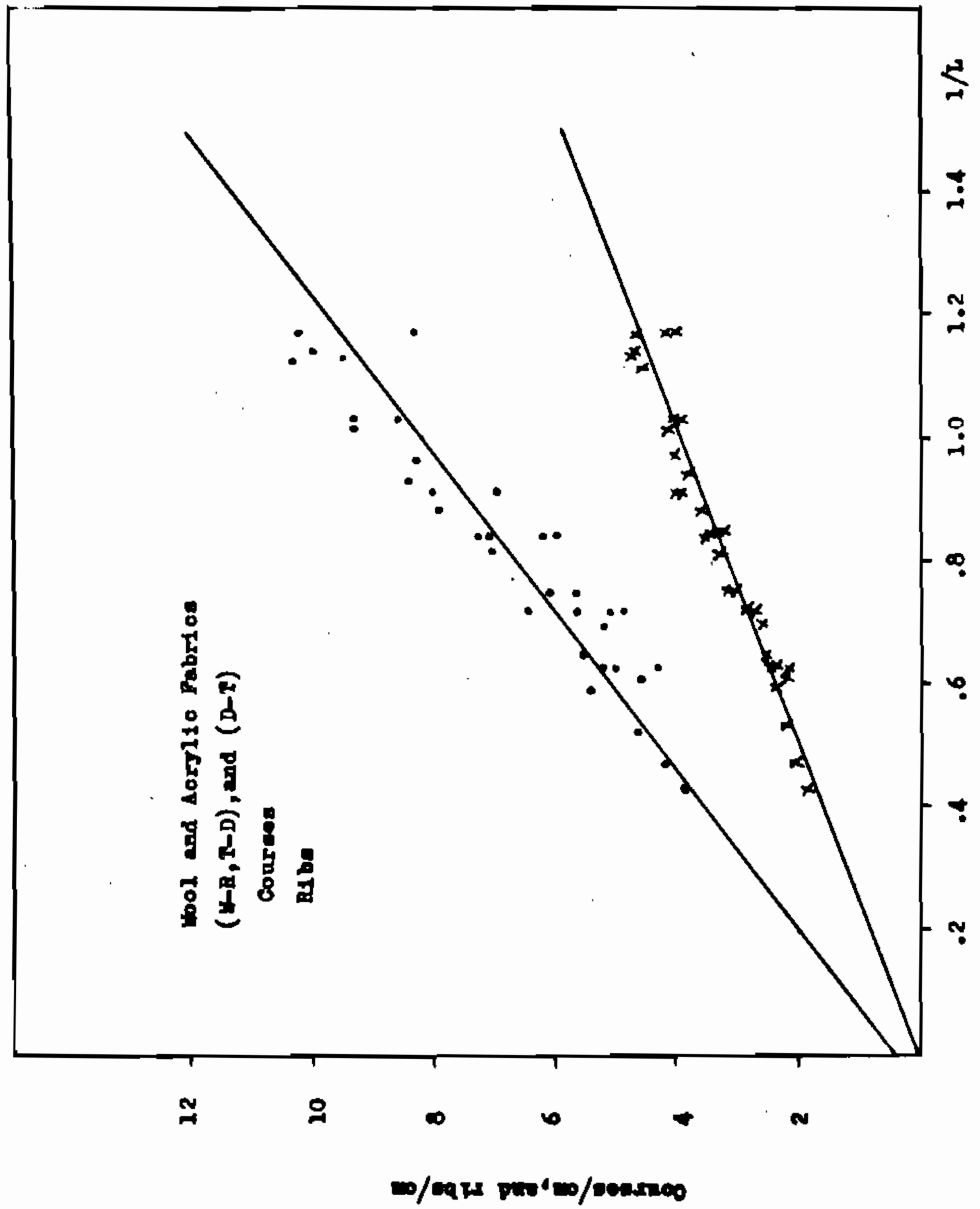

Wool and Acrylic Fabrics
(W-R,T-D),and (D-T)
Courses
Ribs
Courses/cm,and ribs/cm
1/L
.2
.4
.6
.8
1.0
1.2
1.4
2
4
6
8
10
12

Fig.15

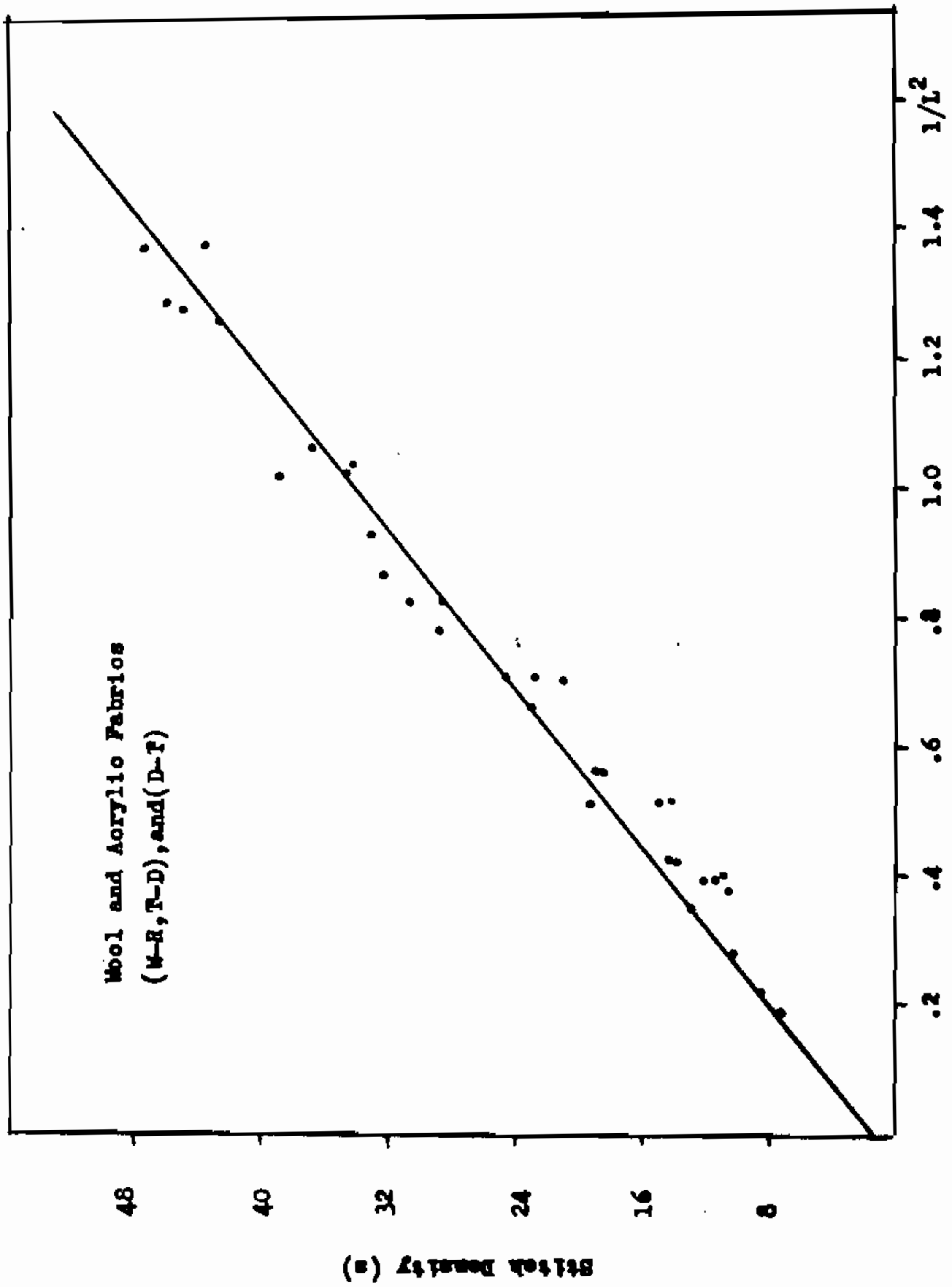

Wool and Acrylic Fabrics
(W-R, T-D), and (D-T)
1/L²
.2
.4
.6
.8
1.0
1.2
1.4
Stitch Density (s)
8
16
24
32
40
48

Fig.16

From the table it is evident that wet relaxation only for wool fabrics is not really relaxed state, since the (W-R, T-D) treatment brought about considerable changes in length and width. Also from the table one can observe that the direct tumbling technique is more effective in causing more changes in length and width, than the W-R, T-D treatment.

II.7.2. Effect of Tuck-Knit and Knit-Knit Loop Length on c/cm, r/cm, and s.

The effect of the tuck-knit and knit-knit loop length on the geometery of half cardigan fabrics knitted from wool and acrylic staple yarns, has been examined. This wae carried out by fixing one of these courses and varying the other. The cover factor of the fixed course (t-k or k-k) has been altered to cover the highest and lowest cover factor possible by the type of knitting machine used. It was found (in the dry state) that by fixing the k-k course length and varying the t-k course, the fabrics tends to increase in width rather in length. The rate of increase in length is negligable if compared with that of width. The opposite exactly occurs for fabrics knitted at fixed tuck-knit course length and varying knit-knit course length.

The best fit lines between c/cm , r/cm and s and 1/L and $1/L^2$ respectively using the least square method are given in Table 7 and 8. These relations are for a limited number of counts namely 2 x 498/2 respectively and 1x 886/2 denier, wool and acrylic staple yarns. The correlation coefficients are very high and ranging between 0.96 and 0.99 and highly significant at the 5% level. The equations given in the tables represent various conditions of cover factor for the fixed course (either k-k or t-k) and relaxation treatments.

From the equations the following points may be observed:- and concerns the intercepts:-

1) almost all, are positive at any of the used relaxed states for wool and acrylic.
2) the intercepts did not vanish after the use of any of the proposed relaxation treatments.
3) the cover factor of the fixed course seems to be in general of little effect on the value of the intercepts after any of the used relaxed states, compared with that of the dry state.
4) the intercepts in the ribs equations at any of the used relaxed states are high, and surprisingly not less than half the value of the ribs/cm obtained at any loop length.

In fact the intercepts in the mentioned equations are of statistical significance and cann't be left out, and in none of these equations the straight line passes through the origin (or near

Table (7): Equations of Half cordigan fabrics knitted from 2 x 498/2 denier wool yarn, at fixed tuck-knit course, and knit-knit course.

Cover Factor* of the fixed course	Relaxation Treatment	
	D-R	W-R, T-D
T-K is Fixed C.F. = 51.9	$c/cm = \frac{9.38}{L} + 1.5$	$c/cm = \frac{7.69}{L} + 1$
	$r/cm = \frac{0.32}{L} + 4.63$	$r/cm = \frac{1.69}{L} + 2$
	$s = \frac{27.4}{L} + 10.1$	$s = \frac{21.3}{L^2} + 16.9$
T-K is Fixed C.F. = 40.2	$c/cm = \frac{5.5}{L} + 1.5$	$c/cm = \frac{2}{L} + 5$
	$r/cm = \frac{2.5}{L} + 4$	$r/cm = \frac{2.34}{L} + 2.2$
	$s = \frac{34.2}{L} + 7$	$s = \frac{32.6}{L^2} + 9.2$
K-K is Fixed C.F. = 48.9	$c/cm = \frac{8.28}{L} + 0.55$	$c/cm = \frac{9.09}{L} + 1.23$
	$r/cm = \frac{0.55}{L} + 4.14$	$r/cm = \frac{0.82}{L} + 3.46$
	$s = \frac{32.1}{L^2} + 9.58$	$s = \frac{34.9}{L^2} + 9.37$
K-K is Fixed C.F. = 40.2	$c/cm = \frac{2.5}{L} + 7.5$	$c/cm = \frac{5}{L} + 8.7$
	$r/cm = \frac{1.34}{L} + 8.17$	$r/cm = \frac{2}{L} + 4.34$
	$s = \frac{8.75}{L^2} + 22.8$	$s = \frac{19.3}{L^2} + 10.6$

* C.F. = Cover factor ($\sqrt{\text{Denier}}/L$ cm).

Table (8): Equations of Half cardigan fabrics knitted from 886/2 denier staple acrylic yarn, at fixed tuck-knit course.

The Fixed course and Its cover factor	Relaxation Treatment		
	D-R	D-T	W-R, D-T
Tuck-Knit C.F. = 43.1	$c/cm = \frac{7.84}{L} - 0.73$	$c/cm = \frac{9.17}{L} + 0.62$	$c/cm = \frac{7.1}{L} + 0.75$
	$r/cm = \frac{0.78}{L} + 3.89$	$r/cm = \frac{0.45}{L} + 3.56$	$r/cm = \frac{1.56}{L} + 2.89$
	$s = \frac{22.5}{L^2} + 9.06$	$s = \frac{24.2}{L^2} + 9.56$	$s = \frac{22.2}{L^2} + 9.25$
Tuck-Knit C.F. = 35.1	$c/cm = \frac{3.8}{L} + 2.2$	$c/cm = \frac{5.2}{L} + 1.6$	$c/cm = \frac{7}{L} + 0.60$
	$r/cm = \frac{0.60}{L} + 4$	$r/cm = \frac{3}{L} + 1.6$	$r/cm = \frac{0.80}{L} + 2.80$
	$s = \frac{11.6}{L^2} + 12.4$	$s = \frac{22.9}{L^2} + 4.12$	$s = \frac{13.8}{L^2} + 9$

the origin except in the case of acrylic fabrics knitted at fixed t-k course (C.F. = 43.1). These results in fact are quite different from that obtained at equal knit-knit and tuck-knit courses, from the same yarns and relaxed by the same methods of relaxation. While the c/cm, r/cm and s in the case of equal courses are directly related to 1/L and $1/L^2$ respectively by simple linear relationships in the form of:-

$$y = bx \qquad \text{..........(13)}$$

they are related to 1/L and $1/L^2$ respectively by a linear relationship in the form of:-

$$y = b_1 X + a_1 \qquad \text{..........(14)}$$

where b_1 and a_1 are constants that differ completely from that of equ. 13. It is possible that the fixed loop creates more restraints in the structure especially when a longer loop is drawn through it. The same is expected in the relaxation process, and it seems that tumbling for ½ for acrylic, and 1 hr for wool was not enough to help the yarn to over-come the high friction at the cross-over points. Hence the loops were not able to achieve a configuration of minimum energy that had been achieved at the same tumbling conditions for equal courses fabrics.

From the above it is evidsnt that full relaxation of fabric especially fabrics of unequal courses will not be achieved unless there is a suitable ratio between loop lengthes of the repeat unit, and or a harsh relaxation treatment that shaken the yarns severly to over-come the frictional restraints at the cross over points.

II.7.3. K-Values of Unequal Repeating Courses Fabrics.

The average K_c, K_r, K_s and K_c/K_r values for wool and acrylic half cardigan fabrics knitted at fixed tuck-knit course and variable k-k course are given in Tables 9 and 10. Also given in these tables the pecentage change (increase or decrease) in the K value at each of the used relaxed state, calculated from the dry state value.

It is evident from these tables that the K values are quite different for wool and acrylic fabrics knitted at fixed tuck-knit course and variable knit-knit course. Also over the range used for cover factor it seems that the K-values are dependent to some extent on the cover factor. The dry relaxed state is not a state of minimum energy and the fabrics at any of the used relaxed states continued to change its dimensions as the percentage change of K-values show in the table. For wool fabrics knitted at fixed tuck-knit course, the (W-R, T-D) treatment was able to cause a remarkable change in K-values, and for

Table (11): K-values of Half Cardigan Wool Fabrics Knitted at Fixed Knit-Knit Course.

Cover Factor of the Fixed course.	K_c	K_r	K_s	K_c/K_r	State
$\frac{\sqrt{Denier}}{L} = 48.9$	8.49	5.55	46.8	1.53	D-R
	9.93	4.66	46.6	2.13	W-R, T-D
% change in K:	+17	-16	-0.5	+40	
$\frac{\sqrt{Denier}}{L} = 40.2$	7.84	5.02	32.9	1.57	D-R
	9.45	4.65	37.6	2.04	W-R, T-D
% change in K	+21	-7	+14.6	+30	

+ = increase .

- = decrease.

From Table 11 one may observe that the relaxation treatment used for wool causes a remarkable change in the K-values at low cover factor as well as at high cover factor. Also that the dry relaxed state is not a state of stable dimensions, since the K-values are still changing as relaxation is going on. The K-values obtained for fabrics knitted at fixed tuck-knit or knit-knit course are generally higher than that obtained for equal courses fabrics knitted from the same type of yarn and at the same range of cover factors. This indicates the dependence of fabric K-constants on the cover factor of the repeating courses, i.e. tuck-knit and knit-knit. This difference in the K-values for the equal and unequal courses half cardigan fabrics may be due to the equal chances of movement of the tuck-knit and the knit-knit loop within the repeat. This will lead to more changes in the angular position of the link yarn joining the knit and the tuck loop. This seems to be difficult with half cardigan fabrics knitted with a fixed course , since high frictional restraints will be created at the cross over points.

Given in Table 12, the K-values obtained by Fitton, and Hopkinson, and by knapton[6] whose used only a 20[5] worsted yarn for knitting his fabrics. Also given in the table the K-values obtained in the present work for wool and acrylic fabrics knitted at equal courses. The K-values given in Table 12 for nylon fabrics (i.e. that knitted by Fitton and Hopkinson[4]) were calculated from the individual values given by the author. Also that obtained by Knapton[6] have been recalculated, since in his work acrylic fabrics the direct tumbling method is more effective in causing more changes in the K-values, than the (W-R, T-D) treatment used for the same fabrics.

Table (9) Wool Fabrics

Cover factor of the fixed course	K_c	K_r	K_s	K_c/K_s	State
$\frac{\sqrt{Denier}}{L} = 51.9$	7.11 8.19	6.38 5.52	44.9 45.2	1.12 1.49	D-R W-R, T-D
% change in K	+15.2	-14	+1	+33	
$\frac{\sqrt{Denier}}{L} = 40.2$	7.32 8.61	5.89 5.09	43.1 43.8	1.25 1.70	D-R W-R, T-D
% change in K	+22	-14	+1	+36	

+ = increase; - = decrease.

L = in centimeters

Table (10): K-values of Half cardigan acrylic fabrics knitted at fixed tuck-knit course.

Cover factor of the fixed course	K_c	K_r	K_s	K_c/K_r	State
$\frac{\sqrt{Denier}}{L} = 43.1$	6.71 8.19 7.42	6.38 5.52 5.71	42.8 45.2 42.3	1.06 1.49 1.32	D-R D-T W-R, T-D
% change in K for: D-T W-R, T-D	 +28 +11	 -14 -11	 +6 +1	 +47 +25	
$\frac{\sqrt{Denier}}{L} = 35.1$	6.66 8.27 7.36	6.24 5.23 4.83	41.6 43.2 35.5	1.08 1.59 1.53	D-R D-T W-R, T-D
% change in K for: D-T W-R, T-D	 +31 +11	 -17 -23	 +4 -15	 +48 +42	

+ = increase; - = decrease

% change in K-values are calculated from that of the dry state.

he used the loop length in the repeat rather than the average length used in the present work. The new K-values were calculated by dividing the K_c and K_r values by two, and the K_s value by four.

Table (12): K-values of half cardigan fabrics knitted from nylon and wool yarns at equal courses.

Type of Yarn	K_c	K_r	K_s	K_c/K_r	State	Author
2x2/70 den. Nylon 6.6	10.50	3.15	32.6	3.37	W-R and F-D	Fitton and Hopkinson
"	9.82	3.30	32.4	3.02		
"	10.50	2.27	24.1	4.62		
"	10.20	2.43	24.8	4.23		
"	10.50	2.50	26.3	4.22		
"	10.00	2.43	24.2	3.97		
"	8.60	2.40	20.7	3.54		
Wool	18.1±3	8.4±0.09	152±4	2.16±0.6	W-O, T-D	Knapton[1]
	9.05±1.5	4.2±0.05	38±1	2.16±0.6		Knapton[2]
Wool	8.45	3.77	33.9	2.24	W-R, T-D	Present
Acrylic	7.29	3.40	30.3	2.14	D-T	"
Acrylic	7.60	3.34	30.0	2.27	W-R, T-D	"

2 = Values re-calculated to be compared with that of the present work.
F-D = Flat drying.

From the values given in Table 12 one may observe that the K-values obtained by the various investigators are different, and that the K_c-values obtained by Fitton and Hopkinson[4] and by Knapton are higher than that obtained in the present work. The K_c/K_r value obtained by Knapton[6] is within the range of values of K_c/K_r obtained in the present work for wool and staple acrylic fabrics.

The differences in K-values between the previous investigators and the present investigator may be due to many reasons, such as yarn variables (denier, type of yarn (staple or continuous), and fibre material) or relaxation treatment. The Wetting out and tumble drying at 70°C for 1 hr used by Knapton gives higher K-values than that obtained in the present work, in which also tumbling was used for the same period (1 hr) but at slightly high temprature (72°C). In the case of Fitton and Hopkinson[4] the fabrics were dried flat, and agitation had been only used during the wetting process. Tumbling during drying is expected to cause more changes in fabric dimensions by compressing the loops, and hence helping them to over-come the frictional restraints at the cross-over points, so it can achieve the configuration of minimum elastic energy.

II.8. CONCLUSIONS

1) Half cardigan fabrics increases in width and decreases in length when relaxed.
2) For wool and acrylic half cardigan fabrics knitted at equal or unequal repeating courses, the dry state is not a state of stable dimensions. Further relaxation hy other methods brings more changes in fabric dimensions.
3) In the fully relaxed state, the c/cm, r/cm and s may be related to 1/L and $1/L^2$ respectively by simple linear relationships passing through the origin. The slopes of these lines are independent of yarn and machine variables.
4) In the fully relaxed state, half cardigan fabric can be described by dimensionless constants, i.e. K_c, K_r, K_s and K_c/K_r, which were found to be independent of yarn and machine variables.
5) Relaxation treatment only would not bring appreciable changes in fabric dimensions unless it is aseessed by fabric structure, i.e. the proportion of loop lengthes in the repeat unit.
6) Half cardigan fabrics knitted at fixed knit-knit and varying tuck-knit courses, and vice-versa, have dimensional properties that differs completely from that of fabrics knitted at equal courses. Intercepts of positive and significant values always exist in the courses, ribs and stitch density equations.
7) The (D-T), and (W-R, T-D) and (W-R, T-D) used for acrylic and wool fabrics respectively led to K-values that are very close, and may be considered constants for half cardigan stitch.
8) The K-values of the half cardigan stitch depends upon the proportion of the repeating courses length in the repeat unit. Fabrics with fixed tuck-knit and varying knit-knit courses and viceaversa, have higher K-valuee than that of fabrics with equal courses.

during the wetting process. Tumbling during drying is expected to cause more changes in fabric dimensions by compressing the loops, and hence helping them to over-come the frictional restraints at the cross-over points, so it can achieve the configuration of minimum elastic energy.

II.8. CONCLUSIONS

1) Half cardigan fabrics increases in width and decreases in length when relaxed.
2) For wool and acrylic half cardigan fabrics knitted at equal or unequal repeating courses, the dry state is not a state of stable dimensions. Further relaxation hy other methods brings more changes in fabric dimensions.
3) In the fully relaxed state, the c/cm, r/cm and s may be related to 1/L and $1/L^2$ respectively by simple linear relationships passing through the origin. The slopes of these lines are independent of yarn and machine variables.
4) In the fully relaxed state, half cardigan fabric can be described by dimensionless constants, i.e. K_c, K_r, K_s and K_c/K_r, which were found to be independent of yarn and machine variables.
5) Relaxation treatment only would not bring appreciable changes in fabric dimensions unless it is aseessed by fabric structure, i.e. the proportion of loop lengthes in the repeat unit.
6) Half cardigan fabrics knitted at fixed knit-knit and varying tuck-knit courses, and vice-versa, have dimensional properties that differs completely from that of fabrics knitted at equal courses. Intercepts of positive and significant values always exist in the courses, ribs and stitch density equations.
7) The (D-T), and (W-R, T-D) and (W-R, T-D) used for acrylic and wool fabrics respectively led to K-values that are very close, and may be considered constants for half cardigan stitch.
8) The K-values of the half cardigan stitch depends upon the proportion of the repeating courses length in the repeat unit. Fabrics with fixed tuck-knit and varying knit-knit courses and viceversa, have higher K-valuee than that of fabrics with equal courses.

REFERENCES

1. Munden, D.L., J.Tex. Inst. 1959, 50, T448.

2. Smirfitt, J.A., J.Tex. Inst. 1965, 56, T248.

3. Centre des Recherches de la Bonneterie, Troyes. Bull. Centre Rech. Bonneterie, 1963, No. 18, 35.

4. Fitton, S., and Hopkinson, J.C., J.Tex. Inst. 1961, 52, P471.

5. El-Gaiar, M.N., M.Sc. Disser. Manchester, 1971.

6. Knapton, J.J.F., and el., T. Res. J. 1968, 1013.

7. Fong, W., and el., Third International Wool Textile Research conference, Paris, Sec. 3, 417 (1965).

8. Doyle, P.J., J.Tex. Inst., 1953, 44, 561.

9. Pierce, F.T., Tex. Res. J. 1947, 17, 123.

10. Postle, R., and De Jonge, S., J.Tex. Inst., 1977, 68, 324.

11. Little, J.J., J.Tex. Inst., 1978, 69, 8.

12. Gowers, C.N., and Hurt, F.N., J.Tex. Inst. 1978, 69, 108.