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A Mathematical Analysis of the CP78 Data

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Contents

1. Introduction

We would like to be in a position to predict the final dimensional specifications of any knitted cotton fabric based only upon a knowledge of the knitting parameters - yarn count / stitch length - and the finishing route used.

There is no shortage of literature containing equations which purport to achieve this aim but, in fact, all of these equations have been developed on grey fabrics whereas we know that commercial finishing processes do change the relaxed dimensions.

The need to be able to predict final performance is an obvious one if we are ever to approach the problem of controlling dimensional stability in cotton knits. Likewise, it is obvious that all deliberations must start from a consideration of the so-called fully relaxed structure.

In all that follows, "fully-relaxed" is defined according to the IIC standard relaxation of one wash and tumble drying, followed by four more cycles of wetting out and tumble drying.

> *Note for digital version: This terminology was later changed to "Starfish Reference State" and "Starfish Reference Relaxation Procedure".*

Research Record No. 120 described a computer programme which allowed the large amount of data generated by our CP78 project on interlock and 1x1 rib to be filed on floppy discs and recalled at will, in various combinations, for interfacing with certain statistical software packages and for tabulation or plotting.

This report describes how a fairly unsophisticated mathematical analysis was carried out using the facilities of that programme, in order to arrive at a set of empirical linear regression equations whose predictive power was good enough to use in building a mathematical model for the interlock and 1x1 rib fabrics of CP78.

The actual model that has been built with these equations will be the subject of a separate report.

2. A Mathematical Analysis

General Approach

According to a good many authors, for plain jersey fabrics:

$$courses/cm = Kc / L \qquad (1)$$

$$wales/cm = Kw / L \qquad (2)$$

where *Kc* and *Kw* are "constants" which depend upon the degree of relaxation of the fabric but not upon the yarn count used to manufacture it. Thus, from a knowledge of the yarn count and stitch length, all the dimensional properties of a given fabric can be calculated, for the given state of relaxation. The yarn count value is required only to calculate the weight.

The dimensional properties of interlock and 1x1 rib fabrics have been considered by *Hurt* (1) and by *Nutting and Leaf* (2) who suggest that, for structures other than plain jersey, the yarn count must be introduced into the calculation for courses and wales. They propose (implicitly) relationships of the type:

$$courses/cm = a + b / L + c \cdot \sqrt{Tex} \qquad (3)$$

$$wales/cm = a' + b' / L + c' \cdot \sqrt{Tex} \qquad (4)$$

However, these authors, in common with most others in the past, have studied only or predominantly grey-state fabrics and / or have dealt with only partially relaxed materials.

Our objective in this investigation is to find rational equations for calculating the dimensional properties of 20 gauge interlock and 14 gauge 1x1 rib fabrics which depend upon materials in the fully-relaxed state and which have been subjected to one of several commercial finishing routines.

Starting from the assumption that equations such as (3) and (4) will be adequate for predicting the dimensional properties of grey-relaxed fabrics, there are three possibilities to account for the effect of finishing routines.

1. The equations remain the same (i.e. there is no change in the value of the coefficients), but the finishing process brings about changes in the stitch length, *L*, and the yarn *Tex* due, for example, to yarn shrinkage.
2. The equations retain the same form but, in addition to any changes brought about in *Tex* and *L*, the coefficients are significantly shifted to different extents by the different finishing routines.
3. A different form of equation is required for one or more of the different finishing routines.

Whilst situation No. 3 should perhaps not be dismissed out of hand, it is considered extremely unlikely in view of the fact that the literature records examples of equations being successfully applied to fabrics knitted from different fibres and yarn types, with only a change in the coefficients to account for these enormous differences.

A very neat result would be if situation No. 1 should prove correct, since the only experimental work then required (once the basic equations had been established) would be to discover the effect of a given finishing routine upon *Tex* and *L*.

Such good fortune can scarcely be contemplated and, in any event, can not be assumed from the outset. Therefore, our analysis has proceeded on the assumption that No. 2 will prove to be the more accurate model of reality.

Therefore, the general approach was as follows:

1. For each finishing routine, establish the relationship between yarn *Tex* as knitted to that in the final finished, fully-relaxed fabric. This enables the yarn *Tex* in the finished fabric to be calculated.
2. For each finishing routine, establish the relationship between stitch length as knitted to that in the final, finished, fully-relaxed fabric. This enables the stitch length in the finished fabric to be calculated.
3. Establish, for a few key finishing routines, the apparently best form of equation linking the (measured) relaxed, finished *Tex* and stitch length to courses, wales, and weight.
4. Assume that the same general form of equation is valid for all other finishing routines.
5. Determine the coefficients of these equations for all finishing routines.

In the next few sections, the results of these analytical steps are summarised, taken in order of the properties examined.

Yarn Count

The yarn count, as knitted, had been measured in our laboratory, by sampling the original cones, and also by Courtaulds Central Technology unit at Heron Mill, by sampling the residual packages after knitting. Weighted averages were calculated for each yarn count from these two series of measurements.

The yarn count in the finished, relaxed state had been measured in our laboratory by withdrawing courses from the relaxed fabrics. For several of the finishing routes, statistical tests were carried out to see whether the fabric tightness had been influential in modifying the change in yarn tex brought about by a given finish. It seemed that there was no effect of tightness, so all of the (5 or 6) values for a given yarn count and finish were averaged to arrive at the estimate for the finished, relaxed count.

Originally, the *Ne* count values had been used, but these were converted to *Tex* before the regression analysis was carried out.

Regression analysis was carried out using the least squares method and the best model was found to be:

$$y = a + b.x$$

where y is the finished relaxed *Tex*, x is the *Tex* as knitted, a, b are constants.

For interlock, the correlation coefficient, r, was always better than 0.98 and averaged about 0.998.

For rib, r was always better than 0.99 and averaged about 0.995.

The constants for the equations are given together with the corresponding values for r^2 in *Figures 1 and 2*. Graphs showing the fit of some of the regressions are shown in *Figures 3 and 4*. Plots of measured vs. calculated results are shown in *Figure 5*.

The regression equations for interlock and 1x1 rib fabrics are rather similar so it was interesting to calculate the average regression for a few of the finishes to see whether the fabric structure plays a decisive role. The results are shown in *Figure 6* where it can be seen that the average regression is a good approximation for both sets of data. The implication is that fabric construction, within the range studied, has only a minor influence, if any, upon the magnitude of the change in yarn Tex brought about by finishing. *Figures 3, 4 and 6* confirm that the different finishing processes do cause a significant change in yarn *Tex*. The largest change is caused by mercerising which resulted in a net increase in *Tex* of about 8%.

Stitch Length

Stitch length had been measured in the grey fabric and in the finished, relaxed material. Earlier extensive trials (3) have established that the stitch length measured on grey fabric is an accurate estimate of the stitch length as knitted and measured by electronic or mechanical run-in meters.

Preliminary analysis established that the best model for predicting stitch length in the finished, relaxed fabrics would be $y = a + b.x$, so the least squares regression analysis was performed for all finishes on this model.

Correlation coefficients were always better than about 0.96 and averaged about 0.991 so the equations can be considered to be reliable within the range studied. Values for the various regression constants and for r^2 are given in *Figures 7 and 8* and plots of some of these are shown in *Figures 9 and 10*. In *Figure 11* both interlock and rib data are plotted together to show that the dominant influence is the finishing process rather than the fabric construction.

Wales

The first model to be checked was that represented by equation (2) which holds that the wales/cm can be predicted solely from the reciprocal of stitch length using the model

$$y = a + b / x$$

where *y* is the finished, relaxed wales/cm and *x* is the finished, relaxed stitch length.

Correlation coefficients were always better, for the various finishing routines, than 0.89, and averaged about 0.94. These are pretty good values but inspection of some of the graphs gives a strong impression of a yarn count effect and, in view especially of the work of *Hurt* (1), it was decided to check the effect of including the yarn tex as a factor in the equation.

Two approaches were taken, for a few of the more important finishing routines:

1. A combined tex-stitch length function, such as the tightness factor ($\sqrt{Tex} / L$) instead of $1 / L$.
2. A separate additional term involving only the tex.

Under approach No. 1 the following models were evaluated.

$$y = a + b.\ Tex / L$$

$$y = a + b.\ \sqrt{Tex} / L$$

$$y = a + b / (Tex.\ L)$$

$$y = a + b / (L.\ \sqrt{Tex})$$

Of these, only the last resulted in a better fit to the data, with average r values at about 0.95.

Under approach No. 2, the following models were evaluated.

$$y = a + b.\ L + c.\ Tex$$

$$y = a + b / L + c.\ Tex$$

$$y = a + b / L + c.\ \sqrt{Tex}$$

All three of these models resulted in an improved fit with average correlation coefficients of about 0.96. The third one was slightly better than the others and, in addition, is of the same form as that deduced by *Hurt* (1) from geometrical considerations so this model was chosen and applied to the whole series of finishing routes.

The final results of applying this model to the calculations of wales are shown in *Figures 12 and 13* where the coefficients and r^2 values for the regressions are tabulated.

Figures 14, 15, 16, and 17 are graphical illustrations of the calculated regressions.

Courses

The analysis carried out on the courses was exactly analogous to that for wales described in the previous section and had a similar outcome. In other words, it was found that the model

$$courses/cm = a + b / st.len.$$

gave a good fit to the data (average r about 0.97) which could not be improved upon by making the second term into a combined function of Tex and stitch length. However, the inclusion of Tex as an independent third term in the model, i.e.

$$courses/cm = a + b / st.\ len. + c.\ \sqrt{Tex} \qquad (5)$$

resulted in a clear improvement with an average r value in the region of 0.991.

The equations are tabulated in *Figures 18 and 19*, and some graphical illustrations are given in *Figures 20, 21, 22 and 23*.

Weight

In principle there are three ways to approach the calculation of weight:-

1. *Weight = courses x wales x Tex x St. Len.* (6)

   where courses and wales are calculated from the regression equations found in the previous sections.

2. *Weight = S x Tex x St. Len.* (7)

   where S, the product of courses and wales, is calculated via a new regression equation involving the finished, relaxed Tex and stitch length. The justification for making a separate regression analysis for S is that the variability in S tends to be less than that in the measured values of courses and wales due to mutual compensation of the latter two when fabrics are distorted.

3. *Weight = f(Tex, St. Len.)*

   i.e. a new regression analysis in which the finished, relaxed weight is related directly to the finished, relaxed tex and stitch length only.

Approach No. 1 needs no further work, since we already have the necessary equations for calculating the finished, relaxed Tex, stitch length, courses, and wales.

The two other approaches were both investigated.

Stitch Density, S

The first model to be tested was derived simply from equations (1) and (2)

$$S = a + b / L^2 \qquad (8)$$

in which the influence of yarn count is neglected.

For the most important finishing routines, this model gave a very good fit with r always better than about 0.97.

However, since the inclusion of Tex had improved both the course and the wale predictions, it seemed logical to check out this possibility for S also.

Since we have chosen *1 / L* and *Tex* as the parameters for predicting courses and wales, it is clear that the following are all candidates for predicting *S*, the product of courses and wales.

$1/L \qquad \sqrt{Tex} \qquad 1/L^2 \qquad Tex/L \qquad Tex$

Three models were tested fairly extensively.

$$S = a + b/L^2 + C.\ Tex$$

$$S = a + b/L^2 + C.\ \sqrt{Tex}/L$$

$$S = a + b/L^2 + C.\ Tex + d.\ \sqrt{Tex}/L$$

The greatest improvement was brought about by the first of these and although there were slight additional improvements from the more complicated models, the difference was not significant.

Therefore, regression analysis was performed over all fabrics and finishes using

$$S = a + b/L^2 + C.\ Tex \qquad (9)$$

with the result that correlation coefficients were found to be always better than 0.98 and to average about 0.995.

Figures 24 and 25 give the values of regression coefficients and r^2 values found. As could have been suspected, the regression equations for *S* turn out to be more reliable than the separate regressions against courses or wales.

Figures 26, 27, 28, and 29 show plots of some of these regressions against the observed results.

Direct Regression Against Weight

This section began also with the simple derivation from equations (1) and (2) which for weight is as follows.

$$Weight = a + b.\ Tex/L \qquad (10)$$

Using this model, a good fit was obtained for the data with correlation coefficients never less than 0.95 and averaging about 0.98.

Nevertheless, since we had found the courses and wales and S relationships had all been improved by adding further terms, it was decided to consider whether corresponding improvements could be made here also.

Consideration of equations (5), (6), (7), and (9) leads to the conclusion that the following parameters should all be candidates for an equation linking weight with Tex and stitch length.

$Tex \qquad Tex.\sqrt{Tex} \qquad Tex/L \qquad Tex.\sqrt{Tex}.L \qquad Tex^2.L \qquad Tex.L$

A wide range of possible models was examined for a selected number of finishing routes, starting with single-term functions, and then adding in a second, and third term.

It was found that there was only a slight improvement in the correlation coefficients with each additional term and that no particular parameter was preferred over all others. It was concluded, therefore, that there was no sound justification for going beyond the simple model of equation (10).

Figures 30 and 31 give the coefficients and r^2 values for this model, and *Figures 32, 33, 34, and 35* show plots of some of the regression equations against the measured data.

3. Discussion

The title of this report starts with the indefinite article and this was deliberate. The analysis undertaken was only one possible way of approaching the topic and had a strictly limited objective, namely the discovery of a set of equations which would predict the fully relaxed dimensions of the 20 gauge interlock and 14 gauge 1x1 rib fabrics which were produced in project CP78.

Thus, although we have paid attention to fundamental geometrical considerations, by using the basic form of equations developed by others from first principles, no real physical meaning can be attached to the coefficients and constants which have emerged, and extrapolations of the results outside this range of fabrics should not be undertaken without the confirmation of hard new experimental data.

No attempt has so far been made to test the significance of the differences between the equations representing different fabrics and finishing routes. In some cases such testing is hardly necessary since a casual inspection of the data will confirm real differences - for example between mercerised and not mercerised fabrics - but it may well be that a more sophisticated analysis would allow some reduction in the number of required equations.

Two obvious examples of this possibility are illustrated in *Figure 6*, where it seems likely that a single set of equations might serve for both interlock and rib fabrics, and in *Figure 10* where it seems likely that the same equation might serve for both crosslinked and not-crosslinked fabrics.

The fact that some finishing routes require significantly different equations from others is a finding of theoretical importance. It means that the yarn count and stitch length alone are not sufficient to explain changes in dimensional properties, even after corrections have been made to allow for the changes in count and loop length caused by the finishing process.

Therefore at least one other factor must be introduced into the reckoning. The obvious candidates are:

Yarn surface friction

Yarn stiffness

Yarn specific volume

Fibre swelling power

Yarn elastic modulus

“Setting” of the loop shape

any or all of which could influence the mechanism of relaxation and / or the shape of the relaxed loop.

However, although the qualitative importance of additional factors is clear, it is not necessary to elucidate these numerically in order to make practical use of the equations developed.

4. Conclusions

1. A set of empirical equations has been developed which can be used to predict the dimensional properties of a range of interlock and rib fabrics, in the fully relaxed state, with a good degree of precision.

2. Although the coefficients and constants of the equations have been empirically determined, the forms of the equations are based upon apparently sound geometrical considerations proposed by previous workers.
3. It is clear that improvements to the analysis could be made and that at least one other parameter besides yarn count and stitch length is needed to fully explain the dimensional changes brought about by different finishing routes, but the present analysis is considered adequate for the time being.

5. References

1. F.N. Hurt: *Hatra Res. Report,* No. 12, 1964.
2. T.S. Nutting & G.AV. Leaf: *Journ. Textile Inst*., 1964, pp T45-T53.
3. J.C. Stevens: *IIC TRD Res. Record,* No. 106, 1979.

Figure 1

INTERLOCK : PREDICTION OF FIN FR TEX FROM TEX AS KNITTED

Model : y = a + bx

FINISHING	a	b	r^2
GREY	-0.8965	1.0558	0.9997
JD	-0.4993	1.0238	0.9985
JDH	0.4689	0.9571	0.9999
JDX2	0.4848	0.9905	0.9996
M	-0.0965	1.0558	0.9997
MJD	0.3861	1.0591	0.9742
MJDH	0.8311	1.0218	0.9947
MJDX2	1.0876	1.0225	0.9987
WD	1.6344	0.8585	0.9993
WDH	-0.9993	1.0238	0.9985
WB	1.2633	0.8931	0.9828
WBT	-1.7937	1.0878	0.9952
CB	-0.3152	0.9905	0.9996
CBT	1.3502	0.8918	0.9978

Figure 2

1 x 1 RIB : PREDICTION OF FIN FR TEX FROM TEX AS KNITTED

Model : $y = a + bx$

FINISHING	a	b	r^2
G	-1.2052	1.0459	0.9854
JD	-0.2345	1.0099	0.9933
JDH	-1.0010	1.0489	0.9936
JDX2	-1.6018	1.1067	0.9926
M	-2.5025	1.1645	0.9915
MJD	-0.1374	1.0662	0.9881
MJDH	-1.6147	1.1432	0.9932
MJDX2	-0.7339	1.1270	0.9943
WD	-0.7306	0.9754	0.9959
WDH	-1.4904	1.0531	0.9933
WB	-2.1873	1.0716	0.9824
WBT	-1.5904	1.0531	0.9933
MWB	-1.4829	1.0918	0.9900
MWBT	-1.4083	1.0914	0.9855

Figure 3

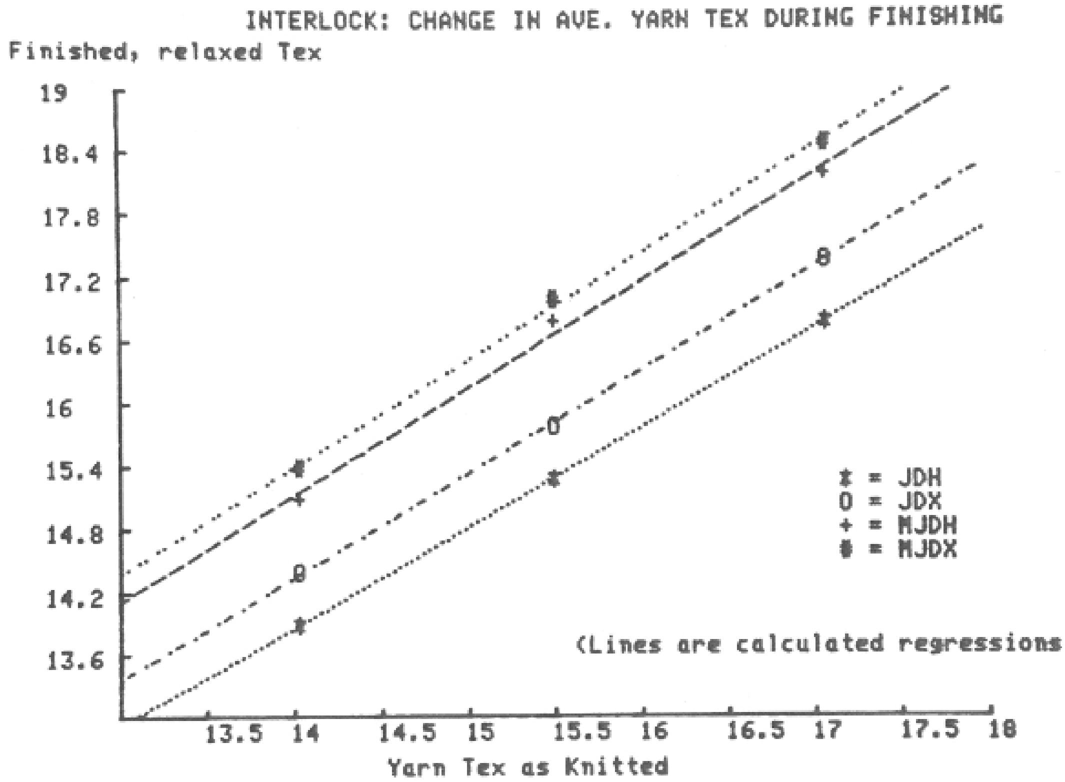


Figure 4

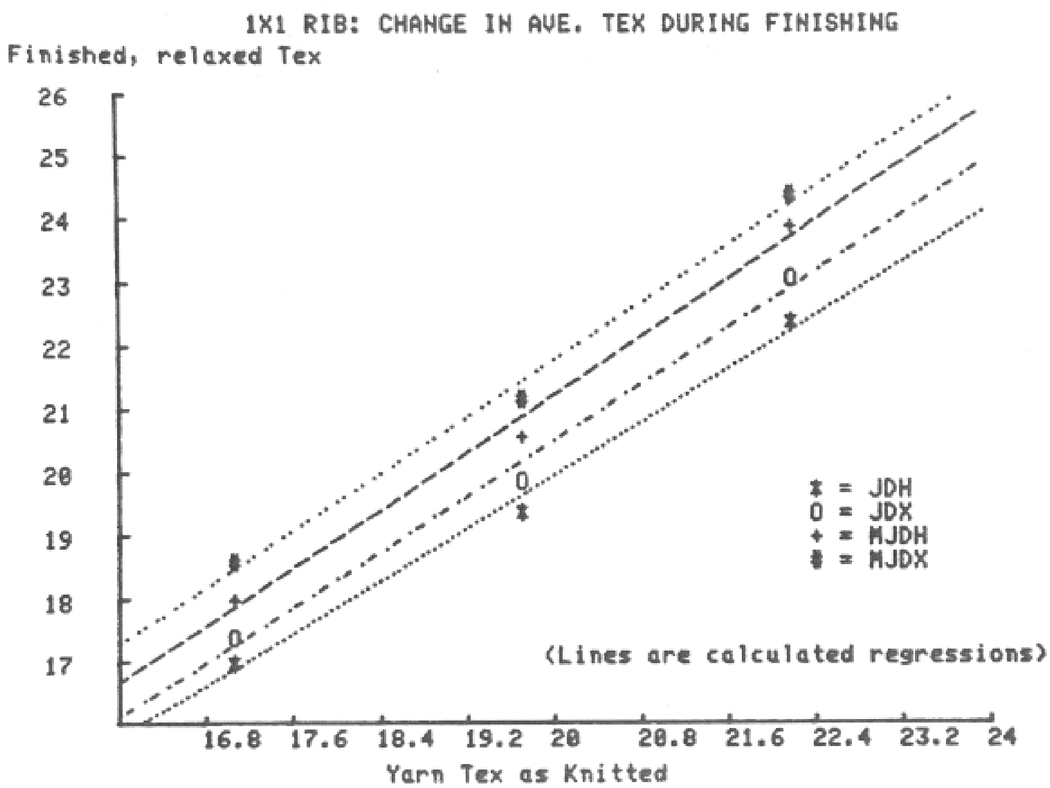


Figure 5

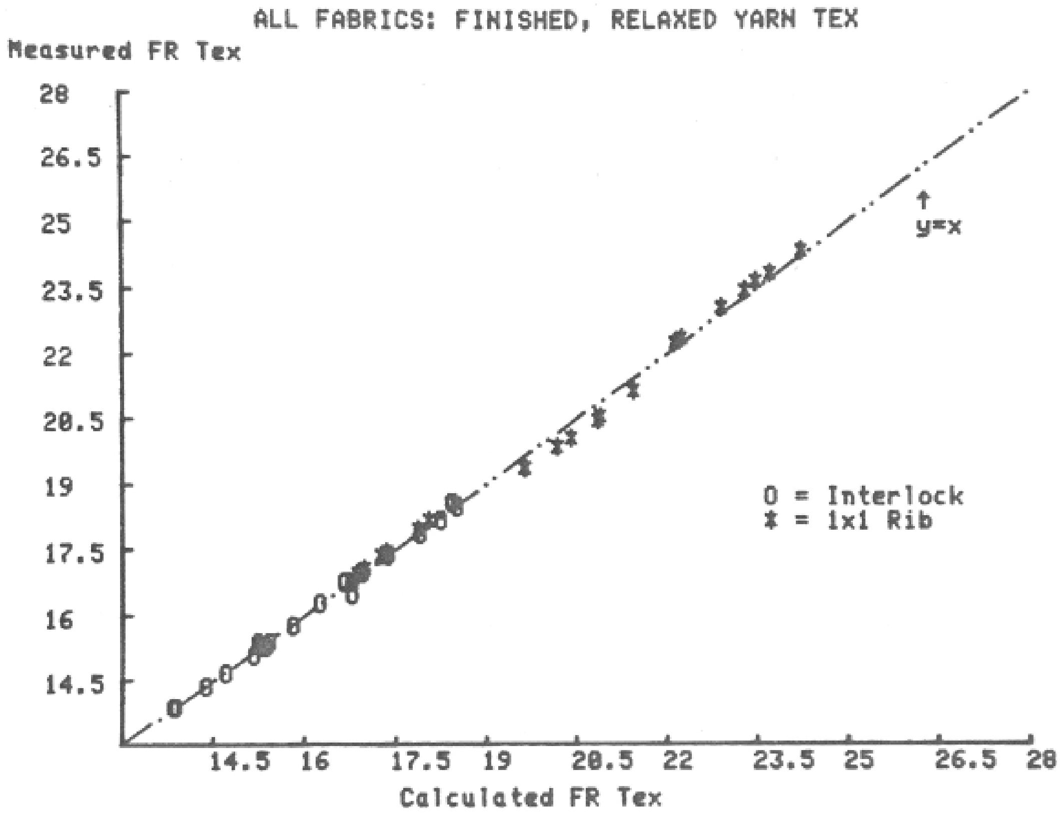


Figure 6

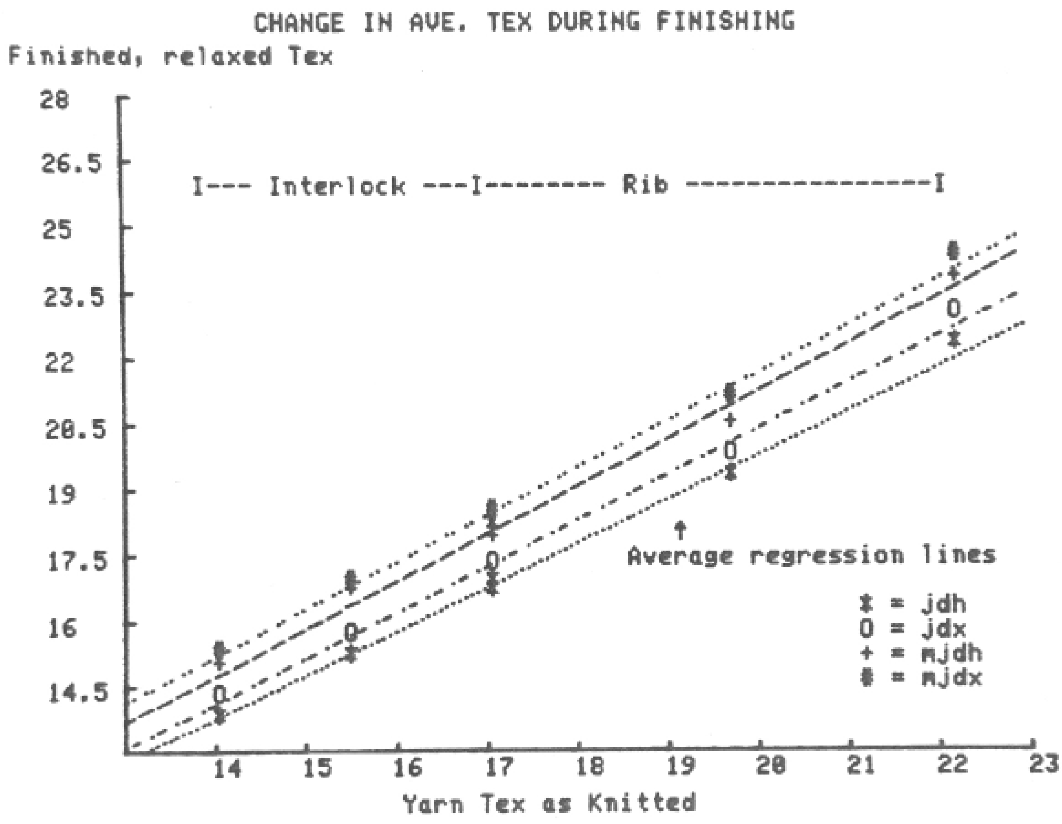


Figure 7

INTERLOCK : PREDICTION OF FIN FR SL FROM SL AS KNITTED

Model : $y = a + bx$

FINISHING	a	b	r^2
G	0.01604	0.9313	0.9633
JD	0.00925	0.9562	0.9690
JDH	-0.003595	0.9987	0.9680
JDX2	0.01078	0.9611	0.9519
M	0.01857	0.864	0.9410
MJD	0.01804	0.8682	0.9671
MJDH	0.02499	0.8445	0.9675
MJDX2	0.00624	0.9147	0.9696
WD	0.00560	0.9554	0.9576
WDH	0.02269	0.9194	0.9769
WB	0.03432	0.8796	0.9542
WBT	-0.00322	0.9847	0.9790
CB	0.02299	0.9131	0.9798
CBT	0.01700	0.9305	0.9930

Figure 8

1 x 1 RIB : PREDICTION OF FIN FR SL FROM SL AS KNITTED

Model : y = a + bx

FINISHING	a	b	r^2
G	0.00468	0.9686	0.9952
JD	0.01088	0.9556	0.9961
JDH	0.00798	0.9596	0.9960
JDX2	0.00817	0.9632	0.9931
M	0.00964	0.8981	0.9935
MJD	0.00326	0.9212	0.9972
MJDH	0.00297	0.9165	0.9988
MJDX2	-0.01061	0.9576	0.9946
WD	-0.00933	1.0176	0.9949
WDH	-0.00030	0.9845	0.9962
WB	0.01293	0.9363	0.9953
WBT	0.00212	0.9717	0.9937
MWB	-0.00162	0.9371	0.9948
MWBT	-0.00230	0.9352	0.9974

Figure 9

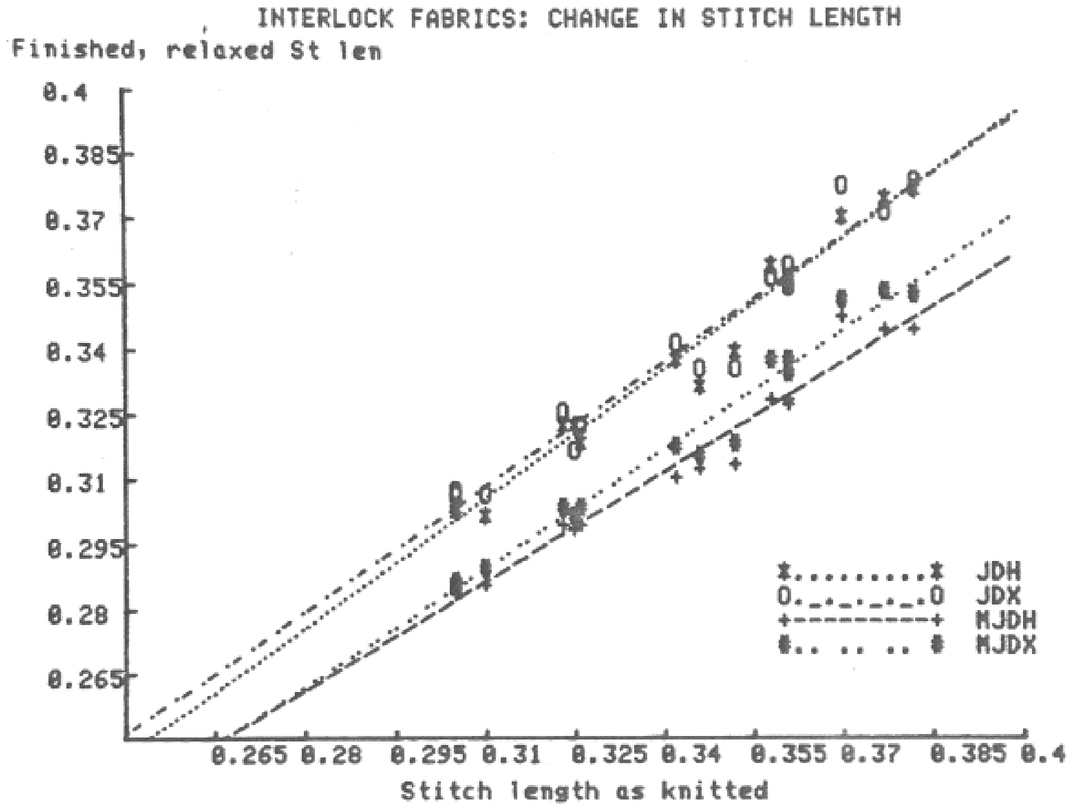


Figure 10

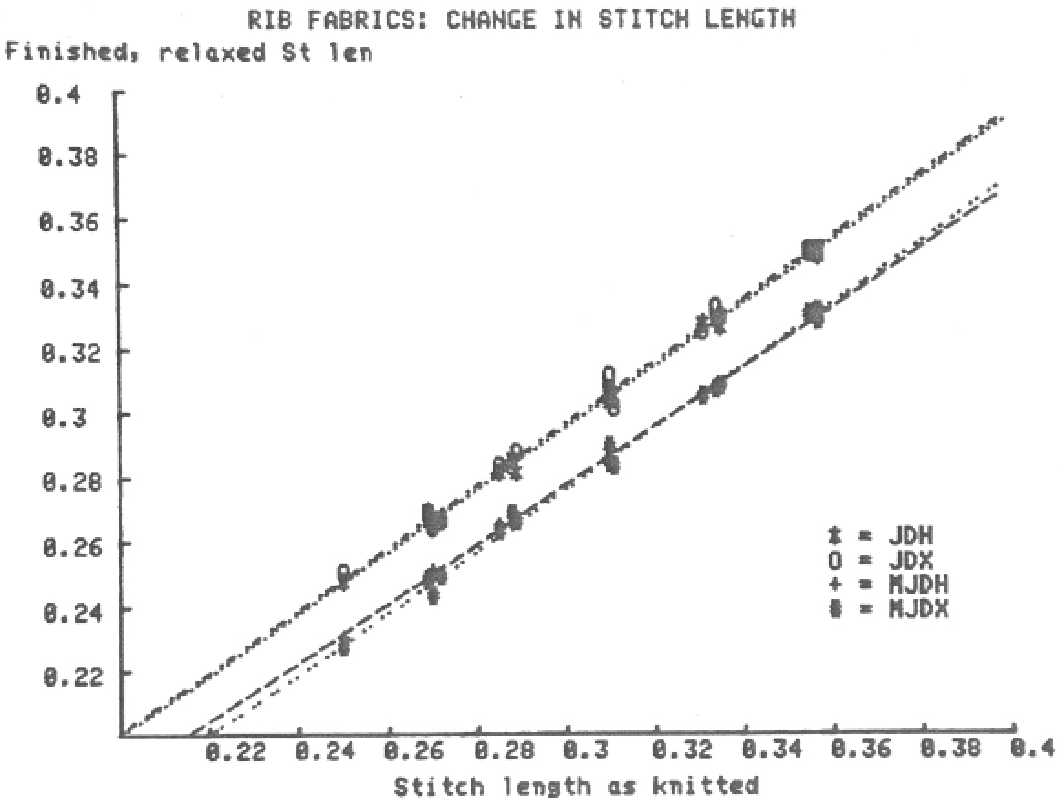
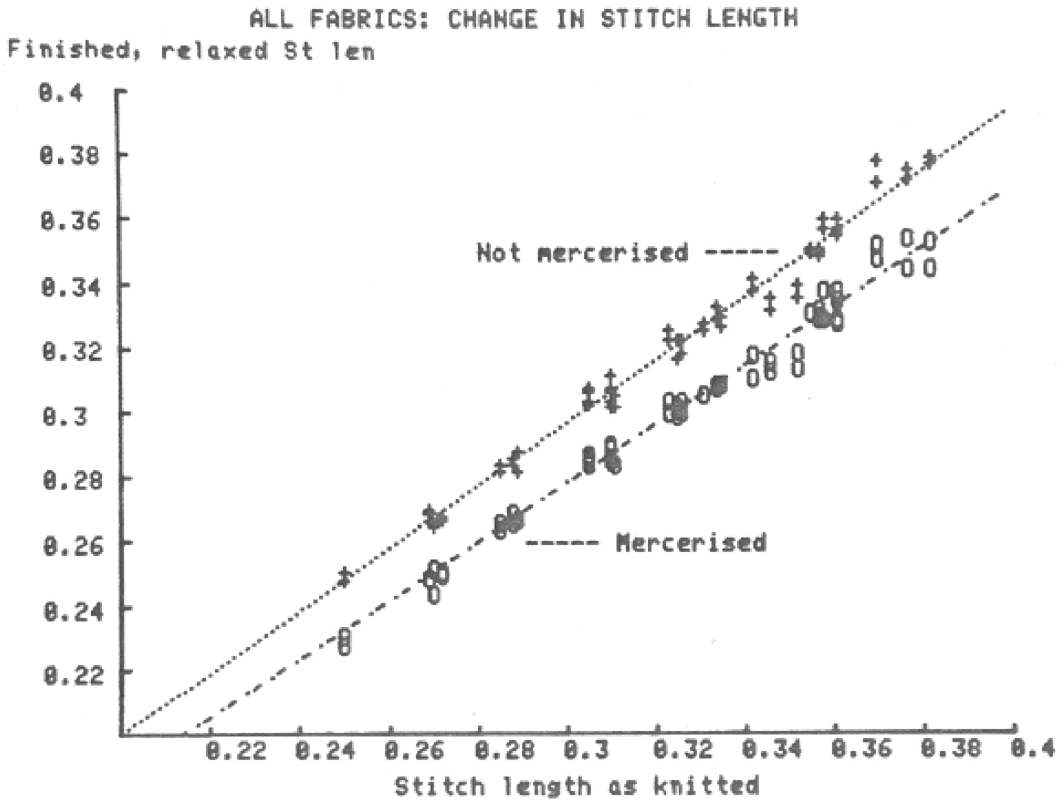


Figure 11



ALL FABRICS: CHANGE IN STITCH LENGTH
Finished, relaxed St len
0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0.24
0.22
Not mercerised -----
----- Mercerised
0.22 0.24 0.26 0.28 0.3 0.32 0.34 0.36 0.38 0.4
Stitch length as knitted

Figure 12

INTERLOCK : PREDICTION OF FIN FR WALES/CM FROM FIN FR TEX & 1

Model : $y = a + b/1 + c.\sqrt{Tex}$

FINISHING	a	b	c	r^2
G	17.0639	2.0916	-2.2016	0.9852
JD	11.7624	2.7001	-1.4778	0.9252
JDH	15.1640	2.0323	-1.7695	0.9640
JDX2	17.4769	2.9406	-2.9267	0.9160
M	14.4263	4.2372	-2.7537	0.9562
MJD	13.3363	3.6714	-2.0275	0.9477
MJDH	16.3962	3.5220	-2.6575	0.9230
MJDX2	15.7255	3.4563	-2.3319	0.9126
WD	16.1036	2.2425	-2.1791	0.9486
WDH	15.7458	2.0897	-1.8434	0.9695
WB	19.4077	2.2975	-2.9820	0.9735
WBT	15.9334	1.8384	-1.8440	0.9382
CB	19.1017	1.7631	-2.4960	0.9948
CBT	19.2164	1.8351	-2.6485	0.9899

Figure 13

1 x 1 RIB : PREDICTION OF FIN FR WALES/CM FROM FIN FR S.L. & TEX

Model : $y = a + b/l + c.\sqrt{Tex}$

FINISHING	a	b	c	r^2
G	1.2382	2.6157	0.1680	0.9657
JD	2.4660	2.4528	-0.0816	0.9640
JDH	3.3157	2.4027	-0.2247	0.9571
JDX2	7.5393	1.7521	-0.6123	0.9379
M	5.4593	3.0188	-0.8220	0.9664
MJD	7.5401	2.5967	-0.9519	0.9732
MJDH	8.1602	2.4850	-1.0036	0.9587
MJDX2	11.2842	2.1911	-1.4166	0.9493
WD	2.7942	2.5116	-0.1660	0.9968
WDH	6.6071	1.9095	-0.4304	0.9695
WB	5.1557	2.0739	-0.4060	0.9874
WBT	0.5373	2.7840	0.1054	0.9909
MWB	9.2795	2.7071	-1.4329	0.9607
MWBT	6.5912	2.8995	-1.0011	0.9962

Figure 14

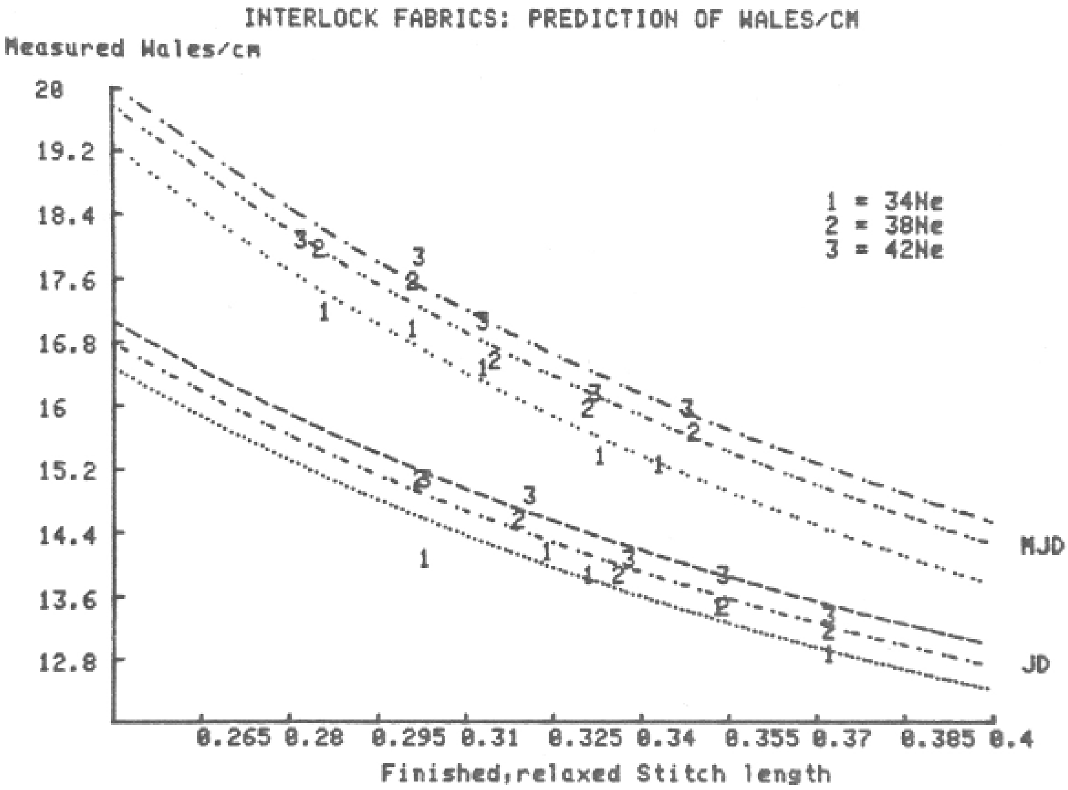


Figure 15

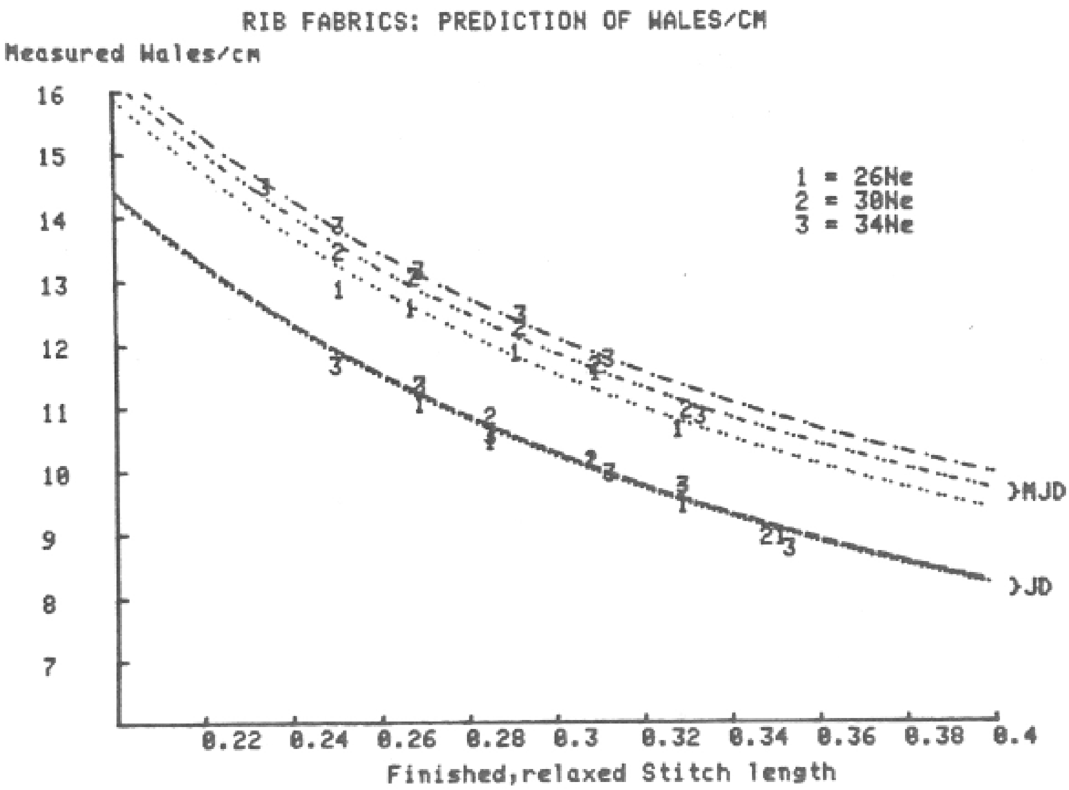


Figure 16

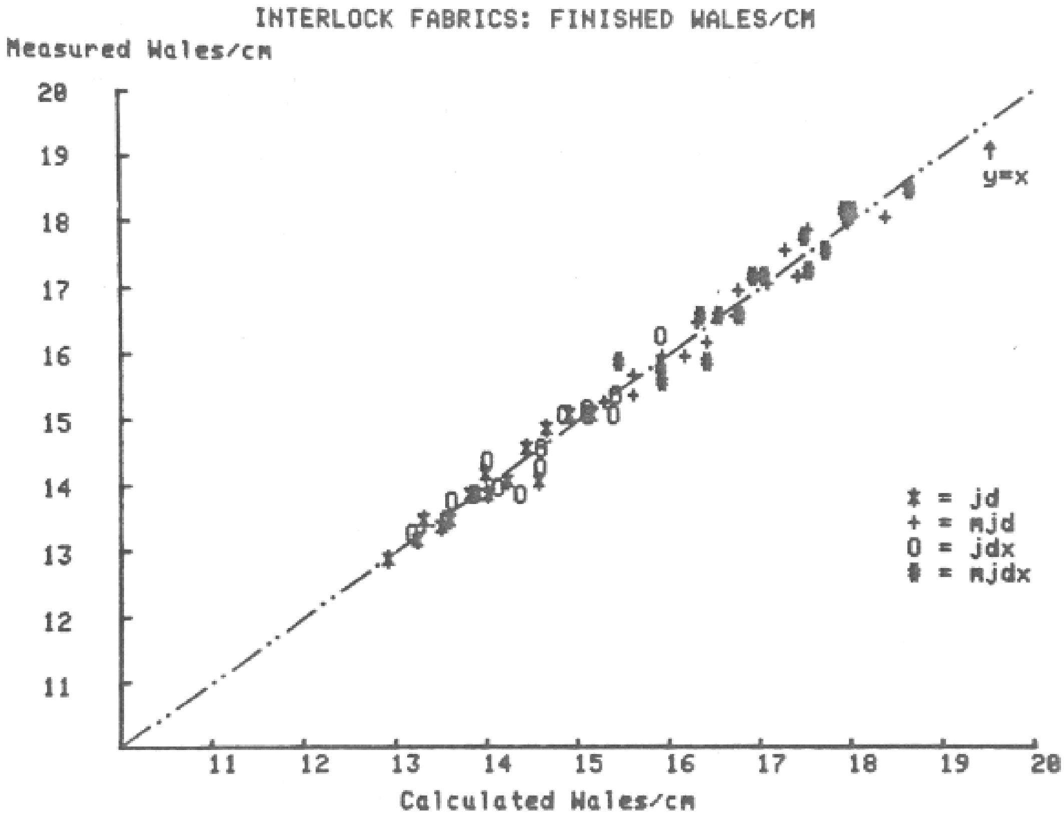


Figure 17

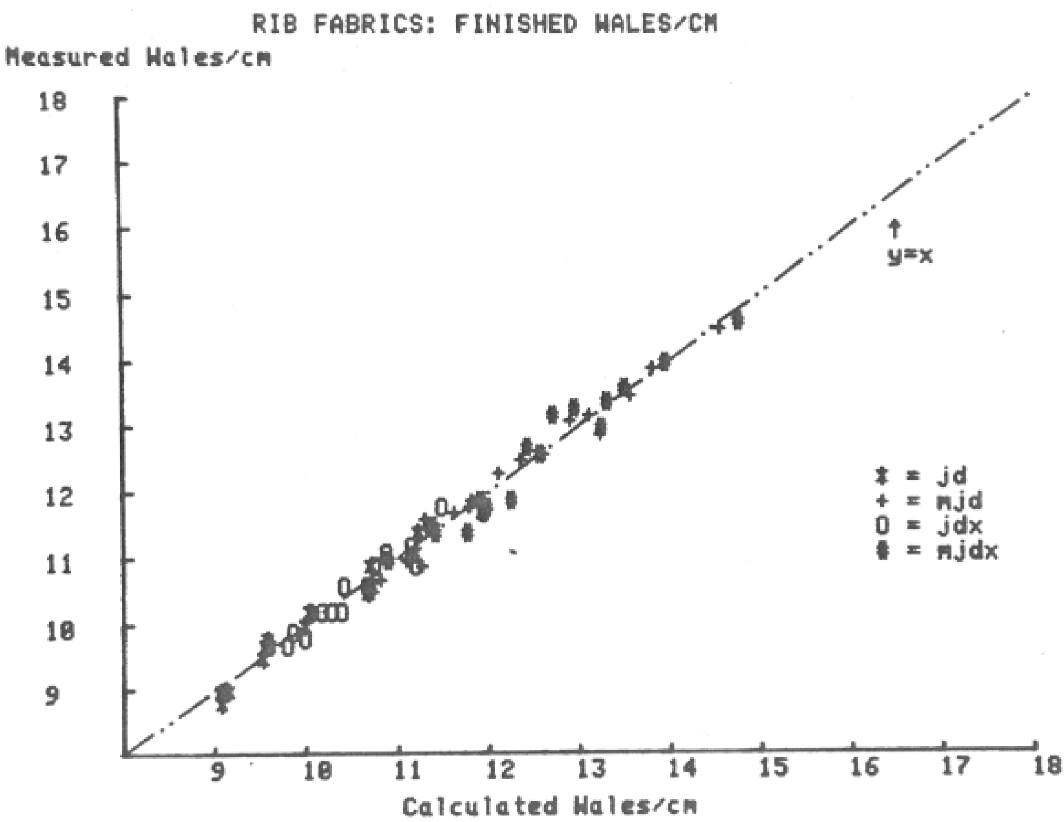


Figure 18

INTERLOCK : PREDICTION OF FIN FR COURSES/CM FROM FIN FR TEX AND 1

Model : $y = a + b/1 + c\sqrt{Tex}$

FINISHING	a	b	c	r^2
G	-3.4444	5.9717	0.5149	0.9686
JD	-3.6681	5.6578	0.5262	0.9206
JDH	-5.5698	5.8426	0.8975	0.9882
JDX2	-15.7990	6.4831	2.2855	0.9736
M	-11.2207	5.2892	2.4129	0.9795
MJD	-4.0277	4.8688	0.7533	0.9597
MJDH	-9.3107	5.2566	1.7112	0.9574
MJDX2	-10.56	5.0982	1.5965	0.9920
WD	-3.3067	5.0481	0.8220	0.9694
WDH	-5.9681	6.1330	0.6481	0.9991
WB	-8.4187	5.9985	1.4648	0.9835
WBT	-2.4430	5.3944	0.2894	0.9924
CB	-0.4846	5.5206	-0.3219	0.9880
CBT	-7.4801	5.8607	1.2035	0.9882

Figure 19

1 x 1 RIB : PREDICTION OF FIN FR COURSES/CM FROM FIN FR TEX AND l

Model : $y = a + b/l + c.\sqrt{Tex}$

FINISHING	a	b	c	r^2
G	-3.7733	5.9159	0.3604	0.9920
JD	-6.1361	5.4029	1.0577	0.9776
JDH	-6.3336	5.7975	0.8114	0.9918
JDX2	-14.6084	6.6195	1.5554	0.9882
M	-7.8216	5.4865	1.1680	0.9842
MJD	-6.7035	4.7323	1.3305	0.9816
MJDH	-7.6776	5.3695	1.1128	0.9861
MJDX2	-13.0074	5.6858	1.6118	0.9894
WD	-4.4196	5.5382	0.5778	0.9983
WDH	-4.0067	5.4528	0.4054	0.9981
WB	-6.3136	5.9714	0.6599	0.9960
WBT	-7.3325	5.8292	0.9423	0.9909
MWB	-5.8826	4.6624	1.1311	0.9746
MWBT	-8.4270	4.8911	1.5136	0.9929

Figure 20

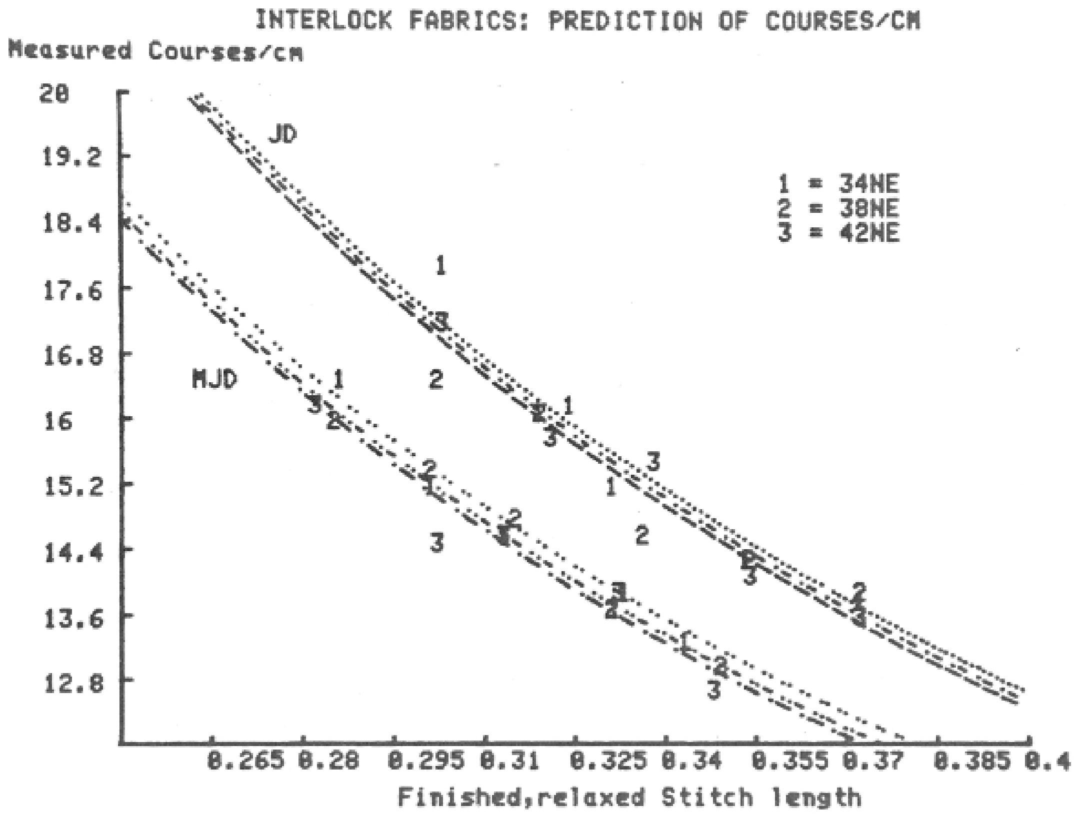


Figure 21

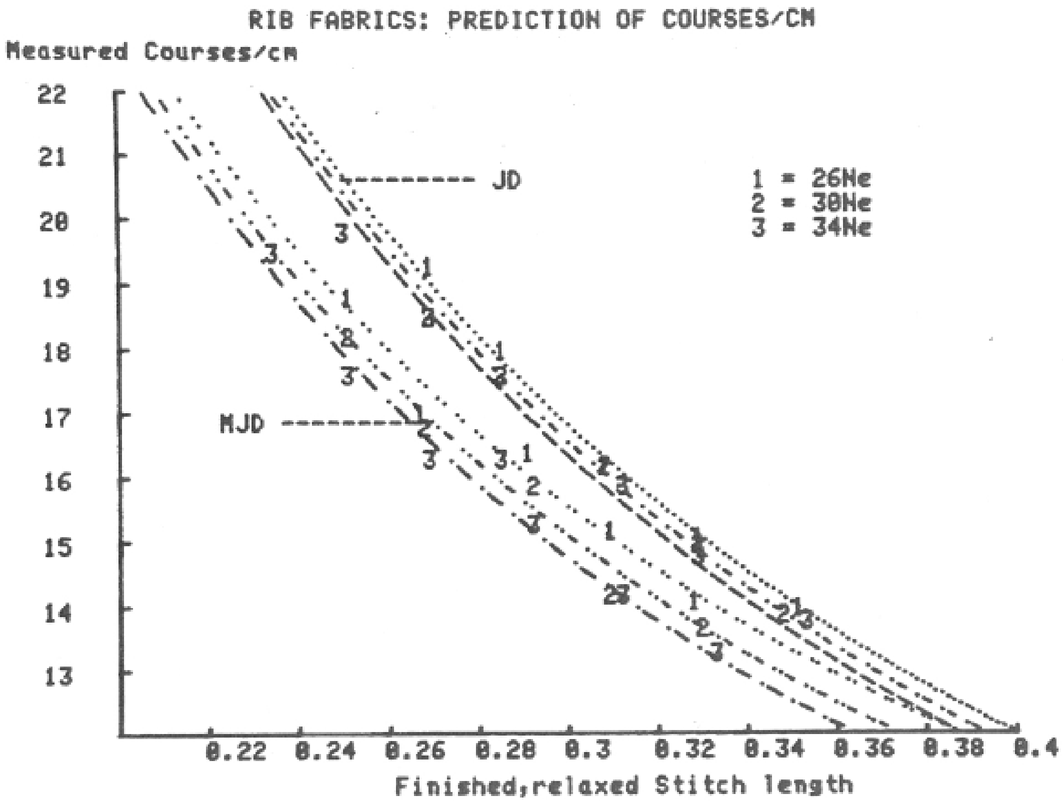


Figure 22

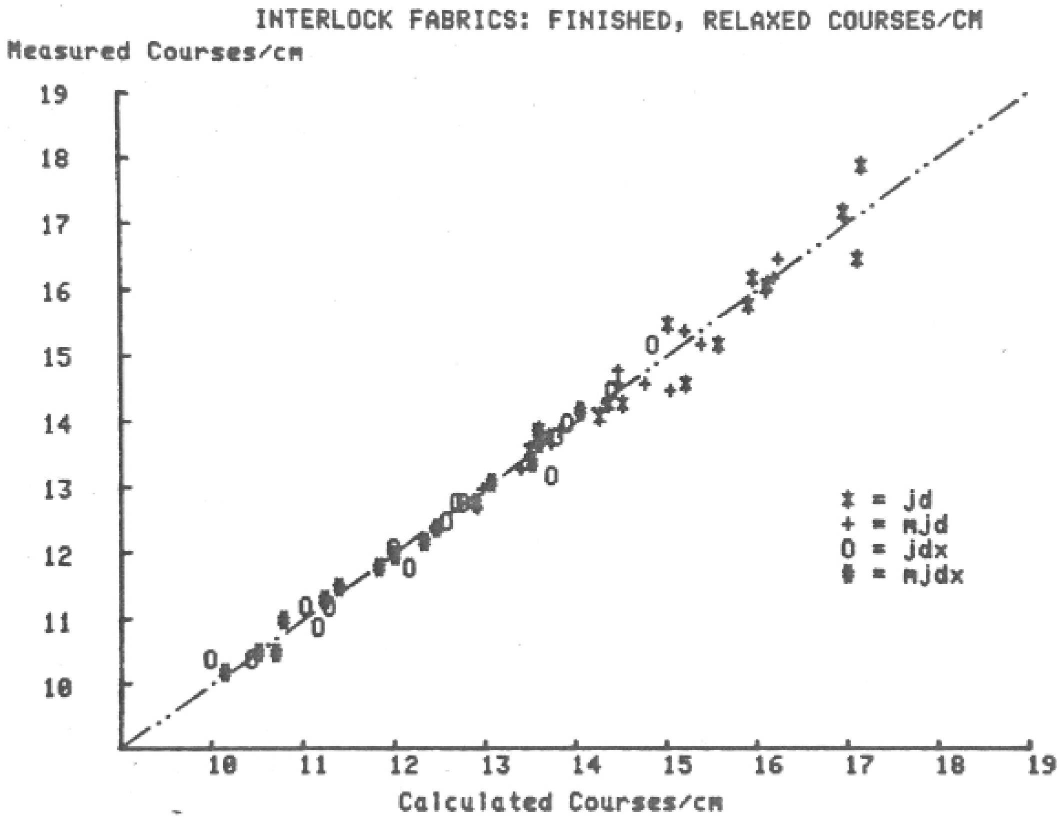


Figure 23

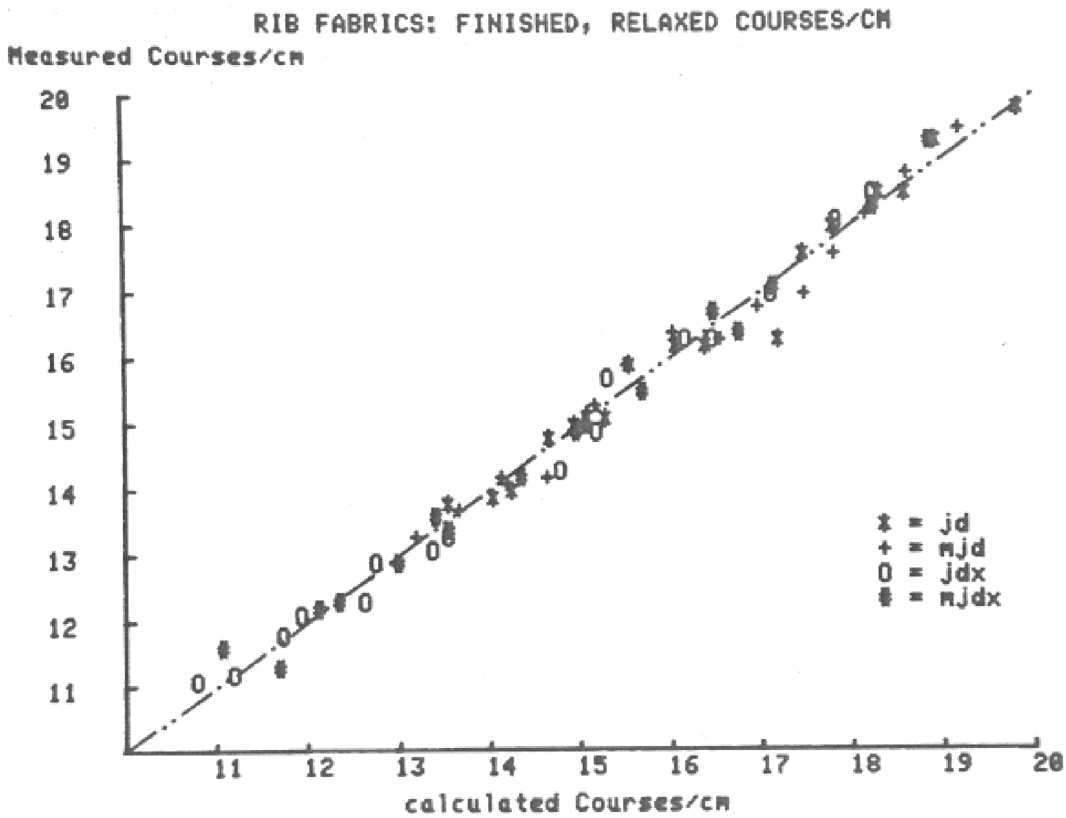


Figure 24

INTERLOCK : PREDICTION OF FIN FR STITCH DENSITY FROM FIN FR TEX & 1

Model : $y = a + b/1^2 + c.Tex$

FINISHING	a	b	c	r^2
G	111.3404	20.5732	-3.5339	0.9827
JD	66.6162	20.0908	-2.0473	0.9710
JDH	75.9169	19.2138	-1.8031	0.9947
JDX2	-9.1862	22.1628	-0.2282	0.9774
M	19.2302	23.9486	-0.2863	0.9836
MJD	61.9043	21.1343	-1.9645	0.9896
MJDH	44.9313	21.6069	-1.3641	0.9893
MJDX2	6.2996	20.2688	-0.1169	0.9895
WD	95.9417	18.0095	-2.7919	0.9714
WDH	64.0036	20.8577	-1.9564	0.9971
WB	72.9418	21.1451	-2.5599	0.9903
WBT	107.4190	17.1936	-3.3033	0.9876
CB	139.3715	17.4721	-5.1897	0.9929
CBT	100.5038	18.0537	-3.2953	0.9892

Figure 25

1 x 1 RIB : PREDICTION OF FIN FR STITCH DENSITY FROM FIN FR TEX & 1

Model : $y = a + b/l^2 + c.Tex$

FINISHING	a	b	c	r^2
G	-11.6334	16.3893	0.8776	0.9940
JD	-10.5772	14.2288	1.1469	0.9837
JDH	-5.8730	15.0480	0.4922	0.9934
JDX2	-24.5862	14.3309	0.9087	0.9905
M	-2.1409	16.7579	0.0977	0.9945
MJD	22.5543	14.1119	0.0039	0.9899
MJDH	20.2748	15.1011	-0.3249	0.9974
MJDX2	1.5245	14.5093	-0.0820	0.9937
WD	0.0226	14.8359	0.4179	0.9990
WDH	22.4744	13.8916	-0.0077	0.9948
WB	3.0474	14.6337	0.2032	0.9934
WBT	-30.1986	15.6865	1.1816	0.9989
MWB	36.9328	14.2752	-1.0069	0.9945
MWBT	7.2465	14.7078	0.1160	0.9951

Figure 26

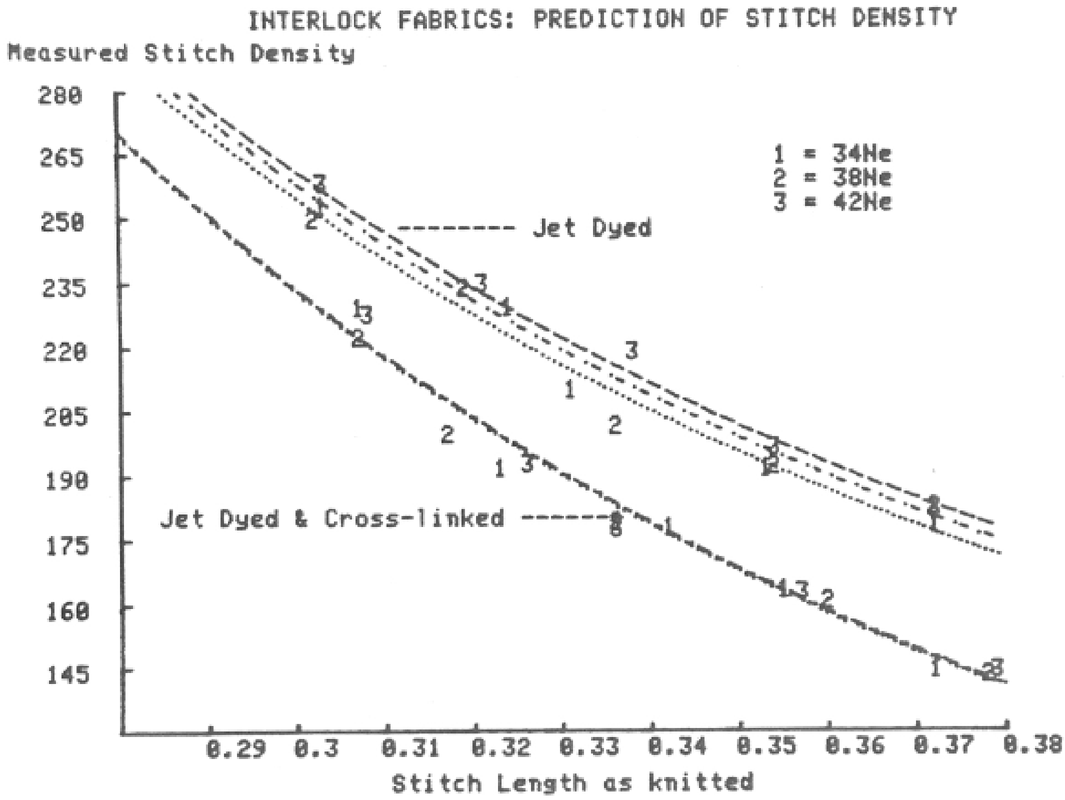


Figure 27

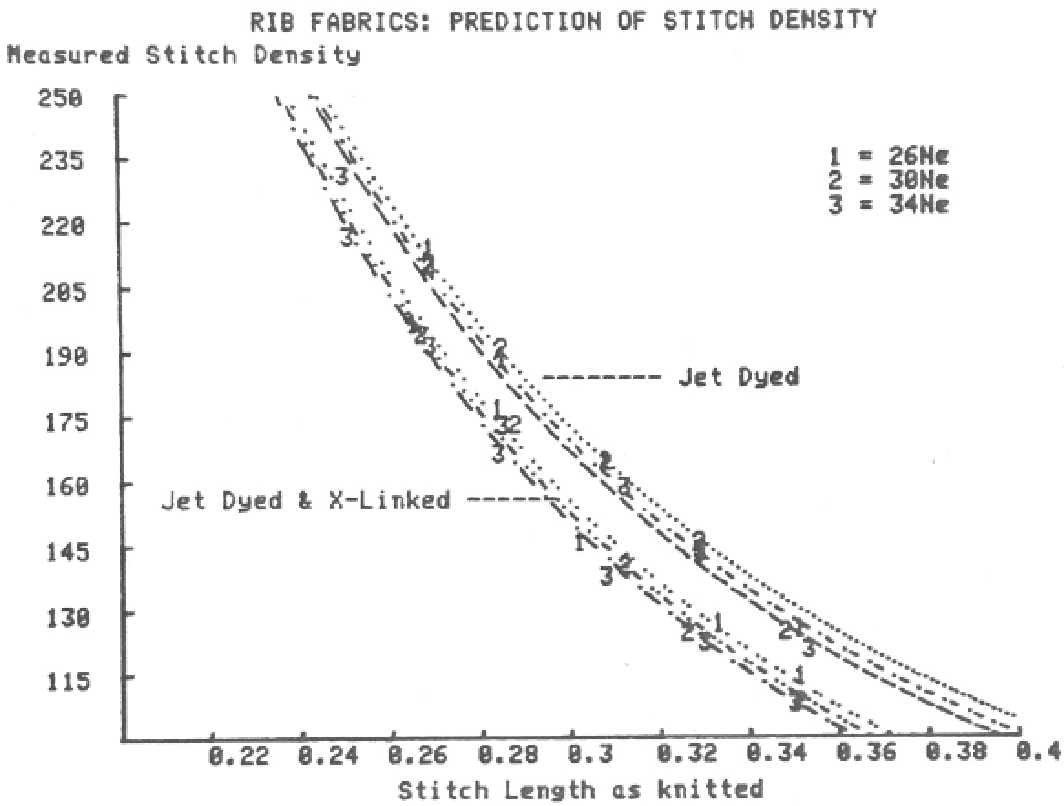


Figure 28

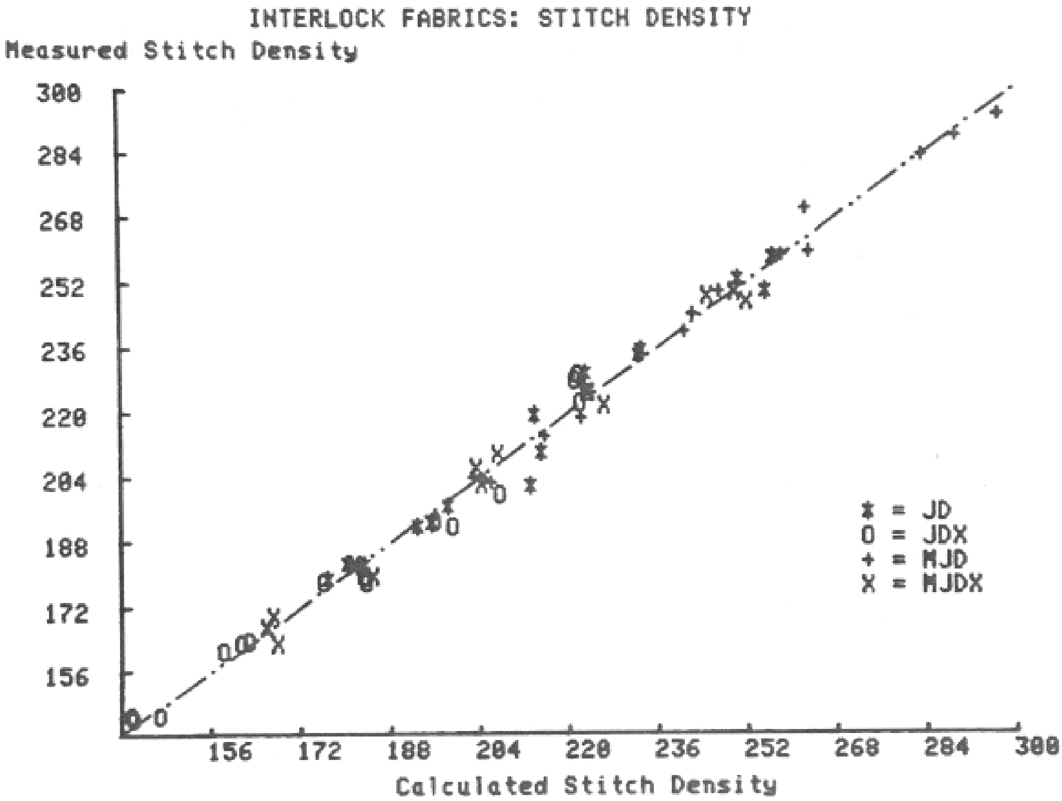


Figure 29

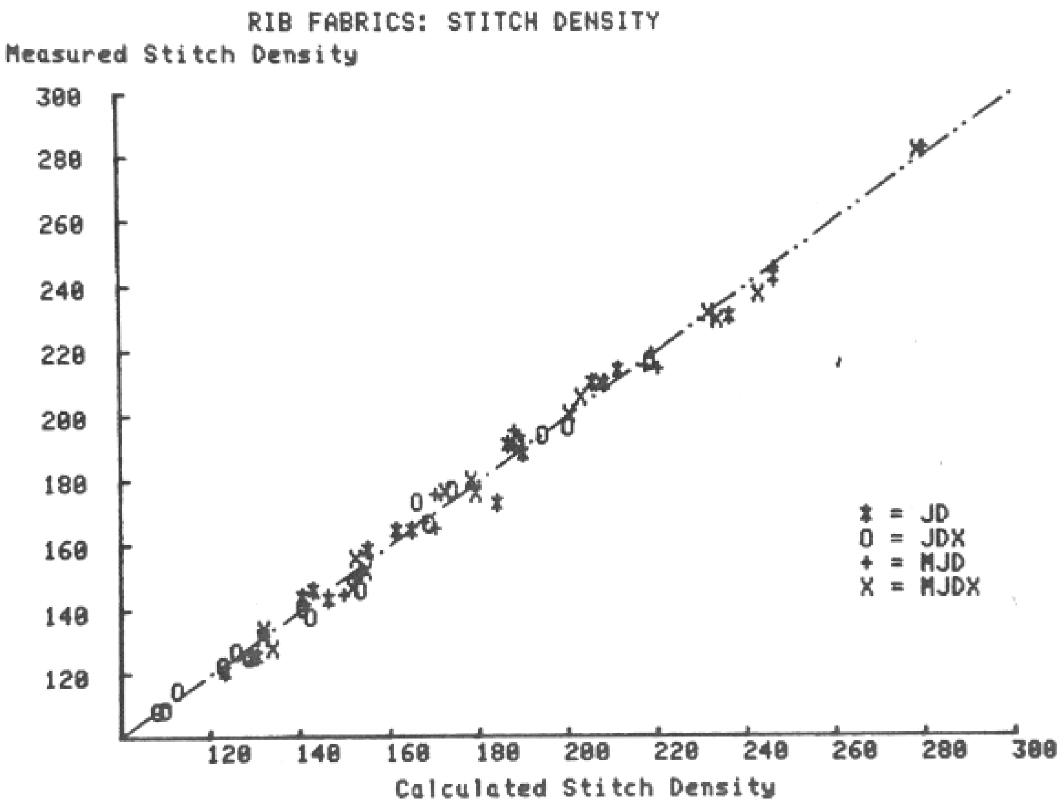


Figure 30

INTERLOCK : PREDICTION OF FIN FR WEIGHT FROM FIN FR TEX & l

Model : y = a + b.Tex/l

FINISHING	a	b	r^2
G	29.8189	4.3451	0.9502
JD	32.0516	4.1147	0.9608
JDH	54.4482	3.5947	0.9743
JDX2	-21.1755	4.0587	0.9694
M	10.5571	4.8823	0.9686
MJD	28.9034	4.2720	0.9609
MJDH	13.8925	4.5190	0.9563
MJDX2	10.8411	3.8292	0.9220
WD	-11.4531	5.0665	0.8708
WDH	17.1297	4.4554	0.9515
WB	8.6259	4.6564	0.8813
WBT	77.4283	2.9458	0.9754
CB	9.6890	4.5230	0.9468
CBT	-9.1298	4.7156	0.8376

Figure 31

1 x 1 RIB : PREDICTION OF FIN FR WEIGHT GM/M^2 FROM FIN FR TEX & 1

Model : y = a + b . Tex/1

FINISHING	a	b	r^2
G	-26.8270	3.6011	0.9804
JD	-19.8486	3.3410	0.9855
JDH	-18.3049	3.2702	0.9919
JDX2	-24.3475	2.7969	0.9507
M	-1.4069	3.2937	0.9743
MJD	-9.0908	3.2609	0.9813
MJDH	3.0437	3.0889	0.9924
MJDX2	-19.6133	2.7795	0.9549
WD	-26.5960	3.5234	0.9352
WDH	-11.1812	3.2707	0.8849
WB	-15.0608	3.2268	0.9550
WBT	-15.4496	3.1309	0.9696
MWB	-0.6419	3.0456	0.9768
MWBT	-33.2111	3.3995	0.9703

Figure 32

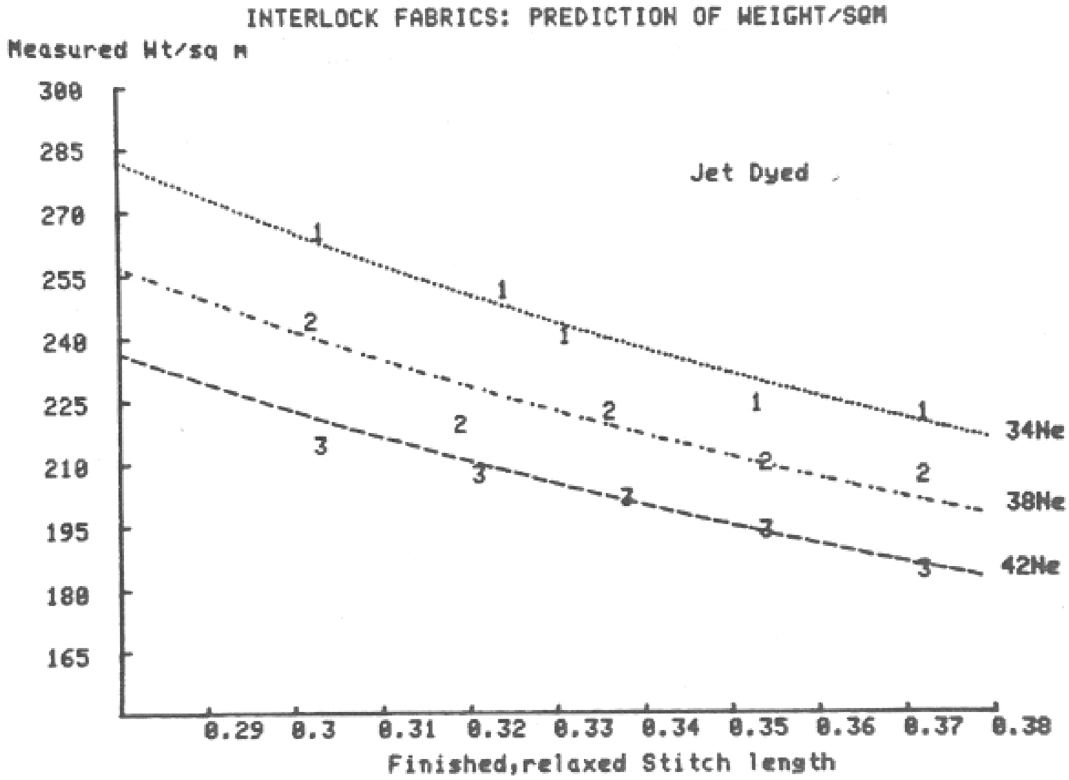


Figure 33

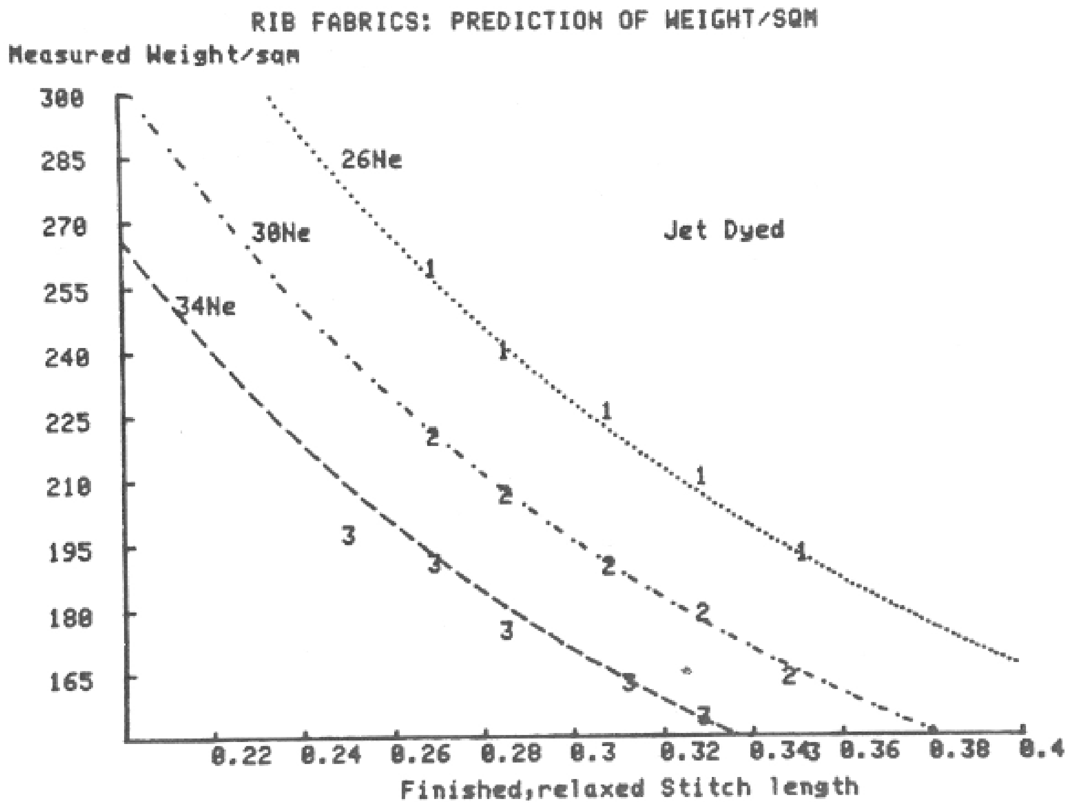


Figure 34

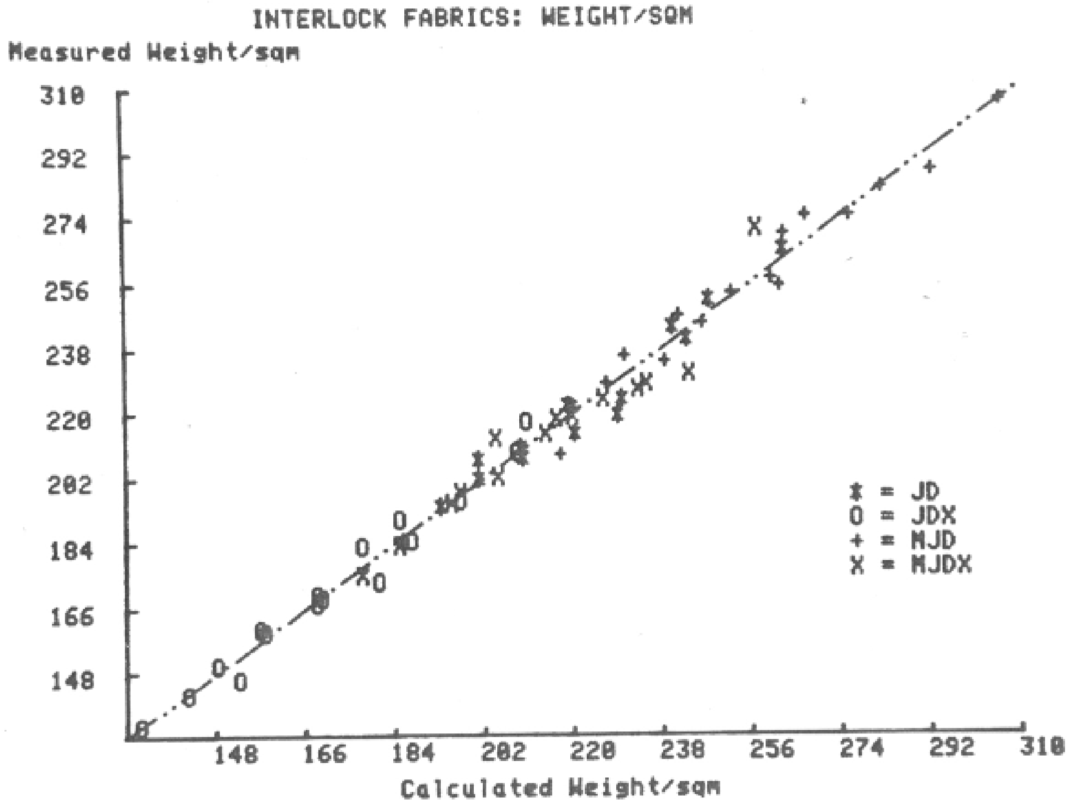


Figure 35