International Institute For Cotton

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Research Record No. 110

The Prediction Of Relaxed Weight Per Unit Area Of Wet Processed Interlock And 1x1 Rib Fabrics

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Contents

1. Introduction

It should be self-evident that the weight per unit area of a knitted fabric is equal to the mean weight of a single knitted loop multiplied by the number of loops in the same area.

The weight of a single loop is proportional to the yarn count in tex, and also to the length of yarn which makes up the loop, the stitch length.

These relationships may be combined into a single equation

$$W = N \,.\, l \,.\, S \,.\, K \qquad (1)$$

where

W is the fabric weight per unit area,

N is the yarn count in tex,

S the stitch density, or number of stitches per unit area

K is a constant.

Many studies of the structural parameters of relaxed knitted fabrics have been reported in recent years, and most workers have concluded that a relationship exists between the stitch density, *S,* and the stitch length, *l,* of a relaxed plain-knit structure, which is approximately of the form

$$S = K_s / l^2 \qquad (2)$$

In the study of knitted structures generally, it has become customary to consider not the length of a single stitch, but the length of yarn in a repeating unit of the knitted structure. For plain single jersey, this is equal to one stitch length, but for 1x1 rib it is taken as the length of two stitches, and for interlock, four stitch lengths.

Thus, the general equation is

$$S = K_1 / n.l^2 \qquad (3)$$

where n = 1, 2 and 4 for single jersey, 1x1 rib and interlock respectively.

If equation (3) is substituted into equation (1), it can be seen that

$$W = K \,.\, N/n.l \qquad (4)$$

W in this case is, of course, the fabric weight at some defined state of relaxation.

If *W* is expressed as grams per square metre, the stitch length in mm and the yarn count in tex, then, for plain single jersey, the constant in equation (4) is numerically equal to K_s in equation (2), i.e.

$$W = K_s \,.\, N/l \qquad (5)$$

and, taking the generalised situation

$$W = K_1 \,.\, N/n.l \qquad (6)$$

A considerable amount of evidence has been published in favour of the existence of a relationship of this type, linking yarn count, stitch length and relaxed weight of knitted fabric, and a selected bibliography can be found at the end of this report. Almost all previous work, however, has been carried out on fabrics which received no commercial finishing treatments, and the knitter needs to know how his fabric behaves, not only in the grey state, but also after

a predetermined finishing treatment which may include such techniques as piece-mercerisation or crosslinking; processes which are known to have marked effects on fabric structure.

Research Records Nos. 83 and 94 describe the production of a series of cotton interlock and 1x1 rib fabrics in a range of stitch lengths and yarn counts, and finished by a variety of methods.

Various trials were undertaken to establish a reliable test method for obtaining full relaxation of these fabrics. The method eventually adopted is described in *Figure 1*.

As part of an extensive testing programme, the relaxed weight of each of these fabrics, at various stages of processing, has been measured.

This report is concerned with a study of these measurements, and proposes an empirical method for predicting the finished fabric weight from information on the fabric knitting parameters.

2. Fabric Production, Processing And Coding

The production of the 15 interlock and 16 rib fabrics is described in *Research Record No. 83*, and the processing treatments, with the exception of piece-mercerisation, are described in *Research Record No. 94*. The piece-mercerisation treatment will be described in a later *Research Record*. During the course of production and processing, each fabric variant was allocated a coded identifier, made up as follows.

- first a letter (I or R) indicating the fabric type - Interlock or Rib,
- then a two-digit number equal to the nominal grey yarn count (Ne), followed by an oblique,
- then a three-digit number indicating the nominal knitted stitch length,
- finally, a finishing code of up to four letters indicating the finishing treatment. A list of finishing codes is given in *Table I.*

For mainly economic reasons, the finishing treatments were grouped into two categories, which may be termed the major series and the minor series. The major series, comprising the mercerisation and jet dyeing trials, included all the fabric construction variants; the minor series, including winch dyeing and various bleaching treatments, were applied only to six selected constructions of each type.

Perhaps unfortunately, the selected fabrics did not include the extremes in each range.

3. Knitting Parameters - Yarn Count And Stitch Length

Measurements of yarn count were carried out on the yarn packages before knitting. These results were reported in *Research Record No. 83.* For the purposes of this report they were converted to tex, and the converted figures appear in *Table II.*

Measurements of stitch length were carried out on samples of the knitted fabrics both before and after a standard relaxation treatment. For the purpose of making predictions based on knitted fabric construction, it was considered that the stitch length before relaxation would serve as an adequate starting point. The unrelaxed stitch length results are also given in *Table II*.

Following the line of earlier work, the ratio of yarn count to stitch length has been calculated for each fabric construction. These figures are also given in *Table II*, and are used as the basis for the calculations which are described later.

4. Fabric Weight Per Unit Area

The results of measurements of relaxed fabric weight, in grams per square metre, are given in *Tables III to VI.*

Table III shows the results on the major series of interlock fabrics, that is the variants which included piece mercerisation or jet dyeing treatments. *Table IV* gives the results on the minor series of interlock fabrics, while *Tables V and VI* show results on the rib fabrics for major and minor series respectively.

5. Fabric Weight And Knitting Parameters

The purpose of this study was to find a method whereby the relaxed weights of a knitted fabric might be predicted from a knowledge of the knitting parameters of yarn count and stitch length, and the processes of dyeing and finishing which had been, or were going to be, applied to that fabric.

From equation (6), it appeared sensible to take the ratio of yarn count to stitch length (*N/l)*, as defined in paragraph 3, as the starting point for prediction, and the first step was an examination of the correlation of the fabric weights according to the general equation

$$W = A.\, N/l \qquad (7)$$

A being a constant, for each fabric type and finishing route.

The results are given in *Table VII*.

It can be seen that, with a few exceptions, correlation of fabric weight to count/stitch length is quite good. One might consider that where the correlation coefficient, r^2, is above, say, 0.9, then substitution into equation (7) would give a reliable enough predictive model for most practical purposes.

Nevertheless, as it was intended that this should be an empirical study, it was decided that some modification to equation (7) might be found which would improve correlation. *Table VIII* gives results of a similar series of calculations based on the equation

$$W = A.\, N/l + B \qquad (8)$$

where *A* and *B* are both constants.

In most cases correlation was only slightly improved using this equation, notable exceptions being the jet dyed and compacted, and the winch bleached and compacted, interlock results.

Other relationships have been examined, but no significant improvements in correlation were observed. A typical set of results is given in *Figure 2* (note that the *A* and *B* figures should be transposed in all but the first line of results).

Figure 3 shows the relationship between fabric weight and *N/l* for the grey fabrics. Both sets of data can be seen to lie closely along straight lines and there are no signs that yarn count has any independent influence. (This last point has been confirmed by multiple linear regression analysis).

6. Use Of Results In A Predictive Model

By substitution into the appropriate equation, the figures given in *Table VII and VIII* can be used in various ways, for example.

1. Knowing the yarn count and stitch length used in knitting a fabric, the relaxed weight can be predicted for a number of finishing routes.
2. For a given yarn count, finishing route and finished relaxed weight, the required stitch length can be calculated.
3. Differences between finished weight and calculated relaxed weight can be used to predict shrinkage performance.
4. Differences in relaxed weight produced by changes in finishing route can be predicted.

It must be pointed out, however, that these equations have been derived from a database which is limited in terms of yarn counts, fabric constructions and finishing treatments, and some care should be exercised if they are being applied to situations outside these limits, for instance, to fine-gauge interlock, or plied yarns. The influence of finishing has been studied in only one dyeworks, and it may be that different results would be obtained in another situation.

7. Comparison With Earlier Studies

Mention was made in the introduction to the report of the earlier work which had been carried out, almost exclusively with grey fabrics, on relaxation of the knitted structure. This has resulted in the postulation of a series of 'constants' said to govern the behaviour of knitted structures in relaxation, and these have been termed "k-values". One of these, K_1, appears in equation (6), and by comparing equations (6) and (7), we see that

$$K_1 = A.n \qquad (9)$$

Using the values for A shown in *Table VII*, K_1 can therefore be calculated to be, for the grey fabrics

interlock $K_1 = 205.3$

1x1 rib $K_1 = 64.3$

In other publications (see Bibliography) Hunter, Cawood and Dobson report a value of 192 for interlock, and Poole and Brown find a mean value of 56.8 for 1x1 rib.

8. Conclusion

A series of equations has been described linking fabric weight per unit area with constructional parameters and finishing routes. It is proposed that these equations could form part of a predictive model for the production and processing of cotton interlock and 1x1 rib fabrics.

9. Bibliography

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TABLE I

FINISHING CODES

G.....Grey or Greige
M.....Mercerised
WB.....Winch Bleached
WD.....Winch Dyed
JD.....Jet Dyed
CBT.....Continuous Bleach, Tubetex compacted
WDH.....Winch Dyed, Hunt & moscrop(Bestan) comp.
WBT.....Winch Bleached,Tubetex compacted
JDH.....Jet Dyed,Bestan compacted
MWB.....Mercerised, Winch Bleached
MJD.....Mercerised,Jet Dyed
MWBT.....Merc.,Winch Bleached,Tubetex compacted
MJDH.....Merc.,Jet Dyed,Bestan compacted

TABLE II. Knitted Fabric Data.

INTERLOCK FABRICS

SAMPLE IDENTIFIER	Tex	SL-mm.	Tex/SL
I34/307	16.84	3.050	5.52
I34/324	16.84	3.261	5.16
I34/340	16.84	3.425	4.92
I34/359	16.84	3.608	4.67
I34/377	16.84	3.767	4.47
I38/307	15.37	3.100	4.96
I38/324	15.37	3.248	4.73
I38/340	15.37	3.519	4.37
I38/359	15.37	3.613	4.25
I38/377	15.37	3.705	4.15
I42/307	13.92	3.046	4.57
I42/324	13.92	3.229	4.31
I42/340	13.92	3.457	4.03
I42/359	13.92	3.576	3.89
I42/377	13.92	3.819	3.64

1x1 RIB FABRICS

SAMPLE IDENTIFIER	Tex	SL-mm.	Tex/SL
R26/267	21.90	2.702	8.11
R26/285	21.90	2.855	7.67
R26/306	21.90	3.115	7.03
R26/326	21.90	3.339	6.56
R26/350	21.90	3.550	6.17
R30/267	19.82	2.717	7.29
R30/285	19.82	2.892	6.85
R30/306	19.82	3.100	6.39
R30/326	19.82	3.306	6.00
R30/350	19.82	3.574	5.55
R34/248	16.84	2.505	6.72
R34/267	16.84	2.692	6.26
R34/285	16.84	2.883	5.84
R34/306	16.84	3.103	5.43
R34/326	16.84	3.348	5.03
R34/350	16.84	3.570	4.72

IIC/MERIDIAN JOINT PROJECT 1978 Table III

INTERLOCK FABRICS Relaxed Fabric Weights, Major Series.

SAMPLE IDENTIFIER	Relaxed Fabric Weight gms./sq.m. G	JD	JDH	M	MJD	MJDH
I34/307	277	265.8	256.2	318.4	307	301.2
I34/324	265.8	252	243	303	287.2	283.4
I34/340	253.2	241.2	234.4	291.4	282.6	284
I34/359	241.2	224.8	226.8	279.6	275	274.5
I34/377	236.8	222.4	215.8	266.1	258	253.4
I38/307	249.6	244.6	233.2	282.6	275.2	272.8
I38/324	238	220	227.4	276.1	270.2	270.8
I38/340	227.6	223	216.4	266.6	254	255.6
I38/359	215.6	210.8	210	253.2	247.8	244
I38/377	205.4	207.6	205.2	242.6	236.6	235.4
I42/307	230.6	214.8	214.4	261.2	256	249.6
I42/324	226.6	208	206.2	243	245.6	235.4
I42/340	208.8	202.3	198.4	236.2	235	240.3
I42/359	199	194.6	195.8	228	229	221.6
I42/377	200.2	184.9	188.8	221.2	209	203.8

IIC/MERIDIAN JOINT PROJECT 1978 Table IV

INTERLOCK FABRICS Relaxed Fabric Weights, Minor Series.

SAMPLE IDENTIFIER	Relaxed Fabric Weight gms./sq.m. WD	WDH	WB	WBT	CB	CBT
I34/340	243	235.2	239.8	226.6	235.6	226
I34/377	213.8	220.2	222.1	209.8	214.2	209
I38/324	228.8	221.6	227.6	216.8	224	216
I38/359	210.6	203.8	210	205.6	203.5	194.6
I42/307	210.2	208.6	217.6	210	205	196.6
I42/340	193.6	193.8	196.2	195.2	195	185.2

IIC/MERIDIAN JOINT PROJECT 1978 Table V

1x1 RIB FABRICS Relaxed Fabric Weights, Major Series.

SAMPLE IDENTIFIER	Relaxed Fabric Weight gms./sq.m. G	JD	JDH	M	MJD	MJDH
R26/267	274	259.8	257.8	305.6	291.4	289.6
R26/285	250.8	241	242.4	291.6	281.6	285.3
R26/306	241.8	226.6	222	272	265.6	*
R26/326	218	211.4	203	248.3	240	247.2
R26/350	194.8	193.2	187.4	222	225	*
R30/267	229.3	220.8	222.2	262.8	258	256.8
R30/285	216	207.2	203.8	247.8	245	*
R30/306	198.8	190.6	185.6	231.8	222.2	224.4
R30/326	191.6	179.5	182.2	198.2	201	*
R30/350	173	164.4	162.6	198.1	197	191.2
R34/248	220.2	198	202.2	246	251	243.4
R34/267	194	191.4	187.6	224.6	221.2	*
R34/285	185.4	175.6	177.8	211.2	204.2	211.4
R34/306	172.8	163.2	161.5	204.2	193.8	*
R34/326	152	155	153.6	188.4	182.2	182.6
R34/350	143.4	145.8	140.9	177.8	170	173.1

IIC/MERIDIAN JOINT PROJECT 1978 Table VI

1x1 RIB FABRICS Relaxed Fabric Weights, Minor Series.

SAMPLE IDENTIFIER	Relaxed Fabric Weight gms./sq.m. WD	WDH	WB	WBT	MWB	MWBT
R26/306	218.2	226	214.6	211.6	244.6	243.4
R26/350	190.2	193.4	193	187	205	199
R30/285	199.4	208.8	200.4	195	218.6	215.2
R30/326	173.6	192.8	174.4	165.6	196	187.2
R34/267	175.6	186.2	176.8	173.2	211.2	200.8
R34/306	155	159.8	153.4	155.8	181.6	173.8

TABLE VII. Coefficients of $W=Ax(N/\ell)$.

FINISHING CODE	INTERLOCK		1x1 RIB	
Major Series	A	R-SQR	A	R-SQR
G	51.31743	0.94202	32.14979	0.95381
JD	48.96528	0.93089	30.79225	0.96161
JDH	48.24175	0.88440	30.50417	0.97052
M	58.63409	0.95599	36.75454	0.94732
MJD	57.10791	0.95490	35.94849	0.96525
MJDH	56.49078	0.91716	36.09107	0.97615
Minor Series				
WD	48.20874	0.88171	29.51202	0.87296
WDH	47.55797	0.85785	30.96167	0.89381
WB	48.68043	0.94570	29.52224	0.87676
WBT	46.80385	0.75253	28.86388	0.86829
CB	47.34121	0.85087		
CBT	45.50116	0.85180		
MWB			33.31871	0.90285
MWBT			32.36088	0.87926

TABLE VIII. Coefficients of $W=Ax(N/\ell)+B$.

FINISHING CODE	INTERLOCK			1x1 RIB		
Major Series	A	B	R-SQR	A	B	R-SQR
G	45.82443	25.85570	0.95592	37.63348	-35.52590	0.97492
JD	42.83237	27.97457	0.95060	33.54746	-17.84957	0.96827
JDH	36.80695	52.15854	0.98009	34.05821	-23.02471	0.98142
M	54.54813	18.63765	0.96145	39.01256	-14.62853	0.95056
MJD	50.16477	31.67034	0.97377	37.85769	-12.36863	0.96776
MJDH	50.39020	27.82711	0.93096	36.37523	-1.86496	0.97621
Minor Series						
WD	49.85435	-7.42862	0.88268	36.11105	-41.80514	0.90335
WDH	42.68930	21.97825	0.86921	36.48630	-34.99880	0.91494
WB	45.30819	15.22302	0.95099	35.32761	-36.77732	0.90127
WBT	32.05942	66.55958	0.95550	33.01729	-26.31210	0.88235
CB	42.93913	19.87193	0.85995			
CBT	43.47449	9.14885	0.85367			
MWB				34.97706	-10.50572	0.90490
MWBT				39.38031	-44.51912	0.90838

Figure 1

'FULLY RELAXED STRUCTURE' — IIC LABORATORY METHOD

1. **CONDITION**
2. **MARK** *fabric sample (50cm length and width)*
3. **WASH** *in automatic domestic washing machine at 60°C*
4. **TUMBLE DRY** *until dry*
5. **WET OUT** *in washing machine (Rinse cycle)*
6. **TUMBLE DRY** *until dry*
7. **REPEAT** *steps 5 and 6 three more times*
8. **RE-CONDITION**
9. **MEASURE** *marked distances*
10. **CALCULATE** *shrinkages (length and width)*

Figure 2

TYPICAL LINEAR CORRELATION SURVEY

SELECT BEST FIT

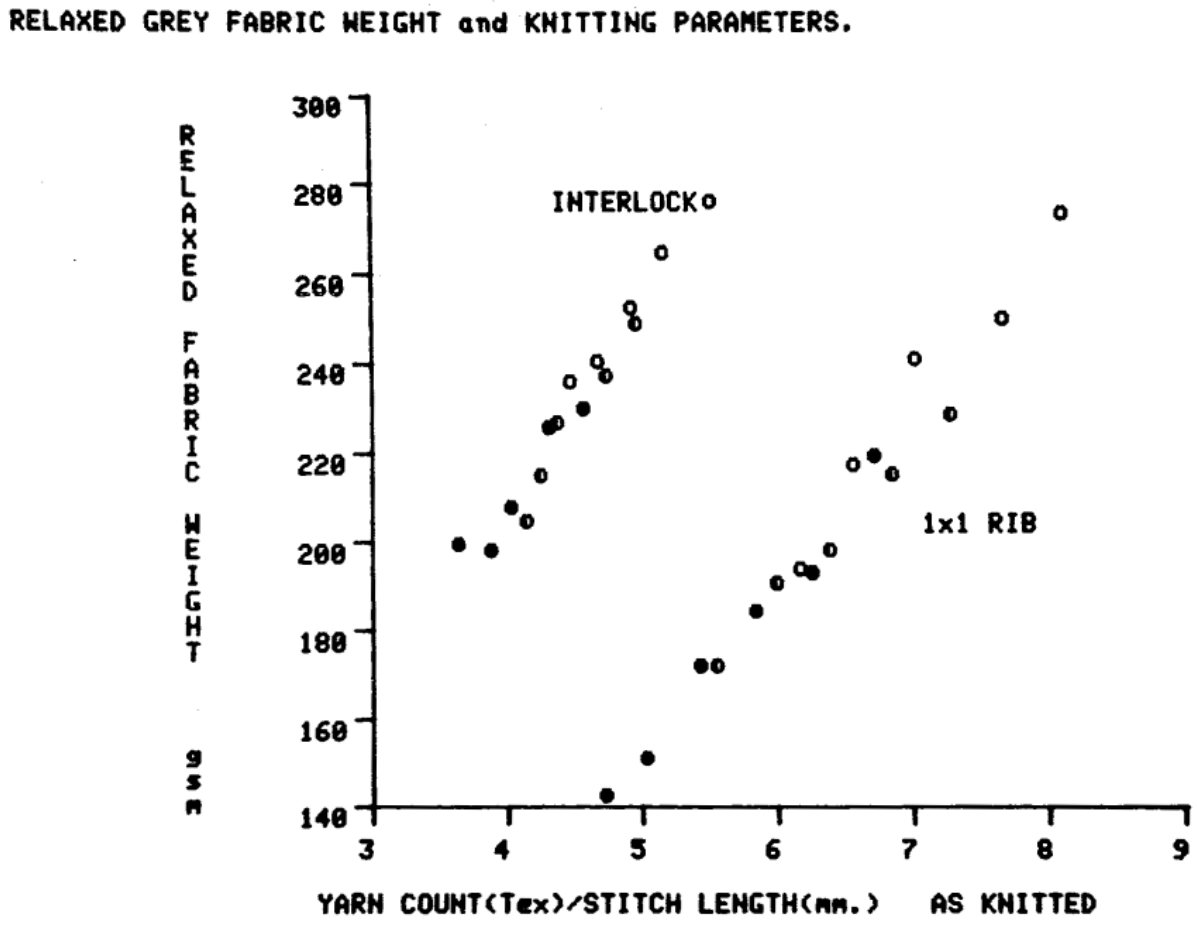
EQUATION	A	B	RES ERROR	R-SQUARE	MAX DEVIATION
Y = A*X	29.51202		77.94716	0.87296	10.73048
Y = A + B*X	-41.88514	36.11105	59.30489	0.90335	9.19999
Y = A*EXP(B*X)	53.75244	0.19584	57.10387	0.90693	10.24663
Y = 1/(A + B*X)	0.01220	-0.00107	56.94931	0.90718	11.27419
Y = A + B/X	406.38764	-1380.32327	68.63619	0.88814	10.28872
Y = A + B*LOG(X)	-226.18470	224.21951	63.82382	0.89728	9.47429
Y = A*X↑B	19.67114	1.21888	58.79753	0.90417	9.44564
Y = X/(A + B*X)	0.04133	-0.00116	58.42053	0.90479	9.69705

EQUATION Y = 1/(A + B*X) HAS MAXIMUM R-SQUARE

EQUATION Y = A + B*X HAS MINIMUM MAXIMUM ABSOLUTE RESIDUAL

RIB WINCH DYED

Figure 3


RELAXED GREY FABRIC WEIGHT and KNITTING PARAMETERS.
RELAXED FABRIC WEIGHT gsm
300
280
260
240
220
200
180
160
140
INTERLOCK
1x1 RIB
3
4
5
6
7
8
9
YARN COUNT(Tex)/STITCH LENGTH(mm.) AS KNITTED