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Cockling in Fully-Fashioned Knitwear

Part IV: The Effect of Fibre Diameter, Crimp and Yarn Linear Density

by

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COCKLING IN FULLY-FASHIONED KNITWEAR PART IV: THE EFFECT OF FIBRE DIAMETER, CRIMP AND YARN LINEAR DENSITY

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ABSTRACT

An attempt was made to correlate certain fibre and yarn properties of some 21 lots of wool with the amount of cockling found in the resulting fully fashioned garments. Mean fibre diameter and crimp frequency were found to have a significant effect on cockling for a specific yarn linear density. When the yarn linear density was varied, by varying the number of fibres per cross-section, it was possible to predict fairly accurately the amount of cockling in a fully fashioned garment.

INTRODUCTION

Cockling in plain single jersey knitwear has been the subject of several reports[1-4]. In Part I[1] different forms of loop distortion were defined and it was shown that cockling was mainly found in fabrics containing wool or mohair. Even with the use of shrinkproofed wool cockling in a subdued form still occurred. It was shown that an average cockle extended over about eight loops and that cockling was generally associated with thick places in the yarn which had relatively lower twist.

Part II[2] showed that relatively *fine* wool which produced more regular yarns (R64 tex/2) did not cockle nearly as much as yarn spun from *coarser* wools. Cashmere (14,8 μm) knitted into fully fashioned single jersey fabric did not cockle at all, whereas a very coarse mohair yarn cockled excessively. A superfine wool of 17,7 μm when spun into a very even yarn and knitted did not cockle but when deliberately spun unevenly, cockling was excessive. It was, therefore, concluded that *yarn evenness* played an important rôle in cockling. It was observed that cockles formed in the fabric when a relatively thick place in the yarn coincided with a relatively thin place in either the preceding or succeeding courses, or both, and that the average difference in yarn linear density between these places was about 50%. Below a difference of about 30%, little or no cockling was observed. The effect of twist in the yarn was also investigated and it was reported that all-wool yarns with lower levels of twist were slightly more prone to cockling. Also, when wool fabrics were knitted at a low tightness (low MTF) they tended to cockle slightly more. Acrylic yarns did not cockle even when deliberately spun with a high degree of irregularity.

It was further shown that when a wool yarn was wetted out, the yarn developed a *higher untwisting torque,* and this torque, together with high yarn irregularity were considered to be important factors in determining the severity of cockling. It was concluded that all-wool yarns for knitting into plain fully-fashioned garments should be spun from wool of sufficient fineness and with a sufficient number of fibres in the cross-section so as to ensure a very regular yarn and a low cockling propensity.

Part III[3] of this series of reports dealt with a comparison between two similar merino wools, one a South African 64's quality and the other an imported 64's quality. The comparison was carried out to determine why the garment knitted from the local wool apparently cockled more than the one knitted from the imported wool even though the yarn spun from the latter was more irregular. The latter, however, had a lower frequency of thick places of relatively *low magnitude* and it was concluded that this difference was mainly responsible for the observed differences in cockling. It was shown earlier that the difference in magnitude of thick and thin places need only be in the region of 40% (± 20%) and that the average difference at a cockle was only 50%.

During these early studies several methods were used to assess the amount (or severity) of cockling in plain fully fashioned knitwear. In a more recent report[4] a method for the subjective evaluation of cockling using *SAWTRI Standard photographs* and a viewing cabinet was described so that cockling could be quantified.

Recently Turpie[5] investigated about 30 different lots of raw wool from a range of different breeds (varying in mean fibre diameter from 19 to 32 μm), in respect of processing performance during topmaking. It was decided to use a selection of these wools in order to investigate the correlation between fibre and yarn properties and cockling and also to determine the minimum number of fibres per cross-section required to ensure a fabric with acceptable cockling.

EXPERIMENTAL

Effect of Fibre Properties

The 21 lots of raw wool used and the full details of processing into tops can be found elsewhere[5]. These 21 lots were spun into a *standard yarn R64 tex S275/2 Z460.* The preparatory process of plying using anti-snarling devices and without prior setting of the singles yarn was used[1]. The yarns were then knitted into garment blanks on a 24 gg Scheller fully-fashioned knitting machine, fitted with a stationary drum type[6] storage feed unit, at a tightness factor of 14,6 (1,25 cover factor) and with a relatively low take-down tension. The fabrics were wet relaxed by washing[7] and allowed to line- dry under ambient conditions of 20° C and 70% RH. The fabrics were then sewn into the form of a sleeve and examined in an ICI Viewing Cabinet and compared with the *SAWTRI standard photographs* for cockling[4].

Testing

The following parameters were considered to affect the extent of cockling (Y) rated according to SAWTRI standard photographs[4]. (5 = no cockling; 1 = severe cockling).

Mean Fibre Diameter (d) : Mean fibre diameter (μm) was measured by the projection microscope method and the CV of diameter calculated.

Mean Fibre Length (ℓ) : Mean fibre length (mm) was measured on an Almeter

Crimp Frequency (C): Staple crimp frequency (crimps/cm) of the raw wool was measured using a textile counting glass.

Stiffness (S) : A relative measure of fibre stiffness was obtained by using the equation $s \propto d^4 (1 + 6 V^2 + 3 V^4)$ where d is the average fibre diameter and V = fractional coefficient of variation of diameter[8].

Twist Liveliness (T) : The number of untwisting turns in a wet relaxed yarn under 10 g tension was measured by a method described earlier[2].

Fibres/cross section (N) : Calculated by using the formula

$$N = \frac{972 \text{ (tex)}}{d^2 \left[1 + \left(\frac{CV_d}{100}\right)^2\right]}$$

Yarn Irregularity (I): was measured on an Uster Evenness Tester and

Deviation from Duerden Crimp Standard (Δ_C): was calculated according to Turpie[5], i.e. $\Delta_c = C - C_D$, where C is the actual crimp and C_D is the calculated crimp (Duerden). ($C_D = 7535.d^{-2,44}$)

RESULTS AND DISCUSSION

The cockling ratings and the measured *or* calculated fibre characteristics for the 21 wool lots are given in Table I, whereas the yarn characteristics, irregularity (I), twist liveliness (T) and fibres per cross-section (N) are given in Table II.

TABLE I

A COMPARISON OF THE COCKLING RATINGS OF VARIOUS LOTS OF WOOL AND THEIR FIBRE CHARACTERISTICS

Wool Lot	Staple Crimp frequency (crimps/cm)	Δ_C ** ($C-C_D$)	mfl (mm)	mfd (μm)	mfd CV (%)	Relative Fibre stiffness (Arbitrary Units)	Cockling Rating*
1	5,3	- 0,47	77,9	19,0	19,6	1,61	3,56
3	6,2	+0,57	69,7	19,2	20,8	1,72	3,77
4	4,4	- 0,60	79,8	20,2	21,8	2,15	3,39
5	5,2	+0,14	83,6	20,1	19,7	2,02	3,76
7	5,8	+1,08	70,0	20,7	21,8	2,37	4,05
9	4,6	- 0,02	80,0	20,9	20,1	2,38	3,24
10	4,8	+0,28	76,2	21,1	20,4	2,49	3,80
11	4,8	+0,38	80,0	21,3	19,1	2,52	3,71
12	4,5	- 0,17	75,9	20,8	20,0	2,33	3,36
13	3,8	- 0,43	80,0	21,7	18,3	2,67	1,91
15	3,5	- 0,43	84,3	22,4	22,3	3,29	3,08
18	5,3	+1,56	81,1	22,9	20,3	3,44	3,28
19	3,7	+0,04	84,2	23,1	20,1	3,55	2,72
20	4,8	+1,39	81,8	23,8	19,8	3,98	2,52
21	3,3	+0,14	70,5	24,6	18,2	4,40	1,61
22	3,0	- 0,13	71,0	24,7	23,3	4,97	1,35
23	4,1	+0,85	75,9	24,3	21,7	4,50	2,19
24	3,0	- 0,13	76,5	24,7	22,1	4,84	1,18
25	3,0	- 0,07	83,3	24,9	22,2	5,01	1,76
27	2,6	- 0,06	67,6	26,5	22,9	6,52	1,24
28	2,9	+0,38	77,4	27,1	23,1	7,17	0,88

** Negative sign indicates undercrimped
Positive sign indicates overcrimped.

* Using SAWTRI standard photographs

Linear regression analysis showed that crimp/cm, stiffness, twist liveliness, yarn irregularity and number of fibres per cross-section, were all related to *mfd* and the cockling ratings. In this investigation mfl was not correlated with fibre diameter most probably because the selection of the wools was limited to 10/12 months wool and, fibre length also had no effect on irregularity.

The graph in Fig 1 shows the relationship between the mean fibre diameter of the wool and the cockling rating measured on the fully fashioned

TABLE II

YARN PHYSICAL CHARACTERISTICS AND COCKLING RATINGS

Yarn Lot No.	Resultant Yarn Linear Density (R tex/2)	Yarn Irregularity (CV %)	Twist Liveliness (No. of turns/ 0,5 m) (mean)	Fibres/ Cross-Section	Cockling Rating*
1	67,8	11,4	17,7	182	3,56
3	64,6	12,4	18,5	170	3,77
4	65,5	11,9	15,9	156	3,39
5	64,6	11,8	17,0	155	3,76
7	65,0	12,5	18,1	147	4,05
9	65,4	12,1	16,7	145	3,24
10	64,0	12,5	16,6	139	3,80
11	64,9	12,4	15,3	139	3,71
12	64,2	12,4	16,0	144	3,36
13	63,8	11,7	17,1	131	1,91
15	64,0	12,6	15,0	124	3,08
18	64,0	13,3	14,9	118	3,28
19	63,4	12,8	16,2	115	2,72
20	65,9	12,4	14,9	113	2,52
21	63,9	12,6	14,3	102	1,61
22	63,4	13,3	13,5	101	1,35
23	63,0	13,6	13,3	104	2,19
24	63,7	13,4	14,3	101	1,18
25	65,1	14,6	13,9	102	1,76
27	64,3	13,6	12,9	89	1,24
28	63,1	14,6	11,4	83	0,88

* SAWTRI standard photographs

garment. It can be seen that the specimens from the finer wools (at a standard R64 tex) gave the highest cockling rating (i.e. least cockling) and that there was a significant difference between overcrimped wools and undercrimped wools with the *overcrimped* wools giving *less* cockling.

A multiple linear regression analysis with the six independent variables d, $CV_{(d)}$, T, N, I and Δ_C (ℓ was considered not to be relevant in this case and C and S were too highly correlated with d) showed that the best fit equation was as follows:

$$Y = 0{,}50\, \Delta_C - 0{,}41\, d + 11{,}89 \qquad (1)$$

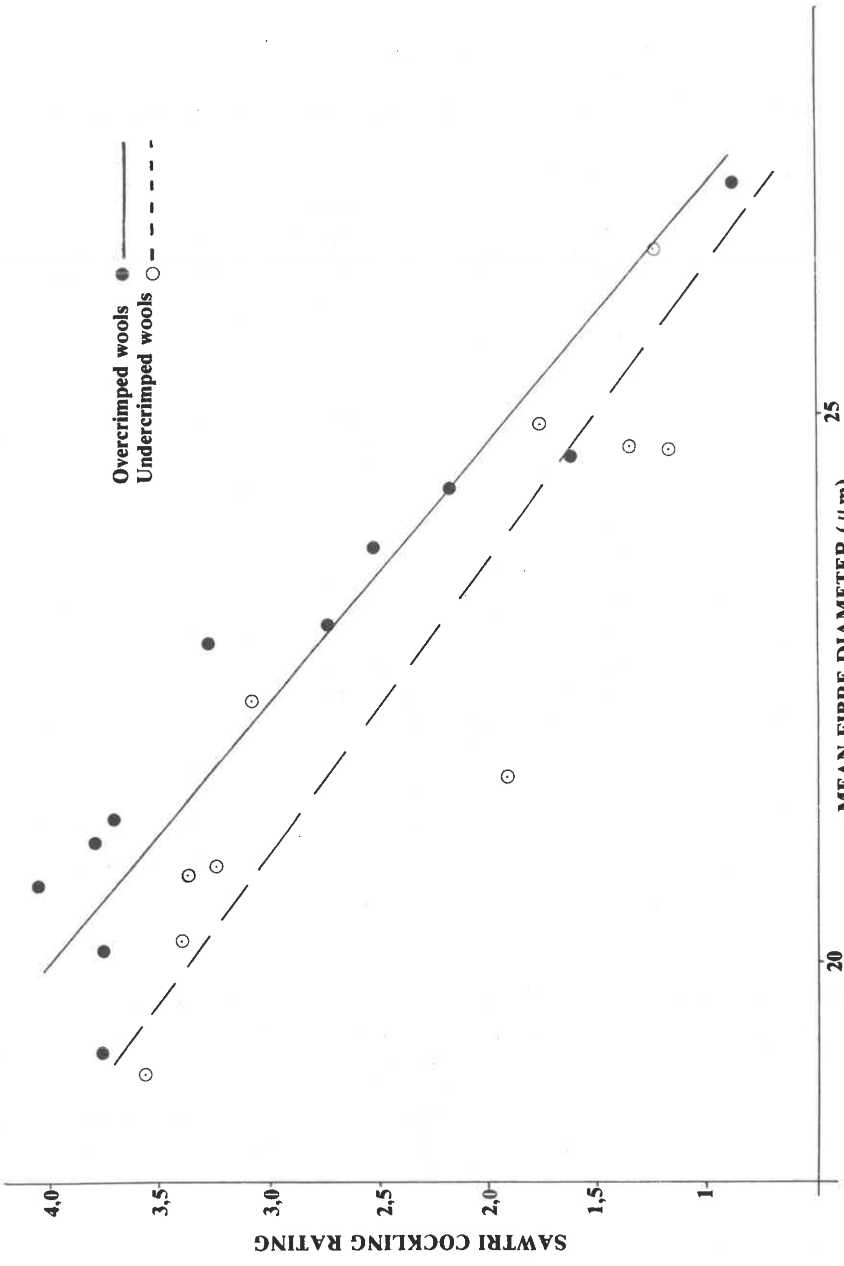

Fig. 1 Effect of fibre diameter and crimpiness on cockling (R64 tex yarn)

This equation indicates that *coarser* fibres and *undercrimped* fibres gave more cockling. The other four variables $CV_{(d)}$, T, N and I were rejected because of their relationship to diameter. The above relationship is significant at the 99% level of confidence with a 88,3% fit, i.e. *for a R64 tex yarn nearly 90% of the observed variations in cockling can be explained by diameter and abnormal crimp of the wool fibre.* (The relative statistical importance of each term is reflected by their contribution, d : 80,6%, Δ_C: 7,7%). The contribution of crimp, therefore, appears very small. The cockling rating scale[4] is considered such that a rating *higher* than 4 is acceptable whereas values *lower* than 4 are considered unacceptable.

Equation (1) indicated that, for yarns of constant linear density (64 tex), *coarser* fibres result in more cockling than *finer* fibres.

Since the number of fibres/cross-section (N) has a profound effect on yarn irregularity a new equation was calculated using N instead of d :

$$Y = 0{,}034\,N - 0{,}54\,\Delta_C - 1{,}8 \qquad (2)$$

which is significant at the 99% level of confidence with an 83,3% fit. Equation 2 indicates that for a 64 tex yarn and the number of fibres in the yarn cross-section varying from 83 to 182, the cockling rating increases by 1 when the number of fibres in the cross-section of the yarn is increased by 30.

Having demonstrated the effects of d, N and Δ_C on the cockling rating when yarns of 64 tex are used, it was decided to determine the effect when both d and N are varied systematically (tex varied from 53,4 to 165,4). Six lots of wool were selected (see Table III) comprising three values of d i.e. approximately 19,0 22,5 and 24,5 µm and a state of undercrimping and overcrimping for each wool. From each of these six wool lots three yarns were spun, each having approximately 150, 200 and 250 fibres per cross-section ensuring that the yarns were spun to a fairly high degree of regularity. The actual yarn linear densities and number of fibres in the yarn cross-section as well as the cockling ratings of the subsequent fabrics knitted are given in Table III. The equation fitted to these new data (using d, d^2, Δ_C, $d\Delta_C$ and N) showed:

$$Y = -0{,}121d + 0{,}0107N + 4{,}26 \qquad (3)$$

which had a fit of 77,4%.

Although these data suggest that perhaps a very small trend with Δ_C might be present, the regression analysis does not show it to be significant at the 95% level of confidence *when the yarn tex has been increased to a level where the yarn irregularity has been minimised* (because of the high number of fibres per cross-section). Fig 2 shows equation (3) extrapolated for wools of various fibre diameters and yarns of various fibres per cross-section.

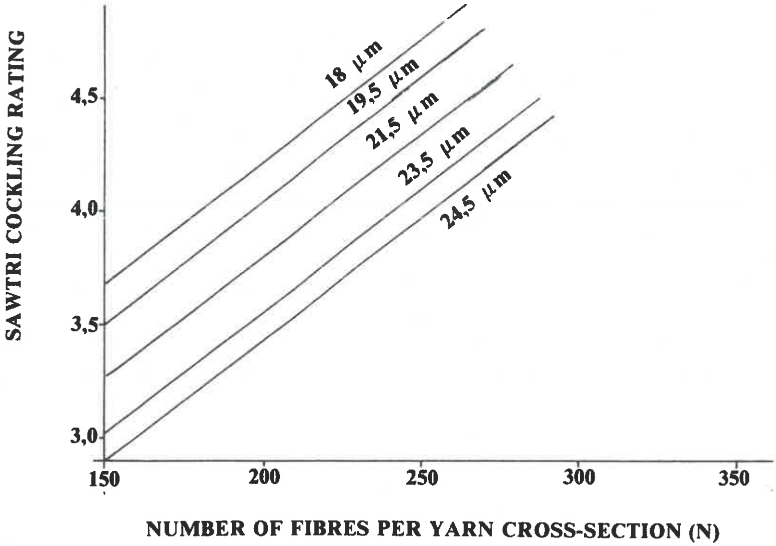

Fig 2 The effect of mean fibre diameter and number of fibres per cross-section on the cockling rating for two ply worsted yarns

TABLE III

THE EFFECT OF D, Δ_C AND N AT VARIOUS YARN LINEAR DENSITIES ON COCKLING

Wool Lot	mfd (μm)	Δ_C **	Calculated Number of Fibres/ Cross-Section	Actual Yarn Linear Density (tex)	Cockling Rating*
1	19	-0,47	138 197 244	53,4 76,0 94,1	3,7 4,2 4,3
3	19,2	+0,57	154 197 248	61,0 78,1 98,1	3,5 4,3 4,6
15	22,4	- 0,43	161 201 244	87,5 108,7 132,1	3,1 3,2 4,1
18	22,9	+1,56	144 200 237	81,0 112,2 133,3	2,9 3,5 4,2
22	24,7	- 0,13	147 194 255	99,3 132,4 165,4	2,5 3,8 3,8
23	24,3	+0,85	147 202 247	93,4 128,7 157,2	2,9 4,1 4,0

** Negative sign indicates undercrimped
Positive sign indicates overcrimped

* SAWTRI standard photographs

SUMMARY AND CONCLUSIONS

Twenty-one lots of different wools varying from 19μm to 27,1μm were spun into a standard yarn (R64 S275/2Z460) and knitted into fully-fashioned garment blanks. The fibre physical properties, mean fibre diameter, CV diameter (%), staple crimp, relative stiffness, and certain yarn physical properties, twist liveliness, fibres/cross-section and yarn irregularity were correlated with the amount of cockling found in the fabrics, rated according to the SAWTRI Standard photographs. A multiple regression analysis showed that diameter and degree of over- and undercrimpiness were the only two significant factors affecting cockling in the present case *using a constant yarn linear density (64 tex).* All the other properties were found to be too highly correlated with fibre diameter and their effects, if any, could therefore not be isolated. It appeared that an *overcrimped* wool produced *less cockling* than an undercrimped wool.

A further investigation involved a fine, medium and coarse wool from both overcrimped and undercrimped varieties which were spun to different yarn linear densities with approximately 150, 200 and 250 fibres in the yarn cross-section and the knitted garments compared for cockling. A regression equation involving fibre diameter and fibres per cross-section (tex) showed that a 77,4% (at the 95% level of confidence) prediction can be made of the amount of cockling that will occur in the garment when these two factors are known. In this case, where yarns with a high number of fibres/cross-section and a high degree of yarn regularity were used, deviation in crimp was not significant at the 95% level of confidence.

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