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Cocking in Fully-Fashioned Knitwear

Part II: An Investigation into the Effect of Various Fibre, Yarn and Fabric Properties on Cockling

by

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COCKLING IN FULLY-FASHIONED KNITWEAR

PART II: AN INVESTIGATION INTO THE EFFECT OF VARIOUS FIBRE, YARN AND FABRIC PROPERTIES ON COCKLING

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ABSTRACT

Cockling in fully-fashioned knitwear has been investigated. A constant yarn linear density of R64 tex/2 was used throughout the investigation and it has been shown that very fine wools produced relatively regular yarns which did not cockle whereas coarser wools produced yarns that cockled very badly. A very fine cashmere yarn did not cockle, whereas a very coarse mohair yarn cockled excessively. A super fine wool of 17,7 µm when spun very evenly did not cockle but when deliberately spun unevenly cockled excessively. It was concluded that it was mainly the evenness of the yarn which determined the amount of cockling. Cockles formed when a relatively thick place in the yarn coincided with a relatively thin place in either the preceding or succeeding courses or both. The average difference in yarn linear density at a cockle was about 50 per cent. Below a difference of 30 per cent little or no cockling was encountered.

Yarns of lower twist levels were more prone to cockling and fabrics with low tightness also cockled more than tight fabrics. Acrylic yarns did not cockle even when spun deliberately with a high degree of irregularity.

Wool yarn developed a higher untwisting torque when wetted out which resulted in more prominence of the cockles after wet relaxation and this torque coupled with high yarn irregularity are the prime factors for cockling.

It was concluded that all-wool yarns for plain single jersey knitwear should be spun from wool of sufficient fineness and with sufficient fibres in the cross-section to ensure a very regular yarn with a much lower propensity for cockling.

INTRODUCTION

Plain single jersey fabrics knitted from all-wool worsted yarns have been found to exhibit cockling. A precise definition of cockling can be found in an earlier report[1] in which it was shown to coincide with a thick place in the yarn. Such thick places exhibited the expected relatively low twist. It was also observed that cockles occurred in fabrics produced from wool and mohair yarns, but were not observed in fabrics knitted from fibres other than wool and it was shown that the CV (*per cent*) of both plying twist and yarn linear density was considerably higher for the all-wool yarns than for the other yarns.

Various workers[2,3,4] have reported a significant correlation between variation in twist and yarn linear density. Other workers[5,6] investigating loop distortion have offered conflicting opinions on the effect of twist. Researchers at the Centre de Recherches de la Bonneterie Troyes[5] stated that, when the number of turns per knitted loop became less than unity, loop distortion occurred. On the other hand, Benson[6] concluded that yarn twist had little effect on loop distortion but, if anything, lower twist levels reduced cockling. Nutting[7] stated that it was the unbalanced torque within the yarn, shown by its twist liveliness, that causes spirality[1], not just the presence of twist alone. Annales Textile Belges[8] published photographs which showed that when a portion of yarn of greater linear density was knitted without any change in tension, then, in order to fit into the same stitch space, these longer loops were forced to lie to the right or to the left as shown in Fig. 14[1]. In this study the effect of fibre diameter, yarn irregularity, twist levels, torque and fabric tightness on cockling in single jersey knitwear has been investigated in an attempt to throw more light on the causes and mechanism of cockling.

EXPERIMENTAL AND DISCUSSION

The effect of Fibre Diameter

Four South African merino wools were selected with widely differing mean fibre diameters, but with similar mean fibre lengths of 60 to 70 mm. Table I gives the results of the fibre properties measured in top form. The four lots were spun to R64 tex S275/2Z460 yarn. All the yarns were cleared, waxed and tested for yarn physical properties prior to knitting.

TABLE I

FIBRE PROPERTIES OF FOUR WOOLS

Lot	Mean fibre diameter (μm)	CV (%)	Mean fibre length (mm)	CV (%)
1	17,7	18,6	61,4	50,3
2	18,3	19,4	68,8	46,0
3	20,8	21,1	70,1	50,2
4	23,3	21,3	69,9	38,8

The yarn properties are shown in Table II.

TABLE II

PHYSICAL PROPERTIES OF FOUR YARNS SPUN FROM S.A. MERINO WOOLS

Lot	Mean Fibre Diam. (μm)	Yarn Linear density (tex)	Irregularity (CV%)	Twist			
				5,0 cm gauge length		2,5 cm gauge length	
				Mean (t.p.m)	CV(%)	Mean (t.p.m)	CV(%)
1	17,7	R63,20/2	10,3	287	6,9	295	14,0
2	18,3	R63.75/2	11,0	261	7,1	278	18,1
3	20,8	R64.02/2	11,7	272	3,8	287	12,8
4	23,3	R63.03/2	12,8	273	3,7	281	22,7

Knitting

Body blanks were knitted on a Bentley Cotton 21gg fully fashioned machine using a storage feed unit which results in a low yarn input tension[9]. The fabrics were dry relaxed, then wet relaxed[10], before being assessed for cockling. Photographs of these fabrics are shown in Figs. 1–4.

It was found that as the fibre diameter increased so the degree of cockling increased. It is clear from Table II, however, that yarn irregularity showed a corresponding increase with fibre diameter and, because of this, it is impossible to say whether the change in fibre diameter as such, or the corresponding change in CV irregularity, is the cause of the differences in cockling.

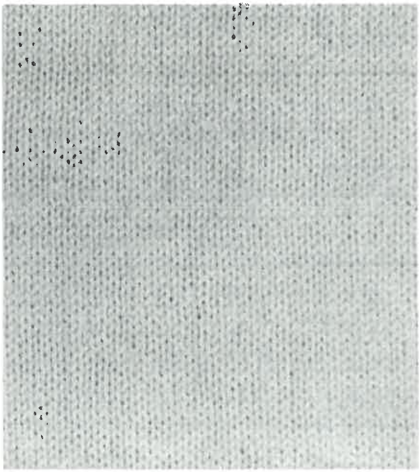

FIGURE 1

Fabric knitted from yarn spun from 17,7 μm wool. (Very little or no cockling.)

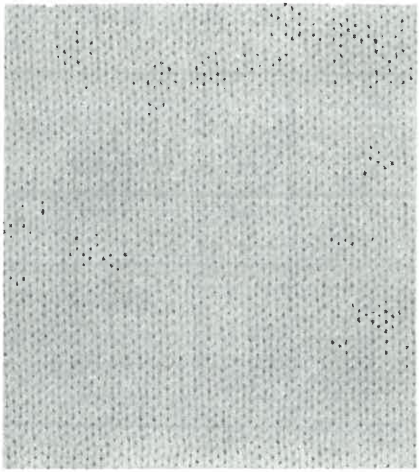

FIGURE 2

Fabric knitted from yarn spun from 18,3 μm wool. (Little or no cockling.)

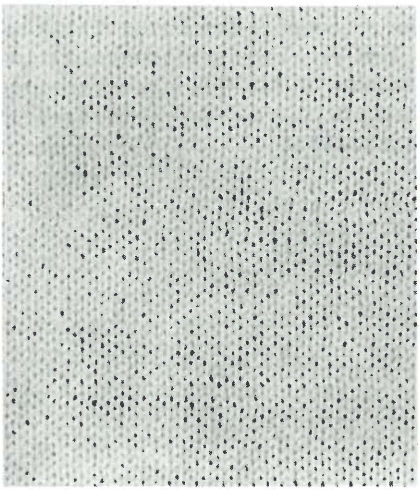

FIGURE 3

Fabric knitted from yarn spun from 20,8 μm wool. (Cockling)

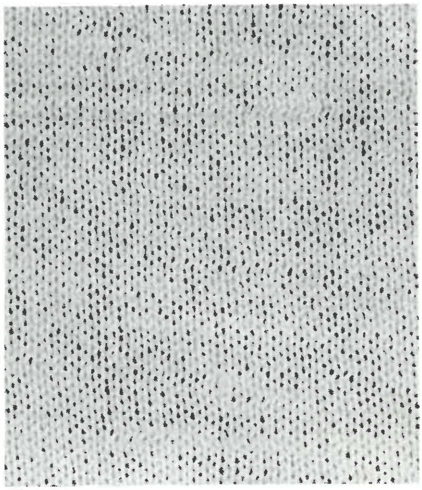

FIGURE 4

Fabric knitted from yarn spun from 23,3 μm wool. (Cockling)

The observations made for the various wools, indicate that cockling is a function of at least mean fibre diameter, or yarn irregularity, or possibly both. To determine which of these two factors is mainly responsible for the cockling, the fine wool (lot 1 : 17,7 μm) was deliberately spun into a regular (normal, CV = 10,3 *per cent*) yarn and into a very irregular (abnormal, CV = 19,9 *per cent*) yarn. See Figures 1 and 5 respectively.

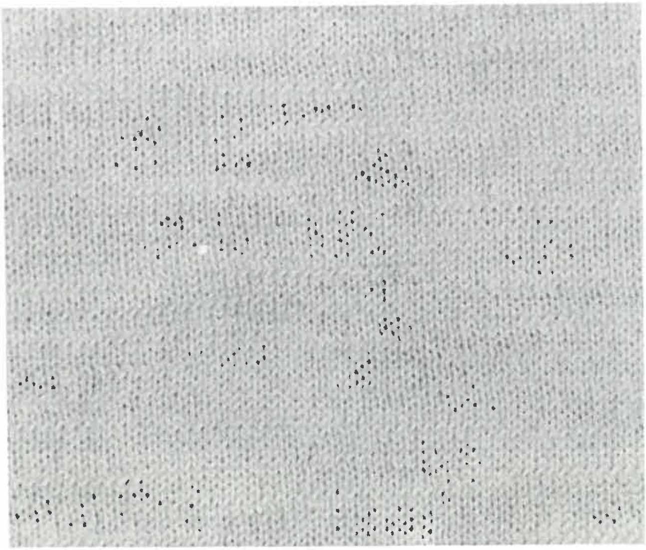

FIGURE 5

Fabric knitted from fine wool (mfd 17,7 μm) spun deliberately into an irregular yarn. (Extreme cockling)

It can be seen from Fig. 5 that the irregular yarn cockled very badly indeed, whilst the fabric knitted from the regular yarn (Fig. 1) did not cockle. This then strongly suggests that it is mainly yarn irregularity and not fibre diameter as such which is responsible for the observed differences in cockling.

This is in agreement with the observations made in an earlier report[1], that the irregularity (and CV of twist) of the wool yarns was much higher than that of yarns other than wool, and that this may be the reason for the fact that the fabrics knitted from the wool yarns cockled, whereas those knitted from yarns other than wool did not. To test this hypothesis a 3,6 dtex acrylic fibre (mfl 40 mm) was spun into a regular yarn (irregularity CV = 11,1 *per cent*) and an irregular yarn (irregularity CV = 19,9 *per cent*). These yarns were knitted into garment blanks as before and assessed for cockling. Neither formed cockles, although the irregular yarn caused very severe corrugations (see Figure 6).

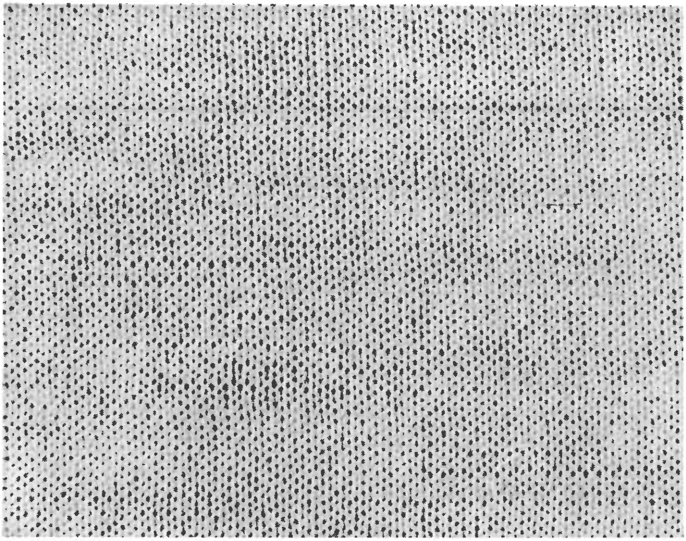

FIGURE 6

A fabric knitted from an irregular spun acrylic yarn (CV = 19,9 per cent) (corrugations but no cockling)

Clearly high irregularity alone is not sufficient to produce cockles and therefore some other fibre or yarn property must be present as well as yarn irregularity. This fibre/yarn property must be responsible for torque differences which occur in the case of wool and which then leads to cockling. This will be discussed later.

To investigate this further a cashmere yarn (14,8 μm) and a mohair yarn (34,3 μm) were knitted as before. The cashmere fabric exhibited no cockling whereas the mohair fabric cockled severely. Figures 7 and 8 show photographs of fabrics knitted from these extremes of fibre diameters. It can be seen that the mohair fabric was completely distorted by cockling.

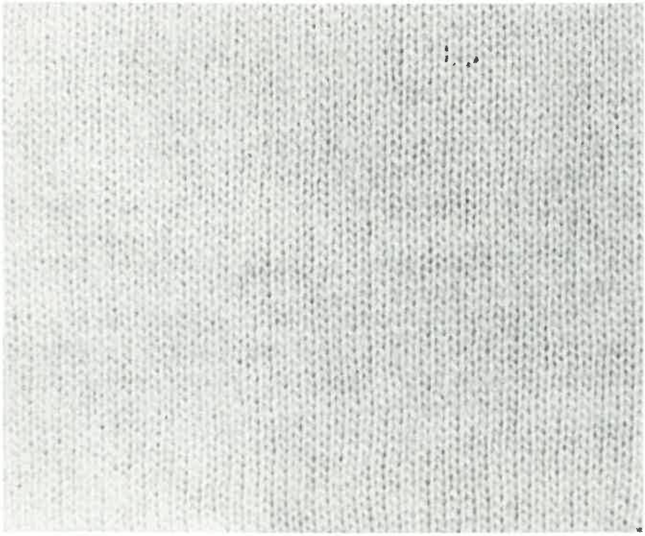

FIGURE 7

Fabric knitted from cashmere (14,8 μm). No cockling whatsoever (singles yarn)

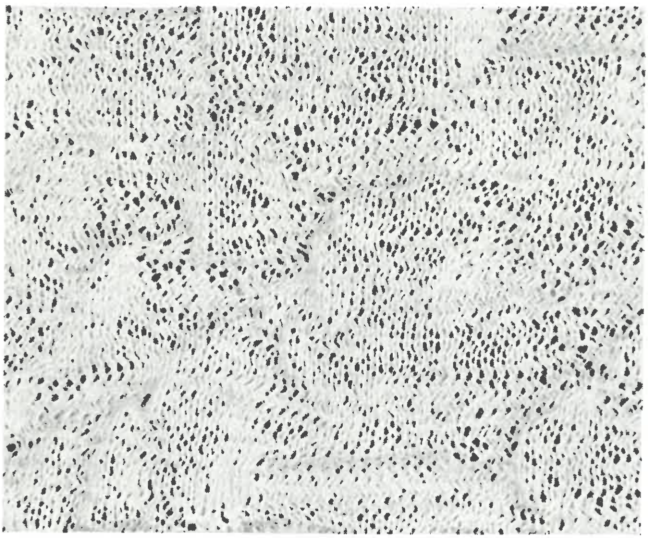

FIGURE 8

Fabric knitted from mohair (34,3 μm). Fabric completely distorted by cockling

The effect of Yarn Irregularity

In Part 1[1] of this report the intensity of cockles in a single jersey fabric was measured by counting, under magnification, the number of distorted loops per unit area. In some cases single distorted loops or small groups of two or three distorted loops were therefore recorded. In actual fact, however, these did not constitute cockles in the fabric as defined[1]. It was decided, therefore, to use an alternative method in an attempt to correlate the number of cockles per unit area with yarn irregularity.

A R64 tex S275/2Z460 all-wool yarn spun from a S.A. merino good average topmaking mixture, known from previous experience to produce cockles in single jersey knitwear, was selected for this initial investigation. The yarn was knitted on a Bentley Cotton 21 gg fully-fashioned machine and the machine details were as reported earlier. The knitted fabrics were wet relaxed[10] and some cockles were selected and marked as shown in Figure 9.

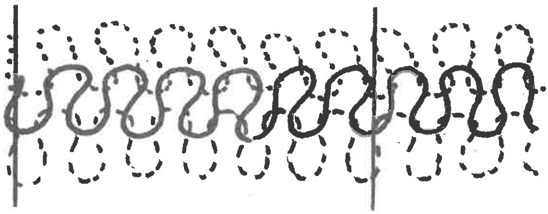

FIGURE 9

Diagramatic illustration of the three portions of yarn which constitute a cockle

On observation of the cockles, marks were made as shown in Figure 9 and the fabric was unravelled and the yarn wound onto a cone. During the unravelling, care was exercised in differentiating between the yarns from different courses. That portion of yarn unravelled directly above and adjacent to the cockle (knitted in the course after the cockle) was tinted BLACK and referred to as "after the cockle". The portion of the yarn containing the distorted loops constituting the cockle was tinted RED and referred to as "the cockle", and the portion of the yarn unravelled directly below and adjacent to the cockle (knitted in the course before the cockle) was tinted BLUE and referred to as "before the cockle". This procedure was repeated for a large number of cockles, and the yarn was wound onto a cone. This yarn was then tested on an Uster Evenness Tester. The yarn speed was reduced to a minimum (four metres per minute) and the recorder was set on the 50 *per cent* scale at maximum speed (one m/min).

As each tinted portion of yarn passed through the capacitator, synchronised markings on the recorder paper were made to indicate the beginning and ending of the tinted portions of yarn. These were marked B (before the cockle), C (the cockle) and A (after the cockle). This method was repeated for all cockles. Later these irregularity diagrams were synchronised and the three portions of yarn superimposed to produce *diagrams* representing the three yarn linear densities at a cockle. A sample of these diagrams is shown in Fig. 10.

It can be seen that in each case the "red" yarn (at the cockle) was significantly thicker than either of the yarns preceding or succeeding it in the fabric and especially thicker than one of them.

A similar experiment was conducted on the same yarn but at positions where no cockles were present, and a sample of these synchronised irregularity diagrams is shown in Fig. 11.

Table III gives the average maximum differences in yarn linear density (%) from a series of irregularity diagrams.

TABLE III

AVERAGE DIFFERENCES IN YARN LINEAR DENSITY BETWEEN ADJACENT COURSES FOR COCKLED AND NORMAL FABRIC AREAS

Synchronised diagrams of average yarn (23,3 μm) (cockles)	Synchronised diagrams of average yarn (23,3 μm) (normal)	Synchronised diagrams of a very regular yarn (17,7 μm) (no cockles)
54,2	34,3	27,6

It was known that when lot 1 (Table II) was knitted into fully fashioned garments, the fabrics were virtually free from cockles, and when this yarn was tested as described above and synchronised irregularity diagrams produced, they were of a completely different character than those of an average yarn. The yarn irregularity (CV) was 10,3 *per cent* and the average difference in yarn linear density between adjacent courses in this yarn was only 27,6 *per cent*. (See Fig. 12).

From the evidence so far, it appeared that short term irregularity had a profound effect on cockling. This can, however, only be said to be true for an all-wool yarn when knitted into plain single jersey fabric. This was fully illustrated earlier when a normal acrylic yarn was spun very regular and produced a fabric free from cockles. An highly irregular yarn was then deliberately spun and knitted into fabric and after wet relaxation[10] it was noted that there was no cockling. The

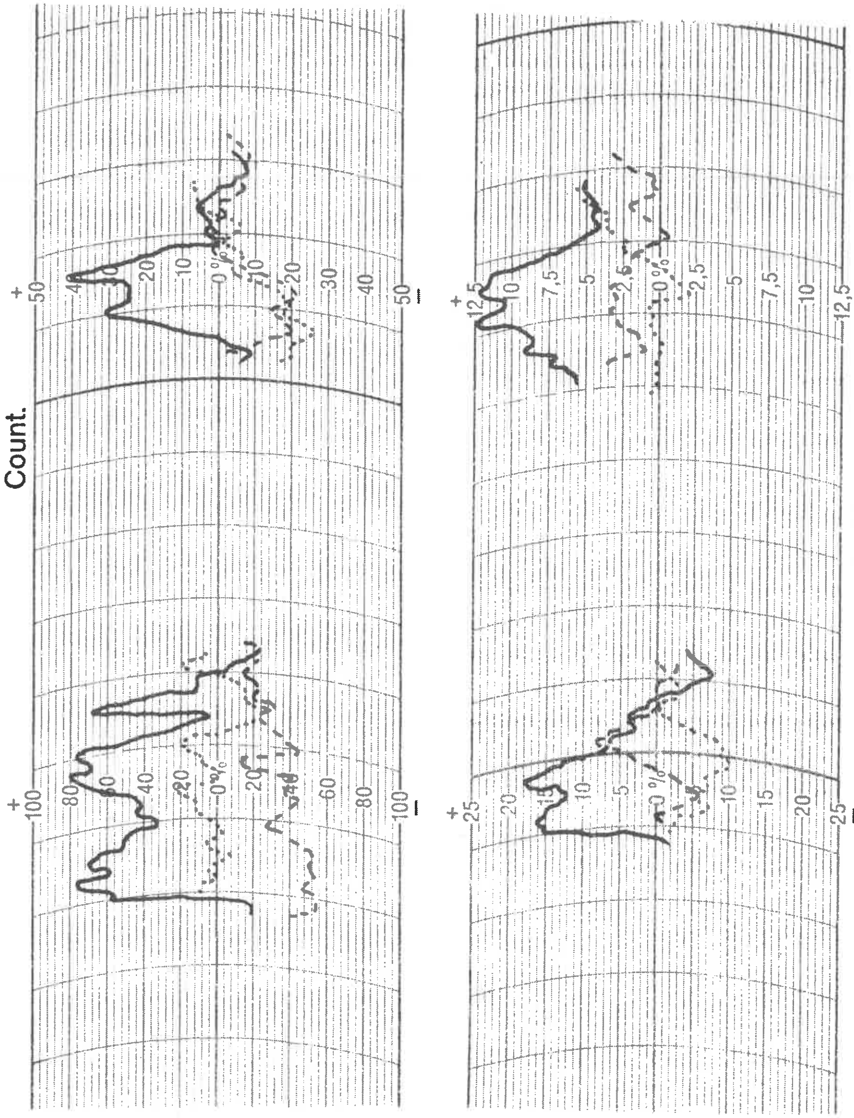

FIGURE 10

Diagrams showing short-term variation in yarn linear density, before --- at – –and after . . . . the cockle, as found in an average all-wool hosiery yarn spun from S.A. merino wool (R64 tex/2)

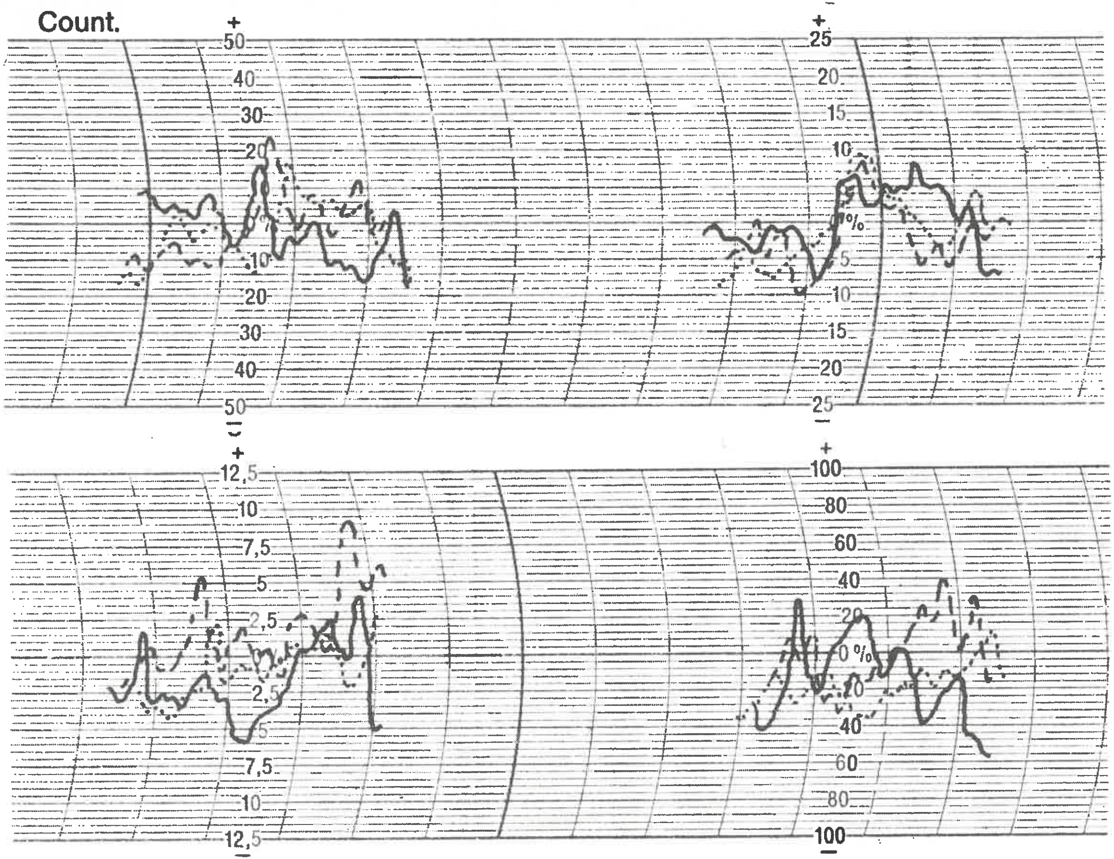

FIGURE 11

Diagrams of an average all-wool hosiery yarn spun from S.A. merino wool (R64 tex/2) showing short-term variation in yarn linear density at places which did not cockle

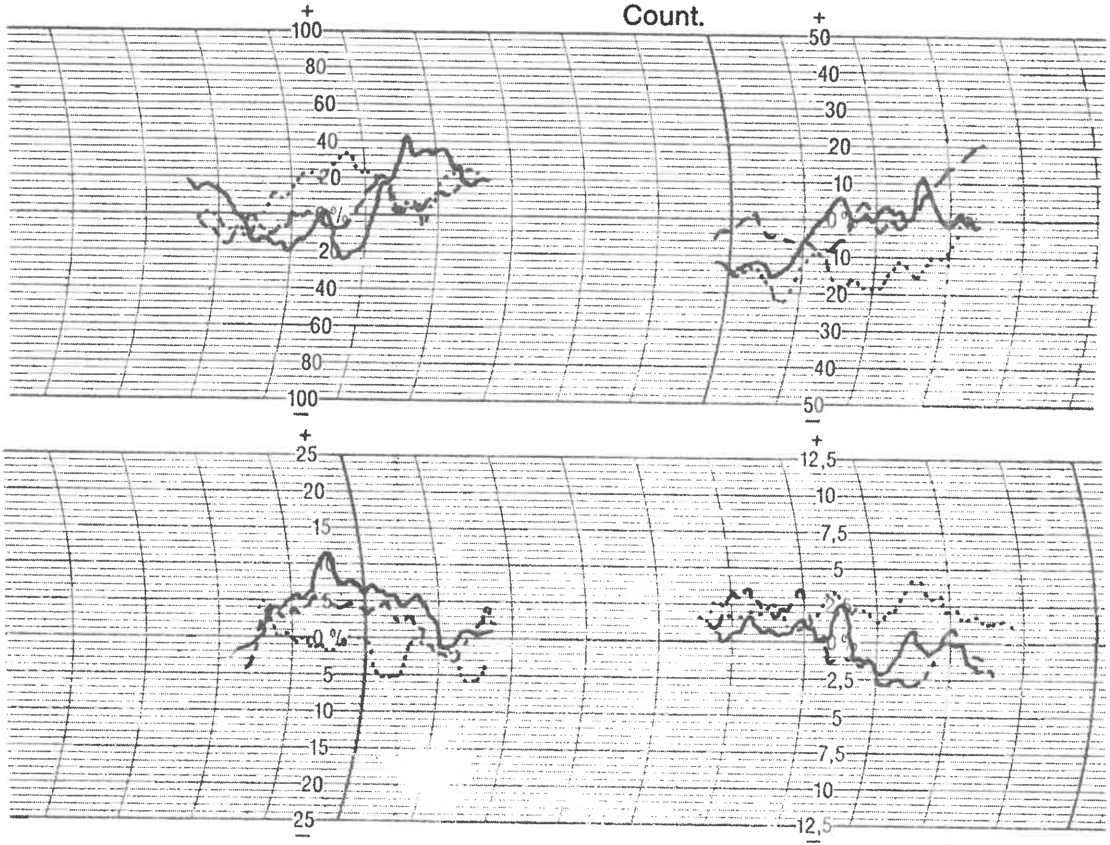

FIGURE 12

Samples of synchronised irregularity diagrams of a very regular all-wool yarn spun from Lot 1. Table II.

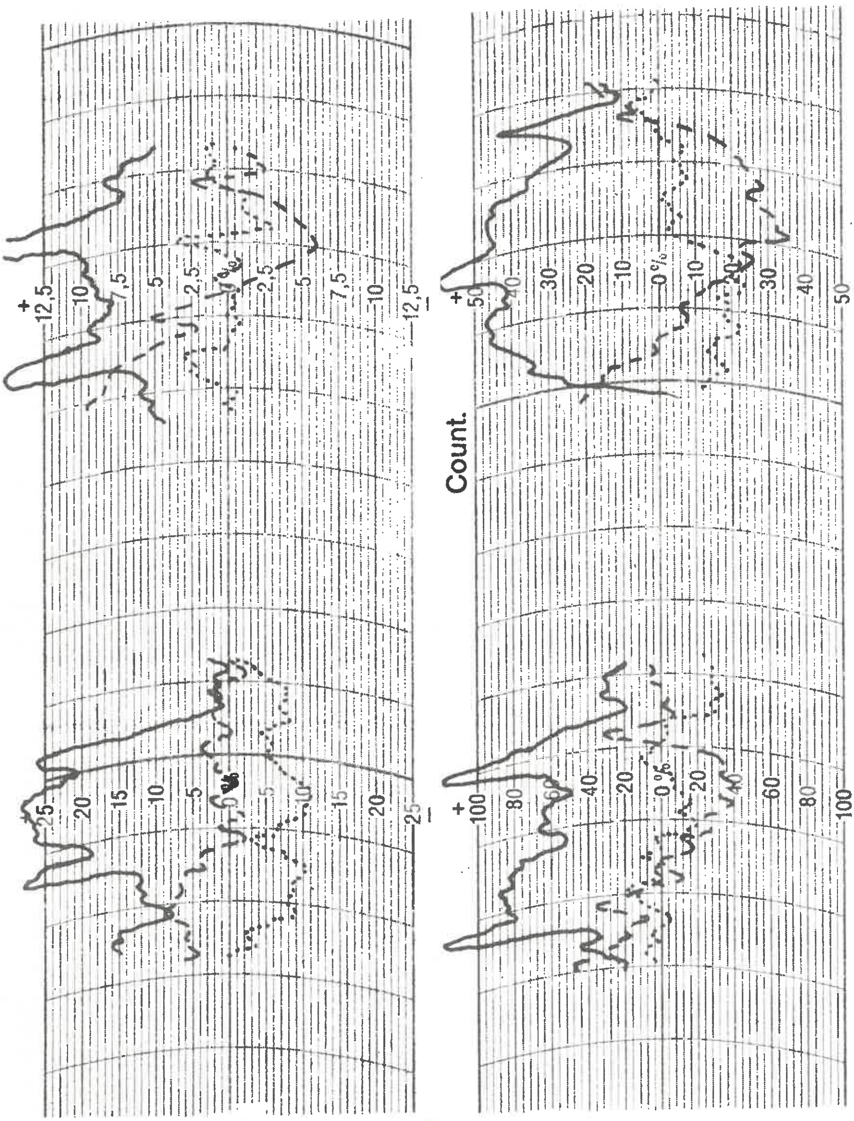

FIGURE 13

Synchronised irregularity diagrams of a highly irregular acrylic yarn (ave. difference > 86,5 *per cent* – did not produce cockling, only corrugations in the fabric)

high irregularity of the yarn did in fact produce corrugations in the fabric, hitherto not observed, but no loop distortion. (See Figure 6).

Figure 13 shows the synchronised diagrams of the irregular acrylic yarn and the average maximum difference in adjacent yarn linear densities was in excess of 86,5 *per cent.*

Effect of yarn twist levels

Yarns:

It was decided to spin six all-wool yarns R64 tex/2 from the same lot of wool, but using various twist levels. A 30 kg lot of wool – S.A. merino 64's quality – was spun and plied into R64 tex/2 yarn with the following levels of twist viz: S253/2Z380, S280/2Z420, S306/2Z460, S333/2Z500, S360/2Z540 (all balanced twist) and a sixth yarn S275/2Z460 similar to other yarns used in this series of experiments. Again the yarns were cleared, waxed and tested for yarn physical properties (see Table IV).

Knitting:

From each yarn lot several body blanks were knitted as previously described.

Cockling:

After knitting, the fabrics were dry relaxed (65 *per cent* RH and 20°C) for a minimum of 48 hours prior to wet relaxation[10] and then subjectively assessed for cockling. It was found that all the fabrics cockled to slightly differing degrees. Fabrics knitted from the low twist yarns cockled more than fabrics knitted from high twist yarns.

TABLE IV

PROPERTIES OF R64 TEX/2 ALL-WOOL YARNS SPUN AND PLIED TO VARIOUS TWIST LEVELS

Yarn lot	Nominal Twist (t.p.m)	Yarn Linear Density (tex)	Irregularity CV (%)	Plying Twist	
				Mean (t.p.m)	CV (%)
5	S253/2Z380	R66,5	13,6	242	11,8
6	S280/2Z420	R63,7	13,8	275	11,6
7	S306/2Z460	R63,2	13,9	290	13,9
8	S333/2Z500	R63,6	13,8	341	14,0
9	S360/2Z540	R65,8	13,6	373	11,5
10	S275/2Z460	R63,4	14,1	276	12,4

It can be seen from Table IV that all the yarns were basically of the same linear density and of similar evenness.

Cockling has been shown[1] to be affected by variation in yarn linear density, which is associated with twist variation, due to the thick and thin places. It was decided to isolate twist variation from yarn irregularity and determine if twist variation alone produced loop distortion. Isolated lengths of very low folding twist yarn were knotted into the normal yarn (lot 10) and then knitted in the normal manner. Figure 14 shows the fabric and the positions of the start and finish of the low twist inserts are clearly marked. To ensure that there was no variation in average yarn linear density throughout, the inserts of low twist yarn were produced by reducing the amount of twist in yarn (lot 10[1]) from S275 to S150.

It can be clearly seen that lines of distorted loops appeared between the marks, indicating clearly, that a change in twist not associated with a change in yarn linear density, formed loop distortion similar to *flashing*[1], but not cockling as defined. It was suspected that it was in fact the torque set up in the yarn by untwisting that caused the loop distortion.

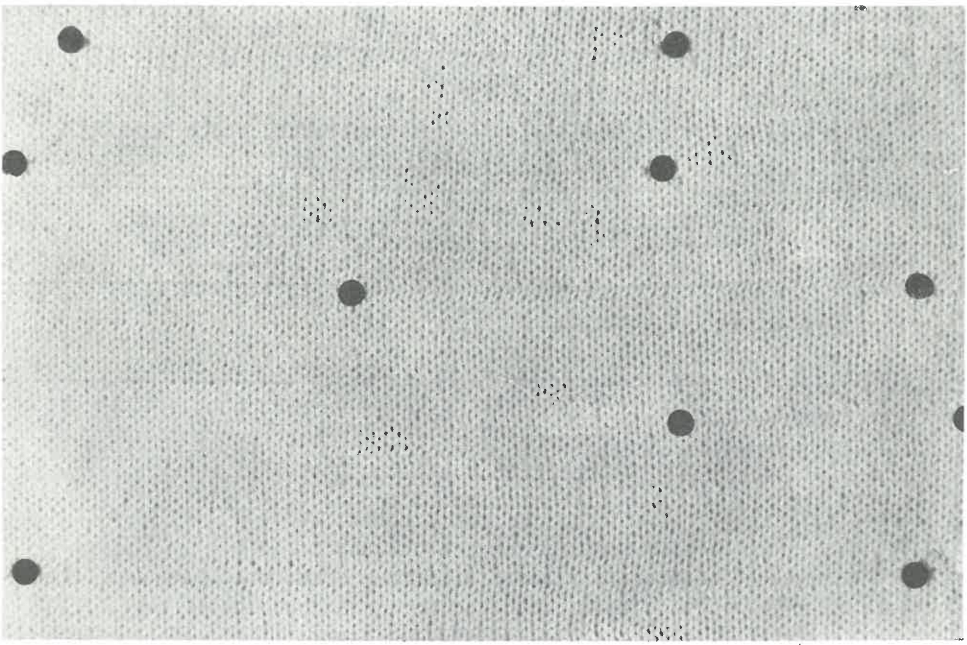

FIGURE 14

Photograph showing the effect of isolated inserts of very low twist yarn – S150/2Z460 in S275/2Z460 of same yarn R64 tex/2

Effect of Relaxation of Yarns

In an attempt to find some physical differences as to why the normal all-wool yarn R64 tex S275/2Z460 caused cockles and a normal acrylic yarn of the same tex and twist did not produce cockles, it was decided to determine whether or not there was some torque in the yarn which, when relaxed in the double bending of the knitted loop and then amplified during wet relaxation, could thus cause loop distortion.

Untwisting Force in Yarn

An acrylic yarn and a wool yarn (23,3 μm) of the same linear density and twist, namely R64 tex S275/2Z460 were selected. Half a metre of each yarn was held in clamps at each end and the upper clamp was secured in a fixed position while the lower clamp hung down freely and the yarn was then allowed to untwist. The number of turns untwisted when the lower clamp finally came to rest, was recorded. The experiment was repeated 10 times and the mean calculated. A similar experiment was carried out but this time the yarns were relaxed (wetted out) in water for 15 minutes to completely release any set in the yarn. The yarn was then dried in an oven and allowed to condition at normal room temperature and humidity. The results are shown in Table V.

TABLE V

UNTWISTING TORQUE IN AN ACRYLIC AND WOOL YARN BEFORE AND AFTER WET RELAXATION

YARN	NUMBER OF TURNS UNTWISTED/0,5 m (mean)
100% Acrylic (control)	6,5
100% Acrylic (wetted out)	6,45
100% Wool (control)	6,25
100% Wool (wetted out)	10,10

The results show that wet relaxation of the acrylic yarn had no effect on the untwisting torque in the yarn. However, in the case of the wool there was a significant build up of the untwisting torque caused by wetting, this was probably due to the property of the wool fibre to swell and thereby create extra untwisting forces in the yarn. This explanation confirms earlier findings that after wet relaxation (treatment C)[11] of garments the cockles appeared to be more pronounced. The results also indicate that because the untwisting forces of the synthetic fibres were unaffected by wet relaxation there was no build up of untwisting torque. Coupled with this is the fact that the normal acrylic yarn had a much lower irregularity[1] and, therefore, no cockling was observed. As was shown when a very irregular acrylic yarn was produced the fabric still did not cockle, but the very large thick places caused corrugations in the fabric. However, because the untwisting torque was very low, there was no actual loop distortion or cockles as previously defined[1].

Untwisting Forces in Fabric

Hanks of irregular acrylic and regular all-wool yarns were wetted out as described above and then dried in an oven. The yarns were then knitted into plain single jersey, wet relaxed and examined.

The fabrics knitted from the normal acrylic yarn and wetted out acrylic yarns appeared to be no different from each other. Both exhibited corrugations but no cockling. The normal wool fabric (control), however, exhibited cockling and the fabric knitted from wetted out yarn, although somewhat softer and fuller in handle, exhibited excessive cockling.

Anti-Cockle Treatment of Yarns

As already shown[11] anti-cockle treatment of fabrics did not eliminate cockling, although it significantly reduced its severity. The cockles are formed at the point of knitting and can be observed in the fabric directly from the machine; after wetting out, the cockles becomes more pronounced. An anti-cockle treatment has the effect of improving the handle and producing a fuller fabric, and to some extent, masking the appearance of the cockles in the fabric, but it does *not remove* cockles. It has the effect of preventing the cockles developing fully during subsequent wet processing operations[12].

It was therefore decided to investigate the use of an anti-cockle treatment on *yarns* prior to knitting.

A bath of water was raised to 90 to 95°C before adding

Sodium bisulphite (3 *per cent* on mass of yarn), and

® Lissapol NX (3 *per cent* on mass of yarn)

to give a liquor to goods ratio of 50:1.

The hanks of wool were immersed in the liquor which was gently circulated for five minutes at 95°C, and then allowed to stand for 15 minutes. The bath was cooled down slowly by adding fresh water and the hanks rinsed twice to remove any residual bisulphite.

The yarns were dried and then knitted as previously. It was observed that the fabric still contained some cockles, but the general appearance of the garment was improved with the cockles more subdued.

The Effect of Fabric Tightness

The same six yarns described earlier were knitted into body blanks at three different tightness factors, viz 13,5; 14,5 and 15,5. Again the fabrics were dry relaxed prior to wet relaxation and then subjectively assessed for cockling. It was noted that in each case the tightest fabric cockled least of all and the slackest fabric the most.

SUMMARY AND CONCLUSIONS

Effect of Fibre Diameter

Yarns spun from four selected wools of mfd 17,7; 18,3; 20,8 and 23,3 μm when knitted into plain single jersey showed very little or no cockling of significance in the case of the 17,7 and 18,3 μm wools but definite cockling when the fibre diameter was increased to 20,8 and 23,3 μm. This effect of increased fibre diameter on cockling was further supported by examining a very fine cashmere yarn (14,8 μm) and a coarse mohair yarn (34,3 μm). Garments knitted from cashmere yarn did not exhibit any cockling, whereas the ones knitted from mohair cockled excessively. These effects are illustrated by photographs. It would appear that the fibre diameter of the wool (cashmere and mohair are animal fibres and can be considered similar to wool) affects the amount of cockling in a fabric. When a constant yarn linear density and fibre density are used the fibre diameter determines the average number of fibres in the yarn cross-section and therefore also the yarn irregularity. To test whether it was the change in fibre diameter or the corresponding change in yarn irregularity the very fine wool (17,7 μm) was spun into a regular and an irregular yarn and it was found that the irregular yarn cockled excessively.

Effect of Yarn Irregularity

When a cockle was closely examined it was found that the yarn at either side of the cockle, i.e. the course before and the course after, played an important part in the appearance of the cockle. It was shown that the portion of yarn which actually cockled was always a thick place whereas the portions of yarn at either side were thinner and one of them very much so. The average difference between the thick and thin portions of yarn adjacent to each other at a cockle was 54,2 *per cent.* In the normal fabric this figure was only 34,3 *per cent.* In a very fine singles wool yarn which produced fabrics virtually free from cockles the difference was only 27,6 *per cent*. An acrylic yarn, even when spun to extreme irregularity, did not cockle, the thick places in the yarn, however, caused heavy corrugations in the fabric.

It has been established therefore that yarn irregularity, i.e. thick and thin places, are the prime cause of cockling in all wool single jersey fabrics.

Effect of Yarn Twist Levels

It was shown that when fabrics were knitted from yarns spun with different twist levels, the respective fabrics cockled to slightly differing intensities. The fabric knitted from yarns of lower twist levels exhibited more cockling than those knitted from higher twist levels, and therefore it would appear that the amount of mean twist in a yarn does affect cockling. Variation in twist, however, is affected by yarn irregularity. When a portion of yarn, from a lot, was untwisted and then re-inserted into the lot and subsequently knitted, a *part-course* of distorted loops were formed, illustrating that a low twist portion in a thread did cause loop distortion. In this instance, there was no change in yarn linear density but the torque set up in the yarn by untwisting made the loops distort (incline) slightly (to the right) as shown in Figure 14. This form of loop distortion was defined as *flashing*[1].

Effect of Torque

When an acrylic yarn and a wool yarn were measured for untwisting force it was found that both yarns exhibited the same untwisting force. After wet relaxation, however, there was a significant increase in the untwisting torque of the wool yarn whilst that of the acrylic yarn remained constant. This could explain why wool cockles and acrylic does not and also why cockles are more prominent in wool fabrics after being wet relaxed.

Effect of Fabric Tightness

Of the three different tightnesses knitted, in every case the tighter fabric cockled the least. The slackest fabric cockled the most and this supports the evidence that the thick loops have more freedom, and move into a more relaxed configuration.

General

It can be concluded that yarn irregularity i.e. thick and thin places, in all-wool yarns are the principal cause of cockling. The property of the wool fibre to swell on wet relaxation creates extra untwisting forces. This coupled with the low twist areas at the thick places allows the loops to distort. This distortion is enhanced when a thick place in the fabric lies adjacent to a thin place. The multiple action of untwisting force in the yarn, double bending due to knitting and thick places in the yarn with lower twist, forces the loops to lean over and out of the plane of the fabric. Consecutive formations of these distorted loops then form a cockle.

In this report some very fine wools have been spun to a standard yarn of R64 tex/2. It must be pointed out, however, that whilst a fine wool yarn when knitted into plain single jersey does not exhibit cockling and a coarser wool yarn does, it may well be that if coarser wools are spun into yarns of higher yarn linear density with a high degree of regularity and knitted on a coarser gauge machine, knitwear free from cockling could be obtained. A study to determine the optimum number of fibres per yarn cross-section to produce fabrics which are free of cockling will be carried out.

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