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Dimensional, Pilling, and Abrasion Properties of Weft Knits Made from Open-End and Ring Spun Yarns

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ABSTRACT

This paper focuses on the dimensional, pilling, and abrasion properties of a series of plain jersey, lacoste, and two-thread fleece fabrics made from cotton ring and open-end spun yarns as well as from blend yarns (50/50 cotton/polyester, dyed). The results show that both structural differences and fiber type play a large part in determining the dimensions of these fabrics. It is apparent that the knits from blend yarns have a lower dimensional stability when compared to fabrics from 100% cotton ring and open-end spun yarns. Findings for the two-thread fleece fabrics suggest that the inlay yarn mainly governs their dimensional behavior in the widthwise direction. The pilling tendency of the test samples and their resistance to abrasion are evaluated with the ICI pilling box (at three different test revolutions) and the Martindale abrasion tester, respectively. In addition, an extensive SEM examination is used to study the effect of fiber type and repeated launderings on both pilling development and the degree of fiber damage within fuzz assemblies. The results show that unlike plain jersey fabrics, lacoste fabrics perform very well, and that in general fabrics knitted from open-end spun yarns have a lower propensity to pilling. In the case of the two-thread fleece structure, the samples from 100% cotton (*i.e.*, both face and fleece yarn) open-end yarns have higher pilling rates compared to FBOE (face yarn is cotton, fleece yarn is 50/50 PET/cotton) and FBB (both face and fleece yarn are 50/50 PET/cotton) fabrics. The SEM study reveals that for the same number of test revolutions, the degree of damage to fibers within the fuzz entanglements tends to increase with an increased number of launderings, and that the kind of damage varies from small cracks and fractures to slight flaking, depending on the fabric and yarn type. Note, however, that any damage occurring as a result of repeated launderings and pilling tests is not as severe as that reported in the literature. The lacoste fabrics have the least resistance to abrasion.

With the rising popularity of cotton, greater demands for quality have been required as end-users have become more aware of its negative properties, and therefore many studies have been reported on the geometry and dimensional properties of knitted fabrics produced from different kinds of yarns [1–2, 4–5, 7–12, 15–16, 22, 24, 27–28]. Although the problem of knitted fabric shrinkage can be solved to some extend by replacing 100% cotton with a cotton/synthetic fiber blend yarn, the severity and longevity of pilling, in turn, greatly increases, and pilling has become a much more serious problem for the knitted apparel industry. In addition to an unsightly appearance, pills on a fabric surface initiate garment attrition and cause premature wear. Because of the importance of this very subject, the mechanism of pill formation, as well as factors affecting it, has been investigated by many researchers since the mid-1950s [3, 6, 8, 13–14, 17–21, 23, 25–26, 29].

Our main objective in this paper is to investigate the effects of some yarn and fabric variables on the dimensional, pilling, and abrasion properties of lacoste and two-thread fleece fabrics (on which little has been reported in the literature), together with those of plain knitted fabrics.

Experimental

For the work, three different fabric types—double pique (lacoste), plain jersey, and two-thread fleece—were knitted on a 28-cut Monarch circular knitting machine with a 30″ diameter. Detailed information about the yarns used to produce these fabric samples are presented in Table I.

As we see from Tables II–IV, each fabric type was produced at three different course lengths (*e.g.*, for lacoste, 640/667/700 cm), and the samples were classified in accordance with the following general form: L (S or F)

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TABLE I. Properties of the yarns.

	Ring	Open-end			
Fiber type	Cotton	Cotton	Cotton	50/50 PET (dyed)/cotton blend	50/50 PET (dyed)/cotton blend
Ne	30.01	30.03	20.02	30.02	20.03
CV_{Ne} %	0.96	0.95	0.48	0.78	0.32
Turns/inch	20.70	20.82	17	20.54	16.57
CV_T %	0.91	0.80	1.19	0.75	1.13
αe	3.80	3.80	3.80	3.75	3.70
Breaking force, gf	361.4	224.5	386	325.7	509.3
CV_B %	9.62	9.56	7.63	9.27	7.35
Rkm	18.36	10.86	13.07	16.54	17.25
Elongation, %	4.92	3.7	4.71	4.95	6.00
%U	11.81	12.49	11.07	12.67	10.79
Thin places (−%50)	7	62	7	38	4
Thick places (+%50)	200	128	60	210	45
Neps (+%200)	336	59	23	231	58
Hairness	5.24	4.54	4.23	5.39	6.06

TABLE II. Dimensional properties of fully relaxed lacoste (dyed and blend spun) samples.

Samples	Wales/cm	Courses/cm	Stitch density, loops/cm^2	Weight, g/m^2	Fabric thickness, mm	Skewness, %
Dyed						
LOE640	12.00	28.50	342.00	246	1.00	1.80
LOE667	11.50	27.00	310.50	230	1.02	3.00
LOE700	11.50	25.00	287.50	225	1.03	5.50
LR640	12.00	29.00	348.00	245	1.03	2.40
LR667	12.00	27.00	324.00	234	1.04	3.50
LR700	11.50	25.00	287.50	225	1.05	7.50
Blend spun						
LB640	12.00	30.00	360.00	260	1.05	6.00
LB667	11.50	29.00	333.50	257	1.09	7.60
LB700	11.00	27.00	297.00	255	1.12	8.00

TABLE III. Dimensional properties of fully relaxed plain jersey (dyed and blend spun) samples.

Samples	Wales/cm	Courses/cm	Stitch density, loops/cm^2	Weight, g/m^2	Fabric thickness, mm	Skewness, %
Dyed						
SOE700	15.00	22.00	330.00	172	0.71	2.50
SOE740	15.00	20.50	307.50	165	0.69	4.40
SOE815	14.00	18.00	252.00	150	0.72	7.40
SR700	16.00	21.50	344.00	177	0.71	3.20
SR740	16.50	20.50	338.25	168	0.73	9.20
SR815	15.00	18.00	270.00	153	0.75	11.80
Blend spun						
SB700	16.00	22.00	352.00	183	0.78	12.40
SB740	16.00	21.50	344.00	179	0.78	13.20
SB815	15.00	19.00	285.00	171	0.79	13.80

TABLE IV. Dimensional properties of fully relaxed two-thread fleece (dyed and blend spun) samples.

Samples	Wales/cm	Courses/cm	Stitch density, loops/cm^2	Weight, g/m^2	Fabric thickness, mm	Skewness, %
Dyed						
F700	14.50	22.50	326.25	263	1.19	1.00
F750	14.00	20.50	287.00	235	1.07	1.50
F800	13.50	18.00	243.00	217	1.08	1.80
Blend spun						
FBB700	14.00	24.50	343.00	276	1.16	10.00
FBB750	13.50	21.50	290.25	253	1.14	10.60
FBB800	12.50	19.50	243.75	231	1.12	11.80
FBOE700	14.50	24.00	348.00	290	1.22	10.50
FBOE750	14.00	21.00	294.00	257	1.18	12.20
FBOE800	13.50	19.00	256.50	236	1.16	12.70

OE (R or B) XXX (three digit number), where OE/R/B stand for yarn type (100% cotton open-end, 100% cotton ring, 50/50 PET/cotton blend open-end). Plain jersey, lacoste, and two-thread fleece are designated S, L, and F in turn, and the three-digit number is used for the different course lengths. For example, FBB800 means a two-thread fleece fabric in which both the face and inlay yarn are 50/50 PET/cotton open-end spun yarn, knitted at the course length of 800 cm. In the case of the two-thread fleece knits from 100% cotton open-end spun yarn, however, FXXX (*e.g.*, F800) is used.

In the case of the two-thread fleece fabrics, the inlay stitch length was held (more or less) constant. Except for the fabrics knitted from the blend yarns (see Table I), some of the yardage of the gray goods was set aside and the remainder was scoured, bleached, and dyed under the same controlled conditions. The fabrics made from blend yarns were only rinsed. All the fabric samples were then subjected to relaxation treatments we explained in an earlier paper [8], but with a difference that washing and tumble-drying was repeated three times. After each relaxation process, areal density, fabric thickness, pilling (for three different tumbling revolutions: 7000, 9000, and 11,000), and abrasion resistance were measured in accordance with the following standards: areal density—ISO 3801, fabric thickness—BS 2544, abrasion resistance—BS 5690, pilling—BS 5811.

Wale and course density were measured using a magnifying glass; ten measurements for each dimension were made at different places on the tubular fabrics. Mean values of courses/cm and wales/cm were then calculated, and the product of these means was used to determine the stitch density of the sample, which is usually considered to indicate shrinkage. Course length was also tested to determine the amount of yarn shrinkage after laundering, and the results are as follows: for lacoste: LOE–1.65%, LR–2.35%, LB–1.35%; for plain jersey: SOE–2.40%, SR–2.87%, SB–1.06%; for two-thread fleece: F–1.08%, FBB–2.52%, FBOE–1.68%.

In order to evaluate the resistance of samples to abrasion, the fabrics were subjected to 20,000 rubs, which is of commercial interest. Furthermore, the weight loss percent of fully relaxed dyed samples was also calculated after the relevant test cycle had been completed, in order to be able to compare the severity of wear in the fabrics, even if there were no holes at the end of the test period.

In addition to the physical tests, samples were also examined under a Jeol model scanning electron microscope (SEM) using a magnification range of 100 to 750×. The SEM study was designed mainly to evaluate the kind and extent of fiber damage and pill entanglement on test fabrics. Samples were taken from the fabrics, which were pilled in accordance with the standard, mounted on 1-cm diameter SEM stubs, and gold coated prior to examination. The SEM photos of the fabrics are presented in Figures 1–5.

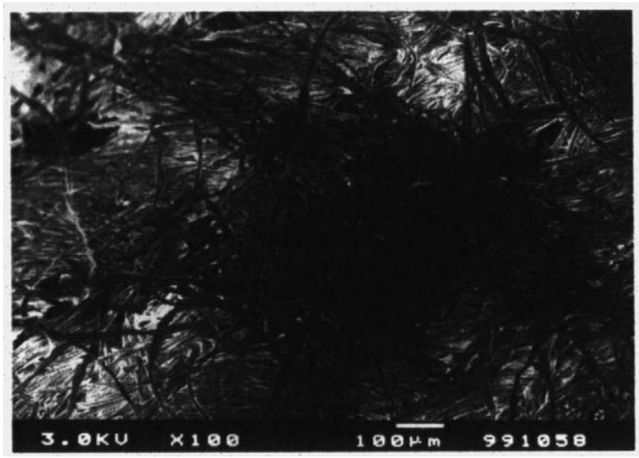

FIGURE 1. SEM photo of SOE815, first washing cycle.

FIGURE 2. SEM photo of SR815, first washing cycle.

Results and Discussion

The results obtained from the measurements, together with the regression equations, are given in Tables II to IV.

DIMENSIONAL PROPERTIES

For each fabric type of given stitch length, as the relaxation process progresses, the course density increases, whereas there is very little change in the wale density. This is not quite what we expected, since unlike our earlier work involving a single laundering cycle [8], the samples here are subjected to three laundering cycles.

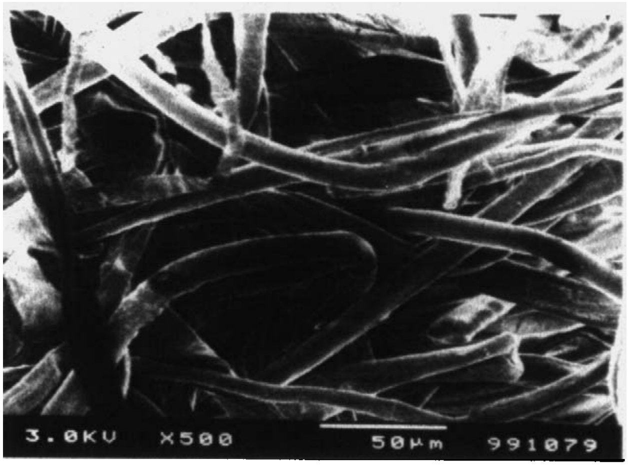

FIGURE 3. SEM photo of SM815, third washing cycle.

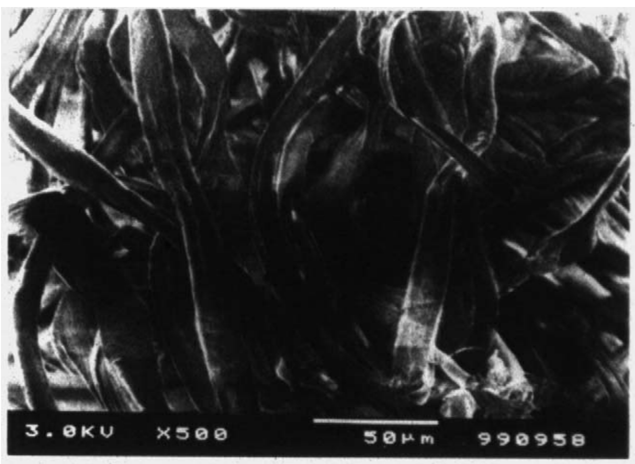

FIGURE 4. SEM photo of FMM800, first washing cycle.

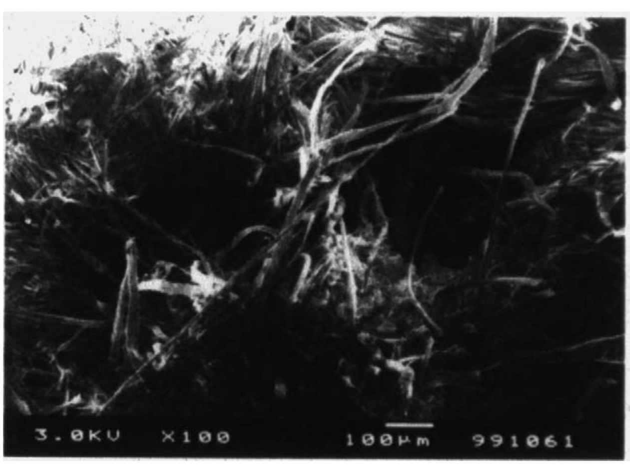

FIGURE 5. SEM photo of LOE700, third washing cycle.

However, the mechanical agitation during the processes may still not be sufficient to remove the residual distortions in the fabrics. Loop distortions resulting from yarn spirality may also influence the relaxation behavior of the samples in the widthwise direction. Furthermore, with an increased number of laundering cycles, the stitch density increases for each fabric type, and at the end of the first washing and tumbling treatment, stitch density reaches its maximum. Note also that contrary to previous works suggesting that open-end spun knitted fabrics have a higher shrinkage tendency than ring spun ones [6, 8, 20, 26], LR and SR samples (ring spun lacoste and plain jersey) have consistently greater stitch and areal density values than LOE and SOE knits (open-end spun lacoste and plain jersey, see Tables II and III). The argument behind this may be the use of different percentages of Agean and Greek cotton fibers in the blends from which the ring and open-end spun yarns were produced.

The shrinkage potential (stitch density) of the fully relaxed blend spun knits (SB, LB, FBB, FBOE) is higher than that of the corresponding fully relaxed open-end and ring spun dyed fabrics (SOE/SR, LOE/LR, and F) (see Tables II–IV). This may be because the blend spun knits, containing dyed polyester fibers, are not subjected to the bleaching and dyeing treatments, which can stabilize the fabrics by heat setting their man-made parts. The skewness values achieved by these fabrics may also imply excessive loop distortions, probably arising from a high degree of yarn twist liveliness (see Tables II–IV). One final note about the blend spun fabrics: the fiber type of the inlay yarn appears to influence the relaxation behavior of two-thread fleece fabrics, since for a given stitch length, both the stitch and areal density values of FBOE knits (face yarn 50/50 PET/cotton, inlay yarn 100% cotton) are greater than those of FBB ones (both face and inlay yarn 50/50 PET/cotton). Furthermore, it also tends to affect the wale spacing of the base fabric rather than its course spacing (see Table IV).

The results of the measurements of cpcm, wpcm, and loops/cm^2 relate graphically to the appropriate functions of the reciprocal of the knitted loop length, and we have found that there are linear relations between these parameters and loop length. From the regression analysis for each fabric type conducted by taking different yarn types into account and the correlation coefficients calculated, it is evident that the stable dimensional properties of each structure depend very much on stitch length. Moreover, so far as the k values (k_c, k_w, and k_s) of lacoste and plain jersey structures are concerned, the blend spun knits tend to have lower k values than the corresponding open-end and ring spun samples. In the case of the two-thread fleece structure, the FBB and FBOE knits achieve higher k values when compared to the F

samples (both face and inlay yarn 100% cotton open-end spun). Accordingly, we tested the differences between the shrinkage values of the yarns statistically and found they were insignificant. In the light of these findings, we can conclude that the differences in k values for each fabric type produced from these yarns depend on the fabrics' relaxation behavior. Note also that for all of the fabrics studied, the highest kr values belong to the tightest fabrics such as LOE640, which may be due to the higher frictional restraints in the compact structure.

Repeated washing and tumble drying also significantly affect loop shape (*e.g.*, for LOE640, kr has a value of 2.33 for the first cycle, which changes to 2.38 for the third cycle), because it alters by distorting and bending out in the third dimension. The plain jersey fabrics appear to attain their fully relaxed state after three laundering cycles, since the kr values (within the range of 1.30–1.33) are quite close to those reported by previous researchers [3, 8]. We have also obtained linear relations with the high correlation coefficients between weight/m^2 and T (tex)/L and t (thickness)/L and K (tightness factor) ($r^2 = 0.90$–1.00 and $r^2 = 0.93$–1.00 respectively).

PILLING PROPERTIES

The 100% cotton samples knitted from ring spun yarns tend to have lower pilling rates (2/2–3) than those constructed from the 100% cotton open-end spun yarns (3–4/3). This may be because the ring spun yarns are hairier than the open-end spun yarns (see Table I), which may allow easy exposure of raised fiber ends to abrading forces. In addition, the well aligned, compact structure of the ring spun yarns may not promote easy fiber wear-off [24]. The results also show that as expected, knits from blend yarns (2/2–3) tend to have a greater tendency to pill than knits from 100% cotton open-end yarns. A comparative study of the results reveals that the lacoste structure has the highest resistance to pilling (4+/4–5). In these samples, we did not observe pill formation, although fuzz density varied slightly from one sample to another depending on the yarn type. The possible explanation for this may be that for the lacoste structure, the rate of pill wear-off is higher than that of pill formation. It may also be because the tumbling time (even for 11,000 revolutions) is not long enough for completion of the pill formation process in these fabrics. Unlike the lacoste structure, the plain jersey fabrics have the lowest pilling rates. The SR (ring spun plain jersey) and SB (blend spun plain jersey) samples, especially, display the least resistance to pilling (2/2–3). For the two-thread fleece structure, F samples (3+/3–4) tend to be more pill resistant than FBB and FBOE samples (2–3/3).

The SEM photos of the plain jersey and two-thread fleece fabrics show that as both the number of laundering treatments and the test revolutions increase, loose fiber assemblies forming on the fabric surfaces turn into much tighter, harder pill entanglements, which have various forms (see Figure 1). Moreover, they also indicate that for the same number of test revolutions (*e.g.*, 11,000), the degree of damage in fibers within the fuzz entanglements tends to increase with an increasing number of launderings. The damage varies from slight flaking (see Figures 2 and 3) to small cracks and fractures (see Figure 4) depending on the fabric and yarn types involved. Note, however, that any damage occurring as a result of repeated washing and pilling tests is not as severe as that reported in the literature [9–12, 16]. This may be because the ICI pilling box does not generate such fiber fatigue.

ABRASION PROPERTIES

The lacoste fabrics show the least resistance to abrasion, and except for the fully relaxed LB samples, there are several holes in the fully relaxed dyed LR and LOE knits when the test cycle (20,000 rubs) are done. The SEM photos of these fabrics suggest that tuck stitches have a negative effect on the abrasion behavior of lacoste fabrics because the holes generally occur at the points where tuck stitches are cast off (see Figure 5). They also show that the fibers around these holes are very heavily damaged as a result of abrasive forces. Unlike the lacoste structure, the plain jersey and two-thread fleece structures perform quite well, *i.e.*, there are no holes in these fabrics. For each fabric type, the weight loss percent after abrasion increases with increasing course length, and the fabrics knitted from open-end spun yarns always have the highest weight loss values (9.35–16.20%), perhaps because the wrapping fibers gradually break due to the abrasive forces, facilitating the removal of loose fibers from the yarn structure. They are followed by the samples from the ring spun (5.86–9.00%) and blend spun yarns (1.52–4.97%), respectively.

Conclusions

Our work focuses on the dimensional, pilling, and abrasion properties of a series of plain jersey, lacoste, and two-thread fleece fabrics made from cotton ring and open-end spun yarns as well as from blend yarns (50/50 cotton/polyester, dyed). The results show that both structural differences and fiber type play a large part in determining the dimensions of these fabrics. It is apparent that knits from blend yarns have a lower dimensional stability compared to fabrics from 100% cotton ring and open-end spun yarns. Findings for the two-thread fleece fabrics suggest that the inlay yarns mainly govern their dimensional behavior in the widthwise direction. The dimensional behavior of the lacoste and two-thread fleece fabrics after the laundering cycles reveals that further research to determine more appropriate washing regimes for these structures would be beneficial.

The pilling rates of the samples indicate that unlike plain jersey fabrics, lacoste fabrics perform very well, and that in general, fabrics knitted from open-end and blend spun yarns have a lower propensity to pill. Of the two-thread fleece structures, the F samples have higher pilling rates compared to FBOE and FBB fabrics. The SEM study reveals that for the same number of test revolutions, the degree of damage in fibers within the fuzz entanglements tends to increase with an increased number of launderings, and that the damage varies from small cracks and fractures to slight flaking depending on the fabric and yarn. Note, however, that any damage here is not as severe as that reported in the literature. The lacoste fabrics have the least resistance to abrasion.

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