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The Influence of Structure Parameters of Weft Knitted Fabrics on Propensity to Pilling

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Pilling of knitted fabrics persist a serious problem for apparel industry. Pilling means generation of pills over the surface of the fabric. The main cause of pilling of knitted fabrics there is mechanical action, first of all abrasion during wear. The main goal of this work was to investigate the influence of main structure parameters of weft knitted fabrics on propensity to pilling. The samples were knitted on a circular single face, rib, and interlock knitting machines from PES yarns, cotton yarns, and cotton yarns combination with PU yarns. The samples were grouped according to knitting structure, raw material, yarn linear density, and fabric density. The test was carried out according to EN ISO 12945-1:2000 Pilling Box method. There were estimated the influence of knitting structure, raw material, yarn linear density, and fabric density on propensity to pilling of weft knitted fabrics. The results of experiments can be used for engineering design of weft knitted fabrics.

Keywords: fabric density, knitting structure, linear density, pilling, raw material, weft knitted fabric.

1. INTRODUCTION

Knitted fabrics provide outstanding comfort qualities, and they have been preferred as fabrics in many kinds of clothing long time. Clothing comfort is an extremely complex phenomenon resulting from the interaction of various physical and non-physical stimuli on a person wearing clothing under given environmental conditions.

In clothing design and manufacturing, fabric characteristics are usually dictated by a specified end-use [1, 2]. A fabric may loose its aesthetic appeal due to wear, which is a combined effect of several factors like abrasion, repeated laundering, the application of forces in dry and wet states, etc. arising from everyday use and service [3, 4].

Some standard terms and definitions such as pills, pilling are applying according to EN ISO 12945-1:2000 [1]. Pills mean entangling of fibres into balls (pills) that stand proud of the fabric surface and the light will not penetrate and will cast a shadow. Pilling means generation of pills over the surface of the fabric. Pills are forming during washing, dry cleaning and wearing of knitted goods.

Pilling is a fabric fault. Fabric pilling is a serious problem for an apparel industry. The development of pills on a fabric surface, in addition to resulting in an unsightly appearance, initiates the attrition of the garment and can cause premature wear.

The mechanism of pill formation and factors affecting it has been drawn attention to by many researchers since the 1950^{s}.

Pilling studies have shown that there are three distinct stages in the life span of a pill [6]:

a) fibres are drowning to the fabric surface because of some mechanical action, and these form fuzz;

b) the fuzz entangles into pills;

c) the pills wear of under continued mechanical action, such as rubbing, laundering, drying, etc., during wear and cleaning.

In a given fabric construction, the rate or extent of which these stages occur is determined by the physical characteristics of the fibres that compose the fabric [7 – 9].

Pill formation is a dynamic process, since pills are constantly forming and wearing off. If the formation rate is greater than the break-off rate, pills will build up on the fabric [8]. The formation rate is influenced by fibre type, the number of fibre ends, linear density, length, cross-sectional shape, yarn twist, hairiness, and fabric construction [6 – 11]. Any combinations that allow fibres to migrate to the yarn surface will increase the formation rate. In a fabric made from a blend of fibres there are more pills than in a similar fabric made from only one of the blend components, because of incompatibility between the fibres [12].

An analysis of the conditions giving rise to pilling on knitted fabrics showed that its development was almost always promoted by a number of factors, the most important of which were the physical characteristics of the fibres, the yarn twist, the yarn linear density, and type of pattern of the fabric. Apart from the above factors, dyeing and finishing also can exert influence over the rate of pill formation [10, 13 – 15].

A great deal of factors affected the pilling behaviour of textile fabrics are described as physical-mechanical properties of fibres and yarns, the construction and surface characteristics of knits. Many of these structural variables have been carefully controlled to reduce pilling, but it continues to be a problem. Sometimes it is difficult to choose needed yarn properties that have effect on pilling of knitted fabrics. An importance of this problem demonstrates the fact the level of pilling of knitted goods is controlled by not only producers but and commercials firms.

The main goal of this work was to investigate the influence of main structure parameters of weft knitted fabrics on propensity to pilling.

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2. EXPERIMENTAL

Propensity to pilling of weft knitted fabrics was determined experimentally. Three sets of samples knitted in an interlock, rib, and plain jersey knitting structure were used. The sets of samples were knitted on a circular single face, rib, and interlock knitting machines from cotton yarns, PES (polyester) yarns, blended cotton/PES yarns, and cotton or PES yarns combination with PU (polyurethane) threads. The characteristics of tested knitted fabrics are presented in Table 1.

More than twenty different knitted fabrics were developed to determine the resistance of fabrics to pilling.

A Pilling Box method [5] was used for determination of fabric propensity to pilling in this work. In this method fabric specimens (of a 125 mm × 125 mm size) mounted around polyurethane tubes (6 mm in diameter) are tumbled in a rotation cork-lined cubic box. The rubbing on the box liner accelerates the pilling process on the fabric. Each of boxes is rotated at a constant rotation frequency (60 r/min ±2 r/min) about a horizontal axis passing through the centres of two opposite faces. Standard testing time (number of revolutions of the box) must agree the customer requirements. The test time required for knitted fabrics is 4 hours (14400 revolutions).

After tumbling, the extent of pilling was assessed visually by comparison with arbitrary standards. Each specimen was placed in view box lighted with a white fluorescent lamp [5]. Distance from an observer eyes to the specimen must be 30 cm – 50 cm. It is recommended that more than one observer assess the specimen after tumbling. Each specimen was graded in according with the grading scheme given in Table 2.

If the grading appeared between two grades, it was reported the "half" grading.

Table 1. Characteristics of tested knitted fabrics

Samples code	Pattern	Yarns		Course density, cm^{-1}	Wale density, cm^{-1}	Fabric density, g/m^2
		Linear density	Percentage composition, %			
I1	Interlock	C 15 tex	100	13	14	180
I2	Interlock	C 15 tex	100	15	16	210
I3	Interlock	C 15 tex	100	17	17	230
I4	Interlock	C 20 tex	100	14	15	230
R1-1	Rib 1×1	C/PES 20 tex	50/50	12	16	200
R1-2	Rib 1×1	C 20 tex	100	10	18	200
R1-3	Rib 1×1	C 20 tex	100	11	18	210
R1-4	Rib 1×1	C 20 tex	100	13	18	230
R1-5	Rib 1×1	C 25 tex	100	11	17	230
R1-6	Rib 1×1	C 30 tex	100	10	15	230
R1-7	Rib 1×1	C 15 tex PU 4.4 tex	97 3	11	18	200
R1-8	Rib 1×1	C 15 tex PU 4.4 tex	97 3	10	15	230
R2-1	Rib 2×2	C 20 tex	100	10	17	190
R2-2	Rib 2×2	C 20 tex	100	11	19	230
R2-3	Rib 2×2	C 20 tex PU 7.8 tex	97 3	13	18	280
R2-4	Rib 2×2	PES 20 tex PU 7.8 tex	97 3	13	18	280
PJ1	Plain jersey	C 20 tex	100	13	16	140
PJ2	Plain jersey	C 20 tex	100	14	18	160
PJ3	Plain jersey	C 20 tex	100	14	20	180
PJ4	Plain jersey	C 20 tex	100	15	22	230
PJ5	Plain jersey	PES 20 tex	100	14	18	160
PJ6	Plain jersey	C 20 tex PU 2.2 tex	96 4	15	21	210
PJ7	Plain jersey	C 20 tex PU 2.2 tex	96 4	18	25	260
PJ8	Plain jersey	C 15 tex PU 2.2 tex	95 5	15	20	180
PJ9	Plain jersey	PES 15 tex PU 2.2 tex	95 5	15	20	180

where: C – cotton yarn, PES – polyester yarn, PU – polyurethane thread.

Table 2. Visual assessment

Grade	Description
5	No change
4	Slight surface fuzzing and/or partially formed pills
3	Moderate surface fuzzing and/or moderate pilling. Pills varying size and density partially covering the specimen surface
2	Distinct surface fuzzing and/or distinct pilling. Pills of varying size and density covering a large proportion of the specimen surface
1	Dense surface fuzzing and/or severe pilling. Pills of varying size and density covering whole of the specimen surface

3. RESULTS AND DISCUSSION

The influence of knitting structure, raw material, yarn linear density, and fabric density on propensity to pilling of weft knitted fabrics were estimated.

3.1. Knitting structure. The influence of knitting structure (the other structure factors are kept constant) on propensity to pilling is evident from the data presented in Fig. 1. There are presented data of fabrics knitted from 20 tex linear density cotton yarns in interlock (*I4*), rib 1 × 1 (*R1-4*), rib 2 × 2 (*R2-2*), and plain jersey (*PJ4*) patterns. The fabric density of whole fabrics was 230 g/m^2.

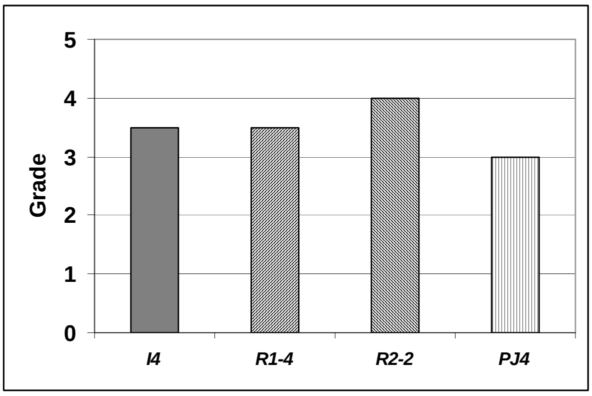

Fig. 1. The influence of knitting structure on propensity to pilling of the weft knitted fabrics: ■ – interlock, ▨ – rib 1 × 1, ▧ – rib 2 × 2, □ – plain jersey

It can bee seen in Fig. 1, the fabric knitted in rib 2 × 2 pattern has the best grade of the visual assessment (4), and the plain jersey knitted fabric has the worst one (3). The rib 2 × 2 knitted fabrics give substantially fewer pills than the interlock, rib 1 × 1 and plain knitted fabric because of less operated surface area. In spite of the fact that the operated surface area of interlock and plain jersey knitted fabrics is similar, interlock fabric has in half grade better visual assessment (3.5) than the plain jersey knitted fabric (3). It seems that a friction between the yarns formative loops in interlock fabrics is more intense than in plain fabrics, therefore resistance to pilling of interlock fabric is better [2].

3.2. Raw material. The influence of raw material on propensity to pilling is apparent from the data presented in Fig. 2. There are presented four sets of samples: (*R1-1, R1-2, R1-7*), (*R2-3, R2-4*), (*PJ8, PJ9*), and (*PJ2, PJ5*). The samples of the same set differ in raw material of the yarns; the other structure factors are kept constant.

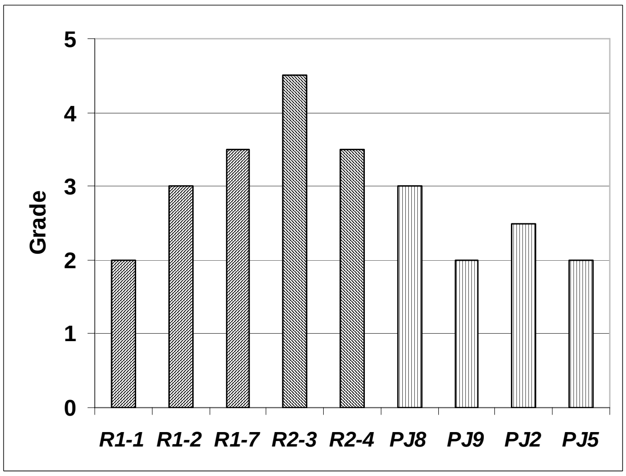

Fig. 2. The influence of raw material on propensity to pilling of the weft knitted fabrics (marked as in Fig. 1)

As demonstrated by Fig. 2, the rib 1 × 1 fabric knitted from cotton (97 %) and PU (polyurethane) (3 %) yarns (*R1-7*) has the better grade of the visual assessment (3.5) than the fabric knitted from the pure cotton yarns (3) (*R1-2*). Filament PU yarn presence could have influence upon the better resistance to pilling of fabric.

In all cases, fabrics knitted from PES (polyester) yarns (*R2-4, PJ9, PJ5*) or their blend with cotton yarns (*R1-1*) have from half till one grade worse visual assessment than fabrics knitted from pure cotton yarns (*R1-2, R2-3, PJ8, PJ2*). PES fibre preclude from miss formed pills through its exceptional strength like it was demonstrated in [12].

3.3. Linear density. The influence of yarn linear density on propensity to pilling is apparent from the data presented in Fig. 3.

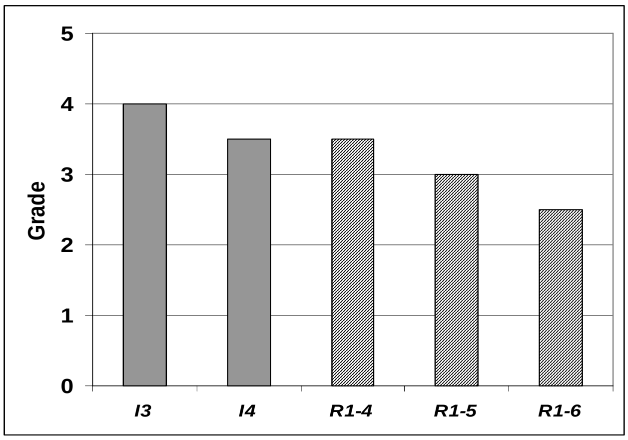

Fig. 3. The influence of yarn liner density on propensity to pilling of the weft knitted fabrics (marked as in Fig. 1)

It can bee seen in Fig. 3, the fabric knitted in interlock pattern from 15 tex linear density cotton yarns (*I-3*) has half grade better visual assessment than fabric knitted in the same pattern from 20 tex cotton yarns (*I-4*). The fabric knitted in rib 1 × 1 pattern from 20 tex linear density cotton yarns (*R1-4*) has half grade better visual assessment than fabric knitted from 25 tex cotton yarns (*R1-5*) and one grade better visual assessment than fabric knitted from 30 tex cotton yarns (*R1-6*). Consequently, propensity to pilling of weft knitted fabric increase by increasing of yarn linear density. The similar results were observed by [9].

3.4. Fabric density. The influence of fabric density on propensity to pilling is apparent from the data presented in Fig. 4. There are six sets of samples: (*I1, I2, I3*), (*R1-2, R1-3, R1-4*), (*R1-7, R1-8*), (*R2-1, R2-2*), (*PJ1, PJ3, PJ4*), and (*PJ6, PJ7*) presented in this Figure. The samples of the same set differ in fabric density, and the other structure factors are kept constant.

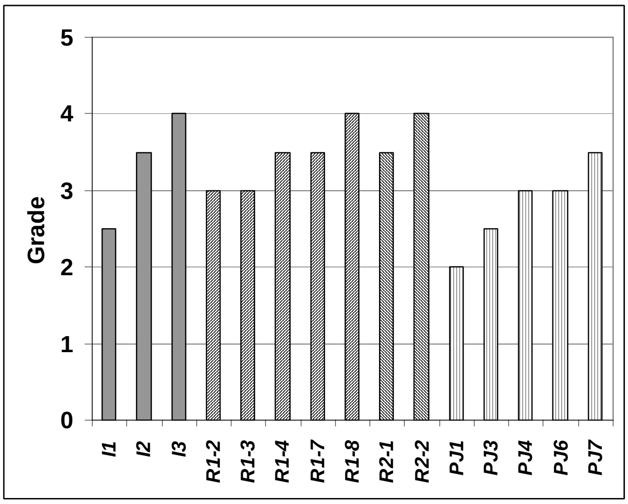

Fig. 4. The influence of fabric density on propensity to pilling of the weft knitted fabrics (marked as in Fig. 1)

As demonstrated by Fig. 4, in all cases propensity to pilling of weft knitted fabric decrease by increasing of fabric density. Fabric of higher density is knitted more tightly. A tight compact knitted construction will have the best pill resistance. *I3* fabric has 50 g/m^2 greater area density and one and a half grade better visual assessment than *I1* fabric. *R1-4* fabric has 30 g/m^2 greater area density and a half grade better visual assessment than *R1-2* fabric. The same results are got from comparison of visual assessment dependence on area density of *R1-8* and *R1-7* fabrics. *PJ4* fabric has 90 g/m^2 greater area density and one grade better visual assessment than *PJ1* fabric, and *PJ7* fabric has 50 g/m^2 greater area density and half grade better visual assessment than *PJ6* fabric.

CONCLUSIONS

Propensity to pilling of examined weft knitted fabrics depends on knitting structure, raw material, yarn linear density, and fabric density.

The rib 2×2 knitted fabric gives substantially fewer pills than the interlock, rib 1×1, and plain knitted fabric because of less operated surface area.

The fabrics knitted from PES (polyester) yarns or their blend with cotton yarns have worse visual assessment than fabrics knitted from pure cotton yarns because PES fibre preclude from miss formed pills through its exceptional strength. Fabrics knitted from cotton or PES yarns combination with PU threads has the better grade of the visual assessment than the fabrics knitted from the pure cotton or PES yarns.

Propensity to pilling of weft knitted fabric increase by increasing of yarn linear density and by decreasing of fabric density.

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