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Effect of backed yarn characteristics on two-thread fleece knitted fabric properties

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The influence of backed yarn linear density and its twist factor on two-thread fleece knitted fabric properties has been studied. Experiments are conducted on both finished and raised fabrics. Four levels of linear density and two levels of twist factor are used for backed yarn. Knitted fabrics weight per square meter, shrinkage, spirality, thermal comfort characteristics, bursting strength and abrasion resistance are tested. Results show that by increasing yarn linear density, the fabric weight per square meter and thickness increase, while shrinkage and spirality improve. Raising process enhances fabric thermal comfort characteristics, while the yarn twist factor exhibits insignificant effect on many fabric characteristics.

Keywords*:* Abrasion resistance, Bursting, Fleece fabrics, Lay-in yarn, Raising process, Thermal comfort

Fleece knitted fabrics are characterized by their distinct thermal insulation and water vapor permeability. These are used as winter cloths because of their thermal comfort properties in addition to better dimension stability. When used as winter garments, fleece knitted fabric suppress its competitor, plush fabric.

Its pile exists from inside not from outside and its backed yarns that always contact human body are made of cotton fibres, unlike plush fabric, in which, its backed yarns that contact human body are made of polyester. This necessitates studying the effect of backed yarn linear density and twisting factor on fleece fabrics properties. The warm-cool feeling of 2-yarn fleece knitted fabrics was investigated, and the influence of yarn type and raising treatment on warm-cool feeling were determined[1]. It was found that raising treatment is the primary factor determining the thermal contact feeling of fleecy fabrics; the yarn type and fibre blend are less important[1].

The structural characteristics of knitted fabrics including pile length, structure compactness and structure type, have an important influence on fabric air permeability. The plush structures have high thermal insulation and bursting strength properties and hence, they are preferred for winter garments in order to protect from cold. On the other hand, fleece structures should be chosen for active outerwear clothing for better moisture management properties and air permeability[2] . The fleece fabrics are subjected to abrasion on their back side because of the presence of loose and coarse fleecy yarn, where the possibility of fibre loss is higher than in face side. The weight loss percentage was raised with increasing the abrasion cycles by Islam *et al.*[3], and they found a measurable effect in the weight loss percentage of polyester based three thread fleece fabric yarn than on all cotton and CVC. Previous studies showed that for all cotton based fleece fabrics, the change in fabric weight loss due to abrasion (from grey to finished state) was not so remarkable. However, the weight loss percentage was found high in all CVC, Polyester and cotton based fleece fabrics[3]. Raising process which is used to produce fleece knitted fabrics is very essential to improve thermal comfort properties. Raw material strongly influences heat and mass transfer in fleece fabrics[4]. The effect of course length and washing processes on physical characteristics and shrinkage behavior of three-thread fleece fabrics were investigated[5]. The laundering and tumble-drying processes have a very important effect on the fabrics' physical and mechanical properties, because the fabrics become tighter and compact after these treatments[5].

The raising treatment is a key factor that controls thermal contact feeling of fleecy fabrics, while yarn type and raw material are less important. The feeling of wetted fleecy fabrics is cool while wetted raised fleecy fabrics exhibit a warmer (more pleasant) feeling than fabrics without raising[1]. In the present work, the influence of some variables, such as backed yarn count twist and stitch length after shrinkage, on two-thread fleece knitted fabric properties has been investigated. Widthwise shrinkage is inversely proportional to stitch length, while lengthwise shrinkage is directly proportional to the stitch length. Both lengthwise and widthwise shrinkages are directly proportional to yarn count. The shrinkage increases with the increase in fleece yarn twist factor[6].

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Experimental

The model of machine used is Terrot S296/30"/24G/96F/ 4 track. The following steps illustrate how to arrange the cam and needles for producing two-thread fleecy:

(i) The fourth track was disabled as shown in Fig. 1.

(ii) Cams were divided into sets, each set consists of 4 cams and arranged with feeders as shown in Fig. 1.

(iii) Needles were divided into four equal sets according to needle butt height and were placed as shown in Fig. 1 and the arrangements inside cylinder grooves from left to right were III, II, I, II.

Figure 2 shows the surface appearance of fleece fabrics. Ground stitches are obvious as they are fine diameters (24.6tex carded waxed yarns), while backed yarn is distinct by their coarse counts. To produce the backed yarn, Giza 90 Egyptian cotton was spun to produce carded waxed yarns with tex counts, 49.21, 36.91, 29.51 and 24.6 tex (12, 16, 20 and 24 Ne) and each yarn count was spun with two levels of twist factor, 2877.726 and 3453.271 α_{Tex} (3 and 3.6 αe). Total of 8 different fabric samples were knitted. Table 1 presents the different properties of backed yarns.

Fig. 1 — Cam, needle arrangements and fabric notation to produce two-thread fleece knitted fabrics

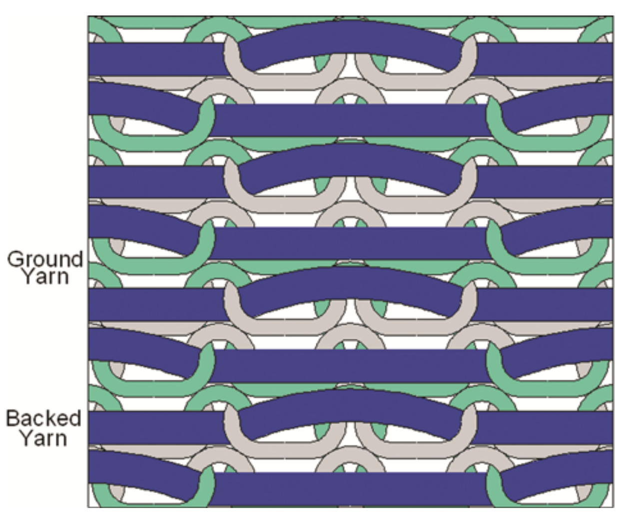

Fig. 2 — Fleece fabric surface appearance

All fabrics were finished (half bleaching and dyeing). The 140/3 Luft Rotoplus Thies Jet dyeing machine was used. The bleaching solution contained the following ingredients for 200 kg knitted fabrics: sequestering agent for iron (1.5 kg), soap (2 kg), sodium hydroxide (3 kg), hydrogen peroxide 50% (6 kg), acetic acid (4.5 kg), sequestering agent for water (1.5 kg), leveling agent (1.5 kg), reactive dye S2G (2.622 kg), and softener (8 kg).

To study the fleece knitted fabrics shrinkage after repeated washing, all samples were washed in a home laundering machine for three consecutive washing cycles. The washing process was carried out at 90°C, and then dried at room temperature in relaxed state. Spirality was measured using AATCC pillow case method 179-2001, where two knitted samples were sewed from three sides and fourth side was kept free, and after repeated washing, the sewing line inclination angle was measured. Fabric samples (40×40 cm) were weighted 5 times using a digital balance of two decimal digits accuracy. Bursting strength was tested on Testometric M350-10CT instrument, according to ISO 13938-2 at head speed of 100 mm/min. Abrasion resistance test was performed using Martindale instrument with 5,000 cycle using 12 kps according to ASTM 4966, 5 readings from each fabric samples were taken on fabric back. Thermal comfort characteristics were measured. Alambeta instrument was used to measure thermal conductivity, fabric thickness, dry thermal resistance, and thermal absorptivity values. These parameters were tested according to ISO EN 31092-1994. Relative water vapor permeability was measured on Permetest instrument based on similar skin model principle as given by ISO 11092. Air

Table 1 — Specifications of backed yarns

Yarn count Ne (tex)	Twist factor (Z direction) α_e (α_{Tex})	Real count Ne	Twist / inch	Breaking Force N	RKM	Breaking elongation %
12 (49.21)	3 (2877.726)	12.25	11.12	680.9	13.84	6.06
	3.6 (3453.27)	11.98	13.05	860.4	17.48	6.96
16 (36.91)	3 (2877.726)	16.13	12.85	501.8	13.6	5.46
	3.6 (3453.27)	16.21	14.5	598.9	16.23	6.33
20 (29.51)	3 (2877.726)	20.71	14.17	347.3	11.76	4.85
	3.6 (3453.27)	20.58	17.25	491.65	16.65	5.96
24 (24.6)	3 (2877.726)	24.69	15.62	298.2	12.12	4.99
	3.6 (3453.27)	24.51	17.95	364	14.79	5.53

permeability was measured on Metefem instrument according to ASTM D737. The working pressure was 100 Pa using 20 cm^2 fabric samples.

Five readings for each fabric sample were recorded and results were statistically analyzed using SPSS software to test the significance of backed yarn linear density and twist factor on all fleece knitted fabric tested properties. Table 2 shows the statistical significance results at 95% confidence level, after uses of Univariate Analysis of Variance by SPSS Program (two-way ANOVA). All tests were performed on back side of fleece fabrics, where it is considered as the main advantage of this type of knitted fabric, and also this side is in contact with human body.

Results and Discussion

Fabric Geometry

Table 3 presents the different geometrical properties of two-end fleece knitted fabrics, such as wales and courses density for three cases of knitted fabrics, namely grey, finished, and fabric after repeated washing (3 washing cycles). The thickness of finished (looped) and raised two-end fleece knitted fabrics are also presented in Table 3.

Table 2 — Statistical significance of yarn parameters on fabric properties

Property	Yarn count	Twist factor	Raising process
Weight	0.000	0.000	0.000
Thickness	0.000	0.051	0.000
Shrinkage w	0.020	0.003	0.000
Spirality	0.000	0.010	0.000
Thermal conductivity	0.000	0.001	0.000
Thermal absorptivity	0.000	0.164	0.000
Thermal resistance	0.000	0.052	0.000
Air permeability	0.000	0.097	0.901
Vapor permeability	0.000	0.157	0.000
Bursting strength	0.005	0.117	0.000
Abrasion resistance	0.000	0.429	0.000

Figure 3(a) presents the influence of backed yarn linear density and twist factor on fleece fabric weight in its three phases; viz grey, finished and raised. It is clear from the figure that as yarn linear density changes from 12 Ne to 24 Ne, fabric weight per square meter increases by a ratio up to 23% and this is attributed to the reduction in yarn linear density that constitutes the stitch as yarn count increases. However, yarn twist factor and fabric condition (grey, finished or raised) exhibit varying effect but significant, where fabric weight decreases by 5% as twist factor increases. Also fabric weight decreases by 5% after raising process, and this is because raising treatment is accompanied by loss in fibres on backed yarn surface.

Fabric Shrinkage

Fleece fabric shrinkage rate increases after washing as backed yarn gets finer particularly in lengthwise, while in finished fabrics (before raising) it is increased by 55% as shown in Fig. 3(b). This is due to the reduction in fabric tightness factor. It is also noticeable that raised fabric shrinkage is less than that of finished fabrics by a ratio of up to 60%, particularly for fabrics knitted from fine yarns. The shrinkage does change in raised fabric when yarn linear density changes either in lengthwise or widthwise. It is obvious also that fabric shrinkage decreases by 20% as the twist factor increases from 3 to 3.6, particularly in finished fabrics.

Fabric Spirality

It is clear from Fig. 3(c) that by increasing backed yarn count of fleece fabrics from 12 Ne to 24 Ne, the spirality increases by a ratio of up to 400% for raised fabrics and 275% for finished fabrics. This is due to the reduction in tightness factor as English yarn count increases with constant stitch length. It is also clear from Fig. 3(c) and statistical analysis that fabric

Table 3 — Geometrical properties of produced fleece knitted fabrics

Yarn count Ne (tex)	Twist factor α_e	Wales / cm			Courses /cm			Thickness, mm	
		Gray	Finished	Washed	Gray	Finished	Washed	Finished	Raised
12 (49.21)	3	10.5	12	12.5	21	18	20	1.1975	1.63875
	3.6	10.5	12	12.5	21	18	20	1.1675	1.5825
16 (36.91)	3	10.5	12	12.5	21	18	20	1.0825	1.4725
	3.6	10.5	12	12.5	21	18	20	1.06625	1.48375
20 (29.51)	3	10.5	12	12.5	21	18	20	0.985	1.41
	3.6	10.5	12	12.5	21	18	20	1.0075	1.32125
24 (24.6)	3	10.5	12	12.5	21	18	20	0.95375	1.35125
	3.6	10.5	12	12.5	21	18	20	1.0175	1.335

raising has a significant effect on spirality where spirality angle decreases by a ratio of up to 98% particularly at fine counts. Furthermore, spirality increases by 20% when yarn twist factor increases and this is due to the increment in yarn twist liveliness by increasing twist factor[7].

Fabric Thermal Comfort

As yarn diameter decreases, fabric thickness decreases accompanied by the reduction in thermal conductivity by a ratio of up to 5%, especially for raised fabrics as shown in Fig. 3(d). This is due to the reduction in number of paths in which heat transfers as backed yarn diameter diminishes. It is also noticeable that the fabric thermal conductivity increases when knitted from higher yarn twist factor. Eventually, it is apparent that fabric raising treatment reduces thermal conductivity by 13% especially at coarse counts which enables raised fleece fabric to keep human body temperature.

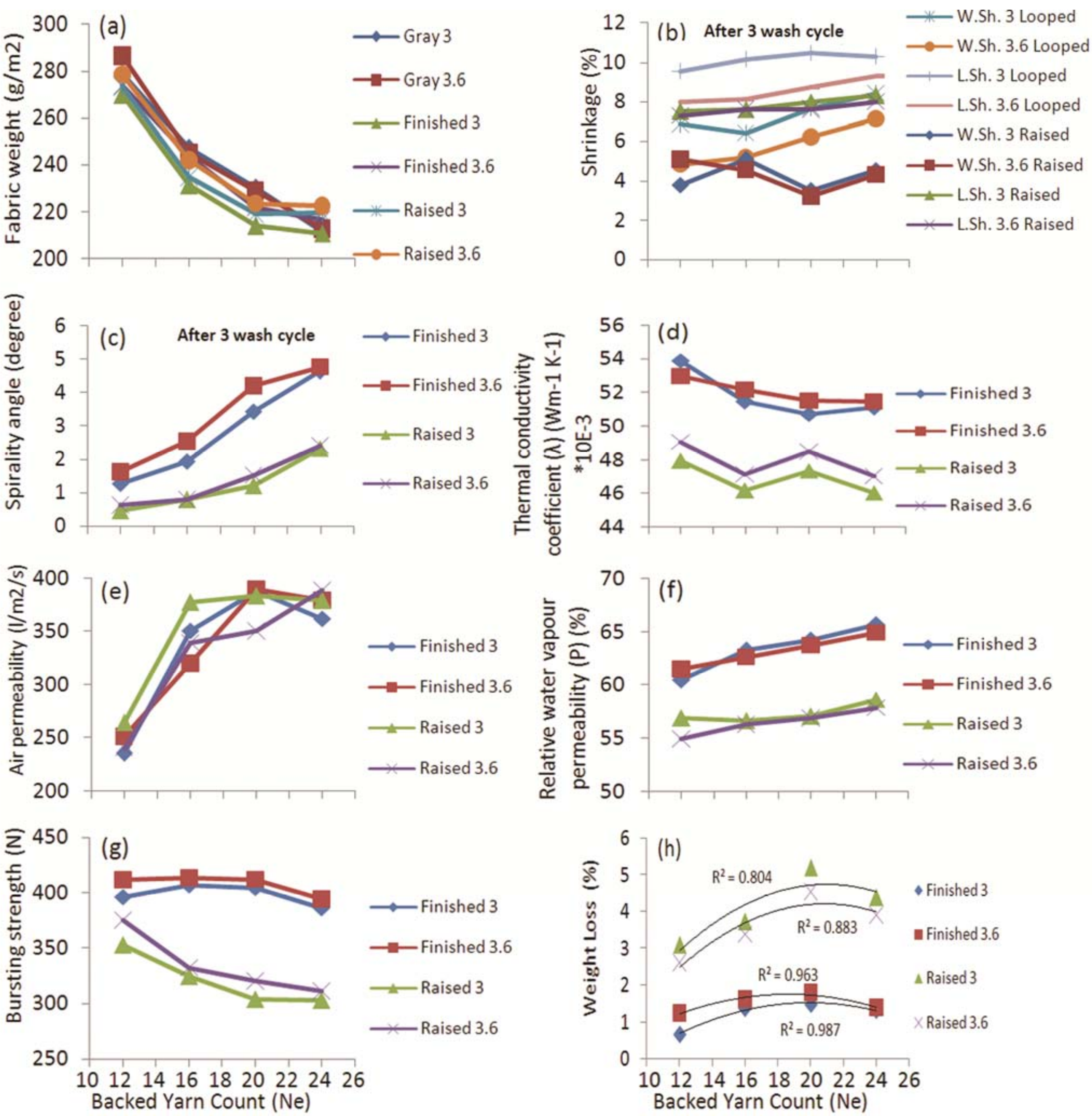

Fig. 3 — Effect of backed yarn count and twists on different properties of grey, finished and raised fleece knitted fabrics

Besides, the thermal comfort characteristics are also evaluated by studying the air and water vapor permeability. It is clear from statistical analysis and Fig. 3(e) that both fleece fabric backed yarn twist factor and raising process have insignificant effect on fabric air permeability. However, the effect of backed yarn linear density is significant, whereas when yarn count increases from 12 Ne to 24 Ne, fabric air permeability increases by 60% and this is due to the relative pores available between stitches as yarn diameter decrease. It is obvious from Fig. 3(f) that as backed yarn count of fleece fabric increases from 12 Ne to 24 Ne, the relative water vapor permeability increases by a ratio of up to 8% particularly for finished fabric. It can be observed that the twist factor has insignificant effect. It is noticeable to mention that once raising process is applied, relative water vapor permeability decreases from 65% to 58%.

Fabric Strength

As expected from raising process, fleece fabric bursting strength decreases by 17%, as shown in Fig. 3(g). Also fabric bursting strength deteriorates as backed yarn count increases from 12 Ne to 24 Ne by a ratio of up to 25% especially for raised fabrics and this is due to the reduction in yarn diameter and consequently number of fibres in yarn cross-section. The twist factor, as shown in the Fig. 3(g) and from statistical analysis, has insignificant effect.

Fabric Abrasion Resistance

It can be seen from Fig. 3(h) that raising process affects fabric weight loss due to abrasion significantly, where weight loss due to abrasion for raised fabrics is higher than in only finished fabrics by a ratio of up to 65%. By increasing English yarn count from 12 Ne to 20 Ne, weight loss ratio due to abrasion increases by a ratio of up to 40% then decreases slightly again as the count increases. The twist factor exhibits non-significant effect.

Results show that the fabric thermal comfort characteristics of fleece fabrics improve after raising process. However, fabric abrasion resistance deteriorates after raising process by 55%. Fabric thermal comfort characteristics are also influenced by backed yarn linear density, where they are improved when knitted from coarse counts. Furthermore, as backed yarn English count decreases, fabric weight per square meter increases, and the shrinkage, spirality, bursting strength and abrasion resistance improve. Finally, for fleece fabric, as backed yarn twist factor increases, spirality increases, and weight per square meter and abrasion resistance decrease. Also shrinkage rate improve. However, its influence on other fabric properties is insignificant. Thus, the optimum settings for producing raised fleece knitted fabrics include the backed yarns with coarse diameter (approximately twice the ground English yarn count) and with a minimum twist factor. Therefore, it is suggested for the future work to compare between three-end fleece knitted fabrics properties made from open-end and ring spun yarns as a backed yarns.

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