Examining of the Effect of Fabric Structural Parameters on Dimensional and Aesthetic Properties in Pile Loop and Cut-Pile Loop Knit Fabrics

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Abstract: ***This paper examines the effects of fabric structural parameters such as pile yarn number (Ne 30, Ne 26 and Ne 24), ground yarn number (90 Td and 70 Td), pile height (2.2mm; 2.5mm and 2.8mm) on the dimensional stability and spirality properties of the pile loop and the cut-pile loop knit fabrics. To determine their relationship and significance, one way ANOVA analyses and Pearson correlation analyses are conducted. It is found that cut-pile loop fabrics have more dimensional stability and less spirality than pile loop fabrics. Increased cpc, wpc and parallel with stitch density increase dimensional stability and they decrease spirality partially. It is observed that shrinkage in wale direction is more than shrinkage in course direction. The higher pile height increases fabric shrinkage, decreases spirality in pile loop fabrics, increases spirality in cut-pile loop fabrics. In pile loop fabrics, the thicker pile yarn increases shrinkage in wale direction and increases spirality. Ground yarn number is not effective on dimensional stability and spirality.***

Keywords: Pile loop knit fabric, Cut-pile loop knit fabric, Dimensional stability, Spirality, Pile yarn, Ground yarn, and Pile height

1. Introduction

Pile loop knit fabrics are widely used by the apparel industry for sportswear and bathrobes due to their good comfort, touch, and aesthetic properties.

The elongated sinker loops are formed over a higher knock-over surface than the normal-length ground sinker loops with which they are plated. The sinker loops show as a pile between the wales on the technical back of the fabric. Cut-pile loop is achieved during finishing; by cropping or shearing the sinker loops in both directions. This leaves the individual fibers exposed as a soft cut-pile loopy surface whilst the ground loops remain intact [1].

Many studies have reported that the mechanical properties of knitted fabrics vary according to knit structures, fibers, yarns, and densities, which in turn affect the knit's hand significantly [2], [3], [4], [8],[10].Although there are many studies related to the dimensional, mechanical, and aesthetic properties of single jersey and its derivatives, a few studies are available about pile loop knit fabrics in the literature [5], [6], [7], [9], [11].

Knapton et al. [2], [3], [4] reported that the dimensional stability and knit performance of such fabrics are influenced by components such as knit structure, stitch length, and cover factor.

Anand and Lawton [6], [7] studied pile-loop knit fabric and presented several empirical models to predict dimensional parameters such as course density, wale density, and stitch density. They reported that the dimensional parameters of pile loop knit fabrics are largely controlled by the stitch length in the ground structure and the state of relaxation. In another study, the same researchers [5] investigated the performance of several knit fabrics, such as pile loop knit, 1x1 knit/miss, and 1x1 cross-inlay, when used as dust filters.

Choi and Ashdown [8] focused on the mechanical properties of weft knits for outerwear as a function of knit structure and density and the relationships between hand, structure, and density in their studies. They reported that tensile properties, stiffness and fullness increase but, compression values, softness and smoothness decrease as knit density increases for fabrics.

Kim et al. [9] analyzed the effect of chemical splitting on the mechanical properties and water absorption of a split-type nylon/polyester microfiber pile knit under various alkaline hydrolysis treatment conditions. They reported that hydrolysis parameters and sodium hydroxide concentration affected the weight loss of hydrolyzed pile knits and their mechanical properties. Onal and Candan [10] investigated effects of fabric tightness, yarn type, fiber blend and laundering cycle on shrinkage of weft knitted fabrics. They found that double pique knits shrink less widthwise but more lengthwise than the other knit types. Yarn type and fiber blend have a relatively more significant contribution to fabric shrinkage lengthwise than widthwise.

Ucar and Canbaz Karakas [11] investigated some physical properties of pile loop knit fabrics. From this study, they saw that the effects of pile type, fiber type, fabric tightness, and relaxation on the physical properties of pile-loop knit fabrics are important. As follows, they determined that cut-pile fabric shows more dimensional changes and less spirality than pile-loop fabric, the ground-face fabric has more drapability than the pile-face fabric, there is no significant relationship between pile type and drape coefficient. In this

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present study, pile loopknit fabrics were produced by using three different pile yarns and two different ground yarns at three different heights of sinkers and it is aimed to investigate the effects of yarn number and pile heights on the fabric properties. In addition, to compare pile loop and cut-pile loopknit fabrics after dying, cut-pile loop fabrics were produced as shearing of pile loop fabrics with enough pile heights. After tests, experimental data were analyzed graphically and statistically.

2. Experimental

In this research, eighteen pile loop knit fabrics and twelve cut-pile loop knit fabrics were produced by using 100% carded cotton ring spun pile yarns and 100% polyester filament ground yarns. Three different pile yarns of Ne 30, Ne 26, Ne 24, and two different ground yarns of 90 denier, 70 denier were used to produce pile loop knit fabrics. The pile yarn properties were given in **Table I**.

Table 1: Pile yarn properties

Yarn Properties	*Yarn number*		
	Ne 30/1	*Ne 26/1*	*Ne 24/1*
USTER (%)	12.1	11.3	11.3
Thin -50%	13	3	2
Thick +50%	182	102	107
Neps +200%	251	104	91
Hairiness	7.1	6.8	7.7
Strength (rkm)	15.4	16.9	18.3
Elongation (%)	4.6	4.6	5.0
Twist (tpm)	820	768	733

Pile loop knit fabrics were produced by using different heights of sinkers are 2.2 mm, 2.5 mm and 2.8 mm. The properties of the machine with 2.2 mm were as, Orizio-JSVRN, 20 gauge, 30 inches, 44 feeders, and 1856 needles. The machines having 2.5 mm and 2.8 properties were as, Keumyong-KM-3SV, 20 gauge, 30 inches, 44 feeders, and 1896 needles. All fabrics were knitted by 20 rpm speed. Produced pile loop knit fabrics were dyed under the same conditions. Dying process included kiering, dying, and washing processes. Then, dyed pile loop fabrics with 2.5 mm and 2.8 mm were sheared to obtain cut-pile loop fabric. Because of the pile height of pile loop fabrics with 2.2 mm was too short to make cut-pile loop, they were not shear.

The structural, physical, dimensional and spirality properties of the pile loop and the cut-pile loop knit fabrics were given in **Table 2**. Sinker height and pile height were accepted as the same expression since the sinker height determined to pile height directly in the pile loop fabrics. So, pile height term was used mostly on the following parts.

Table 2: The structural, physical, dimensional and spirality properties of studied fabrics

Fabric type	*Ground yarn number (Td)*	*Pile yarn number (Ne)*	*Pile height (mm)*	*Courses/cm (cpc)*	*Wales/cm (wpc)*	*Stitch density/cm²*	*Fabric weight (g/m²)*	*Fabric thickness (mm)*	*Dimensional Changes (%)*		*Spirality (degree)*
									Wale direction	*Course direction*	
pile loop	90	30	2.2	12.5	9	112,5	214,35	1,58	-5,36	0,16	4,4
pile loop	90	30	2.5	12.5	9	112,5	230,87	1,85	-2,48	-1,13	5,94
pile loop	90	30	2.8	14	10	140	259,76	1,94	-5,08	-0,89	4,2
pile loop	90	26	2.2	12.5	9	112,5	250,19	1,75	-5,85	-0,09	6,5
pile loop	90	26	2.5	13	9	117	259,34	1,83	-6,11	0,33	6,5
pile loop	90	26	2.8	15	9,5	142,5	319,22	2,18	-5,92	-1,19	6
pile loop	90	24	2.2	12.5	9	112,5	268,48	1,85	-7,53	0,08	5,86
pile loop	90	24	2.5	14	9	126	286,57	1,88	-8,44	1,84	6,57
pile loop	90	24	2.8	15,5	9,5	147,25	331,50	2,16	-7,79	-0,45	4,33
pile loop	70	30	2.2	12	9	108	192,68	1,69	-6,06	1,71	6,33
pile loop	70	30	2.5	13	10	130	236,73	1,85	-6,76	0,24	4,75
pile loop	70	30	2.8	14	9,5	133	242,99	1,75	-5,74	-0,34	4,67
pile loop	70	26	2.2	13	9	117	240,05	1,65	-5,39	0,66	6,9
pile loop	70	26	2.5	12.5	9,5	118,75	240,76	1,75	-5,56	0,58	6,57
pile loop	70	26	2.8	14	9,5	133	279,77	2,07	-6,38	-0,46	7,5
pile loop	70	24	2.2	12.5	9	112,5	254,82	1,69	-4,67	0,58	8
pile loop	70	24	2.5	12.5	9	112,5	264,33	1,82	-6,11	1,47	5,88
pile loop	70	24	2.8	14,5	10	145	320,24	2,01	-5,86	-0,70	4,71
cut-pile loop	90	30	2.5	13	9	117	171,22	1,29	-5,27	-0,84	4,31
cut-pile loop	90	30	2.8	15	9,5	142,5	210,16	1,59	-5,14	-1,52	4,88
cut-pile loop	90	26	2.5	13	9,5	123,5	203,07	1,41	-4,36	1,23	4,25
cut-pile loop	90	26	2.8	15,5	10	155	236,46	1,65	-6,87	-1,71	4,61
cut-pile loop	90	24	2.5	13	9	117	204,37	1,40	-3,09	-0,61	4,6
cut-pile loop	90	24	2.8	15	9	135	250,06	1,73	-4,54	-2,45	6,5
cut-pile loop	70	30	2.5	13	9	117	168,92	1,31	-4,9	-0,21	5,92
cut-pile loop	70	30	2.8	14	9,5	133	185,82	1,51	-6,40	-1,13	6,21
cut-pile loop	70	26	2.5	12	9,5	114	185,89	1,32	-3,65	1,06	4,25
cut-pile loop	70	26	2.8	14,5	9,5	137,75	221,58	1,62	-6,39	-0,68	4,4
cut-pile loop	70	24	2.5	12.5	9	112,5	190,05	1,35	-6,15	0,40	4
cut-pile loop	70	24	2.8	14	9,5	133	239,95	1,71	-5,27	-0,21	5,36

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Before testing all the samples were conditioned in accordance with the standard ASTM D1776-08 [12].As the physical properties i.e. course density (cpc), wale density (wpc), stitch density, fabric weight, and fabric thickness were measured according to standards TS 14971, TS 12127, and TS 7128, respectively [13], [14], [15].

Dimensional stability and spirality tests were applied for all fabrics. The dimensional stability test was made according to TS 4073, TS 5720 [16], [17]. Spirality is the angle between the wale line and a line perpendicular to the course line [18]. The spirality angle was measured ten times for each sample, and mean values are calculated.

3. Results and Discussion

The graphs were drawn to understand and interpret test results clearly in addition to **Table 2**. Moreover, bivariate correlation analyses and also analyses of variance were made in order to determine the relationships between variables and the significance of each factor's contribution. For this aim the statistical software package SPSS 21.0 was used to interpret the experimental data. All the test results were assessed at significance levels $p \leq 0,05$ and $p \leq 0,01$. The statistical analyses results were given in **Tables3,4,5,6**.

Table 2 shows cpc, and wpc values of the samples produced in the same machine were same or very close since machine settings were not changed during production. On the other hand, fabric weight and thickness values of the samples varied depending on pile yarn number, ground yarn number and pile height. The thicker pile and ground yarns and the higher pile height increased weight and thickness values of the samples. As expected, all cut-pile loop samples were lighter and thinner than pile loop samples because of shearing of pile loop fabrics to produce cut-pile loop structure. Therefore, cut-pile loop samples lost weight approximately 19% to 28% and got thin 14% to 30% according to pile loop samples.

Table 3: One way ANOVA results for dimensional changes

Factors	*Dimensional changes*							
	Wale direction				*Course direction*			
	Pile loop		*Cut-pile loop*		*Pile loop*		*Cut-pile loop*	
	F	*Sig.*	*F*	*Sig.*	*F*	*Sig.*	*F*	*Sig.*
Pile yarn number	7,382	,001	,941	,398	1,108	,336	1,157	,324
Ground yarn number	,422	,518	1,938	,171	3,036	,086	2,960	,092
Pile height	,288	,750	9,527	,003	6,520	,003	9,762	,003
Fabric weight	….	….	….	….	….	….	….	….
Fabric thickness	,458	,989	1,223	,361	1,336	,221	,723	,782
cpc	2,324	,043	5,405	,000	2,738	,020	2,523	,036
wpc	,703	,498	3,756	,031	4,441	,015	1,471	,240
Stitch density	3,810	,001	3,971	,002	3,373	,002	2,595	,022

Table 4: One way ANOVA results for spirality

Factors	*Spirality*			
	Pile loop		*Cut-pile loop*	
	F	*Sig.*	*F*	*Sig.*
Pile yarn number	7,220	,001	3,060	,057
Ground yarn number	1,794	,185	,218	,643
Pile height	3,208	,047	5,399	,025
Fabric weight	….	….	….	….
Fabric thickness	,966	,553	1,263	,336
cpc	1,249	,294	2,455	,040
wpc	6,194	,003	,261	,771
Stitch density	2,110	,042	2,779	,016

Table 5: Pearson correlation results for dimensional changes

Sources	*Dimensional changes*			
	Wale direction		*Course direction*	
	Pile loop	*Cut-pile loop*	*Pile loop*	*Cut-pile loop*
Pile yarn number	-,409**	,176	,123	,076
Ground yarn number	-,077	,201	-,204	-,246
Pile height	-,089	-,414**	-,347**	-,418**
Fabric weight	-,367**	-,112	-,275*	-,286*
Fabric thickness	-,224	-,244	-,378**	-,388**
cpc	-,317**	-,384**	-,313**	-,498**
wpc	-,068	-,331*	-,280*	-,017
Stitch density	-,253*	-,424**	-,343**	-,399**

Table 6 : Pearson correlation results for spirality

Sources	*Spirality*	
	Pile loop	*Cut-pile loop*
Pile yarn number	,251*	-,116
Ground yarn number	-,158	-,069
Pile height	-,277*	,324*
Fabric weight	-,105	,161
Fabric thickness	-,110	,304*
cpc	-,258*	,274
wpc	-,377**	-,106
Stitch density	-,344**	,173

3.1 Dimensional Stability

Test results and **Figure 1 and 2** shows that pile type affects dimensional changes. So, shrinkage in wale direction in pile loop fabrics is slightly more than that in cut-pile loop fabrics. Pile type effect is clearer in course direction especially. Cut pile loop fabrics have more shrinkage than pile loop fabrics explicitly in course direction. Moreover, extension in course direction is seen in pile loop fabrics.

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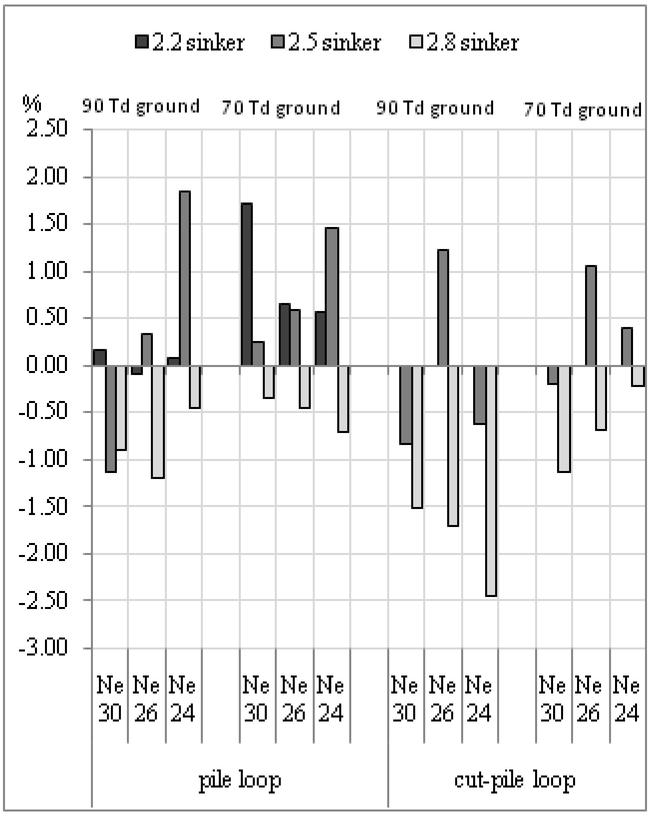

Figure 1: Dimensional changes in wale direction

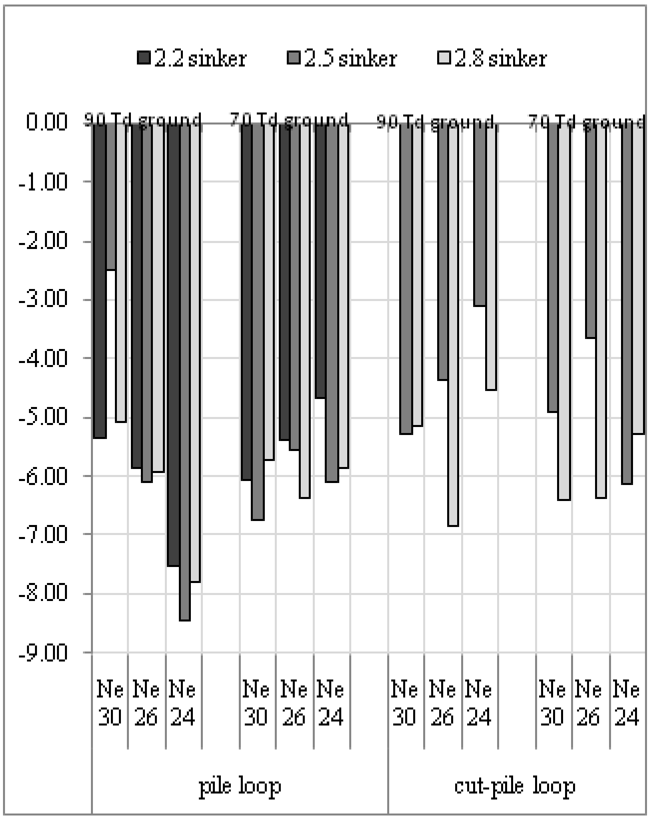

Figure 2: Dimensional changes in course direction

As indicated in the other study [11] dimensional changes are mainly affected by stitch length in knit fabrics. Stitch length and parallel with this stitch density determines tightness of knit fabrics. In other words, when loop is greater cpc and wpc values decrease, thus stitch density decrease. When stitch density or tightness increases, dimensional changes decreases. This is due to increased frictional forces between loops that hinder free movement of the loops. The same findings were seen in this study partially. In pile knit fabrics, increased stitch density decreases widthwise extension. As for cut-pile loop fabrics, increased stitch density causes increasing shrinkage in both wale and course direction. This situation can be clearly seen in samples having 2.8 pile height from figures. Stitch density in these samples has more than that in the other samples and so, these samples have more shrinkage than the others. On the other hand, statistical evaluations also reveal that cpc and parallel with stitch density have a significant effect on dimensional changes for all fabrics. Increased cpc and stitch density increase shrinkage and decrease extension according to correlation test results. It is seen that the effect of wpc is only significant in wale direction of the cut-pile loop fabrics and in course direction of the pile loop fabrics (**Tables 3,5**). Thus, we can say that the effect of wpcis lower than that of cpc.

The test results showed that shrinkage in wale direction is more than shrinkage in course direction for all pile loop and cut-pile loop fabrics. This results is mainly because of the loop shape in the fabric on the knitting machine is in a tensioned form in both lengthwise and widthwise directions[11]. Thus, after relaxation treatments, the loop shape will change, *i.e.*, loop height and loop width will contract with a negligible change in yarn loop length. Contraction in the loop height may reach a value that can increase the loop width, since yarn loop length does not change significantly. Besides, the loop width increases with the effect of the swelling mechanism, so an additional extension in course direction. This can result in a growth in course direction and a shrink in wale direction of fabric.

When the **Figure 1,2** and **Tables 3,5**examines, it is noticed that the higher pile height increases shrinkage except in wale direction of pile loop fabrics. The reason of this is that pile loops cannot find enough space for free movement and adhere to each other. Finally, the fabric shrinks with increasing pile loop length.

The same figures and tables show that pile yarn number have an effect on dimensional stability in wale direction of pile loop fabrics. The thicker pile yarn increases shrinkage in wale direction. This may result from fiber adhesion with increasing fibers in yarn cross section since the thicker yarns have more fibers. On the contrary, the relation between pile yarn number and dimensional changes is not observed in course direction of pile loop fabrics and in all directions of cut-pile loop fabrics.

The results and statistical analyses display that ground yarn is not effective on dimensional changes for all fabrics. This may be due to ground yarns are synthetic filament and so swelling mechanism does not activate.

Pearson correlation results indicate that increased weight and thickness cause an extension in course direction ofall fabrics. Because, weight and thickness increased with increased stitch density and pile height in these fabrics especially. Thus, all of these factors are relatedly effective on dimensional stability.

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3.2Spirality

Spirality is the problem encountered when the wale is not perpendicular to the course direction. This kind of loop distortion affects both the functional and aesthetic properties of fabric.

Figure 3 shows pile loop fabrics have more spirality angle than cut-pileloop fabrics. The ground loop has a tendency to spirality due to torsion on the ground yarn. The spirality that comes from the ground yarn increase with the spirality that comes from torsion on the pile yarn. Such behavior cannot be observed in cut-pile loops, since torsion on the pile yarn has been released. Finally, cut-pile loop fabrics have lower tendency to spirality as seen in this study.

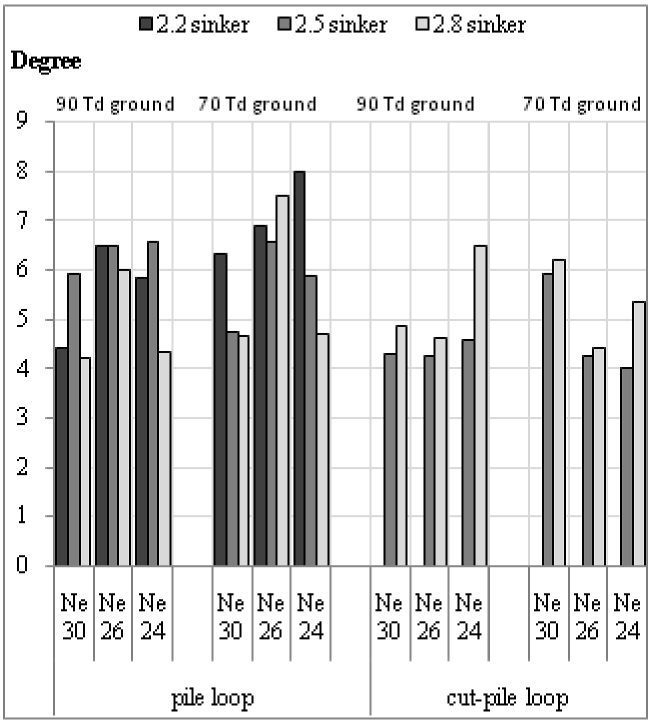

Figure3: Spirality angles of fabrics

The loop distorts according to stitch length and so spirality angle is dependent on loop size. In other words, the greater loop increases spirality angle. As the proof of this, it is observed that increased cpc, wpc and parallel with stitch density decreases spirality angle in pile loop fabrics.

The test results and statistical evaluations reveal that pile height have effect on spirality of fabrics. As this effect is negative in pile loop fabrics, it is positive in cut-pile loop fabrics since these fabrics have different pile type. Pile loops lie opposite of knit direction on fabric surface after knit process. These loops also curl on self with the effect of yarn torsion. So, the balance occurs between pile loops and ground loops which cause spirality in fact, this balance decrease spirality. The effect of balance is more in pile loop fabrics having the higher pile height since the longer pile loops curl any more. On the contrary, this balance does not occur in cut-pile loop fabrics because of shearing. After shearing, cut-pile loops do not lie and stay straight on fabric surface. Also, the curling is not seen in these loops and the yarn torsion increases with increasing pile height. In summary, as spirality decreases in pile loop fabrics, it increases in cut-pile loop fabrics with increasing pile height.

Although it is not appeared that pile yarn number has effect on spirality from *Figure 3* clearly, the statistical results display the thicker pile yarn increases spirality. This may be due to the curling in thicker pile yarn having larger diameter is less than that of thinner pile yarn. On the other hand, the effect of ground yarn, weight and thickness is insignificant on spirality according to **Tables 4, 6**.

4. Conclusion

Revealed the most important data is that cut-pile loop fabrics have more dimensional stability and less spirality than pile loop fabrics in this paper. On the other hand, out of pile type, structural and physical properties have significant effect on dimensional stability and spirality. In detail, increased cpc, wpc and parallel with stitch density increase dimensional stability and they decrease spirality partially. Also, it is found that the effect of wpc is lower than that of cpc on dimensional stability. The other result is shrinkage in wale direction is more than shrinkage in course direction for pile loop and cut-pile loop fabrics. When examined the effect of pile height, the findings indicate that the higher pile height increases fabric shrinkage, decreases spirality in pile loop fabrics, increases spirality in cut-pile loop fabrics. In pile loop fabrics, the thicker pile yarn increases shrinkage in wale direction and increases spirality. However, pile yarn number has not effect on dimensional stability and spirality in the other fabrics. Similarly, ground yarn number is not effective on dimensional stability and spirality. The last finding is that increased weight and thickness cause an extension in course direction of all fabrics, but their effect is insignificant on spirality. As a conclusion, we think the effect of these parameters can reveal in the alternative studies in the future. Especially, we suggest that the next study should be realized with different fabric tightness in addition to the parameters of this paper and Ne 20 pile yarn also can be used.

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References

[1] knittechno.blogspot.com
[2] Knapton, J. J. F., Knitting Performance of Wool Yams: Effects of Yarn/Metal Friction, Stitch Length, and Cover Factor on Knitting Performance, Textile Research. Journal, (31)8, page 22-28, 1968.
[3] Knapton, J. J. F., Ahrens, F. J., Ingenthron, W. W., and Fong, W., The Dimensional Properties of Knitted Wool Fabrics, Textile Research Journal, (3108), page 1013-1026, 1968.
[4] Knapton, J. J. F., Geometry of Complex Knitted Structures, Textile Research Journal, (399), page 889-892, 1968.

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[5] Anand, S.C., and Lawton, P.J., The Development of Knitted Structures for Filtration, Journal of Textile Institute, Vol. 82, page 297–308, 1991.
[6] Anand, S.C., and Lawton, P.J., The Dimensional Properties of Single Jersey Loop Pile Fabrics, Part I: Studies of Fabrics with Flat Continuous-Filament Yarns Used in the
[7] Ground Structure, Journal of Textile Institute, Vol.78, page 326–348, 1987.
[8] Anand, S.C., and Lawton, P.J., The Dimensional Properties of Single Jersey Loop Pile Fabrics, Part II: Studies of Fabrics with Textured Continuous-Filament Yarns in the
[9] Ground Structure, Journal of Textile Institute, Vol. 78, page 349–356, 1987.
[10] Choi, M.S., Ashdown, S.P., Effect of Changes in Knit Structure and Density on the Mechanical and Hand Properties of Weft-Knitted Fabrics for Outerwear, Textile Research Journal, vol.70: page1033-1045, 2000.
[11] Kim, S.H., Kim, S.J., Oh, K.W., Water Absorption and Mechanical Properties of Pile-Knit Fabrics Based on Conjugate N/PMicrofibers, Textile Research Journal,Vol. 73: page 489-495,2003.
[12] Onal, L., Candan, C., Contribution of Fabric Characteristics and Laundering to Shrinkage of Weft Knitted Fabrics, Textile Research Journal, Vol.73, page 187-191, 2003.
[13] Ucar, N., Karakas, H.C., Effect of Lyocell Blend Yarn and Pile Type on the Properties of Pile Loop Knit Fabrics, Textile Research Journal, Vol. 75, page 352-356, April 2005.
[14] ASTM Practice D 1776, “Conditioning Textiles for Testing.”
[15] TS EN 14971, July 2006, “Textiles-Knitted Fabrics-Determination of number of stitches per unit length and unit area”
[16] TSE EN 12127, April 1999, “Textiles-Fabrics-Determination of mass per unit area using small samples”.
[17] TS 7128 EN ISO 5084, August 1996, “Textiles-Determination of thickness of textiles and textile products”.
[18] TS 4073 EN ISO 3759, April 1999, “Textiles-Preparation, marking and measuring of fabric specimens and garments in tests for determination of dimensional change”
[19] TS 5720 EN ISO 6330, April 2012, “Textiles- Domestic washing and drying procedures for textile testing”.
[20] Woolmark Test Method TM 276, May 2000, “Angle of Spirality in Plain Knitted Garments”.

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