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Compression Properties of Weft Knitted Fabrics Consisting of Shrinkable and Non-Shrinkable Acrylic Fibers

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Abstract: High-bulk worsted yarns with different shrinkable and non-shrinkable acrylic fibers blend ratios are produced and then single jersey weft knitted fabrics with three different structures and loop lengths are constructed. The physical properties of produced yarns and compression properties of produced fabrics at eight pressure values (50, 100, 200, 500, 1000, 1500 and 2000 g/cm^2) were measured using a conventional fabric thickness tester. Then, weft-knitted fabric compression behavior was analyzed using a two parameters model. It is found that at 40 % shrinkable fibre blending ratio the maximum yarn bulk, shrinkage, abrasion resistance and minimum yarn strength are obtained. It is also shown that high-bulk acrylic yarn has the highest elongation at 20 % shrinkable fibre blend ratio. The statistical regression analysis revealed that the compression behavior of acrylic weft-knitted fabrics is highly closed to two parameter model proposed for woven fabrics. It is also shown that for weft-knitted structure, there is an incompressible layer (V') which resists against high compression load. Acrylic weft-knitted fabrics with knit-tuck structure exhibit higher compression rigidity and lower softness than the plain and knit-miss structures. In addition, at 20 % shrinkable fibre blend ratio, the high-bulk acrylic weft-knitted fabrics are highly compressible.

Keywords: Fabric compression, Acrylic shrinkable fiber, Weft-knitted fabrics, High-bulk yarn

Introduction

One of the most important geometrical aspects of the knitted structure is the dimension normal to the plane of the fabric, or the fabric thickness [1,2] which manifests the compressional properties. Compressional behaviour of fabrics, along with bending, tensile, shear, and surface characteristics, is strongly related to fabric handle, drape, tailorability [3,4], sound and infrared transmission properties [5]. Thus, the measurement of the compressional properties of fabrics forms an integral part of the objective measurements [6-8].

Bulk characteristics of knitted fabrics have been studied by a number of research workers [1,2,9-14]. Postle [1,2] indicated that bulk density or compressional properties of knitted structures are related to the effective diameter of the yarn inside of the fabric and also to the curvature of the loops out of the fabric plane. Ajayi and Elder [9] investigated the effect of fabric compression on frictional properties of woven, knitted and nonwoven fabrics. It is shown that as the fabric compression increases, the difference between the static and kinetic friction forces increases. Punj *et al.* [11] studied the compressional properties of acrylic and viscose ring and air-jet spun yarn plain knitted fabrics in two dry and fully relaxed states. It is found that acrylic spun yarn knitted fabric shows higher thickness, compression, compressibility and lower thickness loss percentage than viscose in the relaxed state. Aliouche and Viallier [10] measured the compressibility and coefficient of friction of knitted, nonwoven, technical filament cloth and a PVC film under the low load pressure. It is concluded that the hairiness is an important point of tactile feelings and compressibility is a good way to explain fabric frictional coefficient. Taylor and Pollet [12] used the equation proposed by van Wyk [15] to approximate static low-load compression curves of both woven and knitted fabrics and concluded to a three-parameter model which was initially proposed by de-Jong *et al.* [16]. The thickness and specific volume of knitted fabric have been analyzed in relation to yarn type (air-jet textured/flat), stitch length and relaxation treatments by Mukhopadhyay *et al.* [13]. The results showed that the thickness of air-jet textured yarn knitted fabric is independent of stitch length in fully-relaxed state, whereas the specific volume of the fabric increases with the increase in stitch length. Recently, a theoretical model is proposed by Soe *et al.* [14] and the compression properties of plain knitted fabrics are predicted from yarn properties and fabric geometry. It is assumed that plain knit compression can be obtained from a combination of piled layer yarn compression and single layer yarn compression with a contribution factor depending on the fabric geometry [14].

In recent years, several research works have been done on compressional behaviour of fibre [17-21], filament [22], nonwoven assemblies [23-25], and woven and knitted structures [12-14,26-28]. Previous studies by the author [29] investigated the effect of blend ratios of un-relaxed and relaxed acrylic fibers on physical properties of high-bulk yarns. The high-bulk acrylic yarns are mainly utilized in weft knitted fabric structures. However, there is no published work to investigate compression properties of high-bulk acrylic weft knitted fabrics consisting of shrinkable and non-shrinkable acrylic fibre at different blend ratio. In the present study, high-bulk worsted yarns with different shrinkable and non-shrinkable acrylic fibers blend ratios are produced and then

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single jersey weft knitted fabrics with three different structures (plain, knit-miss and knit-tuck) and three different loop lengths (high, medium and low) are constructed. The objectives of present research work are to analyze single jersey weft-knitted fabric compression behavior using a two parameters model and to investigate the relation between the shrinkable acrylic fibre blend ratio and bulk characteristics of high-bulk acrylic yarns as well as single jersey weft knitted fabric compression properties.

Experimental

Spinning and Bulking Processing

In this work, two different shrinkable and non-shrinkable acrylic fiber tops with linear densities of 26.48 and 34.74 ktex were respectively used. Table 1 shows the raw material specifications.

The shrinkable and non-shrinkable acrylic tops were then blended with shrinkable fibre blending ratios of 0/100, 20/80, 40/60, 60/40, 80/20 and 100/0 on a blender gilling machine. The produced blended slivers passed through standard worsted spinning preparation machines and thus 6 samples of acrylic roving with average linear density of 0.80 Ktex were produced. Finally 6 samples of two-fold worsted acrylic yarns were produced using standard worsted ring spinning and two-for-one twister machines [30]. The yarn count and twist level for these 6 blended acrylic worsted yarns were constant at the measure of 30/2 Nm and 210 T.P.M respectively. These 6 sample yarns were then subjected to steaming process and 6 samples of high-bulk yarns were produced. The bulking process was carried out using Superba continuous bulking system [30]. The steaming temperature was at a measure of 94 °C and steam pressure was at a value of 1 bar. To compare the produced yarn properties with conventional produced yarn, a commercial high-bilk acrylic yarn (61.3 % shrinkable fibre in 3.33 dtex, 32.6 % non-shrinkable fibre in 3.33 dtex and 6.1 % non-shrinkable in 5.55 dtex fineness) was also produced with the same specification.

Fabric Processing

To produce weft knitted fabrics, a double jersey flat knitting machine (A.R.S.D, R88-96 Model) was used. The machine gauge was 8 (needle/inch), the fabric width was 50 cm (163 needles) and the cam setting numbers for different loop lengths were adjusted at 15, 16 and 17. The single jersey weft knitted fabrics were produced with three different structures including plain(p), knit-miss(m) and knit-tuck(t) and three different loop lengths (high, medium and low). Figure 1 shows these three fabric structures. As shown in Figure 1(a), the plain structure is a basic structure of single jersey fabric which is produced by the needles knitting as a single set,

Table 1. Raw material specifications (Average values)*

Material	Fineness (dtex)	Tensile strength (cN/dtex)	Elongation (%)	Length (mm)
Shrinkable fiber	2.83 (10.05)	3.29 (14.28)	13.84 (16.29)	118.9 (33.22)
Non-shrinkable fiber	3.51 (9.22)	2.33 (11.63)	31.68 (11.63)	86.1 (39.66)

*The CV% values are indicated in brackets.

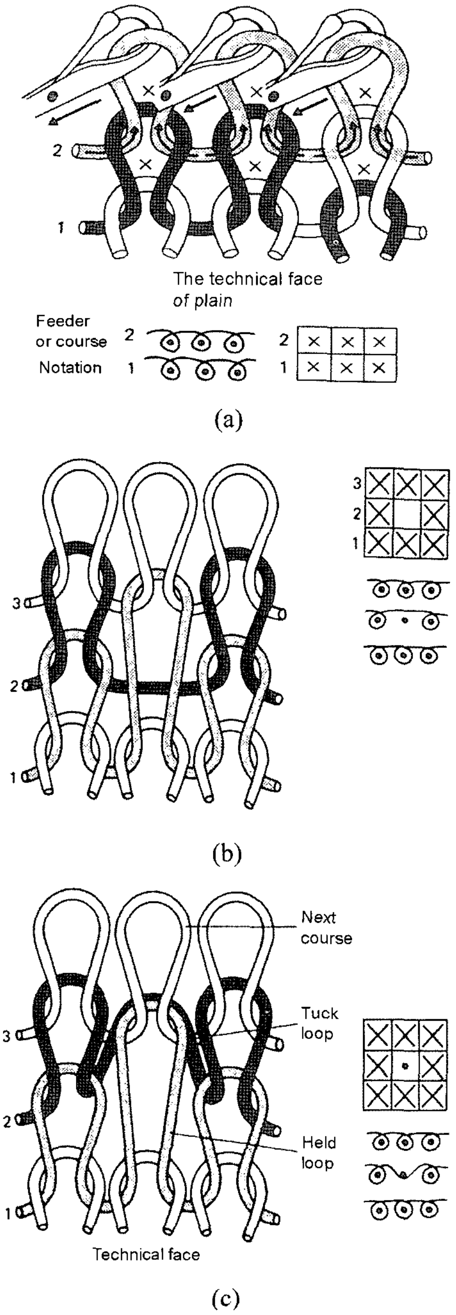

Figure 1. Single jersey weft-knitted fabrics with (a) plain, (b) knit-miss, and (c) knit-tuck structures.

Table 2. Construction parameters of fabrics tested

Fabric ID	Course per centimeter (C.P.C)	Wale per centimeter (W.P.C)	Stitch density (cm^{-2})	Mass per unit area (g/m^2)	Weave
1p15	5.75	4.88	28.03	145.0	Plain
2p15	5.90	4.90	28.91	173.5	Plain
3p15	6.05	4.75	28.74	193.0	Plain
4p15	5.90	4.70	27.73	190.5	Plain
5p15	5.90	4.80	28.32	179.5	Plain
6p15	6.00	5.00	30.00	193.5	Plain
7p15	5.84	4.64	27.10	180.5	Plain
1p16	4.65	4.38	20.34	119.5	Plain
2p16	5.05	4.35	21.97	153.5	Plain
3p16	5.05	4.20	21.21	164.0	Plain
4p16	4.78	4.50	21.49	146.5	Plain
5p16	4.85	4.50	21.83	153.0	Plain
6p16	4.75	4.75	22.56	170.5	Plain
7p16	4.70	4.35	20.45	152.5	Plain
1p17	4.25	3.75	15.94	98.5	Plain
2p17	4.15	4.08	16.91	135.0	Plain
3p17	4.25	4.10	17.43	148.5	Plain
4p17	4.35	4.08	17.73	150.0	Plain
5p17	4.35	3.78	16.42	143.5	Plain
6p17	4.25	4.18	17.74	149.0	Plain
7p17	4.15	3.98	16.50	142.0	Plain
1m15	6.90	5.15	35.54	154.0	Knit-miss
2m15	7.30	4.90	35.77	194.0	Knit-miss
3m15	7.55	4.73	35.67	208.0	Knit-miss
4m15	7.55	4.78	36.05	200.5	Knit-miss
5m15	7.35	4.95	36.38	201.5	Knit-miss
6m15	7.30	5.03	36.68	224.0	Knit-miss
7m15	7.35	4.40	32.34	195.0	Knit-miss
1m16	6.45	4.35	28.06	134.5	Knit-miss
2m16	6.25	4.30	26.88	163.5	Knit-miss
3m16	6.55	4.30	28.17	183.5	Knit-miss
4m16	6.55	4.50	29.48	176.0	Knit-miss
5m16	6.35	4.45	28.26	178.5	Knit-miss
6m16	6.30	4.55	28.67	190.0	Knit-miss
7m16	6.40	4.15	26.56	181.5	Knit-miss
1m17	5.35	4.05	21.67	123.0	Knit-miss
2m17	5.45	4.28	23.30	142.5	Knit-miss
3m17	5.40	4.10	22.14	156.0	Knit-miss
4m17	5.30	4.15	22.00	164.0	Knit-miss
5m17	5.25	4.20	22.05	152.0	Knit-miss
6m17	5.35	4.28	22.87	169.0	Knit-miss
7m17	5.40	4.00	21.60	163.0	Knit-miss
1t15	8.65	3.23	27.90	153.0	Knit-tuck
2t15	8.00	3.45	27.60	169.5	Knit-tuck
3t15	7.90	3.33	26.27	187.0	Knit-tuck
4t15	8.20	3.35	27.47	195.0	Knit-tuck
5t15	8.30	3.25	26.98	181.0	Knit-tuck
6t15	8.10	3.35	27.14	203.0	Knit-tuck
7t15	7.75	3.30	25.58	184.0	Knit-tuck

Table 2. Continued

Fabric ID	Course per centimeter (C.P.C)	Wale per centimeter (W.P.C)	Stitch density (cm^{-2})	Mass per unit area (g/m^2)	Weave
1t16	7.20	2.83	20.34	127.0	Knit-tuck
2t16	7.30	3.15	23.00	150.5	Knit-tuck
3t16	6.60	3.08	20.30	175.0	Knit-tuck
4t16	6.60	3.20	21.12	172.0	Knit-tuck
5t16	6.80	3.25	22.10	166.5	Knit-tuck
6t16	7.20	3.08	22.14	172.0	Knit-tuck
7t16	7.10	2.95	20.95	178.0	Knit-tuck
1t17	7.50	2.29	17.16	120.0	Knit-tuck
2t17	6.55	2.84	18.59	137.0	Knit-tuck
3t17	5.90	2.98	17.55	149.0	Knit-tuck
4t17	5.40	3.13	16.88	143.0	Knit-tuck
5t17	5.60	3.05	17.08	146.0	Knit-tuck
6t17	6.40	2.88	18.40	159.5	Knit-tuck
7t17	6.10	2.80	17.08	149.5	Knit-tuck

*Fabric ID explanations: The numbers 1, 2, 3,.., 7 are referred to yarn type, p, m and t are referred to fabric structures (plain, knit-miss, and knit-tuck respectively) and numbers of 15, 16, and 17 are referred to cam setting values or low, medium and high loop lengths respectively.

drawing the loops away from the technical back and towards the technical face side of the fabric [31]. In a knit-miss structure, the float or welt stitch is the missed yarn floating freely on the reverse side of the held loop which is the technical back of single jersey structures (Figure 1b) [31]. In a knit-tuck structure, a tuck stitch is composed of a held loop, one or more tuck loops, and knitted loops (Figure 1c) [31]. A summary of the fabric-constructed parameters for three fabric structures at three different loop lengths is presented in Table 2.

Yarn Physical Properties

The tensile strength and breaking elongation, percentage of shrinkage, and specific volume were measured using the standard test methods [32,33] as explained elsewhere by the author [29]. The yarn abrasion resistance was investigated by using a Shirley yarn abrasion tester [33]. The abradant paper was P800. Ten yarn specimens were tested simultaneously and the initial tension exerted on each yarn was 0.5N. The experimental results of yarn physical properties are shown in Table 3. All experiments were performed under the standard conditions of 22 ± 2 °C and 65 ± 2 % RH. The experimental results of yarn physical properties were statistically analyzed using ANOVA and Multiple Range Test methods [30].

Fabric Compression Test Procedure

First, the fabric samples were conditioned and fully dried relaxed under the room temperature and humidity conditions of 20 ± 2 °C and 65 ± 2 % RH. for 72 hours. In order to

Table 3. Yarn properties results (Average values)*

Shrinkable fiber blend ratio		0/100	20/100	40/60	60/40	80/20	100/0	Commercial yarn
Tensile strength (cN/tex)	Twisted yarn	13.22 (10.04)	11.97 (5.64)	13.35 (5.62)	14.21 (7.58)	15.38 (5.35)	18.04 (5.43)	16.57 (5.62)
	Bulked yarn	13.57 (7.30)	8.95 (5.94)	8.22 (6.43)	8.94 (5.91)	10.81 (5.76)	13.11 (5.39)	10.48 (7.51)
Elongation (%)	Twisted yarn	21.28 (6.56)	14.40 (7.15)	13.25 (5.15)	12.25 (5.12)	12.24 (4.39)	12.34 (3.96)	15.25 (3.41)
	Bulked yarn	23.40 (6.23)	34.04 (6.85)	28.87 (4.42)	28.23 (4.03)	25.28 (5.10)	27.11 (5.41)	30.27 (3.85)
Abrasion resistance	Twisted yarn	12.30 (7.71)	13.70 (11.44)	16.10 (26.59)	14.80 (22.92)	13.20 (16.29)	13.00 (14.95)	14.00 (12.60)
	Bulked yarn	17.00 (26.45)	20.50 (24.36)	26.10 (15.27)	25.90 (21.42)	22.40 (17.38)	25.90 (21.42)	22.70 (17.63)
Specific volume (cm^3/g)	Bulked yarn	7.69 (4.14)	11.09 (3.90)	12.03 (3.58)	11.16 (8.32)	9.73 (4.02)	7.98 (4.06)	11.92 (3.03)
Yarn shrinkage (%)	Bulked yarn	−2.74 (−1935.54)	15.66 (15.31)	20.04 (11.51)	24.00 (7.16)	20.40 (12.10)	19.62 (17.66)	22.00 (6.66)

*The CV% values are indicated in brackets.

investigate fabric compression properties, we used a Shirley digital thickness tester [34]. By using this thickness tester, it was possible to measure fabric thickness at different pressure including 20, 50, 100, 200, 500, 1000, 1500 and 2000 g/cm^2 (corresponding to 2.039, 5.097, 10.194, 20.387, 50.968, 101.937, 152.905, and 203.874 kPa pressure respectively). The first compression reading was taken 30 seconds under the pressure of 20 g/cm^2. So, thickness at 20 g/cm^2 pressure was recorded as the initial thickness (T_{0c}). Subsequently, the pressure was increased from 20 in steps to 50, 100, 200, 500, 1000, 1500 and 2000 g/cm^2 and the corresponding compression readings were recorded using the same procedure. Fabric thickness under the maximum pressure of 2000 g/cm^2 was registered as maximum thickness (T_m). The first recovery reading was taken after removing corresponding load and allowing the fabric sample to recover for 30 seconds. The subsequent recovery readings were taken using the same procedure. The final fabric thickness under the recovery condition was registered as T_{0r}. 5 tests were conducted for each fabric sample. Thus, the compression and recovery readings were recorded and then plotted.

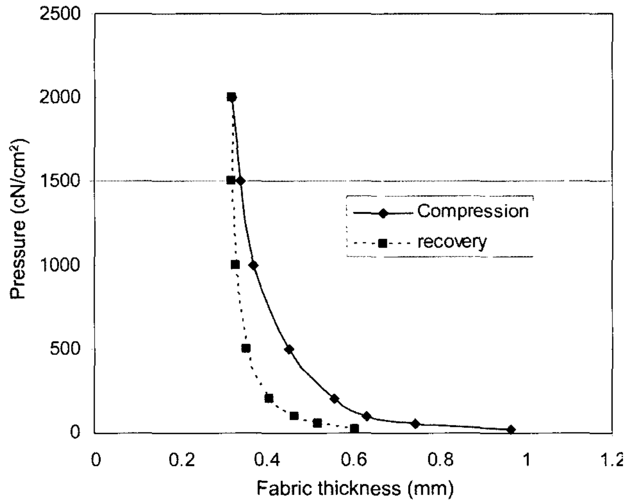

Figure 2. A typical compression and recovery curve of weft-knitted fabric.

Compression Parameters Investigated

A typical compression curve of acrylic weft knitted fabric is shown in Figure 2. It may be considered that the compression curve of weft-knitted structure consists of three zones. At low pressure, the protruding hair fibers from the outer surface of the fabric are compressed and compression characteristic in this first region is presumed to be elastic. Increasing the pressure overcomes the internal fiber and yarn friction and fiber slippages takes place. Thus in this second region, the fabric thickness decreases nonlinearly with increasing pressure. Further increasing the pressure compresses the fibers laterally and in this third region, a highly packed fiber assembly can be considered.

To analyze the compression behavior of knitted structures, we used the two parameters model proposed by de-Jong *et al.* [16] with the following equation type:

$$P = \frac{a}{(V - V')^3} \qquad (1)$$

where:

$$a = K'Y\left(\frac{W}{\rho}\right)^3 \quad (2)$$

P is pressure, a is a constant, V is fabric volume or thickness, V' represents the limiting fabric volume (thickness) at large pressure, K' is a dimensionless constant which depends on fiber orientation and crimp, Y is fiber Young's modulus, ρ is the density of the fibers and W is the mass of fibers assembly.

After rearrangement of equation (1),

$$V = V' + \frac{a^{1/3}}{P^{1/3}} \quad (3)$$

it may be considered that plotting the fabric thickness V against the inverse cube root of the pressure $1/P^{1/3}$ should result in a straight line with intercept V' and slope $a^{1/3}$. In order to verify the validity of this model for the weft-knitted fabric structures and to determine constants a and V', the individual fabric sample thickness (V) was plotted against $1/P^{1/3}$ and then linear statistical regression analysis was performed. A typical weft-knitted fabric thickness and pressure relationship (plotted as the inverse cube root of the pressure $1/P^{1/3}$) is represented in Figure 3. Considering the linear statistical regression analysis for individual fabric sample for both compression and recovery states, the constants of a_c, a_r, V_c', and V_r' are calculated accordingly (where, suffix c refers to the compression and suffix r refers to the recovery state).

In order to evaluate the compression behavior of fabrics, we used different parameters similar to those introduced by Kawabata [6] in KES-F system. The compression parameters include the work of compression WC, the work of recovery from compression W'C, the dissipated compression energy E_m, the resilience of the fabric RC, relative compressibility EMC, linearity of compression LC and fabric compression

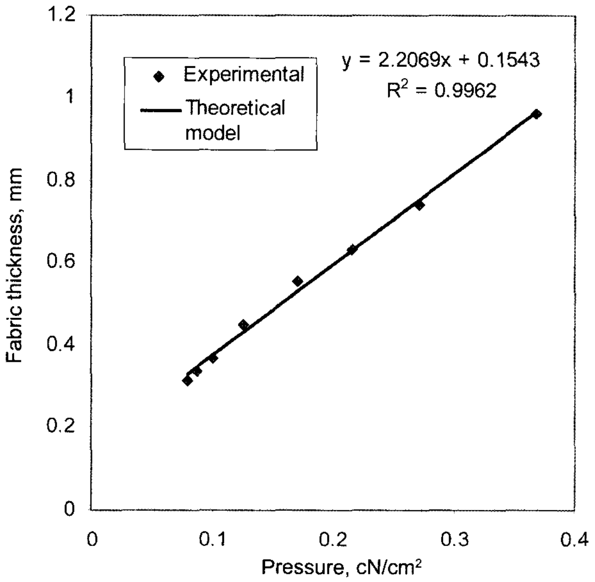

Figure 3. A typical weft-knitted fabric thickness and pressure relationship (Plotted as the inverse cube root).

deformation or fabric surface thickness ΔT as follow:

$$WC = \int_{T_{0c}}^{T_m} P_c\, dV = \int_{T_{0c}}^{T_m} P_c\, dt_c = \int_{T_{0c}}^{T_m} \frac{a_c}{(V - V_c')^3} \cdot dt_c \quad (4)$$

Integrating equation (4),

$$WC = \left| \frac{a_c}{-2} \left\{ \frac{1}{(T_m - V_c')^2} - \frac{1}{(T_{0c} - V_c')^2} \right\} \right| \quad (5)$$

$$W'C = \int_{T_m}^{T_{0r}} P_r \cdot dV = \int_{T_m}^{T_{0r}} P_r \cdot dt_r = \int_{T_m}^{T_{0r}} \frac{a_r}{(V - V_r')^3} \cdot dt_r \quad (6)$$

Integrating equation (6),

$$W'C = \left| \frac{a_r}{-2} \left\{ \frac{1}{(T_m - V_r')^2} - \frac{1}{(T_{0r} - V_r')^2} \right\} \right| \quad (7)$$

$$E_m = WC - W'C$$

$$RC = \frac{W'C}{WC} \quad (8)$$

$$EMC = 1 - \frac{T_m}{T_{0c}} \quad (9)$$

$$LC = \frac{WC}{\frac{P_m}{2}(T_{0c} - T_m)} \quad (10)$$

(11)

$$\Delta T = T_{0c} - T_m \quad (12)$$

where, in these equations suffix c refers to the compression and suffix r refers to the recovery state.

Results and Discussion

Yarn Properties

As shown in Table 2, at 40 % shrinkable fibre blending ratio the maximum yarn bulk, shrinkage, and abrasion resistance and minimum yarn strength are obtained. It is also shown that high-bulk acrylic yarn has the highest elongation at 20 % shrinkable fibre blend ratio. In general, these results are in agreement with previous investigation results obtained by the author [29].

Weft-Knitted Fabric Compression Model

As shown in Figure 2, the behavior of acrylic weft-knitted fabrics in compression and recovery of compression is highly closed to that of model proposed by [16]. The regression coefficient ($\mathbf{R}_c^2$ and $\mathbf{R}_r^2$) for both compression and recovery of compression were obtained at the following values respectively:

$$0.9715 < \mathbf{R}_c^2 < 0.9997$$
$$0.9891 < \mathbf{R}_r^2 < 0.9982$$

It is shown that for weft-knitted structure, there is an incompressible layer (V') which resists against high compression pressure. It is deduced that the compression behavior of weft-knitted fabrics are attributed to effective diameter of the yarn inside of the fabric, the curvature of the loops out of the fabric plane [1,2] and yarn compression properties at the unit cell of weft-knitted structure [14].

Effect of Shrinkable Fiber Blend Ratio on Fabric Compression Properties

The average values of fabric compression properties at different shrinkable fiber blend ratio are shown in Table 4 and Figures 4 and 5. It is shown that with increasing the shrinkable fibre blend ratio up to 40 %, the fabric compression energy (*WC*) and surface thickness (ΔT) significantly increase. Further increasing the shrinkable fibre blend ratio results in a decrease in ΔT, and WC. The variations trend of these compression parameters with shrinkable fiber blend ratio is Polynomial with the order of 3 similar to that of yarn specific volume (Figure 6). As shown in Figure 6, at 40 % shrinkable fiber blend ratio, the highest high-bulk yarn specific volume is obtained. This results in a significant increased of fabric surface thickness and compression energy and hence fabric compression toughness. Furthermore, it is also shown that at 20 % shrinkable fiber blend ratio, the maximum dimensionless EMC parameter or compressibility was obtained for all fabrics and weft-knitted fabrics with higher loop length and knit-tuck structure exhibit highest compressibility values.

It is also shown that weft knitted fabrics with knit-tuck and knit-miss structures exhibit higher ΔT, and WC values than with plain structure. This is because in knit-tuck structure, tuck loops reduce fabric length and length-wise elasticity [31] and increase course density (Table 2). It is deduced that the higher yarn tension on the tuck and held loops causes them to rob yarn from adjacent knitted loops making them smaller and providing greater stability and shape retention [31]. As the loops come closer to each other due to increased of course

Table 4. Fabric compression parameters results

Fabric ID	WC (cN·cm/cm^2)	CV%	W'C (cN·cm/cm^2)	CV%	RC (%)	CV%	EMC (%)	CV%	Em (cN·cm/cm^2)	CV%	ΔT (mm)	CV%	LC%	CV%
1p15	20.36	20.39	7.52	33.34	34.63	16.86	67.20	2.13	12.85	13.05	0.65	6.31	31.66	22.73
2p15	37.77	16.85	10.70	29.88	27.29	13.81	69.64	1.87	27.07	11.76	1.03	2.69	36.58	16.41
3p15	44.85	25.03	12.25	41.02	25.56	16.87	65.57	2.10	32.60	19.10	1.03	3.24	43.48	24.75
4p15	43.44	8.73	11.70	14.15	26.77	5.26	63.15	0.93	31.73	6.74	0.95	2.55	45.96	9.85
5p15	33.41	17.67	10.57	30.19	30.59	12.26	63.99	2.65	22.85	11.88	0.87	4.71	38.41	15.03
6p15	32.85	46.35	14.12	96.33	32.79	42.42	63.01	2.95	18.73	13.23	0.79	2.64	41.77	45.94
7p15	39.71	14.87	11.47	30.97	27.94	14.13	65.66	1.59	28.24	8.36	1.01	2.18	39.42	13.33
1p16	15.84	12.06	6.65	26.48	40.42	15.50	69.23	1.10	9.19	1.68	0.65	3.35	24.51	13.87
2p16	27.07	6.09	9.87	12.14	36.23	5.99	70.58	0.90	17.20	2.65	0.98	1.98	27.51	5.50
3p16	38.72	21.36	11.96	39.86	28.90	18.93	68.30	2.28	26.76	13.22	1.03	2.79	37.38	20.19
4p16	34.20	26.77	11.40	54.52	29.11	28.82	67.16	1.11	22.81	13.88	0.96	3.96	36.10	30.12
5p16	31.61	31.07	11.48	64.69	31.33	30.47	65.18	1.57	20.13	13.28	0.89	2.05	35.87	33.28
6p16	27.33	17.56	9.11	33.21	32.18	13.44	63.06	1.67	18.22	9.80	0.80	4.91	34.50	20.72
7p16	37.16	11.62	10.56	21.86	27.87	9.93	66.39	1.33	26.60	7.58	0.98	3.42	37.81	12.59
1p17	15.86	13.73	5.69	25.65	34.90	12.17	66.48	2.01	10.17	7.14	0.56	6.05	28.67	16.77
2p17	32.87	35.32	12.17	72.71	29.40	38.81	72.24	3.16	20.69	15.87	0.97	5.31	34.22	37.00
3p17	35.18	15.37	10.45	30.10	28.68	13.97	69.29	1.13	24.74	9.22	1.06	3.82	33.46	18.43
4p17	34.74	14.50	10.16	28.52	28.21	14.28	68.02	0.79	24.58	8.75	1.00	4.85	35.11	18.74
5p17	26.94	14.77	9.07	32.10	32.24	16.81	67.81	1.64	17.86	6.12	0.91	2.46	29.59	14.31
6p17	25.79	11.82	9.04	23.01	34.32	10.83	66.07	1.41	16.75	5.85	0.81	1.95	31.81	10.75
7p17	34.46	15.71	10.44	32.47	28.97	16.50	68.77	1.25	24.02	8.57	1.03	2.24	33.63	16.53
1m15	21.18	23.21	8.96	86.24	32.04	58.05	69.92	2.21	12.21	25.90	0.94	10.22	23.00	33.47
2m15	41.17	7.87	11.23	18.24	26.89	10.15	73.60	1.26	29.93	4.04	1.36	4.23	30.27	9.21
3m15	44.88	7.81	12.17	15.65	26.82	8.04	70.05	0.99	32.71	4.91	1.36	3.09	32.99	8.74
4m15	47.40	25.91	13.97	52.84	25.93	27.82	68.05	2.08	33.43	15.57	1.29	3.40	36.72	26.55
5m15	37.40	19.41	11.31	42.33	27.80	23.44	67.54	1.69	26.09	10.05	1.20	2.73	31.27	20.11
6m15	35.64	12.90	10.02	24.82	27.40	11.94	66.85	1.68	25.61	8.26	1.13	3.67	31.44	12.67
7m15	40.23	11.52	11.16	26.14	26.74	15.66	70.57	1.82	29.07	6.01	1.34	4.03	29.93	10.76

Table 4. Continued

Fabric ID	WC (cN·cm/cm^2)	CV%	W'C (cN·cm/cm^2)	CV%	RC (%)	CV%	EMC (%)	CV%	Em (cN·cm/cm^2)	CV%	ΔT (mm)	CV%	LC%	CV%
1m16	18.36	12.35	7.34	32.47	37.55	21.55	69.35	1.78	11.02	2.93	0.83	7.62	22.31	16.72
2m16	34.74	11.07	10.92	22.37	30.54	13.05	74.26	0.83	23.82	5.94	1.28	1.56	27.18	12.32
3m16	42.24	7.01	12.03	14.28	28.23	7.16	71.21	0.77	30.20	4.13	1.33	3.04	31.91	9.25
4m16	40.30	13.33	11.91	25.87	28.58	13.65	69.13	0.45	28.39	8.10	1.23	5.23	33.06	17.83
5m16	32.14	23.16	11.30	58.72	31.20	30.85	68.66	0.74	20.83	5.06	1.09	3.94	29.84	27.73
6m16	29.95	7.62	9.70	16.17	32.00	8.60	66.30	1.12	20.25	3.54	1.00	4.54	29.94	10.96
7m16	37.56	8.67	9.55	16.56	26.70	8.68	74.33	1.36	28.02	6.37	1.39	5.78	27.09	11.57
1m17	16.46	20.13	7.61	66.13	39.14	41.61	68.95	0.90	8.85	20.95	0.71	5.17	23.53	25.08
2m17	29.98	6.73	9.53	18.43	31.23	11.58	73.89	2.91	20.45	1.55	1.15	13.37	26.56	17.01
3m17	36.26	8.99	10.89	19.58	29.49	10.75	72.37	0.93	25.37	4.54	1.25	1.43	28.96	8.91
4m17	36.12	9.89	10.62	21.77	28.79	11.69	69.76	2.06	25.50	5.11	1.16	6.61	31.36	12.39
5m17	31.14	10.44	9.33	21.10	29.23	11.89	69.09	1.48	21.81	5.93	1.04	4.88	30.09	12.33
6m17	26.66	5.41	8.65	12.64	32.19	7.18	67.63	1.30	18.01	1.98	0.96	4.79	27.80	8.93
7m17	34.20	2.59	9.67	7.25	29.36	4.52	73.46	0.51	24.53	0.76	1.27	2.75	27.00	5.40
1t15	24.30	7.59	7.51	19.36	30.32	11.93	69.40	0.64	16.79	2.38	1.03	3.88	23.67	10.81
2t15	43.62	12.02	11.05	21.39	24.78	10.48	69.62	0.66	32.57	8.86	1.27	2.05	34.31	13.62
3t15	52.16	10.27	13.25	17.71	25.06	8.00	68.28	1.07	38.91	7.74	1.32	2.17	39.47	10.58
4t15	50.95	23.00	13.77	44.35	24.79	22.08	68.34	1.53	37.19	15.22	1.32	6.73	39.01	28.04
5t15	43.59	6.54	11.12	11.76	25.37	5.25	68.47	0.30	32.47	4.75	1.24	1.44	35.24	7.81
6t15	39.90	17.91	12.27	31.06	29.33	14.99	66.71	1.36	27.63	12.17	1.17	2.63	34.19	19.49
7t15	46.96	17.15	11.68	32.91	23.54	17.45	69.40	1.62	35.28	11.96	1.32	2.04	35.48	17.41
1t16	20.91	18.25	7.43	66.40	29.89	44.29	68.93	1.77	13.48	10.03	0.95	6.37	22.28	22.65
2t16	40.07	7.82	10.91	16.91	26.83	9.54	73.31	0.41	29.16	4.46	1.39	3.01	28.89	10.38
3t16	48.50	10.21	11.76	22.10	23.72	11.59	71.23	0.76	36.74	6.42	1.45	2.43	33.59	11.64
4t16	43.12	14.63	11.53	33.46	25.42	18.49	71.11	1.02	31.60	8.07	1.36	4.65	31.81	19.11
5t16	37.64	14.70	10.61	36.19	26.62	20.61	71.56	1.62	27.03	6.51	1.29	4.11	29.15	16.24
6t16	35.28	14.08	10.24	32.71	27.64	18.31	69.88	0.56	25.04	6.68	1.21	3.45	29.38	17.11
7t16	42.83	9.93	10.90	25.11	24.72	14.75	74.15	1.37	31.93	4.89	1.45	3.28	29.51	9.91
1t17	18.72	7.64	6.32	21.49	32.97	13.99	73.22	1.10	12.39	0.89	0.93	3.40	20.15	8.98
2t17	36.00	14.05	10.53	38.93	27.20	24.44	76.82	0.65	25.47	4.38	1.45	6.54	25.05	20.64
3t17	40.51	11.67	11.08	28.10	26.34	16.44	73.89	1.20	29.43	5.58	1.41	4.68	28.84	14.55
4t17	38.07	13.76	10.13	37.12	25.09	22.14	73.12	1.80	27.94	5.65	1.34	2.21	28.28	11.95
5t17	35.36	10.33	9.79	29.36	26.73	17.41	72.55	1.17	25.57	3.17	1.29	3.68	27.46	12.07
6t17	31.47	7.88	8.92	21.22	27.73	13.09	71.10	1.36	22.55	2.74	1.23	4.38	25.72	9.75
7t17	35.22	6.77	9.45	20.32	26.25	13.77	77.23	1.05	25.77	2.03	1.55	3.60	22.69	7.78

density, overlapping of loops takes place, which enhances the higher fabric thickness. On the other hand, in knit-tuck structure, the fabric width is increased [31] and hence the wale density is decreased (Table 2). This is because tuck loops pull the held loops downwards causing them to spread outwards and making extra yarn available for width-wise elasticity [31]. In addition, in knit-miss structures that incorporating float stitches tend to exhibit fain horizontal lines, there are narrower because the wales are drawn closer together and the held loop robs yarn from adjacent loops thus reducing width-wise elasticity and improving fabric stability [31]. This in turn results in an increased of course density and hence the fabric thickness. In general, the knitted fabric with knit-tuck structure is more compressible than with knit-miss and plain structures.

On the other hand, statistical analysis results show that loop length has no significant effect on resilience of the fabric RC. From Table 4, we see that the RC value ranging between 23.5 % and 40.4 % (average value=29.15 %) for all weft-knitted fabrics tested in this research and weft-kitted fabrics with knit-tuck structure exhibit lower value

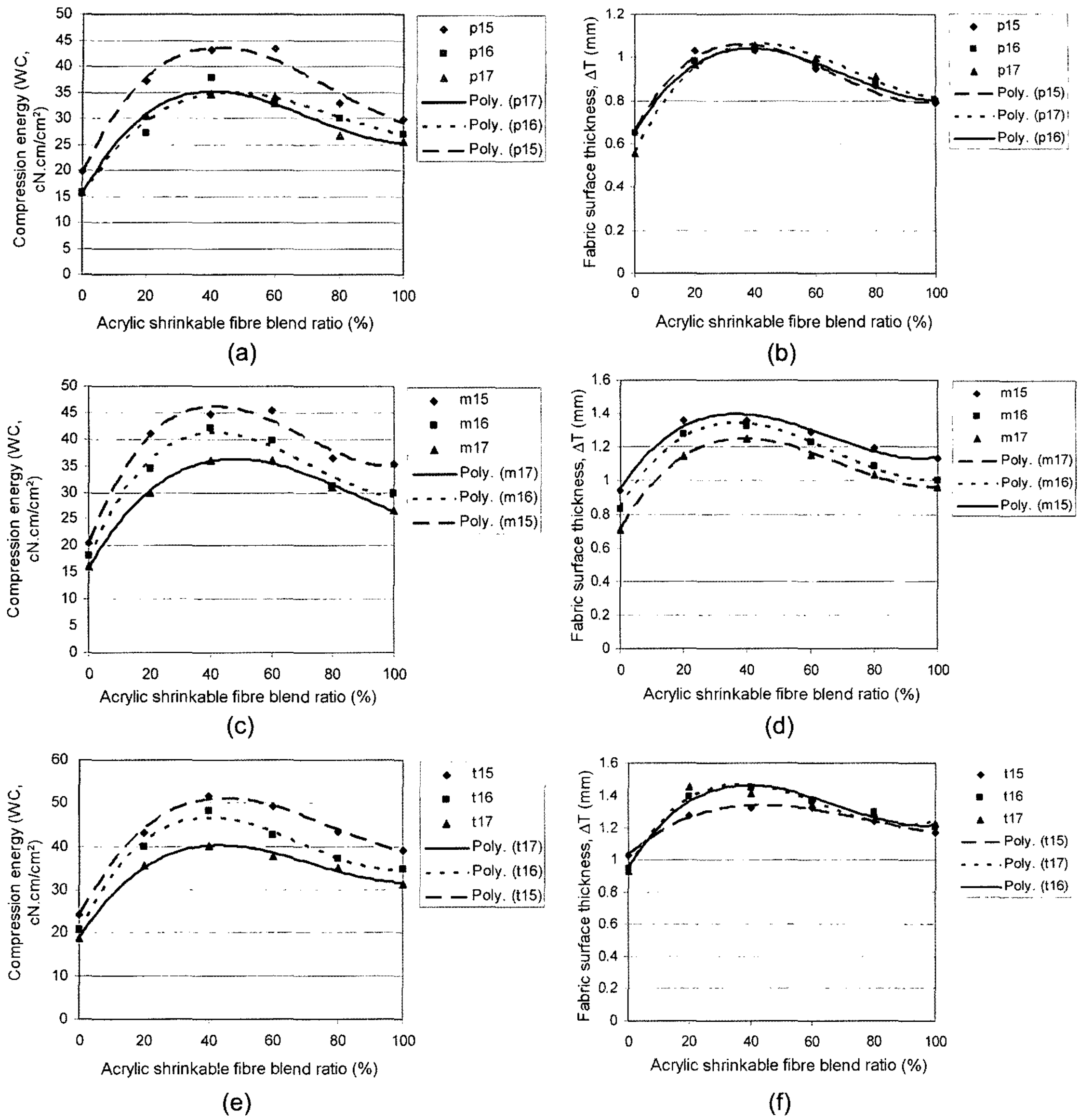

Figure 4. Effect of acrylic shrinkable fibre blend ratio on the fabric compression energy (WC) and fabric surface thickness (T) for (a,b): plain, (c,d): knit-miss and (e,f): knit-tuck weft-knitted structures.

of compression resilience. Another compression parameter is the linearity of the compression LC. It is shown that all fabrics compress nonlinearly have LC value between 20 % and 45 % in which at 40 % to 60 % shrinkable fiber blend ratio, the maximum LC is obtained. de-Jong *et al.* [16] found a similar values for the linearity (LC=22 %~50 %).

Conclusions

The aim of this paper was to investigate compressional properties of weft knitted fabrics consisting of shrinkable and non-shrinkable acrylic fibers with different blend ratio on. In this work, high-bulk worsted yarns with different shrinkable and non-shrinkable acrylic fibers blend ratios are produced and then single jersey weft knitted fabrics with three different structures and loop lengths are constructed. The physical properties of produced yarns and compression properties of produced fabrics at eight pressure values (50, 100, 200, 500, 1000, 1500 and 2000 g/cm^2) were measured using a conventional fabric thickness tester. Then, weft-knitted fabric compression behavior was analyzed using a two parameters model and compression parameters including the compression energy (WC), energy of compression recovery (W'C), dissipated compression energy E_m, compression resilience (RC), relative compressibility (EMC), linearity of compression (LC) and fabric compression deformation or

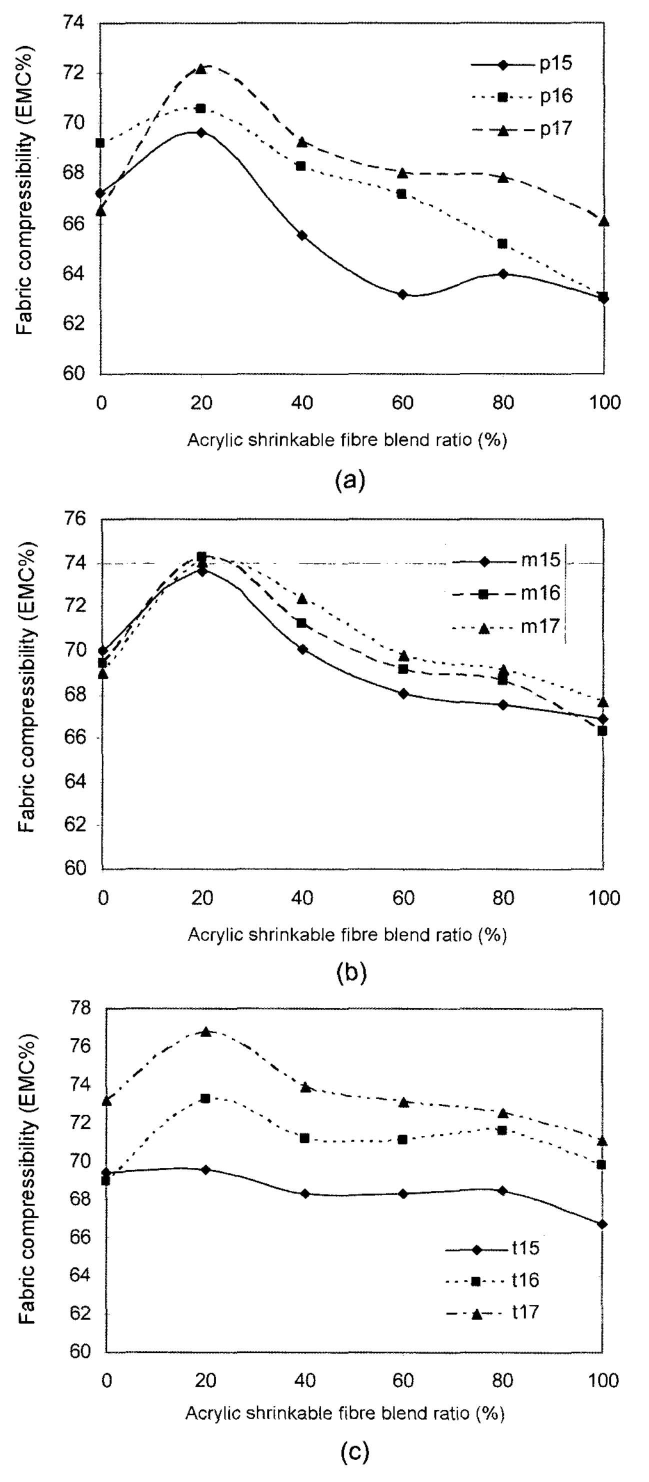

Figure 5. Effect of acrylic shrinkable fibre blend ratio on the fabric compressibility (EMC%) for (a) plain, (b) knit-miss, and (c) knit-tuck weft-knitted structures.

fabric surface thickness (ΔT) were investigated.

The experimental results show that at 40 % shrinkable fiber blend ratio, the highest high-bulk yarn specific volume

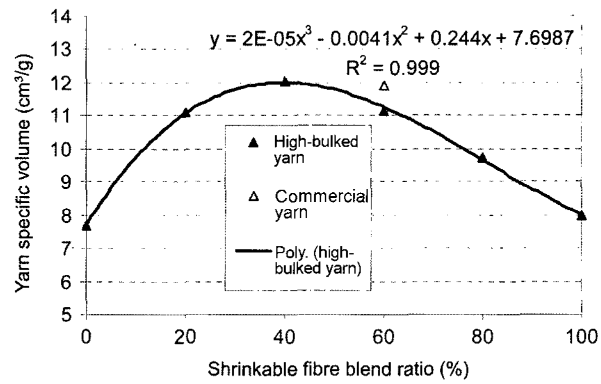

Figure 6. Effect of shrinkable fiber blend ratio on yarn specific volume.

and hence maximum compression energy and fabric surface thickness are obtained. In addition, the statistical regression analysis revealed that the compression behavior of high-bulked acrylic weft-knitted fabrics is highly closed to that of two parameters model proposed by de-Jong *et al.* [16]. It is also shown that for weft-knitted structure, there is an incompressible layer (V') which resists against high compression load. Acrylic weft-knitted fabrics with knit-tuck structure exhibit higher compression rigidity and lower softness than the plain and knit-miss structures. In addition, at 20 % shrinkable fibre blend ratio the high-bulked acrylic weft-knitted fabrics are highly compressible.

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