Journal of the Textile Institute
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t778164490

A theoretical approach to pile yarn-shedding mechanism of chenille yarn

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Online Publication Date: 01 January 2007

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Date Submitted 12 August 2005, Date Accepted 10 January 2006 doi:10.1533.joti.2005.0179

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Abstract: Chenille yarn is a popular fancy yarn and has found widespread use. It is accepted that the main problem of chenille yarn is loss of mass from abrasion. This study examines the mass loss from both theoretical and practical consideration. It is shown that the compressive force on pile yarn fibres increases and the contact area between pile and lock yarn through which compressive forces are transmitted decreases, as pile yarn count (Ne) increases.

Key words: Chenille yarn, abrasion resistance, pile yarn, lock yarn, pile length.

NOTATION

N_m	Length in meter of a gram of weight, metric yarn count ($N_m = 1.693 \times N_e$)
N_e	English yarn count
dtex	Weight in gram of 10,000 meters of fibre (dtex $= \frac{10,000}{N_m}$)
dtex_{py}	Pile yarn count in dtex
dtex_{ly}	Lock yarn count in dtex
dtex_f	Fibre count in dtex
n_f	Number of fibres in cross section of yarn ($n_f = \frac{\text{dtex}_y}{\text{dtex}_f}$)
n_{pf}	Number of fibres in cross section of pile yarn ($n_{pf} = \frac{\text{dtex}_{py}}{\text{dtex}_f}$)
n_{lf}	Number of fibres in cross section of lock yarn ($n_{lf} = \frac{\text{dtex}_{ly}}{\text{dtex}_f}$)
m	Mass (g) ($m = \rho \cdot V$)
ρ	Specific gravity of fibre (g/cm^3)
V	Volume (cm^3) ($V = L \cdot \pi \cdot r^2$)
L	Length in cm of m of mass
l	Length of a twist helix (step) ($l = \frac{100}{860} = 0.1163$ cm for our sample)
R_f	Radius of fibre (cm)
A_f	Cross-sectional area of fibre (cm^2)
A_y	Cross-sectional area of yarn (cm^2)
A_{ly}	Cross-sectional area of lock yarn ($A_{ly} = \pi \cdot R_l^2$)
A_{py}	Cross-sectional area of pile yarn ($A_{py} = \pi \cdot R_p^2$)
R_p	Radius of pile yarn (cm)
R_l	Radius of lock yarn (cm)
ϕ	Packing fraction of fibre
γ	Twisting angle (degree)
τ	Tension force of lock yarn
τ_y	The vertical component of tension force of lock yarn (compressive force on pile yarn)
τ_x	The horizontal component of tension force of lock yarn
τ_{yf}	Compressive force per fibre
A_{ca}	Contact area between a couple of pile lock yarns (cm^2)

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INTRODUCTION

Chenille yarn, which is a fancy yarn, has an interesting appearance and unique characteristics. In recent years its importance has increased. It can be woven and knitted into fabric. Generally, it is preferred as weft yarns in weaving (International Textile Reports, 2004). It is used to produce fashionable fancy products over a wide range from bed-spreads to furniture and automotive upholstery (Kalaoğlu and Demir, 2001).

Chenille yarn has many positive properties but it has also some negative features. The key problem associated with Chenille yarns is the high rate of pile loss against rubbing (Babaarslan and İlhan, 2005; Kalaoğlu and Demir, 2001). This is a particular problem for upholstery fabrics where chenille yarn is used commonly. The pile loss leads to a corruption of the aesthetic appearance of the fabric.

Chenille yarn has a multi-component structure. The first component is composed of two or more yarns twisted together. The lock yarns hold the pile yarns located vertically between the lock yarns and provide strength to the chenille yarn. The second component is the pile yarns which are located vertically and consecutively between the lock yarns. The pile yarns are cut to different lengths and protrude transversely all around the lock yarns (Fig. 1a).

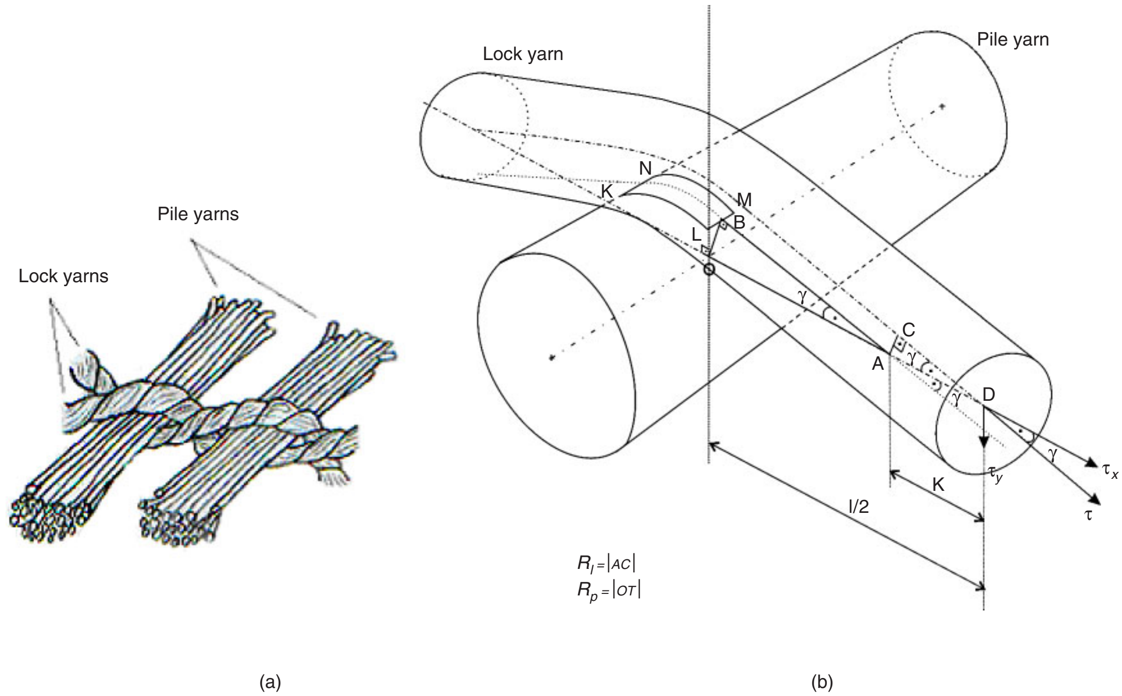

Figure 1 The structure of chenille yarn: (a) the force analysis and (b) contact area.

The pile yarns determine the volume, hand and appearance of chenille yarns. The pile yarns or fibres normally are held by mechanical friction forces between the lock and the pile yarns (Tung and Whitehead, 1997). These friction forces arise due to the twisting of the chenille yarn. As the twist level of chenille yarn is increased, the mass (pile) loss of woven fabric with chenille yarn tends to decrease (Ülkü *et al.*, 2003). Abrasion has a tendency to remove pile fibres from the body of the yarn but a major proportion of the fibres is also broken (İlhan, 2004, Babaarslan and İlhan, 2005).

The main factors that contribute to mass loss are twist of chenille yarn, type of raw material (fibre), pile length and the properties of lock and pile yarns. If the mass loss occurs because of the pile fibres breakages, then the properties of fibres and the pile length are determining factors. Naturally, the weaker fibres tend to be broken and it has been shown that the longer piles are subjected to more friction forces with rubbing (İlhan, 2004, İlhan and Babaarslan, 2005).

Pile fibres are completely pulled out when the effective forces on the pile yarn are greater than the friction forces between the lock and pile yarns. The forces that hold the pile fibres between the couple of lock yarns are the compressive forces provided by the twisted lock yarns. The most important factors that determine the compressive forces are the mass of pile fibres gripped between the lock yarns (pile yarn count) and the twist level of chenille yarn. It has been shown that the compressive forces increase and mass loss decreases as the twist level of chenille yarn increases (Ülkü *et al.*, 2003). It is also clear that as the mass of pile fibres increases while other factors remain constant, the tension in the lock yarns will increase and consequently the compressive forces will also increase.

Studies on chenille yarns carried out so far are generally practical. To gain a deeper understanding, a theoretical study of chenille yarns would be useful. An earlier practical study on the factors that affect the abrasion of chenille yarn and how the mass loss occurred has been carried out (Babaarslan and İlhan, 2005). In this study, the conditions under which the pile fibres are pulled out completely from between the lock yarns are investigated using a theoretical approach.

THEORETICAL APPROACH

In this study, a theoretical approach in which the relation of the pile yarn count with the compressive forces on pile fibres and the contact area of lock-pile yarns has been investigated.

The assumptions are as follows:

1. all the yarns and fibres in the chenille yarns are cylindrical and their radius are constant;
2. twist is distributed uniformly and equally along the yarns;
3. a single pile yarn is gripped in a twist helix of chenille yarn;
4. the raw material is acrylic fibres, its specific gravity is $\rho = 1.18$ g/cm^3 and fineness is 1.3 dtex; and
5. twist level of chenille yarn is 860 tpm and the count of lock yarn is Ne 24/1.

The model of chenille yarn assumed and the analysis of forces for this yarn are given sequentially in Figures 1a and b.

 doi:10.1533.joti.2005.0179

While the chenille yarn is twisted, the lock yarns face to a resistance of the mass of pile fibres. So the tension force "τ" arises (Fig. 1b). As the twist level increases, the increased "τ" forces the lock yarn to extend but it is not possible. Then the chenille yarn will have to be contracted due to twisting (Hearle *et al.*, 1969).

The forces that grip the pile fibres have an effect on the contact area between the lock yarn and pile fibres. If we take the rectangular curved area KLMN as shown in Figure 1b, then the only force acting on it is the vertical component (τ_y) of the tension force (τ). The horizontal component (τ_x) of the tension force (τ) can be neglected since the pile fibres are not affected by the horizontal component (τ_x) (Fig. 1b). Here, the contact area is not probably a perfect rectangular but we accepted it a perfect rectangular curved area to simplify the problem. We must also mention that considering the flattening of lock yarns we neglected that a couple of lock yarns which surrounded the pile yarn in a twist helix are located slightly crosswise to simplify the problem. Because of crosswise location of the lock yarns, there must be τ_z components of τ tension force. τ_z components, which are not shown in Figure 1b, are in both ends of lock yarn piece in Figure 1b and parallel with axial line of pile yarn. Since they have opposite directions according to each other, we can eliminate them. Therefore it seems that τ_y components are unique effective forces on pile yarn.

The main factors affecting the friction forces between the pile and lock yarns are as follows:

- τ_y, the vertical component of tension force;
- the contact area between the lock and pile fibres;
- kind of fibre used in the lock and pile yarn;
- the structure of the lock and pile yarn (ring, OE-rotor etc.); and
- twist level of chenille yarn.

In this work, the last three factors were held constant and only the first two factors have been investigated. The mass of pile fibres (determined by the radius of pile yarn) is gripped between the couple of lock yarns affects τ_y and the contact area, so it will be an effective parameter on the amount of pile loss. τ_y is distributed to pile fibres through the contact area. It is mentioned in an earlier paper that the quantity of compressive forces per a pile fibre is more important contributory factor than the quantity of forces per pile yarn in the prevention of pile loss (İlhan and Babaarslan, 2005).

After developing a theoretical approach on the basis of the assumption mentioned above, we investigated how the count of pile yarn changes the quantity of compressive forces on pile fibres and the contact area between pile and lock yarns using equations derived from the theoretical approach. For this purpose, we have assumed that the count of pile yarn changes from Ne 16 to Ne 60. All the other parameters are constant. The amount of compressive forces per pile fibre and the values of contact areas were calculated. Here, the effects of pile yarn count on the chenille yarn count were neglected.

To investigate the relation between the pile yarn count (pile yarn radius) and the compressive forces per fibre in cross section of pile yarn, we calculated the proportions of all $\dot{\tau}_y$ to the base τ_y of Ne 16 level and plotted a graph.

We obtained the following equation from Figure 1b:

$$tg\gamma = \frac{\tau_y}{\tau_x} \tag{1}$$

The packing fraction of fibres in the yarn cross section ϕ was used to calculate the yarn radii. This value was assumed as 0.3 for our sample yarns with acrylic fibres because we did not find out any accepted value for acrylic fibres in literature. We have neglected the effect of twist to determine ϕ value (Hearle *et al.*, 1969). The packing fraction can be formulated as shown in Equation (2) (Hearle *et al.*, 1969).

$$\phi = \frac{\sum A_f}{A_y} \tag{2}$$

The cross-sectional area of an acrylic fibre can be calculated using equations given in notation as follows:

$$m = \rho \cdot V = \rho \cdot L \cdot \pi \cdot R_f^2$$

$$R_f = \sqrt{\frac{m}{\rho \cdot L \cdot \pi}} \tag{3}$$

$$R_f = \sqrt{\frac{1.3}{1.18 \times 10000 \times 100 \cdot \pi}} = 5.92 \times 10^{-4}\text{cm}$$

This allows us to calculate the cross-sectional area of an acrylic fibre as follows:

$$A_f = \pi \cdot R_f^2$$

$$A_f = \pi \cdot (5.92 \times 10^{-4})^2 = 1.1 \times 10^{-6}\ \text{cm}$$

The values of n_{pf}, A_{py} and R_p can be calculated for every level of pile yarn count neglecting the practical effects of possible projection differences for cross-sectional areas of fibres, the total cross-sectional area of fibres in pile yarn was calculated with Equation (4):

$$\sum A_f = n_{pf}.A_f \tag{4}$$

The value of n_{pf} can be calculated with Equation (5).

$$n_{pf} = \frac{\mathrm{d}tex_{py}}{\mathrm{d}tex_f} \tag{5}$$

We obtain A_{py} from Equation (2) as follows:

$$A_{py} = \frac{\sum A_f}{\phi} \tag{6}$$

After the value of $\sum A_f$ was calculated with Equations (4) and (5), the radius of pile yarn (R_p) was calculated as follows:

$$A_{py} = \pi \cdot R_p^2 \tag{7}$$

$$R_p = \sqrt{\frac{A_{py}}{\pi}}$$

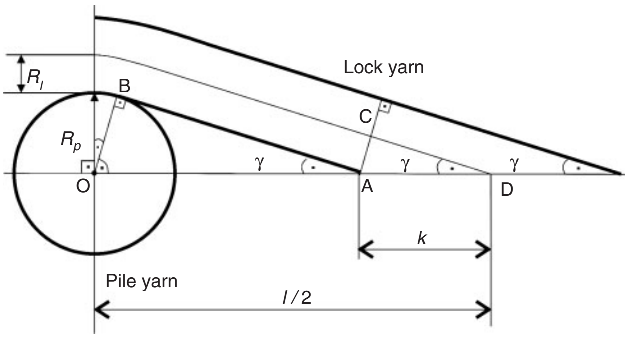

Figure 2 Appearance of a chenille yarn model in cross section of pile yarn.

As seen in Equation (1), if values of γ angles are known, values of $\tan\gamma$ can be calculated. So, it is possible to calculate the proportions of all τ_y to τ_y of Nm 16 level.

The interaction of the pile and lock yarns and location of components in our model of chenille yarn selected are given in Figures 1b and 2.

The following equations can be formulated from *OAB* triangle in Figure 2.

$$\mathrm{Sin}\gamma = \frac{R_p}{\frac{l}{2} - k}$$

$$\mathrm{Sin}\gamma = \frac{2 \cdot R_p}{l - 2 \cdot k} \tag{8}$$

The following equations can be formulated from *ACD* triangle in Figure 2.

$$\mathrm{Sin}\gamma = \frac{R_l}{k}$$

$$k = \frac{R_l}{\mathrm{Sin}\gamma} \tag{9}$$

By using Equation (9) in Equation (8), we have

$$\mathrm{Sin}\gamma = \frac{2 \cdot R_p}{l - 2 \cdot \frac{R_l}{\mathrm{Sin}\gamma}}$$

and $$\gamma = \mathrm{ArcSin}\left(\frac{2 \cdot (R_p + R_l)}{l}\right) \tag{10}$$

In Equation (10), we have to know R_l in order to calculate γ angle. R_l can be calculated using Equations (4–6) and (7) for lock yarn as follows:

$$n_{lf} = \frac{\mathrm{d}tex_{ly}}{\mathrm{d}tex_f}$$

$$A_{ly} = \frac{\sum A_f}{\phi} = \frac{n_{lf}.A_f}{\phi}$$

$$R_l = \sqrt{\frac{A_{ly}}{\pi}}$$

Now, we can calculate all $\tan\gamma$ of every level of pile yarn count and the proportions of the compressive force per pile fibre of all level of pile yarn count to Ne 16 level. We use Equation (1) to do this. If we assumed that $\tan\gamma_1$ and $\tan\gamma_2$ belong to two different levels of our samples. We can obtain the following equations:

$$\frac{\tan\gamma_2}{\tan\gamma_1} = \frac{\frac{\tau_{y2}}{\tau_{x2}}}{\frac{\tau_{y1}}{\tau_{x1}}}$$

$$\frac{\tau_{y2}}{\tau_{y1}} = \frac{\tan\gamma_2}{\tan\gamma_1} \tag{11}$$

Here, it is accepted that $\tau_{x1} = \tau_{x2}$. Because they have equal force and opposite direction (Fig. 1b).

τ_y component of compressive forces has to distribute to all fibres in order to hold them together. We have assumed that the total compressive forces on yarn (τ_y) are distributed equally to all fibres and formulated as following equations.

$$\tau_y = \tau_{yf} \cdot n_{pf}$$

$$\tau_{yf} = \frac{\tau_y}{n_{pf}} \tag{12}$$

For the two yarns we have the following:

$$\frac{\tau_{yf2}}{\tau_{yf1}} = \frac{\tau_{y2} \cdot n_{pf1}}{\tau_{y1} \cdot n_{pf2}} = \frac{\tan\gamma_2 \cdot n_{pf1}}{\tan\gamma_1 \cdot n_{pf2}} \tag{13}$$

Now, we can calculate the proportion of the forces per fibre in the pile yarn cross section of any chenille yarn to other by using Equation (13).

We have mentioned earlier that the contact area between the lock and pile yarns should also be considered. The contact area has to change, depending on the levels of pile yarn count, and so the compressive forces per fibre in the pile yarn cross section will also change. This fact has also been theoretically investigated as follows.

The contact areas ($\overset{\cap}{b}_1$, $\overset{\cap}{b}_2$) between pile and lock yarns for two chenille yarns whose pile yarn radii are different have been shown in Figure 3. In Figure 3, the length of arc ($\overset{\cap}{b}$) represents the contact area between pile and lock yarn.

The proportion of the contact areas is equal to the proportion of the lengths of $\overset{\cap}{b}$ arcs between two samples, as shown in Figure 3. Because the lock yarn radii are same for the two samples, and so the width of the contact areas for the two samples is also same. Therefore the proportion of the contact areas is equal to the proportion of $\overset{\cap}{b}$ arcs between two samples. The length of $\overset{\cap}{b}$ arcs was calculated with Equation (14).

$$\overset{\cap}{b} = \frac{\pi \cdot R_p \cdot \gamma}{90} \tag{14}$$

$\overset{\cap}{b}_1$ and $\overset{\cap}{b}_2$ can be formulated as follows:

$$\overset{\cap}{b}_1 = \frac{\pi \cdot R_{p1} \cdot \gamma_1}{90} \tag{15}$$

$$\overset{\cap}{b}_2 = \frac{\pi \cdot R_{p2} \cdot \gamma_2}{90} \tag{16}$$

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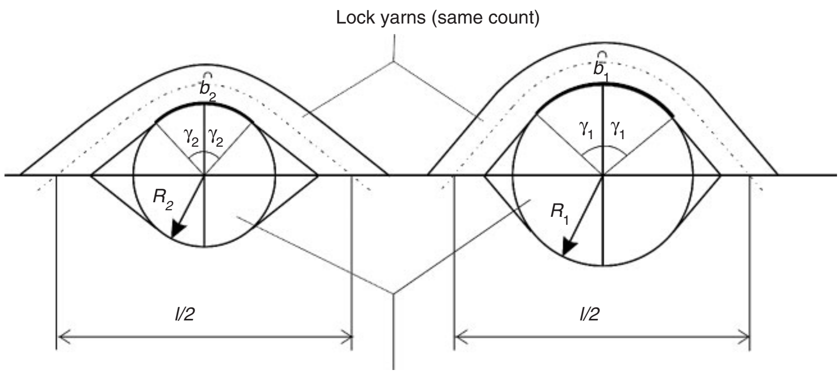

Figure 3 The cross-sectional model of two chenille yarns with different pile yarn radii.

γ angles can be calculated with Equation (10). The proportions of the contact areas of all levels to the value of the base level have been calculated as follows.

$$\frac{A_{ca2}}{A_{ca1}} = \frac{\overset{\cap}{b}_2}{\overset{\cap}{b}_1} = \frac{\pi \cdot R_{p2} \cdot \gamma_2}{90} \cdot \frac{90}{\pi \cdot R_{p1} \cdot \gamma_1} = \frac{R_{p2} \cdot \gamma_2}{R_{p1} \cdot \gamma_1} \tag{17}$$

Equation (17) provides a means of investigating how the contact area changes when there is a change in the pile yarn radii.

As seen in Equation (13), the number of fibres in the cross section of pile yarn directly affects the compressive forces on the pile fibres. We have therefore theoretically investigated how the fineness of fibres affects the compressive forces per fibre. We have assumed that the pile and lock yarn count are constant as Ne 24.

Firstly, the relation of fibre fineness with the γ angles placed in Equation (13) should be determined. Equations (18), (19) and (20) were obtained using some equations given in notation and Equations (3), (4), (6) and (7).

By substitution we have

$$R_p = \sqrt{\frac{n_{pf} \cdot m}{\rho \cdot L \cdot \phi \cdot \pi}} \tag{18}$$

We know that $(\frac{m}{L} = \frac{\mathrm{d}tex_f}{10^6})$. By transforming Equation (18), we have

$$R_p = \sqrt{\frac{n_{pf}.\mathrm{d}tex_f}{\rho \cdot \phi \cdot \pi}} \tag{19}$$

Substituting $n_{pf} = \frac{\mathrm{d}tex_{py}}{\mathrm{d}tex_f}$, we obtain

$$R_p = \sqrt{\frac{\mathrm{d}tex_{py}}{\rho \cdot \phi \cdot \pi}} \tag{20}$$

In this equation, because ρ, ϕ and π are constant, the radius of pile yarn will change directly depending on the pile yarn count. As we accepted that the pile yarn count is constant before, the radius (R_p) will be constant, too. We can say that R_l is also constant with same method. The helix length and pile-lock yarn radii are constant in Equation (10) and γ angles for all levels of fibres fineness will not change. Therefore, if the pile yarn count is constant, as seen in Equation (11), the proportions of forces on yarn will be equal to 1.

$\frac{\tan\gamma_2}{\tan\gamma_1} = 1$ is substituted into Equation (13), then we obtain

$$\frac{\tau_{yf2}}{\tau_{yf1}} = \frac{\tan\gamma_2 \cdot n_{pf1}}{\tan\gamma_1 \cdot n_{pf2}} = 1 \cdot \frac{n_{pf1}}{n_{pf2}} = \frac{n_{pf1}}{n_{pf2}} \tag{21}$$

In Equation (21), it is understood that the forces per fibre and the proportions of the forces directly depend on the number of fibres in the pile yarn cross section when the pile and lock yarn count are constant.

As seen in Equations (10) and (11), the amount of forces on pile yarn is proportional to γ angles or yarn radii. It has been explained above that when the radius of pile yarn is constant the amount of forces on pile yarn is also constant. In this case, as the number of fibres in cross section decreases, the forces per fibre increase. Nevertheless, if flattening of yarn is ignored then the number of fibres in yarn cross section decreases, so the contact area between the fibres decrease, too. So, while the radius of pile yarn and the total amount of forces on yarn do not change, as the number of fibres in cross section decrease, the radius of fibres will have to be increased. Therefore, the contact area between fibres decreases and the amount of pressure per unit area on fibres that hold the fibres together increases. Clearly the interaction between pile yarn and fibre radii needs to be considered. Therefore, it is necessary to perform an optimisation study in order to determine the ideal values for minimum pile loss. Finally, some other factors must be also considered for chenille yarn besides abrasion resistance such as appearance, hand and cost.

THEORETICAL RESULTS

Equations obtained from the theoretical study are used to find out how any change of pile yarn count affects the compressive forces on pile fibres and the contact area between

Table 1 **Calculation of pile yarns radii**

Order no.	Pile yarn count			n_{pf}	$\sum A_f$ (cm^2)	A_{py} (cm^2)	R_p (cm)
	Ne_{py}	Nm_{py}	dtex_{py}				
1	16	27.09	369.17	284	3.12×10^{-4}	1.04×10^{-3}	0.0182
2	20	33.86	295.33	227	2.50×10^{-4}	8.33×10^{-4}	0.0163
3	24	40.63	246.11	189	2.08×10^{-4}	6.94×10^{-4}	0.0149
4	28	47.40	210.95	162	1.78×10^{-4}	5.95×10^{-4}	0.0138
5	32	54.18	184.58	142	1.56×10^{-4}	5.21×10^{-4}	0.0129
6	36	60.95	164.07	126	1.39×10^{-4}	4.63×10^{-4}	0.0121
7	40	67.72	147.67	114	1.25×10^{-4}	4.16×10^{-4}	0.0115
8	44	74.49	134.24	103	1.14×10^{-4}	3.79×10^{-4}	0.0110
9	48	81.26	123.06	95	1.04×10^{-4}	3.47×10^{-4}	0.0105
10	52	88.04	113.59	87	9.61×10^{-5}	3.20×10^{-4}	0.0101
11	56	94.81	105.48	81	8.92×10^{-5}	2.97×10^{-4}	0.0097
12	60	101.58	98.44	76	8.33×10^{-5}	2.78×10^{-4}	0.0094

Table 2 **Calculation of tan γ proportions**

Order no.	Ne_{py}	R_p	R_l	γ	tan γ
1	16	0.0182	0.01487	34.67	0.6917
2	20	0.0163	0.01487	32.39	0.6344
3	24	0.0149	0.01487	30.75	0.5949
4	28	0.0138	0.01487	29.50	0.5658
5	32	0.0129	0.01487	28.50	0.5430
6	36	0.0121	0.01487	27.68	0.5246
7	40	0.0115	0.01487	26.99	0.5093
8	44	0.0110	0.01487	26.40	0.4964
9	48	0.0105	0.01487	25.88	0.4851
10	52	0.0101	0.01487	25.43	0.4755
11	56	0.0097	0.01487	25.03	0.4669
12	60	0.0094	0.0149	24.67	0.4593

the pile and lock yarns that are determining factors for the pile loss. We consider the pile yarn counts graded from Ne 16 to Ne 60. All the proportions of compressive forces on the pile fibres and the contact area between the pile and lock yarns of every level to the values of Ne 16 level were calculated. We have plotted graphs with the data obtained and analysed the results. Firstly, we obtained the radii of pile yarns of every level as seen in Table 1. For these calculations, it is necessary to know the value of lock yarn radius (R_L). This value was calculated using Equations (4–6) and (7) for lock yarn are as follows.

$$n_{lf} = \frac{\mathrm{d}tex_{ly}}{\mathrm{d}tex_f} = \frac{\frac{10{,}000}{Ne \cdot 1.693}}{\mathrm{d}tex_f} = \frac{\frac{10{,}000}{24 \times 1.693}}{1.3} = 189.32 \text{ fibres}$$

$$A_{ly} = \frac{\sum A_f}{\phi} = \frac{n_{lf} \cdot A_f}{\phi} = \frac{189.32 \times 1.1 \times 10^{-6}}{0.3}$$

$$= 6.94 \times 10^{-4} \text{ cm}$$

$$R_l = \sqrt{\frac{A_{ly}}{\pi}} = \sqrt{\frac{6.94 \times 10^{-4}}{3.14}} = 0.01487 \text{ cm}$$

Data in Table 1 were obtained from the equations mentioned above.

Data in Table 2 are obtained by using Equations (7) and (10). Data in Table 3 were obtained using the data from Tables 1 and 2 and Equation (13). We have plotted graphs in Figure 4 in which all the values of every level are as a proportion to the value of Ne 16 level.

As seen in Figure 4, the compressive force per fibre theoretically increases as the pile yarn becomes finer.

Data in Table 4 were obtained using the data in Table 2 and Equation (17) to investigate how any change in pile yarn count affects the contact area between the pile and lock yarn.

The proportion of contact areas was calculated as proportion to the value of Ne 16 level and showed graphically in Figure 5.

Figure 5 shows that the contact area decreases as pile yarn becomes finer.

Our findings show that the contact area between pile and lock yarn decreases as pile yarn becomes finer and all the other factors are constant. The compressive forces per yarn affect smaller areas of fibres as the contact area decreases. It is expected that the tension forces in the lock yarn and the compressive forces on the pile yarn decrease as the pile yarn radius is decreased. However,

 doi:10.1533.joti.2005.0179

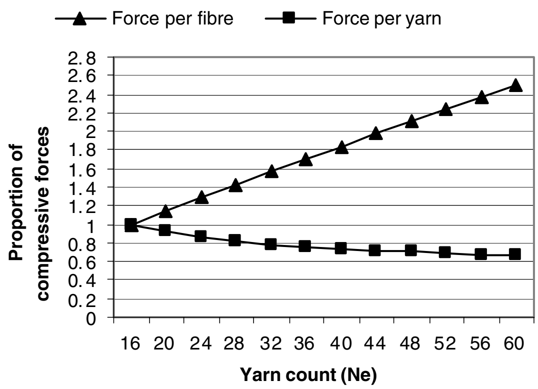

Figure 4 The relation of pile yarn count with the compressive forces per fibre.

Table 3 **The proportions of compressive forces per fibre**

Order no.	Ne_{py}	$\frac{\tan\gamma_{(n)}}{\tan\gamma_{(1)}}$	n_{pf}	$\frac{n_{pf(1)}}{n_{pf(n)}}$	$\frac{\tau_{yf(n)}}{\tau_{yf(1)}}$
1	16	1.000	284	1	1
2	20	0.917	227	1.250	1.15
3	24	0.860	189	1.500	1.29
4	28	0.818	162	1.750	1.43
5	32	0.785	142	2.000	1.57
6	36	0.758	126	2.250	1.71
7	40	0.736	114	2.500	1.84
8	44	0.718	103	2.750	1.97
9	48	0.701	95	3.000	2.10
10	52	0.687	87	3.250	2.23
11	56	0.675	81	3.500	2.36
12	60	0.664	76	3.750	2.49

at the same time the area on which the forces act also decreases and the force or pressure on unit area has to increase. Comparing Figures 4 and 5, we find that the acceleration of the contact area decreasing is more than what of the compressive forces on the yarn. The number of fibres in cross section also decreases as the pile yarn count becomes finer, leading to an increase of the forces per fibre.

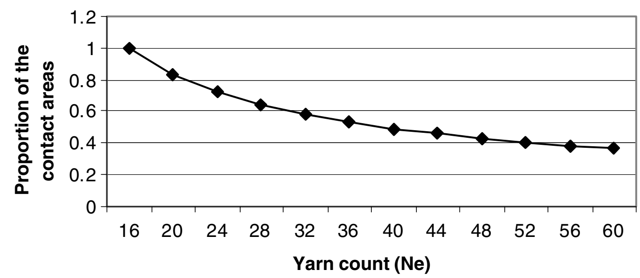

Figure 5 The relation of pile yarn count with the contact area between pile and lock yarn.

CONCLUSIONS

In chenille yarn, pile loss occurs because the pile fibres are broken or completely pulled out from between lock yarns. The forces that hold the pile fibres are compressive forces arising from the lock yarns. The main factors that determine the compressive force are the mass of pile fibre gripped by lock yarns (pile yarn count) and the twist level of chenille yarn. The compressive forces and pile loss decrease as twist of chenille yarn increase. While all the other parameters are constant, the increased mass of pile fibres leads to increase in the tension of the lock yarn and compressive forces.

In this study, we have theoretically investigated how any change of the pile yarn count affects the compressive forces. We have found that the compressive forces per fibre directly increase as the pile yarn becomes finer. In addition to this, the contact area between lock and the pile yarn on which the compressive forces affect decreases in a curvilinear fashion as the pile yarn becomes finer. When we have combined these two results, we can say that the compressive forces per pile fibre should increase as the contact area decreases.

The compressive forces on pile yarns change depending on pile yarn count. The compressive forces that affect the fibres in the cross section are determined by the total force on the yarn and, depending on the pile yarn count and the

Table 4 **Calculation of contact area proportions**

Order no.	Ne_{py}	R_p (cm)	γ	$\frac{A_{ca(n)}}{A_{ca(1)}}$
1	16	0.0182	34.67	1
2	20	0.0163	32.39	0.836
3	24	0.0149	30.75	0.724
4	28	0.0138	29.50	0.643
5	32	0.0129	28.50	0.581
6	36	0.0121	27.68	0.532
7	40	0.0115	26.99	0.492
8	44	0.0110	26.40	0.459
9	48	0.0105	25.88	0.431
10	52	0.0101	25.43	0.407
11	56	0.0097	25.03	0.386
12	60	0.0094	24.67	0.367

number of fibres in cross section, which in turn depend on linear density of the fibre.

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 doi:10.1533.joti.2005.0179