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Impact of abrasion on mass loss and appearance of injected slub yarn fabrics

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Effect of different slub parameters, viz. slub length, slub thickness and slub frequency, on abrasive damage of knitted fabric has been studied. Abrasive damage has been assessed by two ways, namely using loss in fabric mass and deterioration of fabric appearance due to abrasion. The effect of slub parameters, viz. slub length, its thickness and frequency in the injected slub yarn on mass loss of fabric due to abrasion is found to be different than consequent damage in surface appearance. It is observed that the visual effect of abrasion damage of fabric surface appearance is entirely opposite to that of conventional method of measuring abrasion damage in terms of fabric mass loss. In case of slub yarn fabrics, it is possible to have higher damage in surface appearance but lower mass loss of fabric and vice versa due to abrasion.

Keywords: Abrasion damage, Coefficient of concordance, Cotton fibre, Injected slub yarn, Ranking method

1 Introduction

Abrasion is the physical destruction of fibres, yarns and fabrics, resulting from the rubbing of a textile surface over another surface[1]. Abrasion distorts the fabric appearance by pulling out the yarns or removing fibre ends from the fabric surface[2,3]. In case of fancy yarn fabrics, abrasion is an important factor that decides the durability and appearance of fabric after repeated laundering. Abrasion first modifies the fabric surface and then affects the internal structure of the fabric by damaging it[4,5]. Abrasion resistance behavior of fabrics made with different types of conventional yarn as well as with different weave construction were studied by different researchers[6-13]. Very few studies are available for abrasive behavior of fancy yarn fabrics like flocked fabrics[14], fabric from chenille yarn[15]. Moreover, these studies[1-15] do not provide much insight into the abrasive behavior of newly developed injected slub yarns and fabrics. Injected slub yarn is completely different from normal slub yarns in terms of structure and properties. In this structure unlike the normal slub yarn, slubs are developed with the injection of drafted fibres from a roving into a separate base yarn. The base yarn is fed directly before the front delivery roller. The final injected slub yarn is developed with the sequence of untwisting the base yarn followed by re-twisting after injecting the fibres from drafted roving. Therefore, the migration and orientation of injected fibres within the base yarn is very much important for providing final yarn with sufficient strength and abrasion resistance. It is a critical and difficult yarn to manufacture as well as requiring higher amount of care in production. Injected slub yarns are categorized in two groups, namely single base injected slub yarn and double base injected slub yarn. There are different technologies available for injected slub yarn manufacturing. Basic concepts are same, but different additional drives are provided by different attachment supplier to achieve perfection of slub formation as per predefined pattern and to increase productivity. Present study is based on single base injected slub yarn. Schematic diagram of single base injected slub yarn manufacturing mechanism is shown in Fig.1.

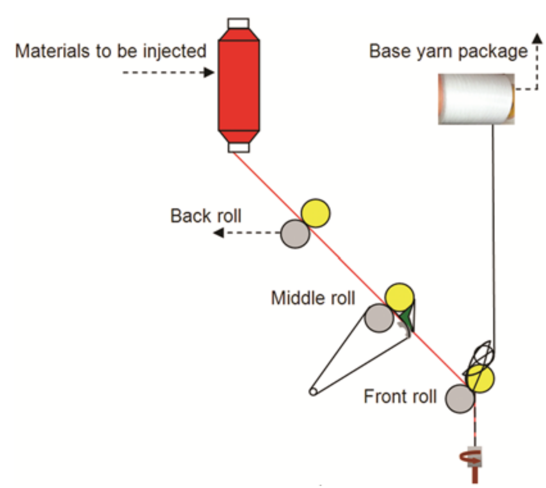

Fig. 1 — Schematic diagram of single base injected slub yarn manufacturing mechanism

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It is to be noted that the structure and surface characteristics of injected slub yarns change with the change in slub parameters like slub length, slub thickness and slub frequency in the yarn. Hence, the above parameters are also likely to influence the abrasion behaviour of corresponding fabric. However, till date no such literature is available related to abrasive behavior of injected yarn made fabric. Therefore, in the present work an attempt has been made to study the influence of injected slub yarn parameters on abrasion resistance behavior of corresponding fabric. It may be noted that several methods of measuring abrasion resistance of fabrics are available; however there is no linear relationship available between successive measurements using any of these methods and progressive amounts of abrasion[16]. In the present study two different methods of evaluation of abrasion resistance of fabric has been adopted, namely visual analysis followed by ranking method and conventional method of measuring fabric mass loss due to abrasion. In practice, however, visual analysis can be considered as more relevant for fabrics produced from injected slub yarns.

2 Materials and Methods

2.1 Materials

A variety of injected slub yarns made out of 100% cotton fibres (both base yarn fibres and injected fibres) were produced with different slub parameters, viz. slub length, slub thickness and slub frequency. Table 1 shows the characteristics of cotton fibres used for producing the aforementioned yarns. The actual values of different slub parameters corresponding to coded levels along with the experimental plan in accordance to Box Bhenken design[17] are given in Tables 2 and 3 respectively. It is to be noted that if the injection % is increased for increasing slub length or slub thickness or slub frequency, base yarn linear density is decreased proportionally to compensate the change in slub dimensions/frequency without changing the yarn linear density. All the yarn samples were produced in ring spinning (LR 6) system with

Table 1 — Raw material characteristics of cotton fibres used

Parameter (HVI)	S6 Grey (for base yarn)	S6 Dyed (for injection)
Fibre length, mm	30.3	28.5
Fibre fineness, micronaire	4.1	4.3
Fibre strength, g/tex	29.5	26.2
Elongation, %	7.12	6.8
Uniformity index	83.19	85
Short fibre index (SFI)	8.28	5.8

Table 2 — Actual values of different parameters corresponding to coded levels

Parameter	Levels of parameters (coded & actual)		
	-1	0	+1
Slub length, mm	30	65	100
Slub thickness, %	140	170	200
Slub frequency, slubs/m	1.5	2.5	3.5

Table 3 — Mass loss and damage in appearance at different level of input parameters

Sample ID	Coded value			Mass loss' % (*Y*m)			Damage in appearance (*Y*s)		
	X_1	X_2	X_3	Actual	Predicted	Residual	Actual	Predicted	Residual
1	1	1	0	11.03	10.86	0.17	4.14	6.478	-2.338
2	1	-1	0	10.58	9.92	0.66	6.29	4.238	2.052
3	-1	1	0	8.52	9.18	-0.66	6.0	6.478	-0.478
4	-1	-1	0	11.43	11.6	-0.17	4.0	4.238	-0.238
5	1	0	1	8.19	7.92	0.264	12.14	11.464	0.676
6	1	0	-1	8.68	8.79	-0.116	13.14	13.606	-0.466
7	-1	0	1	8.23	7.92	0.304	12.0	11.464	0.536
8	-1	0	-1	8.38	8.79	-0.416	11.86	13.606	-1.746
9	0	1	1	7.29	7.31	-0.021	13.29	12.729	0.561
10	0	1	-1	10.34	9.81	0.529	9.68	7.585	2.275
11	0	-1	1	9.17	9.68	-0.511	1.43	3.203	-1.773
12	0	-1	-1	8.96	8.92	0.039	12.57	12.631	-0.061
13	0	0	0	7.75	7.67	0.074	9.0	8.856	0.144
14	0	0	0	7.31	7.67	-0.366	8.71	8.856	-0.146
15	0	0	0	7399	7.67	0.314	9.57	8.856	0.714
16	0	0	0	7.66	7.67	-0.016	8.14	8.856	-0.716
17	0	0	0	7.67	7.67	-0.006	9.86	8.856	1.004

X_1 – Slub length (coded), X_2 – Slub thickness (coded) and X_3 – Slub frequency (coded).

Amsler technology of slub attachment. Slub parameters in the yarn were tested and verified on UT-5 instrument under fancy yarn profile. Yarn count, twist and twist direction were kept same for all the samples. The final yarn linear density of 30 ± 0.5 Ne with twist direction Z over S and final yarn TM of 7.8 were maintained for all the yarn samples. Yarn samples were converted into single jersey knitted fabrics in a 90 feeder circular knitting machine with 30 inches diameter and 28 needles per inch gauge. Knitted fabric specification was maintained at the same level for all the samples (Table 4). Thirteen treatment combinations and four additional center point observations were used to study the effect of these yarn parameters on abrasion resistance of fabrics produced from these yarns and fabric surface appearance. Measurements were repeated at center points of experiments (known as replication) to help identify the sources of variation, to better estimate the true effects of treatments, and to further strengthen the experiment's reliability and validity. The samples were prepared in a random order as the serial number in the order of 1, 8, 2, 9, 3, 17, 6, 12, 10, 11, 16, 5, 7, 4, 14, 15, 13. Reason for randomization is for effective statistical analysis through unbiased estimation of the impact of factors and for validity of inferences drawn.

2.2 Methods

All the samples were conditioned for 24 h at standard atmospheric conditions of laboratory, i.e. 20º ± 2ºC temperature and 65% ± 2% RH before conducting tests. Fabric samples were tested using Abramart abrasion tester following ASTM D 4966-98 Standard test method. Abrasion resistance was assessed after 45000 cycles of abrasion at a fixed pressure of 9 kPa, as standardized for clothing. The abrasion cycles were chosen based on initial trials to achieve consistent and reproducible results. The standard abrading cloth was replaced at the start of each test to ensure effectiveness of abrasive effect and to get accurate results. Mass loss of fabric (with a sensitivity of 1 mg) after a preset number of cycles was measured following ISO 12947-3 standard.

Table 4 — Knitting machine and knitted fabric (single jersey) parameters

Parameter	Value
Machine diameter, inch	30
Machine gauge, needles/inch	28
Fabric mass, g/m^2	130
Stitch length (length of yarn in mm / 100 loop)	32

Percentage of the mass loss was calculated using the formula given below:

$$\text{Mass loss } (Y_m),\ \% = \frac{\text{Fabric mass before abrasion} - \text{Fabric mass after abrasion}}{\text{Fabric mass before abrasion}} \times 100 \quad \text{... (1)}$$

Table 3 shows the mass loss percentage of fabrics due to abrasion. The images of fabric surface after abrasion were captured by Video analyzer instrument as per standard method, IS 1670-1998 RA 2002 and abrasive damage of fabric's surface appearance was estimated by visual analysis followed by ranking method. Details of ranks (R) from seven judges based on visual observation was noted and the coefficient of concordance (W) was calculated with the following formula[18]:

$$W = \frac{12S}{k^2\left(N^3 - N\right)} \quad \text{... (2)}$$

$$S = \sum\left(R_j - \overline{R}_j\right)^2 \quad \text{... (3)}$$

where k is the number of judges (7); N, the number of objects ranked (17); R_j, the individual rank; and $\overline{R}_j$, the average rank.

The significance of W was worked out by calculating the value of χ^2 using the following formula.

$$\chi^2 = k\,(N - 1)\,W \quad \text{... (4)}$$

The value is then compared with table value of χ^2 for (N – 1) degrees of freedom. Calculated values of coefficient of concordance (W = 0.490) for ranks given by different judges upon samples after abrasion is found to be significant [χ^2_{cal} (54.947) > χ^2_{table} (26.296)]. It indicates that there is significant agreement in ranking by different judges at 95% confidence level[18]. Average value of ranks for all samples is given in Table 3. Lowest value of average rank observed is 1.43 for sample 11 and accordingly sample 11 is found to have highest abrasion resistance followed by sample 4 (with average rank value 4) as the second best abrasion resistant fabric and sample 9 (with average rank value 13.29) is found to possess lowest abrasion resistance.

The data as obtained above in both the cases of evaluation was used to carry out regression analysis. The best fitted equations (Table 5) for fabric abrasive damage in terms of mass loss as well as damage in

Table 5 — Regression equations for abrasion damage of fabric in terms of mass loss and deterioration in fabric surface appearance

Parameter	Regression equation	R^2	SE	F	P
Mass loss, % (Y*m*)	$Ym = 7.676 - 0.370X_2 -.435X_3+1.072X_1^2+1.642X_2^2 -0.387X_3^2 +0.840X_1X_2-0.815X_2X_3$	0.92	0.478	15.82	0.001
Surface damage (Y*s*)	$Ys = 8.856 +1.12X_2-1.071X_3-3.498X_2^2 +3.679X_3^2 + 3.643X_2X_3$	0.87	1.498	15.64	0.001

X_1 – Slub length (coded), X_2 – Slub thickness (coded) and X_3 – Slub frequency (coded).

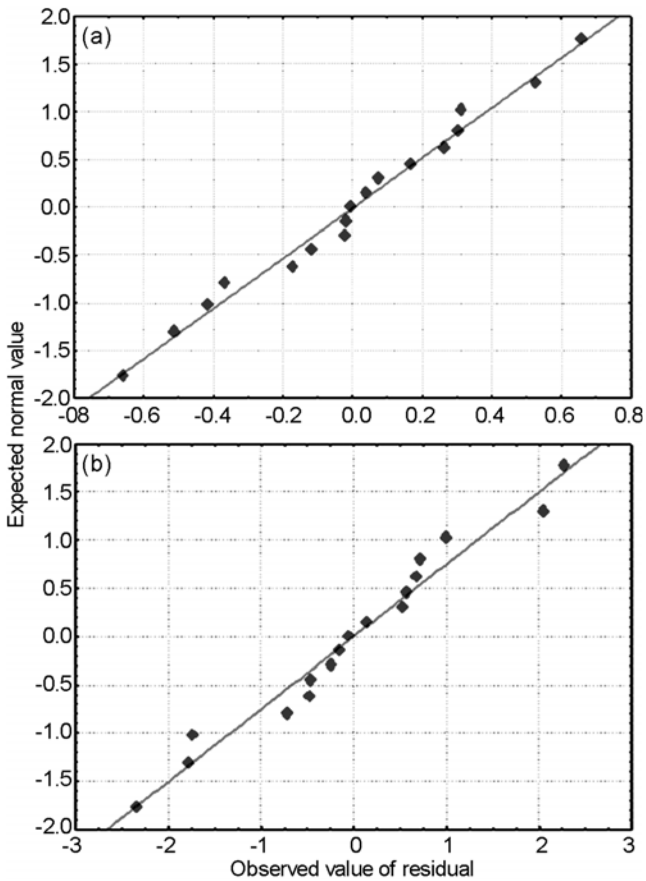

Fig. 2 — Normal probability plot of (a) residuals for mass loss (%) of fabric after abrasion and (b) residuals for loss in fabric appearance after abrasion

fabric surface appearance were generated by step wise (backward elimination) regression analysis using p = 0.05. For validity of regression equations, normal probability plots of residual as given in Fig. 2 have been studied. It may be added that predicted values as given in Table 3 were generated using regression equation. From the normal probability plots it is found that the residuals for each output parameters are fitted close to the normal distribution which validates regression equations. This is specifically more important in case of visual ranking of samples, as in this case discrete data set was generated initially based on subjective assessment of 7 experts. The average values of subjective rating are assumed as continuous function. Besides the above, plot of residuals

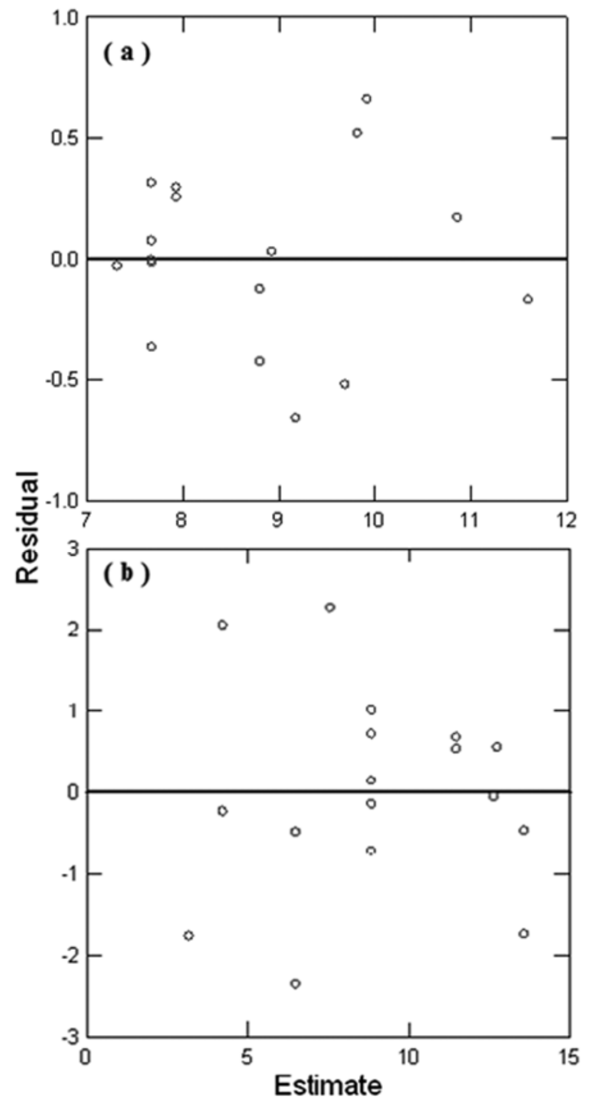

Fig. 3 — Plot of residuals *vs*. predicted value for (a) mass loss (%) of fabric after abrasion and (b) loss in fabric appearance after abrasion

vs. predicted value of abrasion damage (Fig. 3) shows no pattern; which also indicates suitability of regression equation for analysis of results.

3 Results and Discussion

3.1 Mass Loss Results

Regression equations in Table 5 show that all the three factors, such as slub length, slub thickness and slub frequency have significant influence over abrasive damage in terms of fabric mass loss. It can be seen from Fig. 4(a) that with the increase in both slub length and slub thickness, mass loss of fabric due to abrasion initially decreases and then increases. There also exists interaction effect between these two factors. Reduction in fabric mass is maximum when both of these factors are at higher levels. Longer slub in the yarn has lower amount of twist and it reduces further with the increase in slub thickness. During abrasion, fibres from the low twisted portion are easily pulled from the yarn structure and therefore lead to greater mass loss. However, at lower slub length, with the increase in slub thickness up to certain level, fibres in the slub part migrates well inside the base yarn. Besides that the number of fibres in the yarn cross section increases and therefore abrasive force per unit mass of fibre reduces, leading to lower abrasive damage. As slub thickness increases further, yarn compactness reduces predominantly because of twist distribution phenomenon and thus abrasion damage in terms of mass loss tends to increase.

The effect of slub thickness and slub frequency on fabric abrasion damage in terms of mass loss can be seen in Fig. 4(b). It is observed that in the case of yarn with lower slub thickness, fabric mass loss increases (due to abrasion) with the increase in slub frequency but it follows reverse trend at higher slub thickness. In case of yarn with lower slub thickness, fabric surface becomes more uneven with the increase in slub frequency and thus intensity of friction between abrader and fabric surface increases, causing increase in fabric mass loss. However, at higher slub thickness, with the increase in slub frequency, number of fibres under abrader surface increases causing less abrasive force per individual fibres resulting in lower damage to the fabric surface.

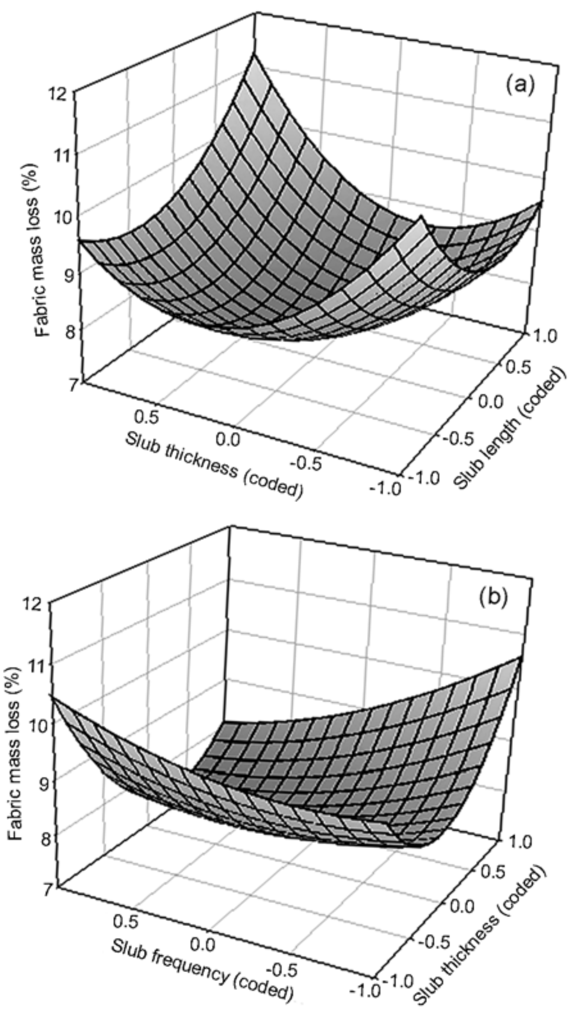

Fig. 4 — Impact of slub parameters of injected slub yarn on fabric mass loss during abrasion (a) effect of slub length and slub thickness and (b) effect of slub thickness and slub frequency

3.2 Damage in Fabric Appearance Results

Regression equation as derived from average ranks of judges on different materials exhibits quite high R^2 value indicating its efficacy to explain the impact of slub parameters on loss in fabric appearance due to abrasion. Interestingly, it is observed that slub length does not have significant influence on visual assessment of abrasion damage. Effect of injected slub yarn thickness and slub frequency along with their interaction effect are found to be significant (Fig. 5). Visual analysis shows that at lower slub thickness, abrasive damage in terms of deterioration in surface appearance of fabric decreases with the

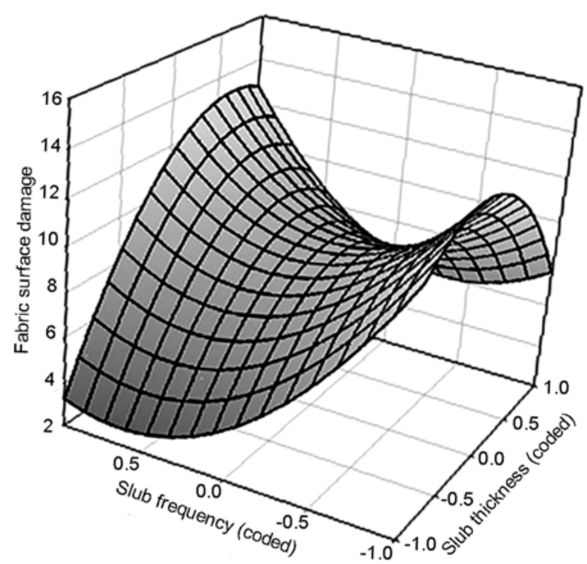

Fig. 5 — Effect of slub thickness and slub frequency of injected slub yarn on abrasive damage of fabric surface appearance

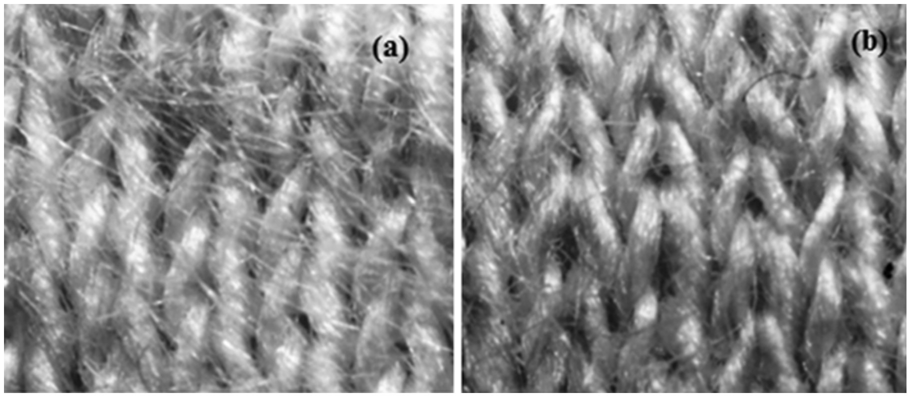

Fig. 6 — Change in surface appearance after abrasion (a) higher damage in surface appearance with less mass loss of fabric and (b) low damage in surface appearance with higher mass loss of fabric

increase in slub frequency. At higher slub thickness, fabric surface damage initially decreases marginally followed by significant increase with the increase in slub frequency. At lower slub thickness with the increase in slub frequency fabric surface roughness increases, resulting in intensive friction between fabric surface and abrader and thus the fibres are plucked off and removed completely. Therefore, fabric surface shows clean appearance instead of higher mass loss. This, in turn, indicates less deterioration in fabric surface appearance under visual observation in spite of higher mass loss as discussed in previous section. On the other hand at higher slub thickness, more number of fibres come under abrader with the increase in slub frequency. This causes less abrasive force per individual fibres and because of less intensive force upon individual fibres, fibres are pulled out from the yarn/fabric surface but not plucked off. This results in better abrasion resistance in terms of fabric mass loss but higher abrasion damage of fabric in terms of fabric surface deterioration.

The aforesaid findings bring out one important aspect in abrasive damage behaviour of injected slub yarn fabrics. It is possible to have higher damage in surface appearance with less mass loss of fabric and vice versa (Fig. 6). It is also seen that visual grade of fabric appearance damage due to abrasion is negatively correlated with fabric mass loss due to abrasion (Fig. 7). However, it can be noted that although the correlation is weak (r = - 0.55), but it is significant as F_{cal} (6.5) > F_{table} (4.54).

4 Conclusion

Present study embodies abrasive resistance behaviour of fabrics made with injected slub yarn as a function of its structural parameters, like slub length, slub thickness and slub frequency. Conscious

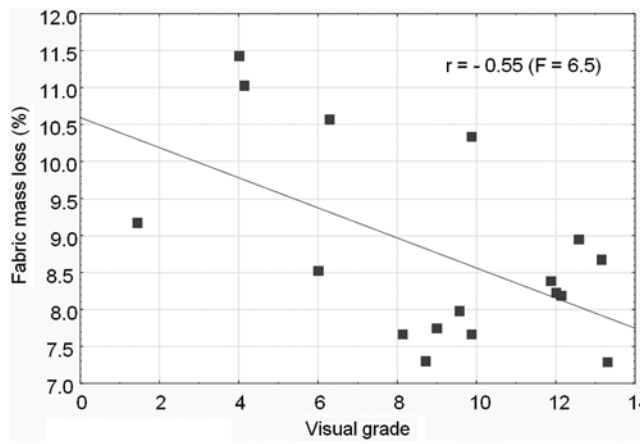

Fig. 7 — Relationship between fabric mass loss and change in visual grade due to abrasion

selection of the combination of these parameters is essential to ensure better abrasion resistance of the fabrics produced. However, the response of slub parameters on abrasion damage is entirely different. It is found that in the present case slub length of fancy yarn does not have influence on surface deterioration due to abrasion, whereas fabric mass loss initially decreases and then increases as the slub length increases. Slub thickness also shows similar effect on fabric mass loss. Slub length and slub thickness also show interactive effect on fabric mass loss. Higher slub length and higher slub frequency lead to significant loss in fabric mass during abrasion. At lower slub thickness, as slub frequency increases, fabric mass loss increases significantly, but surface appearance does not show significant change, whereas at higher slub thickness, significant loss in fabric appearance along with lower mass loss is observed.

Present study reveals that both these aforementioned measurement are negatively related to some extent. It is evident from this study that more deterioration of surface appearance does not necessarily mean more amount of fabric mass loss. It may be noted that in case of fancy yarn and its product there from, visual assessment is more important as it gives more emphasis on the change of look or effect retention (which is more important for effect yarn made fabric) than the change in strength or mass loss of the product.

References

1 Abdullah I, Blackburn R S, Russell S J & Taylor J, *J Appl Polym Sci,* 102 (2006) 1391.

2 Hu J, *Fabric Testing*, 1st edn (*Woodhead Publishing Series in Textiles,76*), 2008.

3 Kadolph S J, *Quality Assurance for Textiles and Apparels*, 2nd edn (Fairchild Publication*)*, 2007.

4 Manich A M, Castellar M D, Sauri R M, Miguel R A & Barella A, *Text Res J,* 71 (2001) 469.

5 Kaloğlu F, Önder E & Özipek B, *Text Res J,* 73 (2003) 980.

6 Collier B J & Epps H, *Textile Properties that Influence, Textile Testing and Analysis* (Prentice Hall, New Jersey), 1999.

7 Özgüney A T, Kretzschmar S D, Özçelik G & Özerdem A, *Text Res J,* 78 (2008) 138.

8 Candan C, Nergis U B & Iridag Y, *Text Res J*, 70 (2000) 177.

9 Candan C & Önal L, *Text Res J*, 72 (2002) 164.

10 Paek S L, *Text Res J*, 59 (1989)577.

11 Akaydin M, *Indian J Fibre Text Res*, 34 (2009) 26.

12 Akaydın M, *Fibres Text East Eur*, 18 (2010) 79.

13 Örtlek H G, Yolaçan G, Bilget Ö & Bilgin S, *Tekst Konfe*, 2 (2010) 115.

14 Bilişik K, *Text Res J*, 79 (2009) 1625.

15 Özdemir Ö & Çeven E K, *Text Res J*, 74 (2004) 515.

16 Saville B P, *Physical Testing of Textiles*, 1st edn (Woodhead Roman Publishing Limited), 1999, pp. 9.

17 Montgomery C D, *Design and Analysis of Experiments*, 8th edn (John Wiley & Sons, New Jersey), 2012.

18 Kothari C R, *Research Methodology, Methods and Techniques*, 2nd revised edn (New Age International Pvt. Limited, New Delhi), 2007, 308.