Predicting abrasion behaviour of chenille fabric by fuzzy logic

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Received 29 September 2005; revised received 26 December 2005; accepted 2 February 2006

The effects of chenille yarn count, pile length and yarn twist level on abrasion resistance of chenille fabric have been studied using fuzzy logic system. Different chenille yarns are produced with varying yarn count, pile length and twist level on a chenille yarn machine. The viscose and acrylic have been used as pile and core yarns respectively and the fabrics are woven from these yarns by using them as filling yarns in the weaving construction. Abrasion resistance of chenille fabrics is measured with a Martindale abrasion tester. Experimental data are used in the establishment of the fuzzy logic model and the construction of basic principles. It is observed that the use of high twist levels and pile lengths brings about an improvement in abrasion resistance and the yarn count has a significant effect on mass loss. Correlation analysis (r = 0.978) confirms strong linear relationship between measured and predicted mass loss values. It is practically possible to obtain positive results with abrasion resistance optimization in a more economical way by fuzzy logic system.

Keywords: Abrasion resistance, Chenille yarn, Fuzzy logic, Pile length, Twist level, Yarn count

IPC Code: Int. Cl D02G3/42, D03D27/00, G06N7/02

1 Introduction

Chenille yarn is a kind of fancy yarns which is fascinating about its texture and gleam. These yarns are produced with the intention of producing an enhanced aesthetic impression. They find a wide range of application area including outerwear fabrics, furnishing fabrics, trims and knitwear.

Chenille yarns have a pile protruding all around at right angles. These are constructed by twisting core yarns together in chenille yarn machines where pile yarns are inserted at right angles and cut to within 1 or 2 mm length to create a surface in which the fibres contained in the pile yarns burst and form a soft pile surface to the yarn. The basic structure of a chenille yarn is shown in Fig. 1.

The core yarn gives the strength to chenille and constitutes 25-30 % of the relative mass. The pile yarn is responsible for the body and bulk of the yarn and constitutes 70-75 % of the relative mass. The pile yarn should provide the desired aesthetic effect for the resulting chenille. The count and number of the pile yarns and how much of them are fed onto the core determine the count of the chenille yarn.24

Chenille is a difficult yarn to manufacture, requiring great care in production and conversion into final articles. Due to the instability of its construction, chenille is susceptible to wear in those areas of the garment where abrasion occurs, such as the underarm, neckline, and waist. Any removal of the pile yarn forming the beard, either during further processing or during the eventual end-use, will expose

Fig. 1 — Chenille yarn structure (a) chenille yarn components and (b) chenille yarn picture
Despite the fact that chenille yarns are used to produce special fabrics with high added value, there is limited research available on the abrasion behaviour of such yarns and fabrics. Recently, several researchers attempted to determine the effect of yarn structure (pile length, twist level, pile material type) on abrasion characteristics. They used conventional statistical test methods for their assessments and predictions.

An alternative method, fuzzy logic, can be defined as a mathematical model to study and define uncertainties. The importance of fuzzy logic has continually increased, especially in engineering studies. Fuzzy logic uses the fuzzy set theory and approximate reasoning to deal with imprecision and ambiguity in decision making. It provides intuitive, flexible ways to create fuzzy inference systems for solving complex control and classification problems. For classification applications, fuzzy logic is a process of mapping an input space into an output space using membership functions and linguistically specified rules.

The present study is aimed at analysing abrasion behaviour of chenille fabrics with fuzzy logic method. The effects of the chenille yarn count, twist level and pile length on the fabric abrasion behaviour have been studied at constant weave construction and yarn material using fuzzy logic. The chenille yarn parameters that affect fabric abrasion have been defined and an experimental study program designed.

2 Materials and Methods

2.1 Preparation of Yarn and Fabric Samples

The experiments involved chenille yarn samples manufactured from viscose pile yarns and acrylic core yarns. Since the viscose chenille yarns are highly vulnerable to abrasive forces, these are preferred to use, expecting that the assessment of the results will be more explicit.

Chenille yarns were produced with a final count of 4 Nm and 6 Nm incorporating two different pile lengths (0.7-1.0 mm) and two different twists (700-850 turns/m in S direction) on a Gigliotti & Gualchieri chenille fancy yarn machine. Pile and core yarn materials were spun into chenille yarn under identical conditions on this machine. 4 Nm count chenille yarns were produced using two core yarns of the count 20/1 Ne (yarn twist 385 turns/m in Z direction, staple acrylic fibre) and one pile yarn of the count 20/1 Ne. The chenille yarns of the count 6 Nm were produced using two core yarns of the count 24/1 Ne (yarn twist 580 turns/m in Z direction, staple acrylic fibre) and one pile yarn of the count 30/1 Ne.

Thereafter, woven fabrics were produced with these chenille yarns using them as filling in the fabric construction on a Dornier weaving machine. For all fabrics, construction was satin [1/4 3(S)] weave, warp yarn was polyester (150 denier, punched) and warp density was 66 ends/cm. Weft yarns were: 4 Nm chenille yarn with weft density of 10 picks/cm and 6 Nm chenille yarn with weft density of 14 picks/cm.

2.2 Measurement of Fabric Abrasion Properties

Abrasion tests of the woven chenille fabric samples were conducted on Martindale wear and abrasion tester in accordance with ASTM 4158-82 (ref. 11). Before starting the abrasion tests, primary trials were made to determine the abrasion cycle that would be suitable for the chenille fabric specimens. According to the results of these trials, abrasion cycles were limited with 10000 rubs and the cut samples were weighed at the beginning and end of 10000 cycles. Mass loss ratios were obtained by dividing mass loss after 10000 cycles to initial mass of the samples. Measurements were repeated three times for each fabric type. The results were also analysed for significance in differences using three-way repeated measure analysis of variance, and the means were compared by Student-Newman-Keuls (SNK) test at 5% significance level in the COSTAT statistical package. Correlation analysis was performed to observe the relationship between actual fabric mass loss values and predicted fabric mass loss values obtained from fuzzy logic.

2.3 Determination of Chenille Fabric Abrasion Behaviour by Fuzzy Logic and Construction of Basic Rules

The aim of this study was to check whether the fuzzy logic system can be used for predicting the chenille fabric abrasion behaviour. To achieve this aim, it was necessary to compare the results obtained by fuzzy logic with those obtained by real measurements.

In fuzzy logic, uncertainty conditions are determined by pre-defined membership functions. If the most approximate element of the results is defined as 1, it can be understood that the other elements are between 0 and 1 and they are changing continuously. The values of every element with the variation between 0 and 1 are called membership degrees and the variation in a subset is called membership
function. After that, the definition of the fuzzy logic rule base is implemented by using either Suggeno or Mamdani’s method. After a solution of the implemented fuzzy logic system has been obtained by using the selected method, the solution is defuzzified. The defuzzification is called as the inverse operation of fuzzification.

Yarn count, pile length and twist level were selected as input variables, whereas fabric mass loss was the output variable. The fuzzy model of this problem is given in Fig. 2. Real values of fabric mass loss have been obtained from the experimental study for comparison with those obtained by fuzzy logic. The Fuzzy Toolbox in MATLAB 6.5 was used for mathematical calculations.

The numbers of the input membership functions and base widths were obtained using the experimental results and expert knowledge (Fig. 3). As eight output variable specifications that are called fabric mass loss were investigated, the output membership function was divided into eight intervals, as shown in Fig. 4. Because of using the experimental results and since the increments in mass loss values are not linear, base widths of each interval are different. It is necessary to determine fuzzy logic rules to make obvious the effect of relationships between the input membership functions and the result. Expert knowledge has been used in the formation of basic rules to define enough of them to reach a correct solution. Elements of these rules are shown in Fig. 5.

3 Results and Discussion

The calculated 3-D output-input dependency results by fuzzy logic system are presented in Fig. 6. The figure shows the relationship among twist level, yarn count and fabric mass loss. Pile length and yarn count which influence the mass loss of fabric are plotted in Fig. 6b. The relationships among pile length, twist level and fabric mass loss are given in Fig. 6c. Yarn parameters, like yarn count, pile length and twist level, are the main effective factors which influence chenille fabric abrasion behaviour.

The results of the analysis of variance test (ANOVA) for mass loss values are summarized in Table 1. The P-values show that there are statistically significant differences between mass loss values for different twist levels, pile lengths and yarn counts. Interactions between twist level and pile length, between twist level and yarn count and also between pile length and yarn count have significant effects on mass loss values.

3.1 Effect of Yarn Count on Abrasion Behaviour

A comparison of the chenille fabrics in terms of abrasion properties according to SNK test results (Table 1) reveals that the abrasion resistance of the
Table 1 — Results of variance analysis and Student-Newman-Keuls tests (SNK) for mass loss values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mass loss, %</th>
<th>P = value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twist level, tpm: 700</td>
<td>12.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0000***</td>
</tr>
<tr>
<td></td>
<td>4.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.0000***</td>
</tr>
<tr>
<td>Pile length, mm: 0.7</td>
<td>11.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0002***</td>
</tr>
<tr>
<td></td>
<td>5.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0002***</td>
</tr>
<tr>
<td>Yarn count, Nm: 4</td>
<td>9.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0007***</td>
</tr>
<tr>
<td></td>
<td>7.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.0007***</td>
</tr>
</tbody>
</table>

*<sup>a</sup>b Denote the significance of the effect of the parameters on mass loss.

As can be observed in Fig. 6, when the yarn becomes coarser (Nm count decreases) the fabric mass loss increases. This situation is especially visible for lower yarn twist values. But when the twist value increases the difference between the mass loss values for different yarn counts becomes less; this difference is still significant at 5% significance level.

It is observed from Fig. 6b that while yarn becomes finer, mass loss values decrease at lower pile lengths. The difference between the mass loss values is decreased at higher pile lengths. This difference is still significant at 5% significance level.

3.2 Effect of Pile Length on Abrasion Behaviour

One of the results of abrasion is the gradual removal of cut pile yarns from the twists of lock yarns. Therefore, factors affecting the cohesion of
yarns will influence their abrasion resistance. Pile length affects the cohesion of yarns and the abrasion properties of chenille fabrics. Chenille yarn with higher pile length can provide a more abrasive resistant yarn structure by preventing the movement of fibres from the core yarns. According to the SNK test results, fabrics woven with chenille yarns of 0.7 mm pile length are abraded more than that of 1 mm pile length. The reason is that the longer fibres incorporated into core yarns confer better than the short fibres because they are difficult to remove from the twists of lock yarn.

As it is observed in Fig. 6b, the increment in pile length leads to decrease in mass loss values at all yarn counts. Figure 6c shows that when the pile length increases there is a significant decrease in mass loss values. This difference decreases at high twist levels but it is still significant at 5% significance level.

### 3.3 Effect of Twist Level on Abrasion Behaviour

The abrasion resistance of a yarn is a function of both the intrinsic abrasion resistance of the fibre composing the yarn and the geometry of the yarn structure. The geometric arrangements of fibres in yarns and yarns in fabrics are equally important when designing fabrics with high abrasion resistance. It is known that yarn twist is directly related to yarn abrasion resistance.

The SNK test results given in Table 1 show that mass loss has a tendency to decrease with increasing twist level. As shown in Fig. 6a, when the twist value increases, the fabric mass loss decreases for all yarn counts. Figure 6c shows that when the twist value increases the fabric mass loss decreases for all pile lengths. It can be concluded that the individual pile fibres in low twist chenille yarns may not be held together well and hence can be easily pulled out. Mass loss is encouraged by inadequate fibre adherence. Also, higher twist yarns will retain cohesiveness, presenting a smaller total surface to be abraded.

The mass loss values calculated by using the fuzzy logic model are plotted in Fig. 7. The effect of twist level on mass loss is higher at short pile lengths while it is lower at longer pile lengths. Increasing twist level beyond 825 turns/m leads to a reduction in mass loss values at all pile lengths. This situation is valid both for 4 Nm and 6 Nm yarn counts.

Moreover, correlation analysis was performed to observe the relationship between actual and predicted fabric mass loss values obtained from fuzzy logic. The relationship between actual and predicted fabric mass loss values is shown in Fig. 8. In this analysis, it is observed that the relationship between measured and predicted fabric mass loss values is positive. The equation for the correlation between the results of measured and predicted mass loss values is:

\[
y = 0.8594 x + 1.2274
\]

where \( y \) is the predicted fabric mass loss; and \( x \), the actual fabric mass loss (measured).
The linear correlation coefficient for the relationship between measured and predicted fabric mass loss values is \( r = 0.978 \). The border value of the correlation coefficient at a random degree \( n-2=6 \) and the significance level \( \alpha=0.05 \), above which the correlation exists, is 0.707.

4 Conclusions

4.1 The abrasion resistance of the fabrics with finer chenille yarns is more than that of the fabrics with coarser chenille yarns. This difference between the mass loss values is high at lower yarn twist values. But when the twist value increases the difference between the mass loss values for different yarn counts becomes less. This difference is still significant at 5% significance level.

4.2 It is found that when yarn count increases (yarn becomes finer), despite the changes in mass loss values at lower pile lengths, the difference between the mass loss values is decreased at higher pile lengths. This difference is still significant at 5% significance.

4.3 Since higher pile lengths affect the cohesion of yarns, there is a significant decrease in mass loss values with the increase in pile length at low twist levels. The increment in pile length leads to decrease in mass loss values at all yarn counts.

4.4 When the twist value increases, fabric mass loss decreases. A high twist level makes the yarn more compact which retains cohesiveness, presenting a smaller total surface to be abraded and increases the pile fibre adherence.

4.5 The fabric mass loss can be easily determined in dependence on yarn count, pile length and twist level by fuzzy logic. Correlation analysis confirmed strong linear relationship with high value of correlation coefficient \( (r = 0.978) \) between measured and predicted mass loss values. It is practically possible to obtain approaches giving positive results with fabric mass loss optimization in a more economical way, without carrying out additional production.

4.6 It will be useful to carry out further studies on the effect of increasing twist level and pile length on production costs and the comparison of the results. Usage properties and hand properties must be borne in mind here. Also, it will be useful to investigate the effect of chenille yarn parameters (twist level, pile length, pile fibre fineness, pile yarn type and fibre material) on the dimensional and physical properties of chenille yarns (yarn shrinkage, dye absorption, etc.) by fuzzy logic.

Acknowledgement

The authors wish to thank the authorities of Erol Türkün Textile, Industry and Trade Co. for the opportunity of the experimental study and to Prof. Recep EREN for very useful discussion.

References