Erhan Kenan Çeven, Özcan Özdemir

Uludag University, Faculty of Engineering and Architecture, Textile Engineering Department,
Gorukle, 16059, Bursa, Turkey
e-mail: rceven@uludag.edu.tr, ozdemir@uludag.edu.tr

Using Fuzzy Logic to Evaluate and Predict Chenille Yarn's Shrinkage Behaviour

Abstract
In this study, a fuzzy logic system is used to determine the effects of yarn parameters on the boiling shrinkage behaviour of chenille yarns. Chenille yarns are produced with different yarn counts, pile lengths, and twist levels on a chenille yarn machine. In the production of such yarns, the core yarn component is selected as acrylic while the pile yarn component is selected as viscose. The boiling water shrinkage of chenille yarns is measured according to a laboratory test method. Experimental data is used to establish the fuzzy logic model and construct basic principles. According to the results, chenille yarns with higher twist levels and shorter pile lengths have lower shrinkage values, and the yarn count has a significant effect on shrinkage. The comparison of the results obtained from the fuzzy logic model and the experiments shows that there is a strong linear relationship between the measured and predicted yarn shrinkage values.

Key words: *shrinkage, chenille yarn, fuzzy logic, pile length, twist level, yarn count.*

Introduction

Chenille yarns are fancy yarns which have a soft, furry surface and a lustrous appearance. Chenille yarns are in great demand due to the special aesthetic appeal they impart to the fabric made using such fancy yarns. They have a wide range of applications, ranging from outerwear fabrics, furnishing fabrics and knitwear to trimmings and decorative fabrics.

Chenille yarn is composed of two highly twisted core yarns plied together, firmly holding short lengths of soft-twisted pile yarns between the twists along the core's length. The piles project out from the core to give a hairy effect. The result is a yarn with a velvet-like surface. The basic structure of a chenille yarn is shown in Figure 1.

The physical characteristics of chenille yarns are affected by both the properties of core and pile yarns (type of yarn, linear density of core & pile yarn, yarn twist, pile length, pile density, geometry of the fibre's cross-section) and the process parameters (rotary head speed, spindle speed, winding speed, calliper size) [1].

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 yarn has a very distinct weakness – it does not have very good inherent abrasion resistance. When the yarns are in use, the abrasion resistance of the chenille yarn is clearly of crucial importance, in particular because the effect sought is always that of the velvety feel of the pile [2].

Figure 1. Chenille yarn; a) Chenille yarn structure, b) Chenille yarn picture.

In addition to this, shrinkage of chenille yarns is an important property, because it determines the processing behaviour of the yarns and the fabric behaviour during the apparel's end use. Fibre or yarn shrinkage refers to the decreased length of a specimen when it is placed for a specific length of time without any constraints in a hot environment, such as boiling water, a dry oven, or a steam chamber. Shrinkage is calculated as the percentage change in the original specimen length. The amount of shrinkage will bring about dimensional changes in the fabrics. Differences in shrinkage behaviour of either warp or weft threads may lead to a cockled appearance in the fabrics after hot wet treatments in the course of finishing [3].

Thus, strict control of dimensional changes should be maintained after manufacturing chenille yarns. The reason for determining the boiling shrinkage of these yarns is the low twist levels of the core yarns used to produce the chenille yarns, as well as the low dimensional stability of these yarns in thermal processing.

A survey of the literature shows that limited research into the physical properties of fancy yarns has been carried out [4 - 8]. Recent investigations on chenille yarns have concerned the determination of the effect of yarn structure on abrasion and shrinkage characteristics [9 - 11]. In these studies, conventional statistical test methods have been used for the assessments and predictions.

Fuzzy logic can be defined as a mathematical model to study and define uncertainties. The importance of this alternative method has continued to increase, especially in engineering studies [12 - 14]. Fuzzy logic theory is a forecast model developed according to fuzzy-set, fuzzy-relation and fuzzy inference in fuzzy theory. Fuzzy logic is a process of mapping an input space onto an output space using membership functions and linguistically specified rules [15].

This study is aimed at analysing the shrinkage behaviour of chenille yarns with the fuzzy logic method, investigating the effects of the chenille yarn count, twist level and pile length on the yarn shrinkage behaviour, and checking whether the fuzzy logic system can be used to predict the chenille yarn's shrinkage behaviour.

Experimental

Preparation of yarn samples

Chenille yarn samples are manufactured from viscose pile yarns and acrylic core yarns according to the experimental design program. Chenille yarns with acrylic core yarns are highly vulnerable to shrinkage, and so we preferred to use acrylic chenille yarns rather than those of other fibre materials. The assessments of the shrinkage results will thus be more explicit.

237 and 158 tex count chenille yarns were produced with two different pile lengths

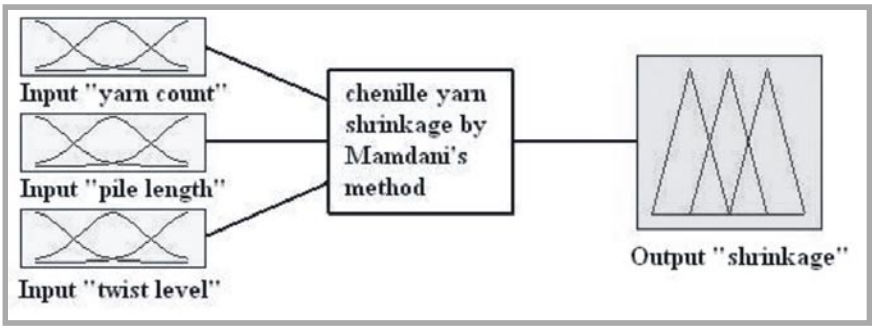

Figure 2. Fuzzy logic model for chenille yarn shrinkage.

(0.7 – 1.0 mm), and two different twists (700 – 850 turns/meter- in the S direction) on a Gigliotti & Gualchieri chenille fancy yarn machine. 237 tex count chenille yarns were produced with two 28.5/1 tex count core yarns (yarn twist of 385 turns/metre in the Z direction, staple acrylic fibre) and one 29.5/1 tex count pile yarn. 158 tex count chenille yarns were produced with two 24.6/1 tex count core yarns (yarn twist of 580 turns/metre in the Z direction, staple acrylic fibre) and one 19.7/1 tex count pile yarn.

Measurement of yarn shrinkage properties

To determine the shrinkage behaviour of chenille yarn specimens, a boiling shrinkage laboratory test method was used [16]. In this test method, one end of a uniform chenille yarn is clamped to a weight for pre-tension, and the other end is attached to the perforated frame which is initially positioned on the vertical metric scale to adjust the testing length of 500 mm. After adjusting the length of the yarn with this pre-tension, the weight clamps are released. The yarn is wound around the frame and then exposed to the test environment, typically boiling water, for 15 minutes. After reconditioning for about 5 minutes in the laboratory test environment, the frame is re-positioned on the vertical scale, and the yarn length is re-measured under the same pre-tension. Shrinkage is calculated as the percentage change of the original specimen length [7]. Shrinkage value (%) is determined by the proportion of the difference of the specimen length after shrinkage to the initial specimen length. All length measurements were repeated three times for each sample.

The results were also tested for significance in differences using a three-way repeated measures analysis of variance, and the means were compared by the Student-Newman-Keuls (SNK) test at a 5% significance level in the Costat statistical package. The correlation analysis was performed in order to observe the relationship between the actual and predicted yarn shrinkage values obtained by fuzzy logic.

Determination of chenille yarn shrinkage behaviour by fuzzy logic

In fuzzy logic, uncertainty conditions are determined by pre-defined membership functions. A membership function is a curve that maps an input element to a value between 0 and 1, showing the degree to which it belongs to a fuzzy set. The value of every element with a variation between 0 and 1 is called the membership degree. The curve can have different shapes for different kinds of fuzzy sets, such as bell (Gaussian), sigmoid, triangle, and trapezoid [17]. In this study, we use a triangle distribution curve to build up the membership functions for the input fuzzy sets. After that, the definition of the fuzzy logic rule base is implemented by using either Suggeno's or Mamdani's method. It is necessary to determine fuzzy logic rules to make apparent the effect of relationships between the input membership functions and the result.

In general, the more intermediate levels are used, the higher the accuracy of the classification will be. However, increasing the fuzzy sets will significantly increase the number of the fuzzy rules in the next step. The final selection of the number of fuzzy sets and their range may be determined by trial. Fuzzification is a stage towards determining the degree to which an input data point belongs to each of the appropriate fuzzy sets by means of the membership functions [15].

After a solution of the implemented fuzzy logic system has been obtained by using the selected method, the solution is defuzzified. Defuzzification is defined as the inverse operation of fuzzification [12].

The yarn count, pile length and the twist level were selected as input variables, whereas yarn shrinkage was the output variable. The fuzzy model of this problem is given in Figure 2.

The Fuzzy Toolbox in Matlab 6.5 was used for mathematical calculations. Experimental results and expert knowledge are used to obtain the numbers of the input membership functions and base widths; these are shown in Figure 3. Having investigated all output variable specifications that are called yarn shrinkage, we divided the output membership functions into eight intervals, as shown in Figure 4. Because we used the real values of shrinkage obtained from the experiments and the increments in shrinkage values are not linear, the base widths of each interval are different. Expert knowledge has been used in devising the basic rules to define enough of them to reach a correct solution; the elements of these rules are shown in Figure 5.

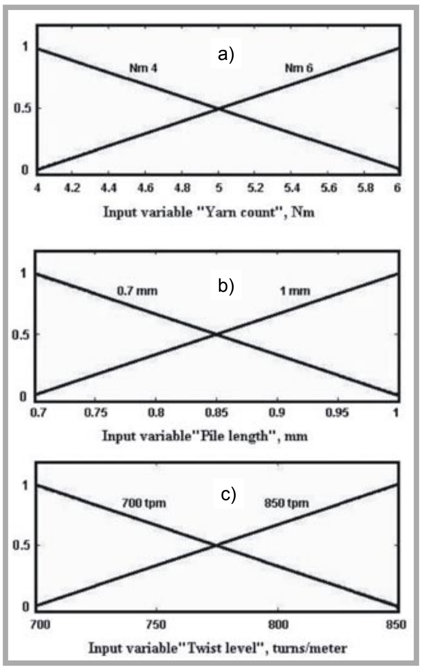

Figure 3. Membership functions for; a) yarn count, b) pile length, and c) twist level.

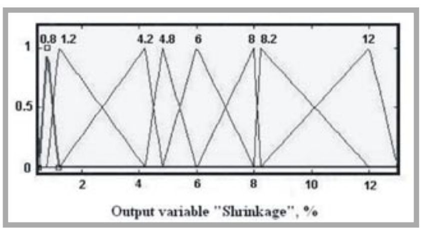

Figure 4. Membership functions of chenille yarn shrinkage.

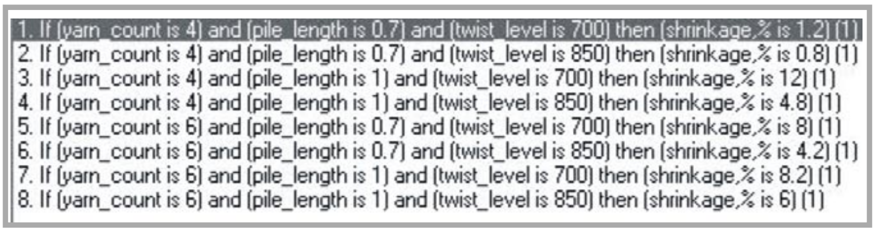

Figure 5. *Some of the defined rules.*

Results and discussion

Yarn count, pile length and twist level, which are discussed below, are the main effective parameters that influence chenille yarn shrinkage behaviour. Figures 6, 7 and 8 show the calculated 3-D output/input dependency results by the fuzzy logic system. Figure 6 shows the relations between twist level, yarn count and yarn shrinkage. Yarn count and pile length, which influence the shrinkage of yarn, are plotted in Figure 7. The relationships between pile length, twist level and yarn shrinkage are given in Figure 8.

The results of the analysis of variance test (Anova) for yarn shrinkage values are summarised in Table I. The *P* values in Table I show that there are statistically significant differences between yarn shrinkage values for different twist levels, pile lengths and yarn counts. Interactions between twist level and pile length, and between pile length and yarn count have significant effects on yarn shrinkage values, while the effect of the interaction between twist level and yarn count on shrinkage is insignificant.

Chenille yarns of different yarn counts possess different shrinkage percentages. A comparison of the chenille yarns in terms of boiling water shrinkage property, according to the SNK test results given in Table I, reveals that the shrinkage values of the fine chenille yarns are more than that of the coarse ones. This situation can be interpreted thus; the yarns will have different twist multipliers as they have different yarn counts at constant twist level. The twist multiplier of 237 tex count chenille yarn is more than that of the 158 tex count chenille yarn. Accordingly, the tightness of yarn struc-

Table 1. *The results of Variance Analysis and Student-Newman-Keuls Tests (SNK) for yarn shrinkage values, %; [a] Here *** denotes the significance of the effect of the parameters on yarn shrinkage; ns indicates that the factor is not significant; [b] Different letters (a, b) next to the counts indicate that they are significantly different from each other at 5% significance level.*

Variance analysis[a]	
	P value
Main Effects:	-
Twist level, tpm	0.0000 ***
Pile length, mm	0.0000 ***
Yarn count, tex	0.0026 **
Interaction:	-
Twist level × Pile length	0.0041 **
Twist level × yarn count	0.7503 ns
Pile length × yarn count	0.0000 ***
Twist level × pile length × yarn count	0.0010 **
Student-Newman-Keuls Test[b]	
	Shrinkage, %
Twist level, tpm	-
700	7.35 (a)
850	3.70 (b)
Pile length, mm	-
0.7	3.55 (a)
1.0	7.50 (b)
Yarn count, tex	-
237	4.70 (a)
158	6.35 (b)

Figure 6.

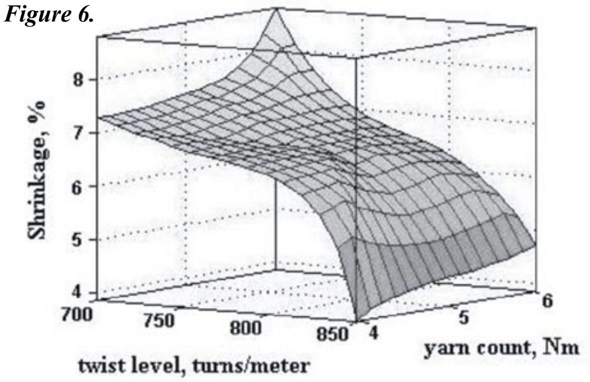

Figure 7.

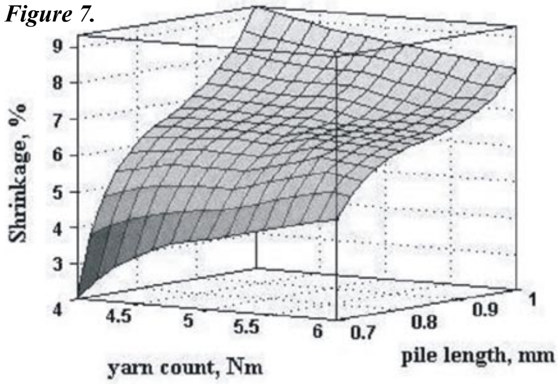

Figure 8.

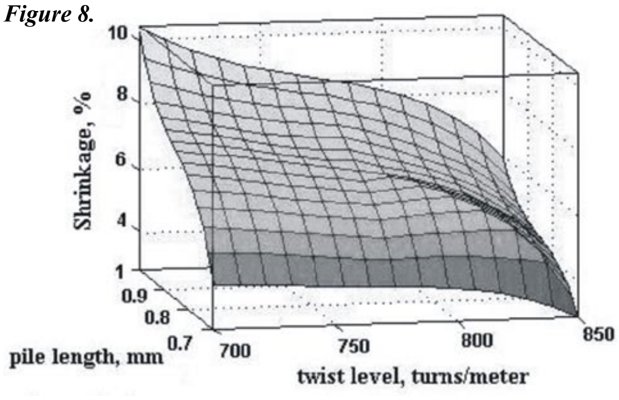

Figure 6. *3-D relationship between twist level, yarn count and yarn shrinkage.*

Figure 7. *3-D relationship between yarn count, pile length and yarn shrinkage.*

Figure 8. *3-D relationship between pile length, twist level and yarn shrinkage.*

ture will affect the water penetration into the yarn. Consequently the yarn count affects the yarn shrinkage.

As can be seen in Figure 6, when the yarn becomes coarser (tex count decreases) the boiling water shrinkage decreases. This situation is especially apparent for lower yarn twist values. However, when the twist value increases the difference between the shrinkage values for different yarn counts lessens. This difference is still significant at 5% significance level. When Figure 7 is inspected carefully, it is seen that while the yarn becomes finer, shrinkage values increase at lower pile lengths. The difference between the shrinkage values decrease at higher pile lengths. This difference is still significant at 5% significance level.

Pile length affects the structure and thus the dimensional stability of chenille yarn. Chenille yarns with higher pile lengths possess a higher shrinkage when placed in boiling water. According to the SNK test results given in Table I, shrinkage values of chenille yarns with 0.7 mm pile length are lower than that of chenille yarns with 1 mm pile length.

Figure 7 shows that when the pile length increases, there is a significant increase in yarn shrinkage values. This situation is significant at all yarn counts. As seen in Figure 8, the increments in pile length lead to an increase in the shrinkage values at all twist levels. This difference decreases at high twist levels, but it is still significant at the 5% significance level.

The increased boiling shrinkage values with increased pile lengths can be interpreted as follows: while the chenille yarns have the same linear density, using different pile lengths will affect the pile density on the surface of the yarns. If the pile length decreases, the pile density of the chenille yarn will increase, the piles will be held more tightly and the yarn

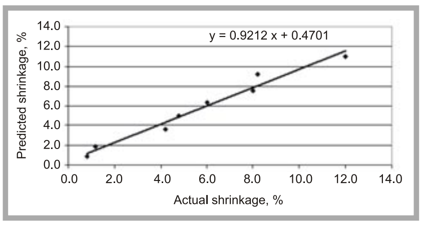

Figure 9. *Relationship between actual yarn shrinkage values obtained from measurements and predicted yarn shrinkage values obtained from fuzzy logic.*

will have a more compact structure. Thus pile length will affect water penetration into the yarn.

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

The SNK test results given in Table 1 show that boiling water shrinkage has a tendency to decrease with the increase in twist level. As illustrated in Figure 6, when the twist level increases, the yarn shrinkage decreases for all yarn counts. Figure 8 shows when inspected carefully that if the twist level is increased, the yarn shrinkage decreases for constant values of all pile lengths.

Based on these results, we may postulate that an increase in twist level is associated with the increase in pile packing degree, roundness of yarn shape and rigidity of yarn structure. These lead to a reduction in water penetration into the yarn structure.

Furthermore, we performed a correlation analysis in order to observe the relationship between actual yarn shrinkage values and predicted yarn shrinkage values obtained from fuzzy logic. The relationship between the actual and predicted yarn shrinkage values is shown in Figure 9. From this analysis, good agreement is observed between the predicted and the actual values, as supported by the high correlation coefficient. The equation for the correlation between the results of actual and predicted mass loss values is: $y = 0.859\,x + 1.227$, where y is the predicted yarn shrinkage, and x is the actual yarn shrinkage.

The linear correlation coefficient for the relationship between the measured and predicted yarn shrinkage values is $r = 0.985$. 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.

Conclusions

Boiling water shrinkage properties of chenille yarns have been analysed and evaluated with the fuzzy logic method. When the predicted and actual values of yarn shrinkage are examined, the following conclusions can be drawn:

- The boiling water shrinkage of the finer chenille yarns is greater than that of the coarser chenille yarns in case of the difference for the tightness of yarn structure. The difference between the shrinkage values for different yarn counts is reduced as the twist value increases. This difference is still significant at 5% significance level.
- Based on these results, we conclude that the difference between the shrinkage values for different yarn counts decrease as the pile length increases. This difference is still significant at 5% significance level.
- Since pile length affects both the pile density and the water penetration into the chenille yarn, increased pile length leads to a significant increase in yarn shrinkage values at all yarn counts. The increments in pile length lead to an increase in shrinkage values at all twist levels. This difference decreases at high twist levels, but it is still significant at 5% significance level.
- Chenille yarns with high twist levels have a rigid structure; this situation leads to a reduction in water penetration. Thus highly twisted yarns have high dimensional stability and low shrinkage property.
- The boiling water shrinkage of chenille yarns can be easily determined in dependence on yarn count, pile length and twist level by fuzzy logic. Correlation analysis confirmed strong linear relationship with a high value of correlation coefficient (r = 0.985) between the actual and predicted yarn shrinkage values. It is practically possible to devise approaches which give positive results of yarn shrinkage optimisation in a more economical way.
- It will be useful to make further studies on determining the effect of chenille yarn parameters (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.

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References

1. Çeven, E. K., 'An Investigation About the Effect of Some Production Parameters on Yarn Properties at Chenille Spinning Machines', Master's thesis, The University of Uludag, Bursa, Turkey, 2002.
2. Gong, R. H., and Wright R. M., 'Fancy Yarns, Their Manufacture and Application, Woodhead Publishing Limited, U.K, 2002, pp.55-56, 81-84.
3. Karakaş, H., 'Shrinkage Behaviour of Textured PET Yarns', ITB International Textile Bulletin 2002, (2), pp. 32-35.
4. Grabowska, K. E., 'Characteristics of Loop Fancy Yarn', Fibres & Textiles in Eastern Europe, 2000, (Jan /Mar), pp. 26-28.
5. Grabowska, K. E., 'Characteristics of Slub Fancy Yarn', Fibres & Textiles in Eastern Europe, 2001, (Jan /Mar), pp. 28-30.
6. Grabowska, K. E., 'Characteristics of Frotte Fancy Yarns', Fibres & Textiles in Eastern Europe, 2001, (Oct /Dec), pp. 16-19.
7. Özdemir, Ö., and Çeven, E. K., 'Effect of Chenille Yarn Parameters on Yarn Shrinkage Behaviour', Textile Res. J, 75(3) (2005) pp. 219-222.
8. Özdemir, Ö., and Çeven, E. K., 'Influence of Chenille Yarn Manufacturing Parameters on Yarn and Upholstery Fabric Abrasion Resistance', Textile Res. J, 2004, 74(6), pp. 515-520.
9. Kalaoğlu, F., and Demir, E., 'Chenille Yarn Properties and Performance of Chenille Upholstery Fabrics', Textile Asia, 2001, (3), pp. 37-40.
10. Kalaoğlu, F., and Özdemir Ö., 'A Study of Wool Chenille Yarn Properties', Proc. 1st International Textile, Clothing & Design Conference, 2002, pp.195-198.
11. Özdemir, Ö., and Kalaoğlu, F., 'The Effect of Material and Machine Parameters on Chenille Yarn Properties', Proc. Tecnitex Autex Conference, 2001, pp.184-189.
12. Zadeh, L. A., 'Fuzzy Sets', Information and Control, 1965, Vol. 8, pp. 338-353.
13. Zadeh, L. A., 'Fuzzy Sets as a Basis for a Theory of Possibility', Fuzzy Sets and Systems, 1978, pp. 3-10.
14. Branco, P., J. and Dente, J. A., 'Fuzzy Systems Modeling in Practice', Fuzzy Sets and Systems, 2001, (121), pp.73-93.
15. Hu, B., Dale, D. S., Huang, Y., Watson, M. D., 'Cotton Color Classification by Fuzzy Logic', Textile Res. J. 2002, 72(6), pp. 504-509.
16. Mega Tekstil Co. Laboratory Test Method.
17. Jang, Roger J.S., and Gulley, Ned. 'MATLAB/Fuzzy Logic Toolbox', Mathworks, INC., Natick, MA, 1997.

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