THE EMPIRICAL MODELING OF SNARLING IN STAPLE YARN

Priya Jaswal & S K Sinha
Department of Textile Technology, National Institute of Technology Jalandhar 144 011, India

Abstract: *In the present work empirical modelling of snarling behaviour in staple yarn was carried out for grey yarn and steamed yarn. This helped in developing the scientific understanding of various stages of snarl formation and snarl removal. Equations were formed, that helped in getting the relation between count, twist multiplier, tension and length of yarn. Stress at which snarl formation starts i.e. critical stress was found to be different for different yarns. The derived equation involving critical stress, count and twist multiplier predicts the tension level that is to be maintained to prevent snarl formation. Similarly tension required to open the snarl was also studied and based on that, equation was formed, which can predict the amount of tension required to remove the snarl, already present in the yarn. Effect of two parameters (count and twist multiplier) was studied on critical stress, required for snarl formation and snarl removal.*

Keywords*: Modelling, Snarling, critical stress, Twist multiplier, Cotton Yarn*

1. Introduction

Since ancient times yarn has been made by spinning or twisting together short lengths of various types of fibres in order to produce a long continuous length, suitable for weaving or knitting into a fabric. This twist insertion is an essential process in yarn spinning because it holds the fibres together, providing coherence in the yarn thereby imparting strength. Due to twisting a torque is developed in the constituent fibres, when they try to release the potential energy arising from stresses build up as a result of twisting (Tavanai et al 1996). This yarn torque causes newly spun yarn to display a tendency to untwist. This property of yarn is called twist liveliness. If a twist lively yarn is free from constraint it will lead to snarling. Thus snarl formation is a result of stability loss with a transition jump to a new equilibrium state with lower energy (Belov et al, 2002). The stability loss leading to snarl formation may occur if super-critical twist i.e. excess twist that will lead to snarl formation even if the tension is held constant is introduced into a tensioned yarn, or if the tension is reduced in a yarn with high residual torque. This may happen not only in twist lively single yarns, but also in well balanced (torque-free) plied yarn produced by the combination of two or more single yarns. If the tension is applied to a snarled yarn, then the snarl gets tightened and with further increase in tension it is eliminated. Several researchers have done work on snarling of yarn, but earlier theoretical models were based on linear and non-linear models of rigid material. The problem of snarl formation was treated as a problem of a long elastic rod subjected to end torque and axial force, but the mechanical behaviour of a yarn is much more complicated than that of an idealised elastic rod. It is possible to build a mathematical model solely out of the abstract concepts. However, if the model is to be made to confront reality it is through the data that the confrontation happens. The models called empirical are based entirely on data and in this equations are developed for the rate of each process and are combined to form a model consisting of dynamic equations for each state variable.

2. Material and Method

2.1 Material used

100% cotton yarn was used that was spun in to three counts (36.9, 29.5, 24.6 tex) having three different twist multipliers (4.3, 4.7, 5.2). Half of the yarn samples were conditioned in Xorella conditioning machine and half of the samples were left in grey state.

2.2 Testing method

Firstly data was collected from Stress- Yarn length curve obtained from testing. After collecting data, model fitting technique was used in order to find an appropriate model. Zwick tensile tester was used for testing. After conditioning samples were clamped between jaws of Zwick tensile tester. Two jaws were then brought close to each other, which lead to increase in slackness in the yarn and also to formation of snarl. As the length of yarn reaches 20cm, jaws were then moved apart, back to 30cm to remove the snarl completely from the yarn. Thus a trace of stress build-up with length of yarn was obtained.

2.2.1 Typical Stress-Yarn length curve

After following the above method a trace of stress build-up with length of yarn was obtained. It consists of two parts as shown in the figure 1. Lower one is obtained during snarl formation and upper one during snarl removal.

Snarl formation: As the slackness in the yarn increases and crosses a critical value the snarl formation takes place. 'A' is the point in the graph where tension goes below critical value and yarn starts bending and leads to the formation of spatial form of equilibrium of fibres. At point 'B' fibres lost their stability and led to the formation of snarl. With the formation of snarl there was slight increase in the tension of yarn. With further increase in slackness, snarl formed continues to develop and the length of yarn decreases. Variability in the tension is due to snarl formation, with the formation of each turn in snarl, tension increases slightly and the process continues. 'C' is the point where saturation point is reached and snarl formation stops.

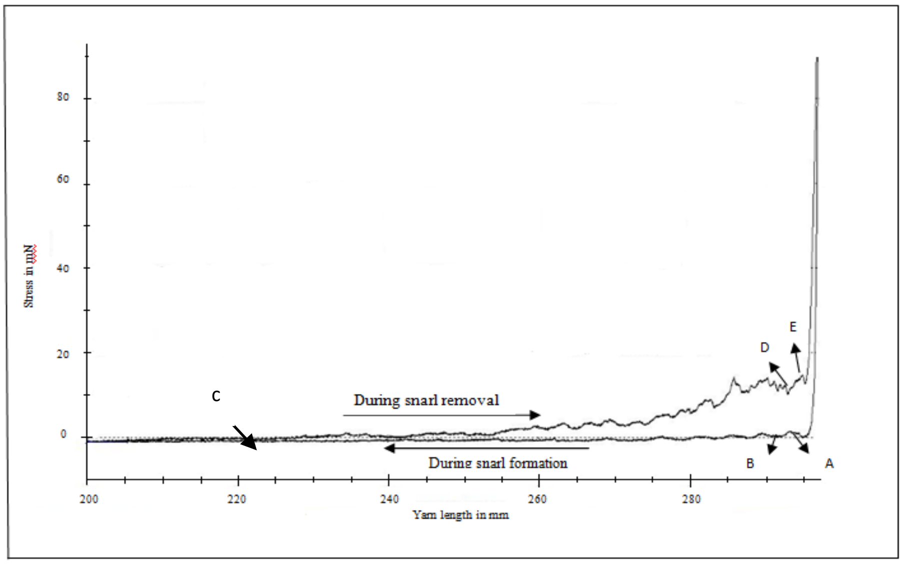


Figure 1: Typical Stress-Yarn length trace for snarl formation and removal in cotton yarn.

Snarl removal: As the snarl was removed by allowing two jaws to move apart, tension in the yarn increases and the slackness decreased. While removal of snarl it rotates in opposite direction as compared to that during snarl formation. As shown in the graph, from 'C' tension in the yarn starts increasing and the loop reopening starts. The loop diameter starts decreasing and loop tightens. 'D' is the point where loop diameter decreases to minimum and kink formation starts and it continues till 'E'. After 'E' loop reopens, which result in decrease in tension and is followed by yarn straightening. With the removal of each turn in snarl, tension first decreases due to increase in slackness and as jaws move apart it increases. There was a very drastic change in the tension as the last turn of the snarl was pulled out. The hysteresis in the graph is due to inter fibre friction in the yarn. More the inter fibre friction, more will be the hysteresis loss. Yarn with finer count is having less hysteresis loss due to low inter fibre friction, because of less surface area of contact.

3. Empirical modelling

By collecting data separately for snarl formation and snarl removal from Stress-Yarn length curve modelling was done.

3.1 Modelling for snarl formation in steamed yarn

In this study, on the mechanism of snarl formation, a graph was plotted between yarn length and tension in the yarn. It was found that the graph obtained was not smooth. Accordingly one variable (X) is plotted as ln X (logarithm of X) thus we obtain logarithm model

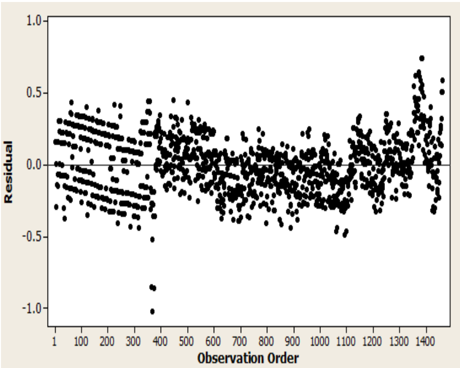
$$Y = a \ln X + b \qquad (1)$$

Where Y is tension (mN) in yarn; X is the length of yarn (mm); 'a' is the slope of line and 'b' is constant.

Based on above model equations were formed for each sample and in order to ensure that model provides an adequate approximation to the true system and verifies that none of the regression assumptions are violated, residual analysis was done. The residual from the quadratic fit plays an important role in judging model adequacy, which is the actual response value (AR) minus the predicted response value (PR).

$$\text{Residual (R)} = AR - PR$$

From the figure 2, it can be seen that the normal probability plots are approximately along a straight line and the residuals scatter randomly on the plot of residual versus the order of the data which indicates that model was found adequate.



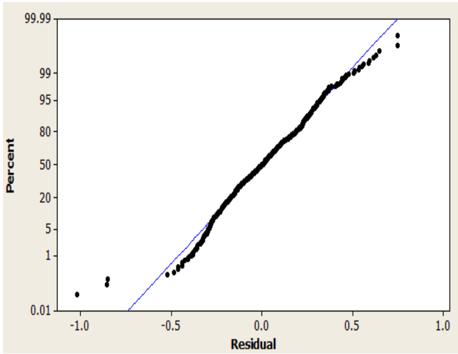


Figure 2: Typical Residual analysis plot for model adequacy checking, of yarn length and tension curve, for steamed yarn during snarl formation

Dependence of coefficient 'a' and 'b' on count and twist multiplier

Since all the equations are of the form Y= a ln X + b; and each sample have different value for a and b, i.e., (a_1, a_2, a_9) and (b_1, b_2, b_9). This difference was due to different variables (i.e. count and T.M) present, indicating that 'a' and 'b' are functions of these two variables.

By finding out the dependence of coefficient 'a', with count and twist multiplier a better prediction may be possible. The notation for a regression equation to predict 'a' from two predictor variables Twist multiplier (T.M) and count (tex) is as follows:

$$Y = b_0 + b_1X_1 + b_2X_2$$

Where, Y represents the dependence of 'a' or 'b' taking X_1 and X_2 as predictor variables.

It was observed that, Twist multiplier is a significant contributor to predict value of 'b', whereas count does not appear to add unique predictive power when the effect of second predictor was held constant. The best fitting model for predicting the value of 'b' is linearly related to twist multiplier and the addition of the count variable did not significantly improve prediction.

Although multiple regressions can be a useful tool, for separating the unique predictive contribution of correlated predictor variables, it does not work well when predictor variables are highly correlated, (high correlation among predictor is referred to as multi co-linearity).

Since it was observed that, there is no correlation among two predictor variables thus model can be used to draw conclusion about the relationship of individual independent variables with the dependent variable. Thus regression equations obtained are:

$$a = 1.2(T.M) - 0.046(Tex) - 0.92 \qquad (2)$$
$$b = -6.49(T.M) + 0.23(Tex) + 6.3 \qquad (3)$$

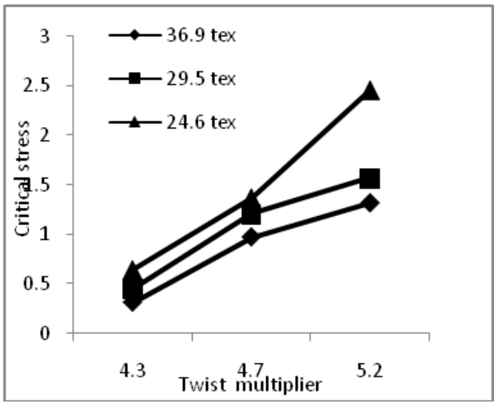
Final equation between tension and length of yarn forming snarl was obtained by putting value of 'a' and 'b' from eq (2) and (3) in eq (1):

$$Y = (1.2TM - 0.04796\,tex - 0.92)\ln X + (-6.49TM + 0.23tex + 6.303)$$

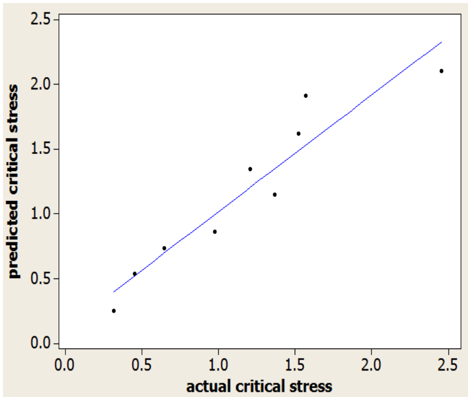
3.2 Critical stress during snarl formation

As it is known that it is necessary to maintain particular tension during all the processes, may be manufacturing or testing, for its smooth operation. For any twisted structure if tension is not maintained, at a certain level, snarl formation will take place. Yarn count, twist multiplier, level of stress and the mode of yarn twisting, plays important role in forming a snarl. It is necessary to understand the role of such parameters in the process of snarling. Hence an attempt has been made to develop a relation involving such parameters for the yarns under study.

Critical stress, defined as the stress or tension level below which the yarn stability is lost and it starts curling upon itself, leading to snarl formation. It was observed from figure 3(a), that with increase in twist multiplier (for a particular count) the critical stress level increases. This implies that a higher level of tension is to be maintained for a yarn with higher twist multiplier, to prevent the initiation of snarl.



a.



b.

Figure 3: Plot of: a. Critical stress with Twist multiplier (T.M), and b. Plot of actual and predicted value of critical stress for snarl formation (mN)

To prevent snarl formation, the yarn tension should be maintained above critical stress. The relationship was developed between critical stress, count and twist multiplier, so that necessary action can be taken to prevent a snarl to form.

Regression equation obtained is:

$$\textbf{\textit{Critical stress}} = (1.52\,T.M - 0.0393\,tex - 4.8484) \qquad (R^2 = 90.6)$$

Similarly equations were formed for Snarl removal and critical stress required for snarl removal

- $Y = (80.21\,T - 10.66\,t + 49.35) + (0.72T - 0.09\,t + 0.39)\,X + (16 * 10^{-4}T - 2 * 10^{-4}t + 7.5 * 10^{-4})\,X^2$
- $Critical\ stress = (10.1934\,T.M - 0.283\,tex - 30.2377)$

Equations formed for grey yarn

- **Snarl formation**: $Y = (2.7T - 0.019t - 7.434)\ln X + (-15.139T + 0.2012t + 38.989)$
- **Snarl removal**: $Y = (155T - 3.6t - 405) + (1.5T - 0.0319\,t - 4.0317)X + (0.00351\,T - 0.00007t - 0.010032)X^2$

Where 'Y' is tension in yarn, 'X' is yarn length, 'T' is Twist Multiplier, 't' is Yarn Tex.

4. Conclusion

This study helps in getting information about various changes in tension condition during snarl formation and snarl removal. An empirical model was proposed for snarling in staple yarn. The proposed empirical model can be used to predict the critical length and critical stress to be maintained to prevent formation of snarl. It also gives information about tension required to remove a formed snarl in a yarn.

References

[1] Belov E, Lomov S, & Bradshaw M," Study of Yarn Snarling; Part 1: Critical Parameters of Snarling", Journal of the Textile Institute (2002), pp. 341-365.
[2] Belov E, Lomov S, Truevtsev N, & Harwood R," Study of Yarn Snarling; Part 2: Mathematical Modelling", Journal of the Textile Institute, Vol. *93* , No. 4, (2002)pp. 366-385.
[3] Murrells C, Xa B, & Cheng K,"Twist liveliness measurment and its application to predict fabric spirality", The Hong Kong Polytechnic University.
[4] Tavanai H, Denton M, & Tomka J, "Direct objective measurment of yarn torque level", Journal of Textile Institute , Vol. 1 No. 1, (1996)pp. 50-58.
[5] www.sagepub.com/upm-data/16828_chapter_11 Multiple regression with two predictor variables.

5. Corresponding Address

Priya Jaswal,
Department of Textile Technology,
National Institute of Technology,
Jalandhar 144 011, India.
E-Mail: priyajaswal21@gmail.com