Prediction of False Twist Textured Yarn Properties by Artificial Neural Network Methodology

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ABSTRACT
The false twist texturing method is one of the most common texturing techniques. This process depends on parameters such as tension, twist, and heater temperature. As false-twist texturing is a process which includes close interactions between machine working parameters and textured yarn properties, the effect of process parameters on yarn properties have been widely investigated. In this study the effect of first heater temperature, setting overfeed, and D/Y on the tenacity of set yarns and the effect of twist, texturing speed, and first heater temperature on crimp stability of stretch yarns are predicted using artificial neural network methodology.

Keywords: False twist texturing, Yarn properties, artificial neural network

INTRODUCTION
One of the main disadvantages of man-made fibers is the flat geometry and smooth surface. The fiber waviness or crimp increases its volume, resilience, and some other properties. Therefore, texturing methods have been developed to overcome this problem. The false-twist texturing method is the most common process. This process is dependent on some main parameters, such as tension, twist, and temperature. The properties of the textured yarn can be altered by changing these parameters [1]. Draw ratio, D/Y ratio, overfeed, texturing speed, and heater temperatures are the main process parameters. The ratio of the disk surface speed to the yarn speed is usually referred to as D/Y ratio which is calculated by Eq. (1)

$$D/Y = \frac{\text{circumferential speed of disks (m/min)}}{\text{throughput speed of yarn }(\frac{\text{m}}{min})} \qquad (1)$$

Draw ratio is the ratio of central shaft speed to the input shaft speed as shown in *Figure 1* and is calculated by Eq.(2) :

$$Draw\ ratio = \frac{\text{center shaft speed}(\frac{\text{m}}{min})}{\text{input shaft speed}(\frac{\text{m}}{min})} \qquad (2)$$

As false-twist texturing is a process which includes close interactions between machine working parameters and textured yarn properties, the effect of process parameters have been widely investigated [2-9]. Silva et al. [10] used PLS (partial least square) methodology to model the process and genetic algorithm to optimize the false twist polyester texturing process. It has been proved that this method is extremely effective in determining process conditions which yield desired specific quality goals. The results show that the cooperation of model and optimization structure can present multiple solutions for machine parameters by providing multiple product properties or desired quality levels. The prediction of yarn properties, such as linear density (Dtex), elongation, tenacity and boiled water shrinkage have reported results of R^2 between 0.80 and 0.99. However there are no documents in which the artificial neural network (ANNs) has been used to predict the effect of false twist texturing parameters on different properties of yarn. Currently, neural networks are used to predict various processes behaviors for many problems [11-12]. Gradually it was proven that it can address complex engineering problems successfully. Many researchers have turned to ANNs when they were challenged by a multi-parameter and non-linear problem, without an obvious or straightforward analytical solution. In this study the effect of first heater temperature, setting, overfeed, and D/Y on the tenacity of set yarns and the effect of twist and texturing speed and first heater temperature on crimp stability of stretch yarns were predicted using artificial neural network.

MATERIAL AND METHOD
<u>Experimental Designs</u>
It is known that many variables including D/Y ratio, twist, heater temperature, overfeed, and texturing

speed influence the properties of textured yarns. Therefore to study the effect of these parameters on sample characteristics such as crimp and tensile properties, two series of set and stretch yarns were prepared in different texturing parameter levels. So, different texturing effects were obtained by adjusting the values of the D/Y, first heater temperature and overfeed in production of set yarns. Accordingly for stretch yarns the twist, heater temperature, and texturing speed were varied. Production conditions of set and stretch samples are shown in *Table I and Table II* respectively.

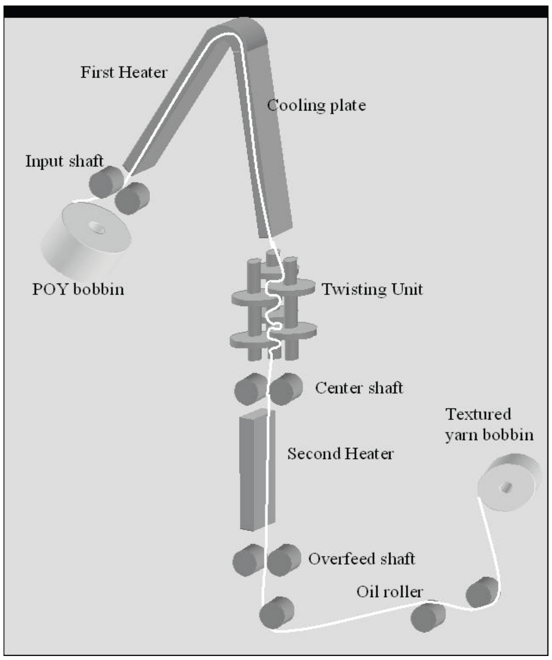

FIGURE 1. Barmag M profile false-twist texturing machine [1].

TABLE I. Production conditions of set samples.

Yarn sample	First heater temperature(°C)	D/Y	Setting overfeed (%)
1	180	1.8	4
2	180	1.8	7.5
3	180	2.1	4
4	180	2.1	7.5
5	205	1.8	4
6	205	1.8	7.5
7	205	2.1	4
8	205	2.1	7.5

TABLE II. Production conditions of stretch samples.

Yarn sample	First heater temperature(°C)	Twist (tpm)	Speed (m/min)
1	170	1969	50
2	170	2954	50
3	170	1969	120
4	170	2954	120
5	205	1969	50
6	205	2954	50
7	205	1969	120
8	205	2954	120

The parameter changing levels were obtained based on the statistical 2f factorial design model which provided two boarder values for each parameter. On this basis, 8 different running conditions for each yarn were defined. Each property was measured 6 times, so that there were 48 data for each yarn. Statistical analyses were carried out to specify the significant level of different processing parameters. The ANOVA test was used to determine the significance level of each variable.

Materials

POY samples (Polyester yarns), (250 denier, 48 filament, and zero twist) which are common in industry, were used as feed yarns in the false-twist texturing process.

Texturing Unit

A Barmag FK 1000 false twist texturing machine was used for preparing set yarns with the friction twister, and Scragg Shirley CS 12600 Minibulk false twist texturing machine was used for stretch yarns with pin twister.

The crimp properties were measured according to the DIN 53840.

Artificial Neural Networks Models

Neural networks are used in many problems to predict various processes. In this model, the least unit former is called a neuron, which can be divided into three layers: input layer, hidden layer and output layer. The hidden layer itself can be formed of some sub hidden layers. Multi-layer perceptron neural networks are responsible for approximately 80% of all practical applications. A typical feed forward network with a single hidden layer is shown in *Figure 2*. In the MPL, the units are arranged in distinct layers, in which each unit receives weighted input from one unit in the previous layer. A neural network is usually trained so that a particular input leads into a specific output. The process of training adjusts the weight and bias values in order to slide down the error surface. Among the various kinds of algorithms for training neural networks, back propagation is the one most widely used [13]. The supervised learning technique is the most frequently used for ANN training. In back propagation algorithm weight adjustment is carried out through the mean square error of the output response to the sample input. The back propagation algorithm uses the steepest decent method, which is essentially the first order method to determine a suitable direction of gradient movement. Trainlm is often the fastest back propagation algorithm and is highly recommended as a first-choice supervised algorithm. Trainlm is a network training updating weight and bias values according to Levenberg-Marquardt optimization [14]. We used this function for training our network. The available data are divided into three groups. The first group is the training set. The second group is the

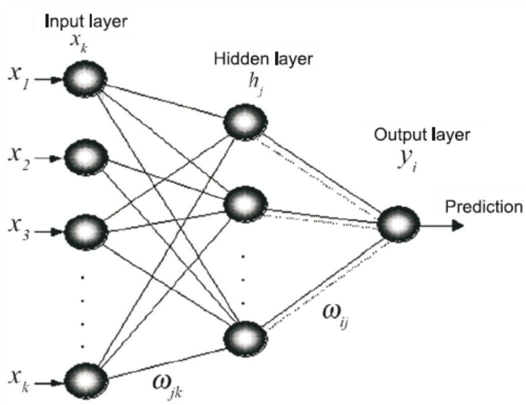

FIGURE 2. Multi - layer feed forward network [13].

validation set which is useful when the network begins to over-fit the data so that the error on the validation typically begins to rise. During this time (simultaneously) the training is stopped for a specified number of iterations (max files) and the weights and biases at the minimum of the validation error are returned. The last group is the test set, which is useful to plot the test set error during the training process. The error monitored by max files is called MSE (Mean Square Error) and it is computed by Eq. (3).

$$\mathrm{MSE} = \frac{1}{\mathrm{m}\sum_{k=1}^{m}(\mathrm{y_k} - \mathrm{t_k})^2} \tag{3}$$

RESULTS AND DISCUSSION

In this study, statistical analyses were carried out to specify the significant level of different processing parameters. ANOVA test was used to declare the significant level of each variable. The 95 percent confidence levels were used for all conclusions. This means that the P values less than 0.05 show significant levels. Among different texturing parameters, first heater temperature, D/Y and setting overfeed had significant effect on tenacity of set yarns and first heater temperature, twist and speed had significant effect on crimp stability of stretch yarns. Therefore they were selected as inputs of the network. It is expected that modeling of a characteristic using parameters with significant effect on it leads into acceptable results.

The results of ANOVA test for set and stretch yarns are shown in *Table III and Table IV* respectively.

TABLE III. The results of ANOVA for set yarns.

	F	Sig
First heater temperature(°C)	6.411	0.015
D/Y	5.045	0.030
Setting Overfeed(%)	4.512	0.047

TABLE IV. The results of ANOVA for Stretch yarns.

	F	Sig
First heater temperature(°C)	5.010	0.036
Twist (tpm)	13.495	0.001
Speed (m/min)	4.230	0.053

In order to predict the crimp stability of stretch yarns based on twist, texturing speed, and first heater temperature and the tenacity of set yarns based on setting overfeed, D/Y and first heater temperature, a multilayer perceptron neural network with the error back propagation algorithm was used. To obtain the highest prediction accuracy, different networks were used and finally one hidden layer network with three nodes and training rate of 0.05, for crimp stability of stretch yarns was obtained. For tenacity of set yarns one hidden layer with four nodes and training rate of 0.07 was used. Linear function of excitation for the output layer and hyperbolic tangent function for the hidden layer were used in both networks. *Figure 3 and Figure 4* shows the measured and predicted values of train data for set and stretch yarns respectively.

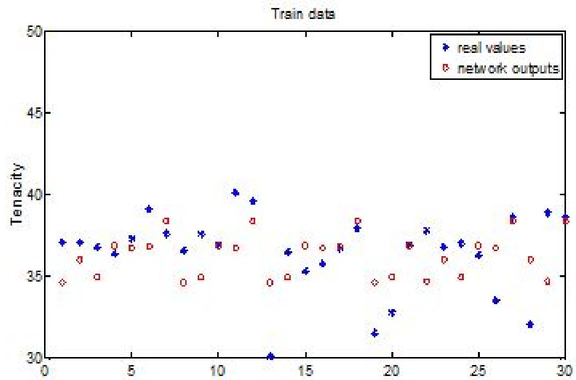

FIGURE 3. The measured and predicted values of train data for set yarns.

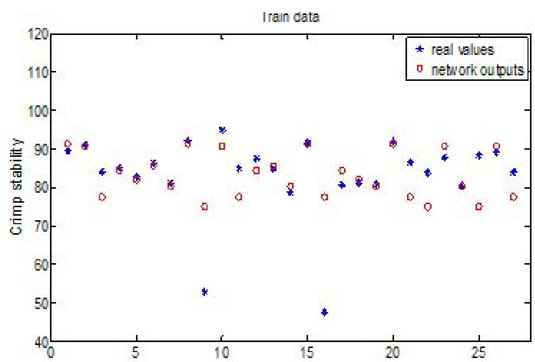

FIGURE 4. The measured and predicted values of train data for stretch yarns.

Figure 5 and Figure 6 show the measured and predicted values of test data for set and stretch yarns respectively. The correlation coefficient between the results predicted by the network and measured values for crimp stability of stretch yarns and tenacity of set yarns were 99.29% and 91.5% respectively. These results show that the neural network model can be very useful to predict the values of crimp stability of stretch yarns and tenacity of set yarns.

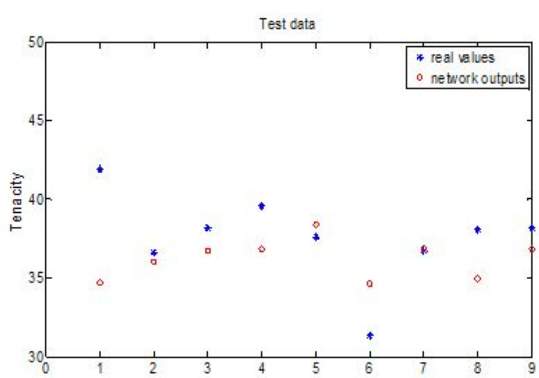

FIGURE 5. The measured and predicted values of test data for set yarns.

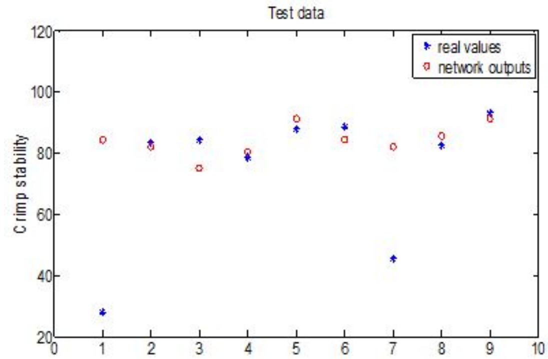

FIGURE 6. The measured and predicted values of test data for stretch yarns.

CONCLUSION

In this study, an artificial neural network was used to predict the effect of false twist texturing parameters on the crimp and tensile properties of textured yarns. Neural networks with different structures were used and finally some networks were obtained to predict the crimp stability of stretch and tenacity of set yarns. The correlation between the predicted results by the network and measured values for crimp stability of stretch and tenacity of set yarns were 99.29% and 91.5% respectively. It was concluded that the neural network model can be used to accurately predict the properties of stretch and set yarns.

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