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Prediction of Fabric Stiffness

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Abstract: In this research it is aimed to predict fabric stiffness by ANNs (artificial neural networks) using inputs like some fabric parameters and finishing treatments. For this aim 27 various fabrics were weaved with using 3 different weft densities, 3 different weft yarn sizes, 3 different weaving patterns. The fabrics were produced of using 100% Pes on the warp yarn and 100% cotton on the weft yarn. And 3 concentrations of 2 finishing treatments were applied on the 27 various fabrics. The stiffness properties of fabrics were tested by stiffness tester with using ASTM (American society for testing and materials) D 4032-94 circular bending test method. Then prediction models were tried to be established with using production parameters for inputs and measured stiffness values for outputs by ANN techniques at MATLAB® programme. ANN models were established to predict fabric stiffness with the selected 5 inputs such as weft yarn number, weft density, weaving pattern, finishing treatments and concentrations. While the network models were established, it was used feed-forward and back propagation network. While the network models were established with the aim of determining optimum network, 10 alternative models were established by changing of transfer function, neuron numbers and number of hidden layers. The best results whose regression degree is R = 0.96, were obtained with two hidden layer networks with 30 neurons.

Key words: Stiffness, softness, prediction, ANN.

1. Introduction

The latest researches carried on consumers show that modern consumers supply their clothing requirements by the line of their new life styles which is more dynamic and more comfortable [1]. So that, today as a result of rising of people's living standards, expectations of consumers from cloths are not only veiling themselves, protecting and looking good but also they expect to feel well and comfortable at every hour of the day. In this context, while the performance characteristics of the product used to be important in the textile sector, the comfort characteristics are becoming important in recent times. Certainly the fabric handle is one of the most important features in comfort properties. In general, fabric handle can be assessed by the help of subjective and objective methods [2, 3]. The bending resistance of the fabrics, which is one of the objective measurement methods, is an indicator of the stiffness of textile product [4, 5]. In this study, the fabric stiffness value, which is a way to evaluation of the fabric handle was tried to predict via fabric parameters that was thought to be effective on fabric stiffness. ANN (artificial neural network) model is used as a prediction modeling technic.

ANN has proved useful for many prediction-related problems in textiles such as the prediction of characteristics of textiles; identification, classification and analysis of defects; process optimization; and marketing and planning. Researchers have already tried to use neural networks to predict various comfort-related properties such as human sensory perceptions and overall comfort index [6-8].

At this study ANN prediction models for predicting fabric stiffness were tried to be established by the help of MATLAB® programme with using selected some yarn and weaving parameters for inputs.

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2. Materials and Methods

In this study, only one type of warp yarn was used in fabrics. Thus, variations may occur from the warp yarn that was eliminated. For the warp yarn 70/72 100% Polyester IMG was used. In the weft yarn 100% cotton yarns were used. The weaving patterns which were used in the fabric production are 2/2 Z Twill weave, 3/1 Z Twill weave and 4/2 Z Twill weave. And the weft densities, which were used in the fabric production, are 30-32-34 yarn/cm. So, 27 kinds of fabrics were produced. Sample fabrics were numbered in order to make the study easier. The sample fabrics' properties and codes were given in Table 1. Pre-treatment and dyeing processes of woven fabrics were applied to operating conditions. After dyeing, finishing treatments for softness and water repellent were applied to fabrics at laboratory conditions. Softness and water-repellent finishing treatments were applied in 3 concentrations. So, 162 different finishing treated sample fabrics were gathered. The finishing treatments, which were applied on the sample fabrics, codes and recipes, were given in Table 2. Stiffness test was applied to the 162 finishing treating applied fabrics and 27 finishing treating unapplied fabrics. At the end, stiffness test was applied to 189 fabrics at total. The stiffness properties of fabrics were tested on stiffness tester with using ASTM (American society for testing and materials) D 4032-94 circular bending test method [9]. And 567 measurements were gathered via making 3 measurements from each of 189 fabrics. After measuring stiffness values of the sample fabrics, prediction models were tried to be established by ANN techniques. ANN models were established to predict fabric stiffness with the selected 5 inputs such as weft yarn number, weft density, weaving pattern, finishing treatments and concentrations. While the network models were established, it was used feed-forward and back propagation network. While the network models were established with the aim of determining optimum network, 10 alternative models

Table 1 Fabric properties and codes.

Fabric code	Weaving pattern	Weft yarn number	Weft density	Fabric code	Weaving pattern	Weft yarn number	Weft density
1	2/2 Z Twill	20/1 OE	30	15	3/1 Z Twill	24/1 OE	34
2	2/2 Z Twill	20/1 OE	32	16	3/1 Z Twill	30/1 OE	30
3	2/2 Z Twill	20/1 OE	34	17	3/1 Z Twill	30/1 OE	32
4	2/2 Z Twill	24/1 OE	30	18	3/1 Z Twill	30/1 OE	34
5	2/2 Z Twill	24/1 OE	32	19	4/2 Z Twill	20/1 OE	30
6	2/2 Z Twill	24/1 OE	34	20	4/2 Z Twill	20/1 OE	32
7	2/2 Z Twill	30/1 OE	30	21	4/2 Z Twill	20/1 OE	34
8	2/2 Z Twill	30/1 OE	32	22	4/2 Z Twill	24/1 OE	30
9	2/2 Z Twill	30/1 OE	34	23	4/2 Z Twill	24/1 OE	32
10	3/1 Z Twill	20/1 OE	30	24	4/2 Z Twill	24/1 OE	34
11	3/1 Z Twill	20/1 OE	32	25	4/2 Z Twill	30/1 OE	30
12	3/1 Z Twill	20/1 OE	34	26	4/2 Z Twill	30/1 OE	32
13	3/1 Z Twill	24/1 OE	30	27	4/2 Z Twill	30/1 OE	34
14	3/1 Z Twill	24/1 OE	32				

Table 2 Finishing treatments' code and recipes.

Finishing treatment	Finishing code	Chemical	Concentration		
			Low (gr/lt) (W)	Middle (gr/lt) (X)	High (gr/lt) (Z)
Softness	Y	Arristan 91	10	20	30
		pH	pH 5-5, 5	pH 5-5, 5	pH 5-5, 5
Water repellent	S	Tubicoat Nano X	40	50	60
		pH	pH 3, 5-4	pH 3, 5-4	pH 3, 5-4

were established by changing of transfer function, neuron numbers and number of hidden layers. The specialties of the established alternative ANN models were given in Table 3. MATLAB neural network tool box was used for all the programming [10].

While ANN models were established 137 samples were used from 189 samples. The stiffness values of some sample fabrics which are used for training at the network, are listed in Table 4. Throughout the study, 70% (95 samples) were used for training, 15% (21 samples) were used for cross validation and 15% (21 samples) were used for test from the total 137 samples. MSE (mean squared error) was used for cross validation. The established model was also tested by the firstly seen 52 sample fabric.

Among the established networks, the best results were gathered from the third network of them with the 0.96 *R*-value (Fig. 2). While the third network was established Tansig function was used at the first layer and Purelin function was used at the second layer. The model of the network is given in Fig. 1. The regression results of training are given in Fig. 2. And the training state was given in Fig. 3.

Table 3 Topology of established ANN models.

Network number	Network structure			
	Training function	Transfer function	Hidden layer	Number of neurons
1	Trainlm	Tansig	2	10
2	Trainlm	Tansig	2	20
3	Trainlm	Tansig	2	30
4	Trainlm	Tansig	2	40
5	Trainlm	Tansig	1	10
6	Trainlm	Tansig	1	20
7	Trainlm	Tansig	1	30
8	Trainlm	Tansig	1	40
9	Trainlm	Tansig	2	10
10	Trainlm	Logsig	2	20

Table 4 Some of sample fabrics' stiffness values from training data.

Fabric number	Inputs					Targets
	Weaving pattern	Weft yarn number	Weft density	Finishing treatment	Finishing concentration	Stiffness value
3	2/2 Z Twill	20/1 OE	34	0	0	0.148
5	2/2 Z Twill	24/1 OE	32	0	0	0.087
9	2/2 Z Twill	30/1 OE	34	0	0	0.072
12	3/1 Z Twill	20/1 OE	34	0	0	0.090
15	3/1 Z Twill	24/1 OE	34	0	0	0.093
22	4/2 Z Twill	24/1 OE	30	0	0	0.054
17 YW	3/1 Z Twill	30/1 OE	32	Y	Low	0.054
26 YW	4/2 Z Twill	30/1 OE	32	Y	Low	0.062
1 YX	2/2 Z Twill	20/1 OE	30	Y	Middle	0.072
20 YX	4/2 Z Twill	20/1 OE	32	Y	Middle	0.071
7 YZ	2/2 Z Twill	30/1 OE	30	Y	High	0.039
25 YZ	4/2 Z Twill	30/1 OE	30	Y	High	0.067
13 SW	3/1 Z Twill	24/1 OE	30	S	Low	0.053
18 SW	3/1 Z Twill	30/1 OE	34	S	Low	0.081
21 SX	4/2 Z Twill	20/1 OE	34	S	Middle	0.073
23 SX	4/2 Z Twill	24/1 OE	32	S	Middle	0.063
6 SZ	2/2 Z Twill	24/1 OE	34	S	High	0.080
11 SZ	3/1 Z Twill	20/1 OE	32	S	High	0.081

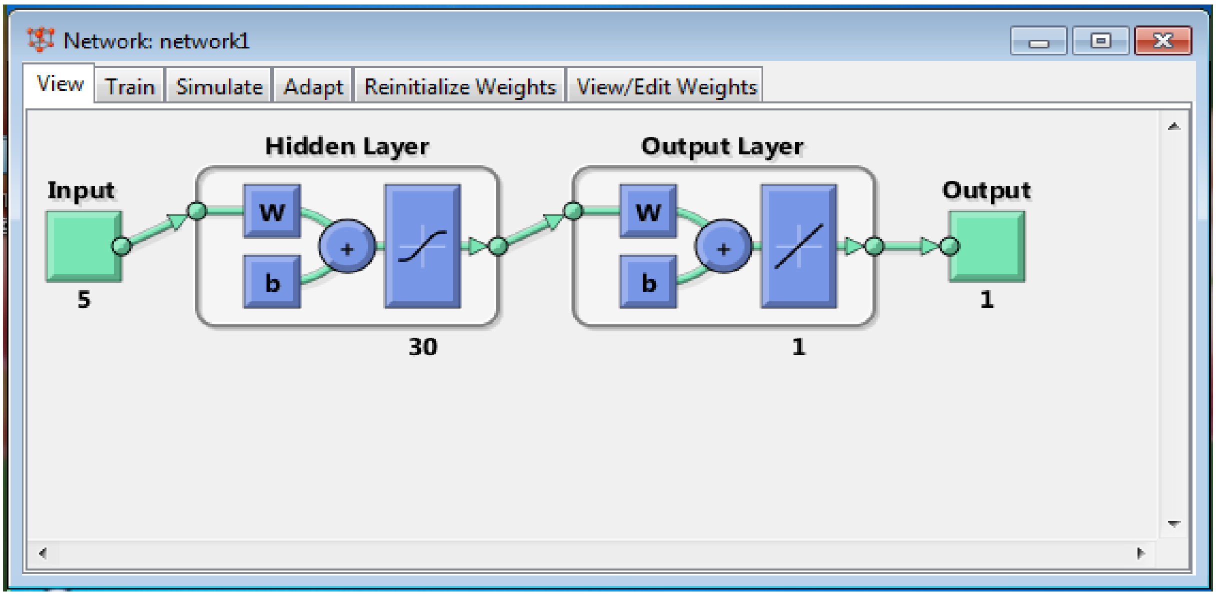

Fig. 1 The model of the third network.

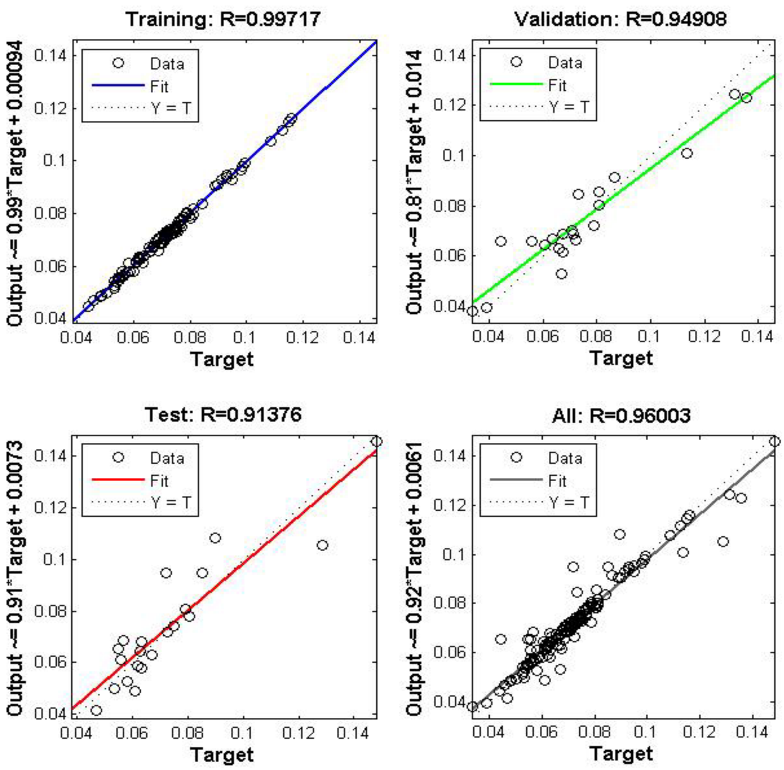

Fig. 2 Regression results.

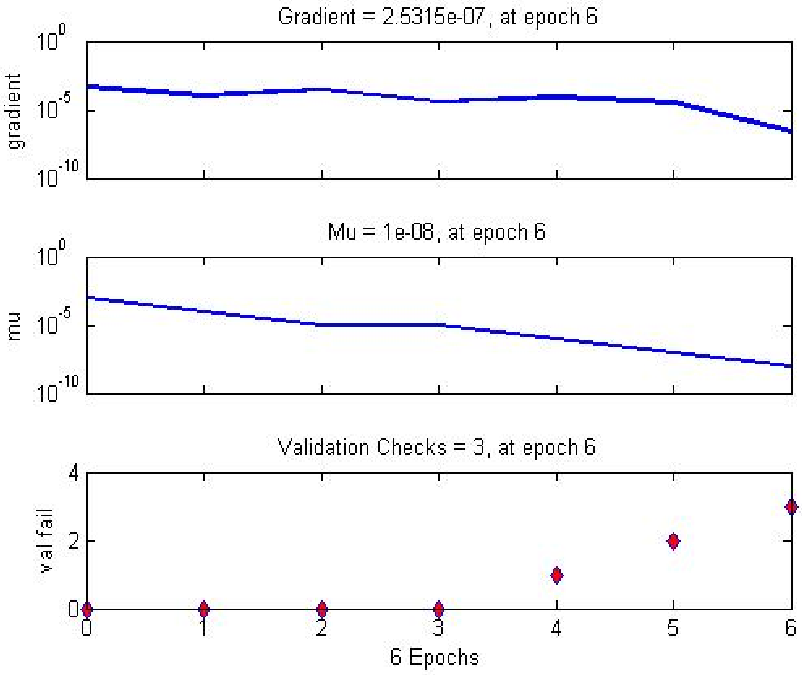

Fig. 3 Training state.

Table 5 Some of test data samples' targets and prediction values.

Fabric number	Inputs					Measured	Prediction
	Weaving pattern	Weft yarn number	Weft density	Finishing code	Finishing concentration	Stiffness value	Stiffness value
7	2/2 Z Twill	30/1 OE	30	0	0	0.05067	0.046669
8	2/2 Z Twill	30/1 OE	32	0	0	0.06367	0.062784
19	4/2 Z Twill	20/1 OE	30	0	0	0.06300	0.063809
8 YW	2/2 Z Twill	30/1 OE	32	Y	W	0.07300	0.051863
8 YX	2/2 Z Twill	30/1 OE	32	Y	X	0.07400	0.052547
13 YZ	3/1 Z Twill	24/1 OE	30	Y	Z	0.05100	0.051489
18 YZ	3/1 Z Twill	30/1 OE	34	Y	Z	0.06967	0.068133
10 SW	3/1 Z Twill	20/1 OE	30	S	W	0.06667	0.059747
15 SW	3/1 Z Twill	24/1 OE	34	S	W	0.08667	0.078614
21 SW	4/2 Z Twill	20/1 OE	34	S	W	0.07367	0.079328
9 SX	2/2 Z Twill	30/1 OE	34	S	X	0.07067	0.069564
18 SX	3/1 Z Twill	30/1 OE	34	S	X	0.06367	0.063488
25 SX	4/2 Z Twill	30/1 OE	30	S	X	0.05100	0.059676
13 SZ	3/1 Z Twill	24/1 OE	30	S	Z	0.06400	0.066183
14 SZ	3/1 Z Twill	24/1 OE	32	S	Z	0.07267	0.066599
16 SZ	3/1 Z Twill	30/1 OE	30	S	Z	0.07167	0.061664
17 SZ	3/1 Z Twill	30/1 OE	32	S	Z	0.07467	0.069741

3. Results and Conclusions

In the scope of the study, ANN models were established to predict fabric stiffness with the selected inputs such as weft yarn number, weft density, weaving pattern, finishing treatments and concentrations. While the network models established it was used feed-forward and back propagation network. While the network models were established with the aim of determining optimum network, alternative models were established by changing of network parameters. In established networks, the best performance was gained in the third network which was established by using 30 neurons in hidden Layer, Tansig function in Layer 1 and Purelin function in Layer 2. The performance of the third network was also tested with the first seen 52 sample fabrics by the network. Some of the test samples' measurements and their prediction values estimated via ANN model, were given in Table 5. As a result of the test it was determined that it is very close to the measured values obtained with the estimated values.

This study shows that ANNs can be used as a tool to predict the stiffness of a fabric before the production. The findings of this study, show that the stiffness properties of fabric can be predicted accurately by using fabric properties that weft yarn number, weaving pattern, weft density, finishing treatments and concentration of finishing treatments.

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