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A Research on Effect of Finishing Applications on Fabric Stiffness and Prediction of Fabric Stiffness

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Abstract: In this study fabric stiffness/softness is examined which is an important element of applications on finishing processes of fabric. It is also studied the prediction of the fabric stiffness/softness with help of different parameters. Specific to this aim three different weft densitoes (30 tel/cm), 3 different yarn numbers (20/1, 24/1, 30/1 Nm) and 3 different weaving patterns were used and 27 different fabrics were weaved. During the weaving process warp yarn is 100% polyester and weft yarn is 67-33% cotton/polyester. Three different finishing processes are applied to the 27 different fabrics (softness finishing treatment, crosslinking finishing and antipilling finishing) in 3 different concentrations and at the end there are 243 sample fabrics gathered. Stiffness test was applied to the samples according to the ASTM (American Society for Testing and Materials) D 4032-94 the Circular Bending Method. Test results were evaluated statistically. It was seen that the established model was related with $p < 0.0001$ also, Artificial Neural Network (ANN) model was formed in order to predict the fabric softness using the test results. MATLAB packet model was used in forming the model. ANN was formed with 5 inputs (fabric plait, weft yarn no, weft density, weft type, finishing concentration) and 1 output (stiffness). ANN model was established using feed forward-back propagation network. There were many trials in forming the ANN and the best results were gathered at the values established with 0.97317 regression value, 2 hidden layers and 10 neurons.

Key words : Softness, stiffness, bending rigidity, artificial neural network.

1. Introduction

At the result of the developing life standards and technology which affected the whole parts of the life, from now on instead of the standards of the supplies, the expectations of the demands direct not only the product but also the production process in textile sector as well as the other sectors. The recent studies show that the modern consumers meet their clothing needs to the direction in their new life style which is more dynamic and comfortable [1]. Indirectly the results of the developing life standards, consumers expect from the clothing not only covering, protecting and looking good but also feeling comfortable in the cloth at every time of the day. In this context, the descriptive factor in the consumer demand and quality sense was the performance features such as strength, specificity etc. beforehand but today the comfort features are important as well as performance features. Among the comfort features the most prominent features are yarn, weaving and fiber in terms of fabric handle. The resistance of the fabric against the bending is a symbol of stiffness of the fabric product [2]. In general, fabric behavior can be assessed by subjective and objective methods [3]. The stiffness value is needed to be defined in order to decide whether the fabric is being able to formed, sewed and able to evaluate the objective visualtiy of the fabric [4]. In this study, the effects of the finishing applications on the fabric stiffness/softness which are important comfort elements are examined and aimed to predict the fabric stiffness/softness via different parameters. The softness of the fabric was interpreted depending on the values of the fabric bending resistance.

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2. Material and Method

One type warp yarn was used on the fabrics produced to use in the study. In this way, the variations resulted from the warp yarn were eliminated. Warp yarn is 70/72 100% Polyester IMG yarn, weft yarn is 63-33% cotton/polyester. 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. In order to make the study easier the samples were numbered. The sample fabrics numerations used in the study and their features were given in Table 1. The pre-finishing applications and dying application were made under the factory standards and the finishing applications were made under the laboratory circumstances. Softness finishing process, crosslinking finishing process and antipilling finishing processes which are thought to be effective on the comfort specialties were applied at three different concentrations and at the end 243 different sample fabrics were gathered. The finishing concentrations and the inscriptions applied to the sample cloth were given in Table 2.

ASTMs (American Society for Testing and Materials) were applied to the 270 total sample fabrics (in numbers as; 243 different finishing processes applied and 27 fabrics on which finishing process did not applied), grounding D 4032-94 the Circular Bending Test Method using the Circular Bending Measurement Device Digital Pneumatic Tester Device

Table 1 Fabric specialties and numbers.

Fabric number	Weaving pattern	Weft yarn number	Weft density	Fabric number	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 The codes of the finishing applications and the inscriptions.

Finishing treatments	Finishing code	Chemicals	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
Crosslinking	B	Reaknitt ZFR	50	60	70
		CHT Catalyst	21	21	21
		Polyavin Pen	10	10	10
		pH	pH 4-4.5	pH 4-4.5	pH 4-4.5
Antipilling	A	Arristan epd	30	40	50
		pH	pH 4.5-5	pH 4.5-5	pH 4.5-5

[1]. Statistical analysis was made on the results data of themeasurement and ANN model were established in order to be able to make predictions on stiffness value.

3. Results and Conclusions

3.1 Statistical Analyzed Results

Finishing applications were made and stiffness test was applied on the fabrics 270 total, the results were studied through variance analysis. The analysis was formed using Design Expert 6.0.8® packet program at $\alpha = 0.05$ reliable level. "Full Factorial" analysis was preferred in establishing the statistical model. In this examination, the meaning of the items on the results was increased while the F and p values were decreasing. Besides in order to define a factor effective on a result the p values should be under the point 0.05. "% contribution" defines the percentage of the total variance examined in the factor. The effect of the factor on the results increases as this value increases. On the established statistical model the p value was found as $p < 0.0001$, this value shows that the model is meaningful. The variance results of the established model are given in Table 3.

When Table 3 is examined, the most effective parameter on the softness of the fabric is seen as weft yarn number. The second most effective parameter is defined as type of the finishing process. In addition to these the matching of the items is also effective on the fabric.

3.1.1 The Diagnosis of the Established Model

After the data collected from the experiment design were interpreted with the help of the variance analysis, the appropriateness of the established model should be checked. To achieve this % distribution and remnant value-experiment number graphics, the % distribution graphic is given in Fig. 1 and the remnant value-experiment number graphic is given in Fig. 2.

3.1.2 Analyzed Results

When Fig. 3 is examined it is seen that finishing processes have a meaningful effect on fabric softness. Antipilling finishing applications at low level softened the 2/2 Z Twill weave, and stiffed at middle and high concentration. Besides at the end of the analysis, all fabric types became stiffed after the crosslinking finishing applications as expected at. This situation is thought because of the chemical which has resin essence.

When Fig. 4 is examined, it is seen that the effect of the Antipilling applications on fabric softness depends on not only finishing concentration but also fabric pattern. Low concentrated antipilling application increases the softness of the fabric at 2/2 Z Twill weaved

Table 3 Variance results of the established model.

Factor	F-value	p-Value	Contribution %
Model	120.43	< 0.0001	-
A—Weaving Pattern	160.13	< 0.0001	5.87
B—Weft Yarn Number	951.51	< 0.0001	34.86
C—Weft Density	170.15	< 0.0001	6.23
D—Finishing Treatment	606.04	< 0.0001	33.31
E—Concentration	3.81	0.0233	0.14
AB	39.57	< 0.0001	2.90
AD	17.45	< 0.0001	1.92
BC	30.69	< 0.0001	2.25
BD	42.66	< 0.0001	4.69
CD	9.71	< 0.0001	1.07
DE	14.88	< 0.0001	1.64
R^2 value		0.9487	
Standard devaluation		9.085E-003	
CV %		9.22	

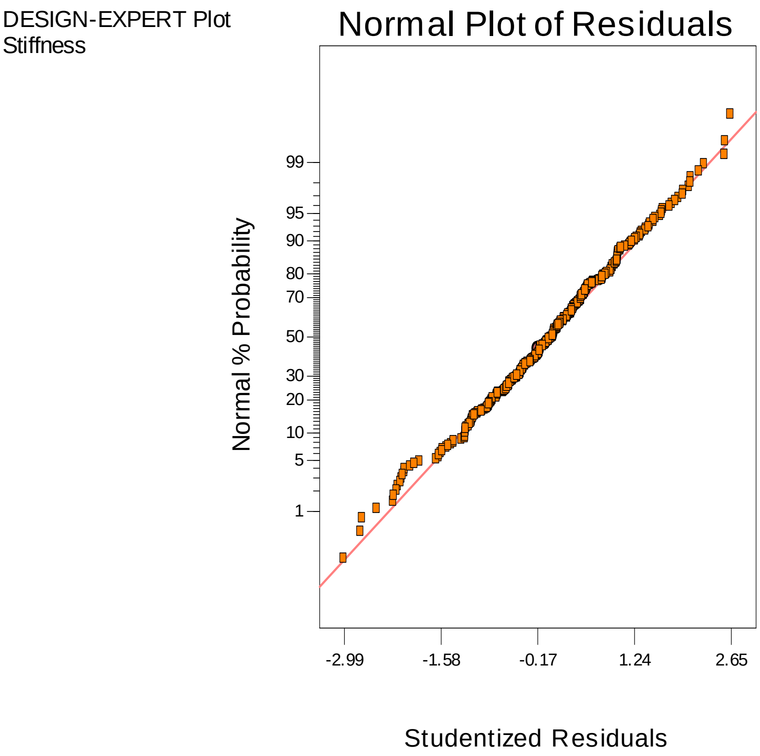

Fig. 1 Normal % distribution curve.

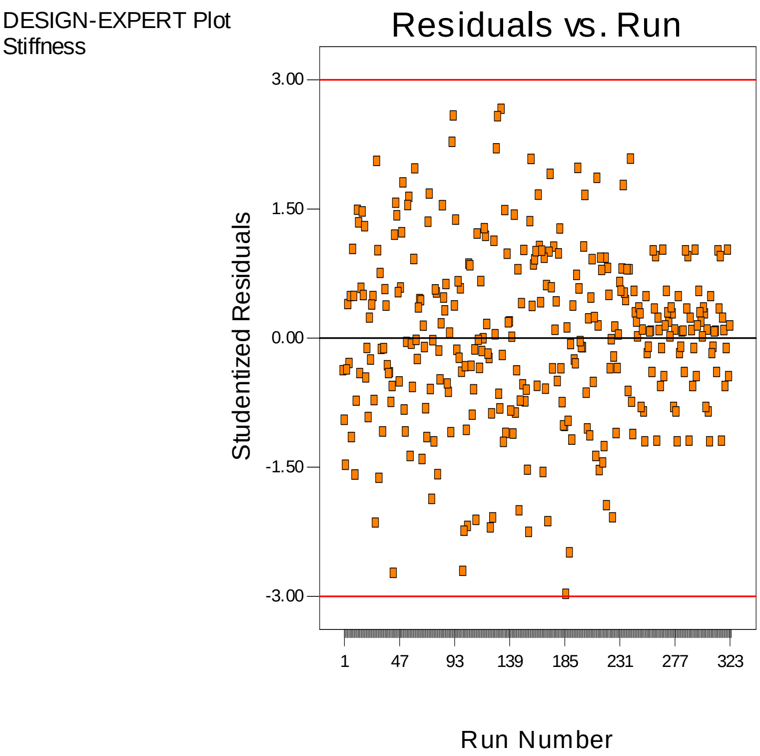

Fig. 2 Remnant value-experiment number graphic.

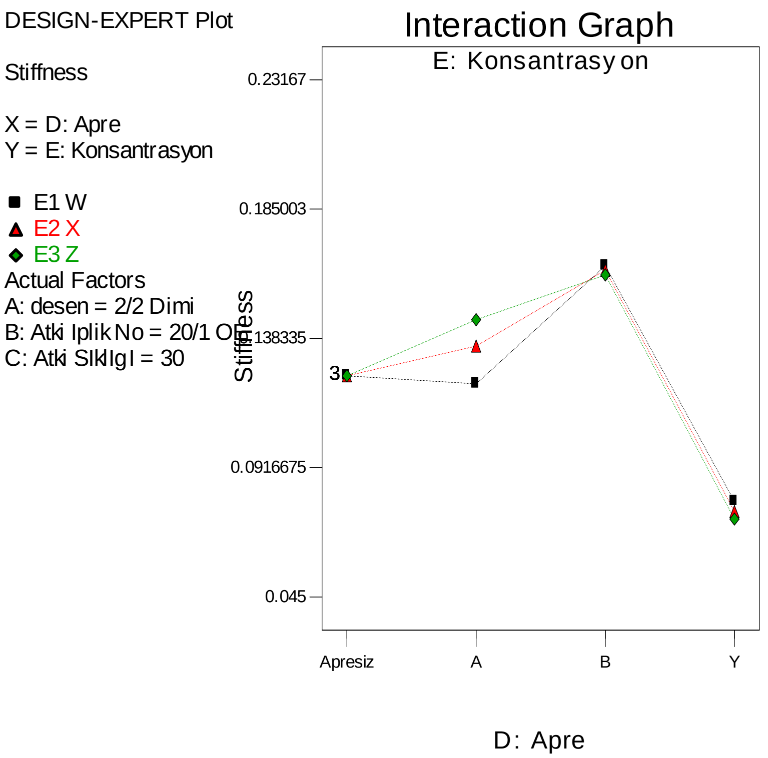

Fig. 3 **Effect of finishing type and concentration fabric on fabric softness.**

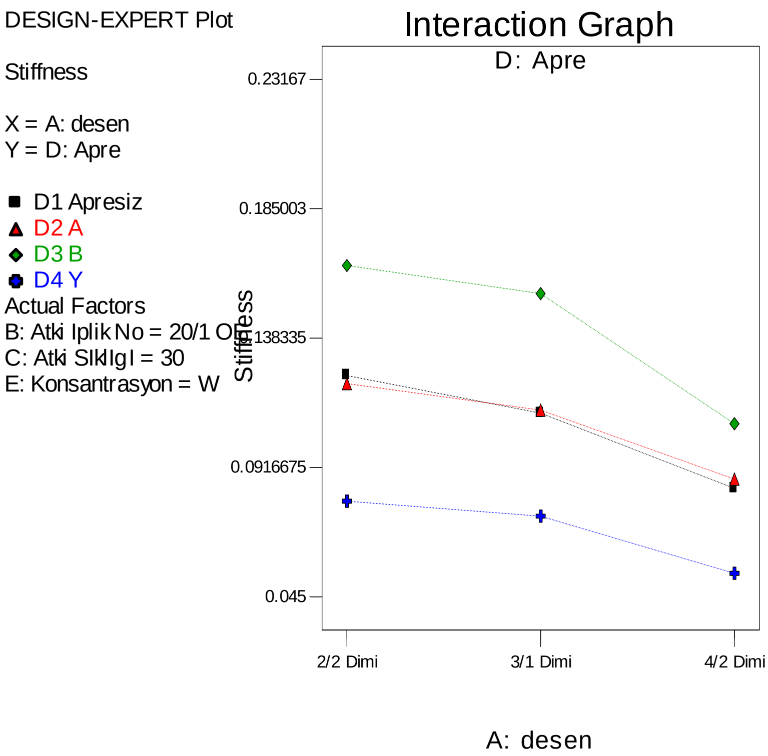

Fig. 4 **Effect of finishing type and pattern on fabric softness.**

fabric, causes no change at 3/1 Z Twill weaved fabric and stiffed the fabric of 4/2 Z Twill weaved fabric.

3.2 Model of Artificial Neural Network

MATLAB packet model was used in forming the ANN model [6]. While the ANN was establishing 80% (216 pieces) of the total 270 samples were selected for education and 20% (54 pieces) were selected for test. During the education of the 216 pieces samples 70% were used for education and 15% were used for cross validation. Established model were tested with the 54 samples which it had not seen beforehand. ANN model was established using feed forward-back propagation network [7, 8]. At interception stage MSE (mean square error) was used. Ten different ANN models were established using different network parameters in order to get optimum prediction modeling. The topologies of the established models were given in Table 4. The best results were gained at the first network among the established network models. The network model of the established network was given in Fig. 5 and the regression results of the network were given in Fig. 6.

When Fig. 6 is examined it can be seen the values of the established model as; for training R = 0.97112, for interception R = 0.9764, for test R = 0.9808 and the general regression value is R = 0.97317. These values show that the learning and the prediction ability of the established network model is pretty good.

In Table 5, the stiffness test measurement results and specialties of some samples are selected in random method from the 216 pieces education pieces. In Table 6, the stiffness test measurement results (measured stiffness value) and specialties of some samples selected in random method from the 54 pieces training pieces selected from the firstly met samples. It was also given the prediction value formed by artificial

Table 4 Topologies of established YSA models.

Network number	Network structure			
	Training function	Transfer function	Hidden layer	Neuron number
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	Logsig	2	10
10	Trainlm	Logsig	2	20

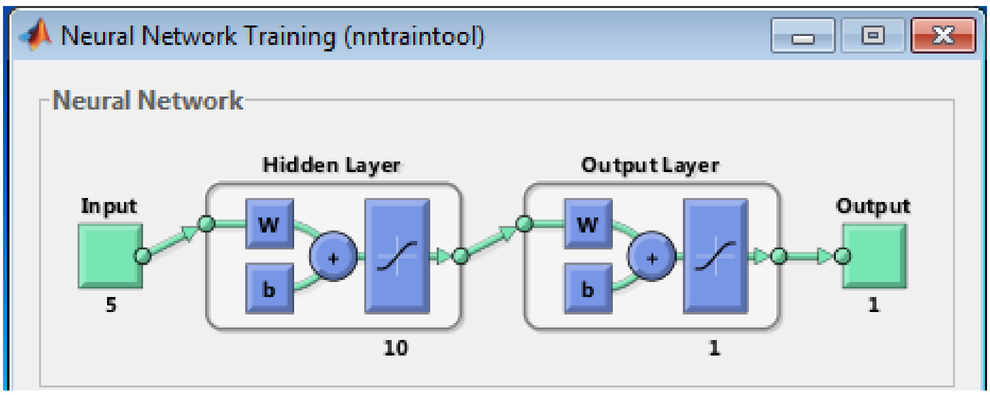

Fig. 5 The model of the established network.

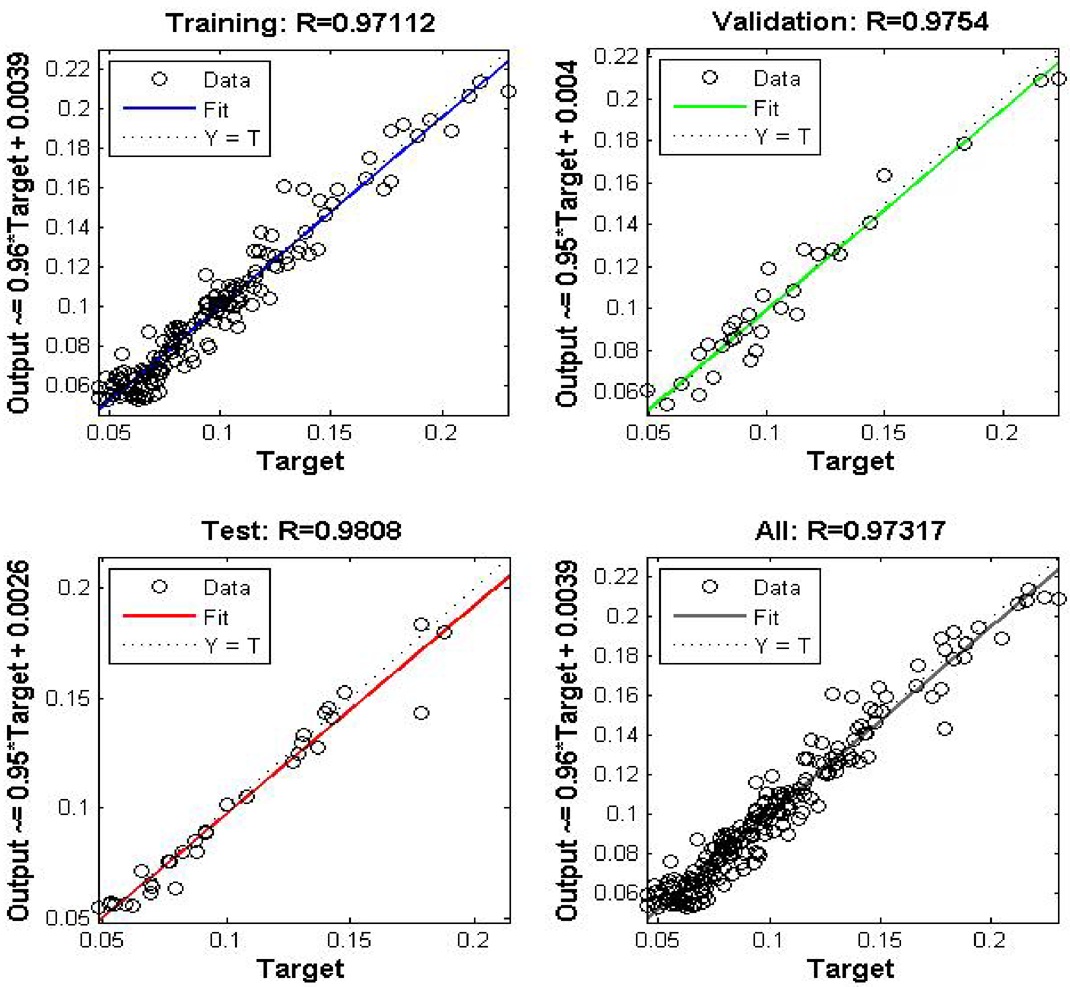

Fig. 6 Regression results.

Table 5 Specialties of some fabric samples from the training group and stiffness values.

Fabric number	Inputs					Targets
	Weaving pattern	Weft yarn number	Weft density	Finishing treatments	Concentrations	Stiffness value
16	3/1 Z Twill	30/1 OE	30	0	0	0.0600
17	3/1 Z Twill	30/1 OE	32	0	0	0.0767
19	4/2 Z Twill	20/1 OE	30	0	0	0.0920
21	4/2 Z Twill	20/1 OE	34	0	0	0.1270
22	4/2 Z Twill	24/1 OE	30	0	0	0.0653
85	2/2 Z Twill	24/1 OE	30	A	z	0.1040
86	2/2 Z Twill	24/1 OE	32	A	z	0.1130
88	2/2 Z Twill	30/1 OE	30	A	z	0.1083
89	2/2 Z Twill	30/1 OE	32	A	z	0.1003
115	2/2 Z Twill	30/1 OE	30	B	w	0.0920
117	2/2 Z Twill	30/1 OE	34	B	w	0.1220
118	3/1 Z Twill	20/1 OE	30	B	w	0.1450
228	3/1 Z Twill	20/1 OE	34	Y	x	0.0980
229	3/1 Z Twill	24/1 OE	30	Y	x	0.0660
230	3/1 Z Twill	24/1 OE	32	Y	x	0.0727
231	3/1 Z Twill	24/1 OE	34	Y	x	0.0520

Table 6 Specialties of the some fabric samples from the test group and predict of stiffness value.

Fabric number	Inputs					Measured	Prediction
	Weaving pattern	Weft yarn number	Weft density	Finishing treatment	Concentration	Stiffness değeri	Stiffness değeri
27	4/2Z Twill	30/1 OE	34	0	0	0.0677	0.067763
28	2/2 Z Twill	20/1 OE	30	A	w	0.1287	0.1222
29	2/2 Z Twill	20/1 OE	32	A	w	0.1483	0.15297
30	2/2 Z Twill	20/1 OE	34	A	w	0.1630	0.17818
60	2/2 Z Twill	24/1 OE	34	A	x	0.1193	0.11376
61	2/2 Z Twill	30/1 OE	30	A	x	0.0730	0.077431
90	2/2 Z Twill	30/1 OE	34	A	z	0.1140	0.11895
91	3/1 Z Twill	20/1 OE	30	A	z	0.1483	0.14139
92	3/1 Z Twill	20/1 OE	32	A	z	0.1537	0.14139
133	4/2Z Twill	30/1 OE	30	B	w	0.0913	0.099119
134	4/2Z Twill	30/1 OE	32	B	w	0.0863	0.070434
242	4/2Z Twill	30/1 OE	32	Y	x	0.0607	0.065407
267	4/2Z Twill	24/1 OE	34	Y	z	0.0623	0.06049

neural network model. When Table 6 is examined, real values of the test samples are closely similar to established ANN model's prediction values. This situation proves the correctness of the artificial neural network model.

It is seen that it is possible to predict the fabric softness successfully with the established Artificial Neural Network Model using the fabric production parameters as inputs.

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