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Prediction of Fabrics' Air Permeability Properties by Artificial Neural Network (ANN) Models

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Abstract: In this research it is aimed to predict fabrics' air permeability properties by ANNs (artificial neural networks) before production with using inputs like some fabric parameters and finishing treatments. For this aim 27 various fabrics were weaved. After dyeing finishing treatments for antipilling were applied to fabrics in 3 concentrations. ANN models were established to predict fabrics' air permeability values with the selected 6 inputs such as weft yarn number, weft density, weaving pattern, fabric weight, fabric thickness and finishing treatment concentrations. The best results whose regression degree is R = 0.99366, were obtained with two hidden layer networks with 5 neurons.

Key words: Air permeability, ANN, prediction, antipilling finishing.

1. Introduction

An important factor on the perception of comfort is the continuous dynamic interaction of the garments along with the body movement. Because of this, physical movement skin temperature, sweating percentage and moisture percentage on the skin etc. are continuously changing during the wearing length. These effects cause mechanical and thermal warnings. These warnings define the users' comfort perception. As the environment and human factors effecting microclimate cannot be interfered directly, it is only possible to make better garment via changing the specialties of the garment [1, 2]. This situation, brings forward some comfort specialties as water-vapor permeability, air permeability etc.

2. Experimental

In this study, only one type of warp yarn was used in fabrics. Thus, variations may occur from the warp yarn and was eliminated. For the warp yarn 70/72 100% Polyester IMG was used. In the weft yarn 67-33% Pes-Co 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 are given in Table 1. Pre-treatment and dyeing processes of woven fabrics were applied to operating conditions. Combined bleaching (bleaching and optic bleaching) was applied to the produced fabrics as well as reactive dying operations under the corporation circumstances as given prescriptions in Tables 2 and 3. After dyeing finishing treatments for antipilling were applied to fabrics at laboratory conditions. The finishing treatments were applied in 3 concentrations. So, 81 different finishing treated sample fabrics were gathered. Finishing treatments, which were applied on

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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 TWİLL	20/1 OE	30	15	3/1 Z TWİLL	24/1 OE	34
2	2/2 Z TWİLL	20/1 OE	32	16	3/1 Z TWİLL	30/1 OE	30
3	2/2 Z TWİLL	20/1 OE	34	17	3/1 Z TWİLL	30/1 OE	32
4	2/2 Z TWİLL	24/1 OE	30	18	3/1 Z TWİLL	30/1 OE	34
5	2/2 Z TWİLL	24/1 OE	32	19	4/2 Z TWİLL	20/1 OE	30
6	2/2 Z TWİLL	24/1 OE	34	20	4/2 Z TWİLL	20/1 OE	32
7	2/2 Z TWİLL	30/1 OE	30	21	4/2 Z TWİLL	20/1 OE	34
8	2/2 Z TWİLL	30/1 OE	32	22	4/2 Z TWİLL	24/1 OE	30
9	2/2 Z TWİLL	30/1 OE	34	23	4/2 Z TWİLL	24/1 OE	32
10	3/1 Z TWİLL	20/1 OE	30	24	4/2 Z TWİLL	24/1 OE	34
11	3/1 Z TWİLL	20/1 OE	32	25	4/2 Z TWİLL	30/1 OE	30
12	3/1 Z TWİLL	20/1 OE	34	26	4/2 Z TWİLL	30/1 OE	32
13	3/1 Z TWİLL	24/1 OE	30	27	4/2 Z TWİLL	30/1 OE	34
14	3/1 Z TWİLL	24/1 OE	32				

Table 2 Bleaching+optic bleaching prescription.

Chemical	Concentration
Optic bleaching agent	0.38%
Combine bleaching agent	1.15 gr/lt
Liquid caustic	4 gr/lt
Bleaching agent	0.25%
Hydrogen peroxide	7 gr/lt
Wetting	1 gr/lt
Anti-peroxide enzyme	0.7
Acetic acid	1

Table 3 Reactive dying prescription.

Chemical	Concentration
Superfix Blue H.erdici/169	0.049%
ReaktiveSuncion Crimson h-el	0.0033%
Soda	10 gr/lt
Salt	20 gr/lt

Table 4 Finishing treatments' code and recipes.

Finishing treatment	Finishing code	Chemical	Concentration		
			Low (gr/lt) (W)	Middle (gr/lt) (X)	High (gr/lt) (Z)
Antipilling	A	Arristan EPD	30	40	50
		pH	pH 4.5-5.0	pH 4.5-5.0	pH 4.5-5.0

the sample fabrics, codes and recipes, were given in Table 4. Air permeability test was applied to the 81 finishing treating applied fabrics and 27 finishing treating unapplied (at total 108) fabrics. Air permeability test was applied at a test device which is SDL-Atlas property based on "Defining Air Permeability at Textile-Fabrics" test TS 391 En ISO 9237 [3]. The test was applied at 20 cm^2 area and 200 Pa pressure drop [3]. And 324 measurements were gathered via making 3 measurements from each of

108 fabrics.

After measuring air permeability values of the sample fabrics, prediction models were tried to be established by ANN (artificial neural network) techniques. The prediction models were tried to be established with using production parameters for inputs and measured air permeability values for outputs by ANN techniques at MATLAB®R2014a programme. ANN models were established to predict fabrics' air permeability values with the selected 6 inputs such as weft yarn number, weft density, weaving pattern, fabric weight, fabric thickness and finishing treatment concentrations. While the network models were established with the aim of determining optimum network, 3,781 alternative models were established by changing of training function (Trainlm, Trainrp, Trainscg), transfer function (Tansig, Logsig, Purelin), neuron numbers (5, 10, 15, 20, 25, 30, 35) etc. While ANN models were established, 76 samples (70%) were used for training, 16 samples (15%) were used for cross validation and 16 samples (15%) were used for test from the total 108 samples. MSE (mean squared error) was used for cross validation.

3. Results and Discussion

Some of the specialties of the established alternative ANN models of top 10 which have max. %R values are given in Table 5. Among the established networks, the best result who regression degree is R = 0.99366, was gathered from 1, network of which is listed in Table 5. While the network was establishing Logsig function was used at the first layer and Purelin Function was used at the second layer. The regression results of training are given in Fig. 1.

Trainlm, Trainrp and Trainscg were used as training function. The best results were yielded by Trainlm function. However it was yielded that 0.98972% R value with using Trainrp training function with two hidden layers (in first hidden layer Logsig function and the second hidden layer Purelin function) and 20 neurons in each hidden layer. This combination of networks has emerged again as a network structure can be considered successful. Also 0.98838% R value that can be considered successful was obtained by another network structure which was established with Trainscg, which is another training function, and two hidden layers (in first hidden layer Tansig function and the second hidden layer Purelin function) and 20 neurons in each layer.

When Fig. 1 is examined the regression values can be seen as follows; for training R = 0.99388, for cross validation R = 0.98975, and for test R = 0.99688. The general regression value of the network is R = 0.99366. These values show that the learning and guessing ability of the network is quite good.

Table 5 Some specialties of established ANN models.

Network number	Network structure				R%
	Training function	Transfer function		Number of neurons	
		Hidden layer 1	Hidden layer 2		
1	Trainlm	Logsig	Purelin	5	0.99366
2	Trainlm	Logsig	Purelin	20	0.99293
3	Trainlm	Logsig	Purelin	10	0.99283
4	Trainlm	Logsig	Tansig	10	0.99271
5	Trainlm	Logsig	Purelin	30	0.9927
6	Trainlm	Tansig	Purelin	5	0.99235
7	Trainlm	Logsig	Purelin	25	0.99203
8	Trainlm	Tansig	Purelin	20	0.99176
9	Trainlm	Tansig	Purelin	10	0.99158
10	Trainlm	Tansig	Purelin	15	0.99158

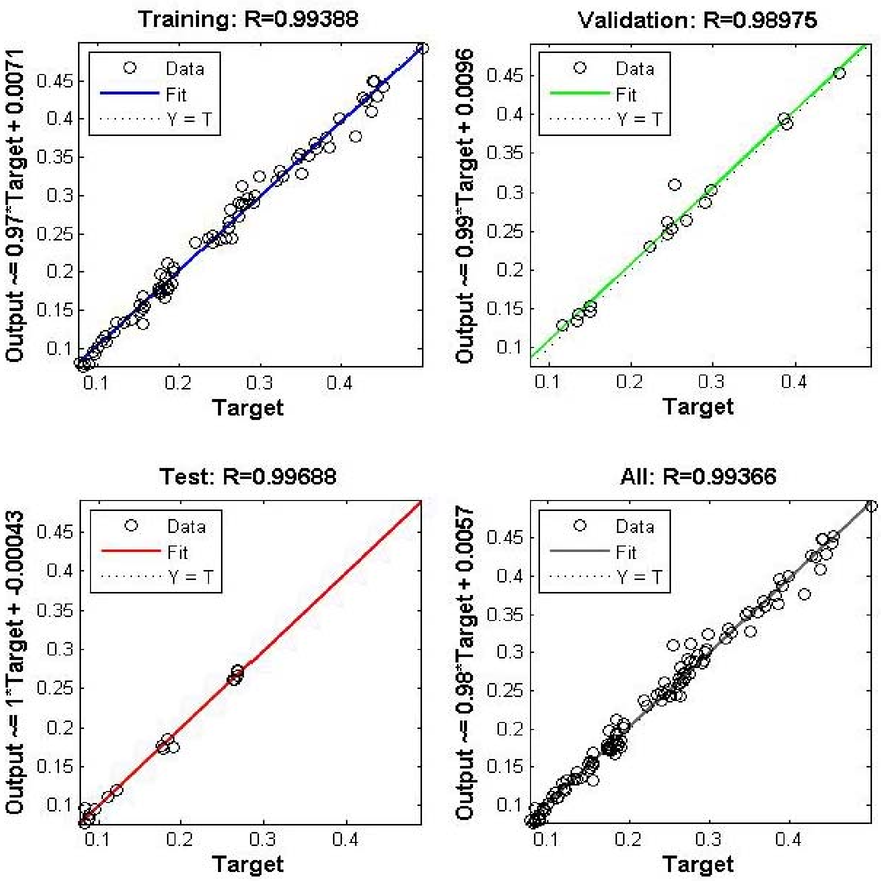

Fig. 1 Regression results.

4. Conclusions

In this research it is aimed to predict fabrics' air permeability properties by ANNs before production with using inputs like some fabric parameters and finishing treatments. While the network models were established with the aim of determining optimum network, alternative models were established by changing of network parameters. Among the ANN Models established in the concept of the study the best guessing results for the fabric air permeability were gathered at the network formed as ~0.994 regression value, with two hidden layers (in first hidden layer Logsig function and the second hidden layer Purelin function) and 5 neurons. These results show that fabric air permeability can be guessed in high correlation by using parameters such as weft yarn number, weft density, weaving pattern, fabric weight, fabric thickness and finishing treatment concentrations before manufacture. These findings support the studies of the Tokarska (2004), Militky and others (2003), Oğulata (2006) and Haleem and others (2013) [4-8].

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