Research Article
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Prediction of air permeability properties with artificial neural network models of fabrics which applied softness and water repellent finishing treatments

Abstract

In this research it is aimed to predict fabrics' air permeability properties by 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, softness and water repellent finishing treatments were applied to fabrics in 3 different concentrations. Artificial neural network models were established to predict fabrics' air permeability values with the selected 7 inputs such as weft yarn number, weft density, weaving pattern, fabric weight, fabric thickness, finishing treatment and finishing treatment concentrations. The best results which regression degree is R=0,99821 were obtained with two hidden layer network with 20 neurons. It also designed an interface for estimation using the matlab gui program.

Keywords: Artificial Neural Network (ANN), Prediction, Air Permeability, Softness, Water Repellent, Comfort

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Introduction

Clothing is the most important and fundamental need of the human. The first mission of the cloth is to protect the body from the all uncomfortable environment conditions (hot, cold, wind, injures, chemicals, etc.). In time the wearing mission is carried out from its origin. It is expanded and took its form within economic, trade, political, religious, cultural, and touristic and fashion expectations. The latest consumers` research results made in the last century show that consumers meet their clothing needs according to the their life conditions which is more dynamic and comfortable.[1] As a result of this the expectation of the consumers on clothing is not framed into covering, protection and looking good in it only, but also they expect the clothing to be comfortable and good in it at every hour of the day. The changing expectations of the consumers brought the concept of 'comfort'. Endurance, pureness etc. characteristics were once important on the customer demand and quality sense whereas lately besides these performance characteristics comfort characteristic stand out.

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.[2] As the environment and human factors effecting microclimate cannot be interfered directly, it is only possible to make better garment via changing the characteristics of the garment.[3] This situation, brings forward some comfort characteristics as water-vapor permeability, air permeability etc.

Oğulata has established a theoretical model for air permeability by using fabric structure characteristics in the study. He revealed the effects of weft and warp yarns density`s, yarn counts and fabric porosity on air permeability.[4] In their study Oğulata and Mezarcıöz established a theoretical model using D'Arcy formulation in order to guess fabric air permeability.[5] Erenler, made some applications on guessing comfort characteristics in 2013 dated study of hers and she revealed that comfort characteristics can be successfully guessed by ANN Models.[6] At the studies of Erenler and Oğulata in 2013, it is defined that fabric stiffness can be successfully predicted via ANN Models by using the fabric parameters at which finishing processes are applied.[7,8] Militký and the others have carried a study on the air permeability of the woven fabrics with different weft yarn counts and they revealed that the success of the NN model was more likely successful than regression model which were established with fabric constructions as inputs and the NN model established with fabric porosity as input.[9]

In this study air permeability features of the fabrics which were weaved at different characteristics were tried to be guessed at pre-production stage. At this study it was aimed to establish artificial neural network models which were able to predict the comfort characteristics sourced from the parameters' data at pre-production stage. And it was also designed an interface to facilitate forecasting applications by the help of MATLAB GUİ programme.

Material and method

At the research, 27 different shirting fabrics were produced defined in independent variables as 3 different weft yarn count (Ne 20/1, Ne 24/1, Ne 30/1), 3 different weft yarn density (30,32,34) and 3 different weaving pattern (2/2 Z Twill, 3/1 Z Twill, 4/2 Z Twill). At the experimental study, warp parameters were not chosen as variables. That's why, one type warp yarn was used at fabric production and the parameters related to warp yarn were hold stable. As warp yarn 70/72 100% Polyester IMG (intermingled) yarn was used at the study in the production of the sample fabrics. The fabric characteristics were given at Table 1. 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 at the Table 2 and Table 3. And the finishing treatments were applied at laboratory conditions by using given prescriptions at the Table 4. Two finishing treatments were applied in 3 different concentrations on fabrics which are softness and water repellent. So there are 162 different sample fabric were gathered.

Table 1 Fabric Properties and Codes

Fabric No	Weaving Pattern	Weft Yarn Count (Ne) (theoretical)	Weft Density (yarn/cm) (theoretical)	Fabric No	Weaving Pattern	Weft Yarn Count (Ne) (theoretical)	Weft Density (yarn/cm) (theoretical)
1	2/2 Z Twill	20/1 OE	30	15	3/1 Z DİMİ	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 Bleaching+Optic Bleaching Prescription

Kimyasal	Derişim
Chemical	Concentration
Optic Bleaching agent	% 0,38
Combine Bleaching agent	1,15gr/lt
Liquid Caustic	4gr/lt
Bleaching agent	% 0,25
Hydrogen Peroxide	7gr/lt
Wetting	1gr/lt
Anti-peroxide enzyme	0,7

Table 3 Reactive Dying Prescription

Chemical	Concentration
Superfix Blue H.erdici /169	% 0,049
ReaktiveSuncion Crimson h-el	% 0,0033
Soda	10gr/lt
Salt	20gr/lt

Air permeability tests were applied to the 189 total sample fabrics (in numbers as; 162 different finishing process applied and 27 fabrics on which finishing process did not applied). 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[13]. The test was applied at 20cm^2 area and 200Pa pressure drop.[10] After measuring air permeability values of the sample fabrics, prediction models were tried to be established by artificial neural network (ANN) techniques.

Artificial neural network models were established to predict fabric stiffness with the selected 7 inputs such as weft yarn number, weft density, weaving pattern, thickness, weight, finishing treatments and concentrations. While the network models establishing, it was used feed-forward and back propagation network.[11] While the network models established with the aim of determining optimum network, 144 alternative models were established by changing of training function (trainlm, trainscg, trainrp, trainbr vb), transfer function (logsig, tansig, pürelin), neuron numbers (5,10,20,30) and number of hidden layers. While establishing ANN models %70 of 189 samples (133 items) were used for training, %15 (28 items) were used for cross validation and %15 (28 items) were used for test. MSE (Mean Square Error) was used to cross validation. MATLAB neural network tool box was used for all the programming and it was also designed an interface to facilitate forecasting applications by the help of MATLAB GUİ programme.

Table 4 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
Water Repellent	S	Tubicoat Nano X	40	50	60
		pH	pH 3,5-4	pH 3,5-4	pH 3,5-4

Results and discussion

In the content of the study 144 alternative models were established with using alternative network parameters to determine optimum ANN model. The characteristics of the 10 established alternative ANN models which have the best regression values were given in Table 5. Among the established networks, the best results were gathered from 136. Network of them with the 0,99821 R-value with 2 hidden layer and 20 neurons. The regression results of network are given at the Figure 1.

Table 5 Topologies of Established ANN Models

Network Number	Number of Neurons	Training Function	Transfer Function 1	Transfer Function 2	R Value
136	20	'trainbr'	'tansig'	'tansig'	0,99821
139	20	'trainbr'	'logsig'	'tansig'	0,998097
100	15	'trainbr'	'tansig'	'tansig'	0,998083
141	20	'trainbr'	'logsig'	'purelin'	0,99803
102	15	'trainbr'	'tansig'	'purelin'	0,99796
105	15	'trainbr'	'logsig'	'purelin'	0,99782
138	20	'trainbr'	'tansig'	'purelin'	0,997674
64	10	'trainbr'	'tansig'	'tansig'	0,997593
69	10	'trainbr'	'logsig'	'purelin'	0,997449
67	10	'trainbr'	'logsig'	'tansig'	0,997337

Table 6 Test Data Samples' Properties, Targets, Measured and Prediction Values

Inputs									
Weaving Pattern	Weft Yarn Count (Ne) (Measured)	Weft Density (yarn/cm) (Measured)	Weight (gr/m2)	Thickness (mm)	Finishing treatment	Concentraion	Measured Values	Prediction Values	Absolute Error
2/2	18,70	39	167	0,334	0	0	74,15	79,95	5,80
2/2	25,05	34	133	0,31	0	0	229,17	217,88	11,29
3/1	25,12	36	134	0,324	0	0	218,67	253,64	34,97
3/1	25,12	40	146	0,334	0	0	119,33	125,71	6,37
2/2	18,68	36	165	0,316	S	40	86,9	85,65	1,25
3/1	25,12	34	134	0,308	S	40	210	184,73	25,27
4/2	21,55	36	160	0,334	S	40	133	127,17	5,83
4/2	25,04	36	143	0,32	S	40	182	196,13	14,13
2/2	21,37	33	154	0,32	S	50	154	153,07	0,93
3/1	18,99	35	166	0,326	S	50	87	78,66	8,34
3/1	25,11	35	143	0,312	S	50	135	145,69	10,69
3/1	30,31	33	121	0,286	S	50	332	343,61	11,60
4/2	30,97	38	130	0,304	S	50	252	297,29	45,29
3/1	18,99	35	163	0,318	S	60	86,4	81,80	4,60
3/1	25,12	39	149	0,31	S	60	108	124,45	16,45
4/2	30,51	36	126	0,3	S	60	305	308,96	3,96
2/2	18,70	39	169	0,32	Y	10	72,5	71,17	1,33
4/2	30,51	36	125	0,296	Y	10	306,33	283,82	22,51
2/2	24,88	37	144	0,302	Y	20	130	131,81	1,81
2/2	30,24	34	119	0,278	Y	20	340,33	340,76	0,42
3/1	21,53	35	155	0,328	Y	20	140,83	144,33	3,49
3/1	18,99	37	164	0,33	Y	20	83,67	96,81	13,14
3/1	21,56	39	168	0,332	Y	20	76,77	75,94	0,83

Table Continued....

4/2	30,97	39	130	0,306	Y	20	240	246,63	6,63
2/2	18,68	37	163	0,32	Y	30	93,1	95,24	2,14
2/2	30,24	35	120	0,288	Y	30	364	364,30	0,30
3/1	18,99	38	164	0,33	Y	30	87	93,40	6,40
4/2	24,94	34	149	0,328	Y	30	148	140,22	7,78
MAE / MAPE							**9,77 / 6,03**		

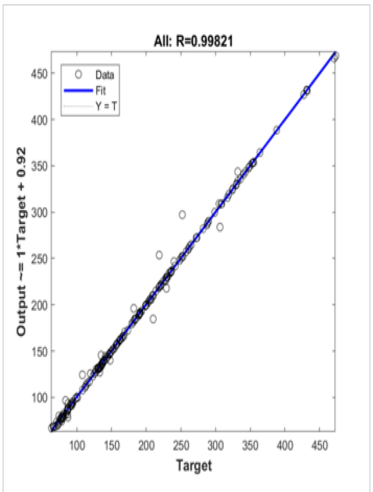

Figure 1 Regression Results of Network 136.

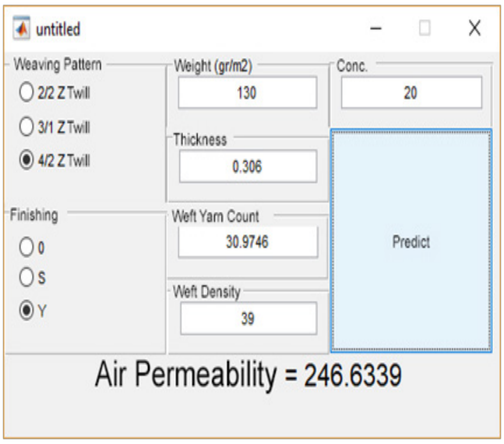

Figure 2 The prediction data of sample 4.

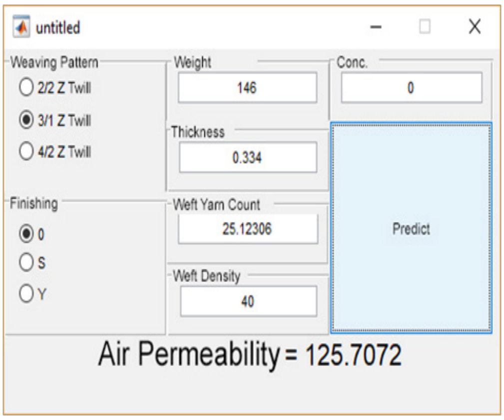

Figure 3 The prediction data of sample 24.

In Table 6 there were given the properties of the 28 test samples which used for testing at ANN model and also given measurement values and prediction values for them. When examining Table 6 it's seen that it is very close to the measured values obtained with the prediction values. This situation proves the convenience of the established artificial neural network model.

In addition, an interface is designed with the help of matlab gui and the estimation process is also done with the help of interface. Examples of estimation with Matlab gui are given in Figure 2 and Figure 3.[12]

Conclusion

In the scope of the study, ANN models were established to predict fabric air permeability characteristics with the selected inputs such as weft yarn number, weft density, thickness, weight, 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. 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 ˜0,99821 regression value, two hidden layer and 20 neurons. The findings of this study, shows that the air permeability properties of fabric can be predicted accurately by using fabric properties that weft yarn number, weaving pattern, weft density, thickness, weight, finishing treatments and concentration of finishing treatments before manufacture and it shows also artificial neural networks can be used as a tool to predict the air permeability values of a fabric before the production. These findings support the studies of the Militky and others, Oğulata[4] and Oğulata & Mezarcıöz[5]. And it's too easy to predict the air permeability characteristics with using to interface which developed with matlab gui.

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Conflict of interest

Author declares there is no conflict of interest in publishing the article.

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