(REFEREED RESEARCH)

INVESTIGATION AND PREDICTION OF CHOSEN COMFORT PROPERTIES ON WOVEN FABRICS FOR CLOTHING

GİYSİLİK DOKUNMUŞ KUMAŞLARDA SEÇİLMİŞ KONFOR ÖZELLİKLERİNİN İNCELENMESİ VE TAHMİNLENMESİ

Alev ERENLER[1], R. Tuğrul OĞULATA[2]

[1]Sinop University, Gerze Vocational School, Sinop, Turkey
[2]Çukurova University, Department of Textile Engineering, Adana, Turkey

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ABSTRACT

In the content of the study, it was investigated that the effects of various production parameters on the fabric comfort properties of clothing aimed woven fabrics by statistical analyze and it was tried to predict the comfort properties of fabrics by using production parameters. In the scope of the study, it was analyzed by using statistical methods that the effects of selected production parameters which were weft fiber type, weft density, weft yarn count, weaving pattern, fabric thickness and fabric weight on the fabric comfort properties which were fabric air permeability, stiffness and relative water vapor permeability(RWVP).Also it was established suitable Artificial Neural Network (ANN) Models by using MATLAB® programme for predicting fabric air permeability, fabric stiffness and fabric relative water vapor permeability with using selected production parameters as inputs. As a consequence, the statistical models established for each one of the comfort specialties was seen to be meaningful with the value of $p<0.0001$. Also the production parameters examined in the study were defined to be meaningful on the comfort specialties statistically. In the content of the study, it was revealed that the fabric comfort specialties can be predicted successfully before manufacture via established ANN Models.

Keywords: Artificial Neural Network (ANN), Relative Water Vapor Transmission, Air Permeability, Stiffness, Comfort.

ÖZET

Çalışma kapsamında giysi amaçlı dokunmuş kumaşlarda farklı üretim parametrelerinin kumaş konfor özellikleri üzerine etkileri istatistiksel olarak incelenmiş, üretim parametrelerinden yola çıkılarak kumaş konfor özelliklerinin tahmin edilmesine çalışılmıştır. Çalışma kapsamında üretim parametresi olarak atkı elyaf cinsi, atkı sıklığı, atkı iplik numarası, dokuma örgüsü, kumaş kalınlığı ve kumaş gramajının kumaş hava geçirgenliği, kumaş yumuşaklığı ve bağıl su buharı geçirgenliği (RWVP) üzerine etkileri istatistiksel olarak incelenmiş ve bu üretim parametreleri girdi olarak kullanılarak kumaş hava geçirgenliği, kumaş yumuşaklığı ve bağıl su buharı geçirgenliğinin tahmin edilmesi için uygun Yapay Sinir Ağı (YSA) modelleri MATLAB® paket programı kullanılarak kurulmuştur. Sonuç olarak; her bir konfor özelliği için ayrı ayrı kurulan istatistiksel modellerin $p<0.0001$ değeri ile istatistiksel olarak anlamlı oldukları görülmüştür. Ayrıca çalışma kapsamında incelenen üretim parametrelerinin incelenen konfor özellikleri üzerinde istatistiksel olarak anlamlı oldukları belirlenmiştir. Çalışma kapsamında kurulan YSA modelleri yardımıyla kumaş konfor özelliklerinin üretim öncesinde başarılı bir şekilde tahminlenebileceği ortaya konulmuştur.

Anahtar Kelimeler: Yapay Sinir Ağı (YSA), Bağıl Su Buharı Geçirgenliği, Hava Geçirgenliği, Yumuşaklık, Konfor.

Corresponding Author: Alev ERENLER, aleverenler@gmail.com

1. 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, 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. specialties were once important on the customer demand and quality sense whereas lately besides these performance specialties comfort specialties 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 specialties of the garment [3]. This situation, brings forward some comfort specialties as water-vapor permeability, air permeability etc.

In their studies Marmaralı and Oğlakçıoğlu found that production parameters like raw material (fiber and yarn specialties), fabric structure (construction, density, thickness, weight, etc.) and finishing applications have important effects on the thermal comfort specialties [4]. In their study özdil at al (2009) investigated that moisture transport properties of knitted fabrics, which have cotton yarns that had produced with using various yarn twists. and yarn counts. And they are specify that yarn count and yarn twist have important effect on the fabric moisture transport [5]. In his study Avcı (2007) investigated socks which was knitted with using various fiber types and he was determined that the wet behavior properties of socks is affected directly with fiber type [6]. Oğulata (2006), has established a theoretical model for air permeability by using fabric structure specialties in the study. He revealed the effects of weft and warp yarns density`s, yarn counts and fabric porosity on air permeability [7]. In their study Oğulata and Mezarcıöz established a theoretical model using D'Arcy formulation in order to guess fabric air permeability [8]. Erenler made some applications on guessing comfort specialties in 2013 dated study of hers and she revealed that comfort specialties can be successfully guessed by ANN Models [9]. 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 [10,11]. 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 [12].

In this study, relative water vapor permeability, air permeability and fabric stiffness specialties of the fabrics which were weaved at different specialties were tried to examined statistically and it was also 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 specialties sourced from the parameters' data at pre-production stage.

2. MATERIAL AND METHOD

At the research, 81 different shirting fabrics were produced defined in independent variables as 3 different fiber mixture percentage at weft yarn (%100 Co, %33-67 Pes/Co, %67-33 Pes/Co), 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 specialities were given at Table 1.

Table 1. Fabric Constructions

	Fabric Constructions									
Fabric No	Fiber Type	Weaving Pattern	Warp Yarn Count (Denier) (theoretical)	Warp Yarn Count (Denier) (Measured)	Warp Density (yarn/cm) (theoretical)	Warp Density (yarn/cm) (measured)	Weft Yarn Count (Ne) (theoretical)	Weft Yarn Count (Ne) (Measured)	Weft Density (yarn/cm) (theoretical)	Weft Density (yarn/cm) (Measured)
1	%100 Co	2/2 Z Twill	70	69,55	50	54	Ne 20/1	18,87	30	32
2	%100 Co	2/2 Z Twill	70	69,47	50	55	Ne 20/1	18,83	32	34
3	%100 Co	2/2 Z Twill	70	69,04	50	53	Ne 20/1	18,86	34	37
4	%100 Co	2/2 Z Twill	70	69,18	50	54	Ne 24/1	25,22	30	33
5	%100 Co	2/2 Z Twill	70	69,07	50	55	Ne 24/1	25,12	32	35
6	%100 Co	2/2 Z Twill	70	69,23	50	54	Ne 24/1	25,10	34	37
7	%100 Co	2/2 Z Twill	70	69,02	50	54	Ne 30/1	30,43	30	34
8	%100 Co	2/2 Z Twill	70	69,93	50	56	Ne 30/1	30,32	32	36
9	%100 Co	2/2 Z Twill	70	69,66	50	55	Ne 30/1	30,23	34	38
10	%100 Co	3/1 Z Twill	70	69,52	50	52	Ne 20/1	18,92	30	34
11	%100 Co	3/1 Z Twill	70	69,12	50	52	Ne 20/1	21,55	32	36
12	%100 Co	3/1 Z Twill	70	70,04	50	52	Ne 20/1	21,60	34	38
13	%100 Co	3/1 Z Twill	70	69,15	50	54	Ne 24/1	25,16	30	34
14	%100 Co	3/1 Z Twill	70	70,12	50	55	Ne 24/1	25,14	32	37
15	%100 Co	3/1 Z Twill	70	69,07	50	52	Ne 24/1	25,03	34	39
16	%100 Co	3/1 Z Twill	70	69,10	50	54	Ne 30/1	30,31	30	33
17	%100 Co	3/1 Z Twill	70	69,88	50	54	Ne 30/1	30,42	32	36
18	%100 Co	3/1 Z Twill	70	69,63	50	52	Ne 30/1	30,05	34	38
19	%100 Co	4/2 Z Twill	70	70,15	50	53	Ne 20/1	21,95	30	32
20	%100 Co	4/2 Z Twill	70	69,47	50	52	Ne 20/1	19,15	32	34
21	%100 Co	4/2 Z Twill	70	70,64	50	52	Ne 20/1	19,00	34	37

Table 1.

	Fabric Constructions									
Fabric No	Fiber Type	Weaving Pattern	Warp Yarn Count (Denier) (theoretical)	Warp Yarn Count (Denier) (Measured)	Warp Density (yarn/cm) (theoretical)	Warp Density (yarn/cm) (measured)	Weft Yarn Count (Ne) (theoretical)	Weft Yarn Count (Ne) (Measured)	Weft Density (yarn/cm) (theoretical)	Weft Density (yarn/cm) (Measured)
22	%100 Co	4/2 Z Twill	70	69,69	50	54	Ne 24/1	25,66	30	33
23	%100 Co	4/2 Z Twill	70	69,96	50	54	Ne 24/1	25,66	32	35
24	%100 Co	4/2 Z Twill	70	69,71	50	53	Ne 24/1	25,44	34	38
25	%100 Co	4/2 Z Twill	70	70,81	50	53	Ne 30/1	30,86	30	33
26	%100 Co	4/2 Z Twill	70	70,84	50	53	Ne 30/1	30,23	32	35
27	%100 Co	4/2 Z Twill	70	70,39	50	54	Ne 30/1	30,31	34	37
28	%33-67 Pes-Co	2/2 Z Twill	70	70,07	50	49	Ne 20/1	21,37	30	33
29	%33-67 Pes-Co	2/2 Z Twill	70	69,85	50	48	Ne 20/1	18,68	32	37
30	%33-67 Pes-Co	2/2 Z Twill	70	70,01	50	47	Ne 20/1	18,70	34	39
31	%33-67 Pes-Co	2/2 Z Twill	70	69,77	50	52	Ne 24/1	25,05	30	34
32	%33-67 Pes-Co	2/2 Z Twill	70	69,71	50	49	Ne 24/1	24,88	32	36
33	%33-67 Pes-Co	2/2 Z Twill	70	70,09	50	50	Ne 24/1	25,18	34	38
34	%33-67 Pes-Co	2/2 Z Twill	70	70,34	50	50	Ne 30/1	30,24	30	33
35	%33-67 Pes-Co	2/2 Z Twill	70	70,87	50	51	Ne 30/1	30,15	32	37
36	%33-67 Pes-Co	2/2 Z Twill	70	70,56	50	49	Ne 30/1	30,14	34	39
37	%33-67 Pes-Co	3/1 Z Twill	70	70,48	50	49	Ne 20/1	21,53	30	33
38	%33-67 Pes-Co	3/1 Z Twill	70	69,88	50	49	Ne 20/1	19,00	32	35
39	%33-67 Pes-Co	3/1 Z Twill	70	69,42	50	50	Ne 20/1	21,56	34	38
40	%33-67 Pes-Co	3/1 Z Twill	70	70,15	50	48	Ne 24/1	25,12	30	36
41	%33-67 Pes-Co	3/1 Z Twill	70	69,34	50	49	Ne 24/1	25,11	32	38
42	%33-67 Pes-Co	3/1 Z Twill	70	69,04	50	47	Ne 24/1	25,12	34	40
43	%33-67 Pes-Co	3/1 Z Twill	70	70,09	50	52	Ne 30/1	30,31	30	34
44	%33-67 Pes-Co	3/1 Z Twill	70	69,52	50	49	Ne 30/1	30,28	32	37
45	%33-67 Pes-Co	3/1 Z Twill	70	69,23	50	50	Ne 30/1	30,38	34	40
46	%33-67 Pes-Co	4/2 Z Twill	70	69,93	50	48	Ne 20/1	21,54	30	31
47	%33-67 Pes-Co	4/2 Z Twill	70	69,26	50	47	Ne 20/1	21,55	32	35
48	%33-67 Pes-Co	4/2 Z Twill	70	69,98	50	52	Ne 20/1	21,54	34	38
49	%33-67 Pes-Co	4/2 Z Twill	70	70,39	50	50	Ne 24/1	25,19	30	33
50	%33-67 Pes-Co	4/2 Z Twill	70	69,74	50	49	Ne 24/1	25,04	32	37
51	%33-67 Pes-Co	4/2 Z Twill	70	69,47	50	50	Ne 24/1	24,94	34	39
52	%33-67 Pes-Co	4/2 Z Twill	70	69,55	50	48	Ne 30/1	30,29	30	33
53	%33-67 Pes-Co	4/2 Z Twill	70	69,88	50	49	Ne 30/1	30,51	32	36
54	%33-67 Pes-Co	4/2 Z Twill	70	69,52	50	49	Ne 30/1	30,97	34	40
55	%67-33 Pes-Co	2/2 Z Twill	70	70,67	50	49	Ne 20/1	21,65	30	35
56	%67-33 Pes-Co	2/2 Z Twill	70	69,58	50	54	Ne 20/1	21,55	32	38
57	%67-33 Pes-Co	2/2 Z Twill	70	70,73	50	52	Ne 20/1	21,63	34	40
58	%67-33 Pes-Co	2/2 Z Twill	70	69,71	50	52	Ne 24/1	24,99	30	36
59	%67-33 Pes-Co	2/2 Z Twill	70	70,23	50	52	Ne 24/1	25,19	32	38
60	%67-33 Pes-Co	2/2 Z Twill	70	69,71	50	52	Ne 24/1	25,09	34	40
61	%67-33 Pes-Co	2/2 Z Twill	70	70,31	50	52	Ne 30/1	30,35	30	36
62	%67-33 Pes-Co	2/2 Z Twill	70	70,59	50	51	Ne 30/1	30,11	32	37
63	%67-33 Pes-Co	2/2 Z Twill	70	70,56	50	52	Ne 30/1	30,01	34	39
64	%67-33 Pes-Co	3/1 Z Twill	70	69,82	50	51	Ne 20/1	18,71	30	35
65	%67-33 Pes-Co	3/1 Z Twill	70	70,07	50	52	Ne 20/1	19,00	32	38
66	%67-33 Pes-Co	3/1 Z Twill	70	69,88	50	52	Ne 20/1	18,88	34	39
67	%67-33 Pes-Co	3/1 Z Twill	70	70,64	50	49	Ne 24/1	25,18	30	35
68	%67-33 Pes-Co	3/1 Z Twill	70	70,31	50	51	Ne 24/1	24,99	32	37
69	%67-33 Pes-Co	3/1 Z Twill	70	70,45	50	52	Ne 24/1	25,16	34	39
70	%67-33 Pes-Co	3/1 Z Twill	70	70,48	50	52	Ne 30/1	29,91	30	35
71	%67-33 Pes-Co	3/1 Z Twill	70	70,37	50	52	Ne 30/1	30,35	32	39
72	%67-33 Pes-Co	3/1 Z Twill	70	70,59	50	51	Ne 30/1	29,63	34	39
73	%67-33 Pes-Co	4/2 Z Twill	70	70,31	50	46	Ne 20/1	18,93	30	34
74	%67-33 Pes-Co	4/2 Z Twill	70	70,75	50	49	Ne 20/1	18,67	32	36
75	%67-33 Pes-Co	4/2 Z Twill	70	70,39	50	47	Ne 20/1	18,72	34	39
76	%67-33 Pes-Co	4/2 Z Twill	70	70,98	50	48	Ne 24/1	24,96	30	34
77	%67-33 Pes-Co	4/2 Z Twill	70	70,78	50	49	Ne 24/1	25,05	32	37
78	%67-33 Pes-Co	4/2 Z Twill	70	70,92	50	49	Ne 24/1	25,63	34	40
79	%67-33 Pes-Co	4/2 Z Twill	70	70,29	50	47	Ne 30/1	30,11	30	34
80	%67-33 Pes-Co	4/2 Z Twill	70	70,34	50	47	Ne 30/1	30,27	32	36
81	%67-33 Pes-Co	4/2 Z Twill	70	70,12	50	49	Ne 30/1	30,38	34	39

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.

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

In the scope of the comfort tests; stiffness, air permeability and relative water vapor tests were applied to the sample fabrics. While testing 3 replications were applied and their mean averages were taken.

Relative water vapor tests of the sample fabrics were done at PERMETEST device according to the ISO 11092 "Textile Physiological Affects- Determined Circumstances Thermal and Water Vapor Resistance Test"[13]. The stiffness level test of the sample fabrics were done at Digital Pneumatic Stiffness device based on "Circular Bending Test Method" ASTM D 4032-94 test[14]. 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[15]. The test was applied at 20 cm^2 area and 200Pa pressure drop.

3. RESULTS AND DISCUSSION

In the content of the study, the weft fiber type, weaving pattern, fabric weight, fabric thickness, weft yarn count and weft density values of 81 samples were used as input for the ANN Models and their values are given at Table 4. The stiffness, air permeability and RWVP scale results of 81 samples being examined in the study, which were used as outputs in the ANN Models were given at Table 4 also.

Table 4. The Input Values of Fabrics and Test Results as Output Values

	INPUT VALUES						OUTPUT VALUES (TEST RESULTS)		
Fabric No	Fiber Type	Weaving Pattern	Weight (gr/m2)	Thickness (mm)	Weft Yarn Count (Ne) (Measured)	Weft Density (yarn/cm) (Measured)	Stiffness (Kgf)	Air Permeability (ı/m²/s)	RWVP (%)
1	%100 Co	2/2 Z Twill	155	0,31	18,87	32	0,0853	119,17	62,50
2	%100 Co	2/2 Z Twill	160	0,33	18,83	34	0,1160	113,50	60,10
3	%100 Co	2/2 Z Twill	169	0,34	18,86	37	0,1480	74,13	59,90
4	%100 Co	2/2 Z Twill	136	0,31	25,22	33	0,0747	242,83	66,65
5	%100 Co	2/2 Z Twill	146	0,29	25,12	35	0,0867	122,83	65,05
6	%100 Co	2/2 Z Twill	150	0,29	25,10	37	0,1176	93,98	64,40
7	%100 Co	2/2 Z Twill	139	0,29	30,43	34	0,0507	185,83	68,05
8	%100 Co	2/2 Z Twill	124	0,27	30,32	36	0,0637	184,67	67,10
9	%100 Co	2/2 Z Twill	126	0,27	30,23	38	0,0720	173,67	65,20
10	%100 Co	3/1 Z Twill	160	0,32	18,92	34	0,0720	93,38	62,20
11	%100 Co	3/1 Z Twill	164	0,32	21,55	36	0,0760	73,33	61,33
12	%100 Co	3/1 Z Twill	171	0,32	21,60	38	0,0897	56,52	60,90
13	%100 Co	3/1 Z Twill	142	0,30	25,16	34	0,0693	159,33	66,90
14	%100 Co	3/1 Z Twill	147	0,30	25,14	37	0,0698	118,67	64,87
15	%100 Co	3/1 Z Twill	153	0,31	25,03	39	0,0930	103,00	63,17
16	%100 Co	3/1 Z Twill	120	0,28	30,31	33	0,0502	205,50	69,90
17	%100 Co	3/1 Z Twill	125	0,29	30,42	36	0,0503	181,17	69,03
18	%100 Co	3/1 Z Twill	129	0,29	30,05	38	0,0572	151,17	67,90
19	%100 Co	4/2 Z Twill	153	0,33	21,95	32	0,0630	130,50	64,90
20	%100 Co	4/2 Z Twill	160	0,33	19,15	34	0,0803	103,83	64,13
21	%100 Co	4/2 Z Twill	165	0,33	19,00	37	0,0900	83,80	63,45
22	%100 Co	4/2 Z Twill	138	0,32	25,66	33	0,0540	207,00	67,80
23	%100 Co	4/2 Z Twill	143	0,32	25,66	35	0,0557	167,00	66,15
24	%100 Co	4/2 Z Twill	149	0,32	25,44	38	0,0777	140,00	66,00
25	%100 Co	4/2 Z Twill	117	0,29	30,86	33	0,0497	296,50	71,10
26	%100 Co	4/2 Z Twill	122	0,30	30,23	35	0,0568	242,17	68,28
27	%100 Co	4/2 Z Twill	127	0,29	30,31	37	0,0552	179,83	67,60
28	%33-67 Pes-Co	2/2 Z Twill	151	0,33	21,37	33	0,0960	160,00	55,40
29	%33-67 Pes-Co	2/2 Z Twill	164	0,33	18,68	37	0,1367	85,68	52,40
30	%33-67 Pes-Co	2/2 Z Twill	167	0,33	18,70	39	0,1513	74,15	50,40
31	%33-67 Pes-Co	2/2 Z Twill	133	0,31	25,05	34	0,0580	229,17	59,35
32	%33-67 Pes-Co	2/2 Z Twill	144	0,31	24,88	36	0,0840	136,83	57,20

Table 4. The Input Values of Fabrics and Test Results as Output Values

	INPUT VALUES						OUTPUT VALUES (TEST RESULTS)		
Fabric No	Fiber Type	Weaving Pattern	Weight (gr/m2)	Thickness (mm)	Weft Yarn Count (Ne) (Measured)	Weft Density (yarn/cm) (Measured)	Stiffness (Kgf)	Air Permeability (ι/m²/s)	RWVP (%)
33	%33-67 Pes-Co	2/2 Z Twill	150	0,32	25,18	38	0,1063	94,62	53,95
34	%33-67 Pes-Co	2/2 Z Twill	120	0,29	30,24	33	0,0473	352,50	61,80
35	%33-67 Pes-Co	2/2 Z Twill	126	0,29	30,15	37	0,0830	257,33	61,40
36	%33-67 Pes-Co	2/2 Z Twill	131	0,29	30,14	39	0,0700	190,17	58,15
37	%33-67 Pes-Co	3/1 Z Twill	155	0,34	21,53	33	0,0933	158,00	55,50
38	%33-67 Pes-Co	3/1 Z Twill	164	0,35	19,00	35	0,1357	91,73	54,90
39	%33-67 Pes-Co	3/1 Z Twill	167	0,34	21,56	38	0,1430	81,38	52,25
40	%33-67 Pes-Co	3/1 Z Twill	134	0,32	25,12	36	0,0673	218,67	59,90
41	%33-67 Pes-Co	3/1 Z Twill	144	0,33	25,11	38	0,0780	139,17	56,13
42	%33-67 Pes-Co	3/1 Z Twill	146	0,33	25,12	40	0,0887	119,33	56,03
43	%33-67 Pes-Co	3/1 Z Twill	120	0,31	30,31	34	0,0710	349,33	60,90
44	%33-67 Pes-Co	3/1 Z Twill	127	0,30	30,28	37	0,0761	234,83	59,77
45	%33-67 Pes-Co	3/1 Z Twill	133	0,30	30,38	40	0,0813	185,17	58,00
46	%33-67 Pes-Co	4/2 Z Twill	148	0,36	21,54	31	0,0887	229,83	68,95
47	%33-67 Pes-Co	4/2 Z Twill	158	0,37	21,55	35	0,1050	151,50	67,50
48	%33-67 Pes-Co	4/2 Z Twill	171	0,37	21,54	38	0,1473	91,22	66,65
49	%33-67 Pes-Co	4/2 Z Twill	132	0,34	25,19	33	0,0547	308,83	71,05
50	%33-67 Pes-Co	4/2 Z Twill	141	0,35	25,04	37	0,0600	202,33	70,35
51	%33-67 Pes-Co	4/2 Z Twill	149	0,34	24,94	39	0,0767	149,67	68,70
52	%33-67 Pes-Co	4/2 Z Twill	116	0,32	30,29	33	0,0620	473,17	73,80
53	%33-67 Pes-Co	4/2 Z Twill	124	0,32	30,51	36	0,0682	347,33	72,85
54	%33-67 Pes-Co	4/2 Z Twill	129	0,32	30,97	40	0,0720	288,50	70,70
55	%67-33 Pes-Co	2/2 Z Twill	162	0,33	21,65	35	0,1293	134,83	66,95
56	%67-33 Pes-Co	2/2 Z Twill	167	0,32	21,55	38	0,1477	94,43	66,50
57	%67-33 Pes-Co	2/2 Z Twill	170	0,32	21,63	40	0,1673	83,67	66,45
58	%67-33 Pes-Co	2/2 Z Twill	138	0,31	24,99	36	0,0873	267,67	71,65
59	%67-33 Pes-Co	2/2 Z Twill	146	0,31	25,19	38	0,0993	185,33	70,53
60	%67-33 Pes-Co	2/2 Z Twill	147	0,31	25,09	40	0,1023	152,00	70,30
61	%67-33 Pes-Co	2/2 Z Twill	124	0,30	30,35	36	0,0640	417,50	76,40
62	%67-33 Pes-Co	2/2 Z Twill	128	0,29	30,11	37	0,0763	319,83	73,90
63	%67-33 Pes-Co	2/2 Z Twill	132	0,29	30,01	39	0,0834	263,00	65,35
64	%67-33 Pes-Co	3/1 Z Twill	156	0,33	18,71	35	0,1010	184,33	63,15
65	%67-33 Pes-Co	3/1 Z Twill	166	0,33	19,00	38	0,1357	110,67	61,90
66	%67-33 Pes-Co	3/1 Z Twill	169	0,34	18,88	39	0,1507	82,95	58,00
67	%67-33 Pes-Co	3/1 Z Twill	136	0,32	25,18	35	0,0693	269,00	69,30
68	%67-33 Pes-Co	3/1 Z Twill	143	0,32	24,99	37	0,0800	174,17	68,90
69	%67-33 Pes-Co	3/1 Z Twill	146	0,32	25,16	39	0,0837	149,67	68,57
70	%67-33 Pes-Co	3/1 Z Twill	120	0,30	29,91	35	0,0600	452,33	76,10
71	%67-33 Pes-Co	3/1 Z Twill	129	0,30	30,35	39	0,0767	292,33	72,45
72	%67-33 Pes-Co	3/1 Z Twill	132	0,30	29,63	39	0,0780	264,33	71,15
73	%67-33 Pes-Co	4/2 Z Twill	156	0,37	18,93	34	0,0920	244,17	68,85
74	%67-33 Pes-Co	4/2 Z Twill	163	0,37	18,67	36	0,0943	178,83	68,10
75	%67-33 Pes-Co	4/2 Z Twill	170	0,37	18,72	39	0,1270	119,33	64,40
76	%67-33 Pes-Co	4/2 Z Twill	135	0,33	24,96	34	0,0653	367,00	60,23
77	%67-33 Pes-Co	4/2 Z Twill	144	0,34	25,05	37	0,0690	222,83	57,70
78	%67-33 Pes-Co	4/2 Z Twill	149	0,33	25,63	40	0,0763	189,83	56,95
79	%67-33 Pes-Co	4/2 Z Twill	124	0,32	30,11	34	0,0630	499,50	62,20
80	%67-33 Pes-Co	4/2 Z Twill	129	0,31	30,27	36	0,0657	390,33	60,95
81	%67-33 Pes-Co	4/2 Z Twill	135	0,31	30,38	39	0,0677	281,67	58,40

Statistical analysis were applied to the data acquired from the tests. As a result of the tests ANN models were established using the parameters of the statistically meaningful data of the variance analysis as inputs in order to guest the comfort specialties.

3.1. Statistical Analyze

In the study firstly, it was examined that the effects of the production parameters as the weft fiber type, weaving pattern, fabric weight, fabric thickness, weft yarn count and weft density on the comfort properties as fabric stiffness, fabric air permeability and fabric relative water vapor permeability of sample fabrics by using statistical analyze. For this aim, the weft fiber type and weaving pattern were selected as categorical independent variables, fabric weight, fabric thickness, weft yarn count and weft density were selected numerical independent variables. And the comfort properties, which are fabric stiffness, fabric air permeability and fabric relative water vapor permeability, were selected dependent variables.

3.1.1. Variance Analyze

In order to examine the effects of factors on outcome one-way analysis of variance was applied with the data obtained as a result of experimental studies. The study was done at Design Expert 6.0.8® packet program, at α=0.05 reliability level. While establishing statistical model "full factorial" analysis was preferred. At Table 5 the variables which were used at variance analyze applications were given with their codes.

At Table 6 relative water vapor permeability (RWVP), at Table 7 stiffness and at Table 8 air permeability variance values were given at 0,95 meaningfulness level. At this study, the meaningfulness of the examined values on the results increase, as the F value increases and p value decreases. Also, a factor should be under 0.05 p value in order to be effective on the result. "%Contribution" represents the factor share on the examined total value. As this value increases the effect of the factor on the result increases also. While applying statistical analysis double and triple interactions were added besides basic factors. The aim was to increase the model`s power, it means R^2 value. When Table 6, Table 7 and Table 8 are examined, it can be seen that the established models are meaningful in general. It is also seen that weft fiber type, weaving pattern, weight, thickness, weft yarn count and weft density are effective parameters on the relative water vapor transmission (RWVP), fabric stiffness and fabric air permeability by statistical at α=0.05 reliability level.

Table 5. Variables Used at Variance Analysis, Their Codes and Levels

Code	Factor	Level
A	Weft Fiber Type	%100 Co
		%33-67 Pes-Co
		%67-33 Pes-Co
B	Weaving Pattern	2/2 Z Twill
		3/1 Z Twill
		4/2 Z Twill
C	Weight (gr/m2)	Numerical
D	Thickness (mm)	Numerical
E	Weft Yarn Count (Ne)	Numerical
F	Weft Density (yarn/cm)	Numerical

Table 6. Variance Analysis Table for RWVP Values

Factor	F Value	P Value	% Contribution
MODEL	77.81	< 0.0001 Significant	-
A- Weft Fiber Type	204.82	< 0.0001	16.49
B- Weaving Pattern	18.02	< 0.0001	4.48
C- Weight	23.44	< 0.0001	17.31
D- Thickness	13.02	0.0007	2.39
E- Weft Yarn Count	7.54	0.0084	0.92
F- Weft Density	4.09	0.0487	0.070
AB	98.50	< 0.0001	46.19
AD	19.19	< 0.0001	2.84
AE	14.07	< 0.0001	2.28
BE	7.88	0.0011	1.82
CF	0.051	0.8221	0.011
DE	14.49	0.0004	0.55
ABF	4.32	0.0045	0.66
ACF	2.75	0.0738	0.25
AEF	4.07	0.0231	0.15
CDE	33.38	< 0.0001	1.45
R^2 Value	0.9787		
Standard Deviation	1.08		
CV %	1.68		

It is seen that on Table 6 the most effective parameter is fabric weight (%17,31 contribution) and the second most effective parameter is weft fiber type (%16,49 contribution) on the RWVP. Whereas fabric weight is the most effective parameter with %60,91 contribution and weaving pattern is the second most effective parameter with %8,98 contribution on the fabric stiffness (as can be seen at Table 7). And for the air permeability, the most effective parameter is fabric weight with %61,3 contribution as shown at Table 8. The second most effective parameter is defined as weft fiber type (%13,22 contribution).

Table 7. Variance Analysis Table for Stiffness Values

Factor	F Value	P Value	% Contribution
MODEL	22.94	< 0.0001 Significant	-
A- Weft Fibre Type	6.33	0.0225	7.29
B- Weaving Pattern	17.21	0.0013	8.98
C- Weight	10.08	0.0131	60.91
D- Tickness	5.88	0.0415	1.04
E- Weft Yarn Count	7.75	0.0238	0.36
F- Weft Density	20.48	0.0019	0.29
AD	0.77	0.4952	1.57
AE	0.52	0.6156	0.72
AF	0.41	0.6759	2.129E-003
BC	2.00	0.1981	3.58
BD	1.25	0.3366	0.36
BE	1.11	0.3752	0.24
BF	0.57	0.5849	2.03
CD	0.020	0.8908	5.05
CE	2.77	0.1348	0.39
CF	0.027	0.8728	0.22
DE	0.14	0.7154	0.024
DF	0.013	0.9137	0.78
EF	0.11	0.7475	0.14
ABC	1.47	0.2964	1.21
ABD	2.20	0.1589	0.58
ABE	0.59	0.6773	0.29
ABF	1.07	0.4327	0.64
ACD	8.503E-003	0.9915	1.40
ACE	0.27	0.7678	0.17
ACF	0.83	0.4717	0.29
ADE	0.087	0.9178	0.22
ADF	0.30	0.7519	1.769E-003
AEF	0.31	0.7386	0.056
BCD	0.081	0.9233	0.039
BCE	0.28	0.7654	0.072
BCF	0.53	0.6063	0.14
BDE	0.094	0.9112	4.478E-003
BDF	0.88	0.4520	0.069
BEF	1.36	0.3097	0.28
CDE	0.12	0.7362	1.231E-003
CDF	0.85	0.3825	0.031
CEF	0.54	0.4829	0.038
DEF	0.020	0.8918	1.188E-003
R^2 Value	0.9952		
Standard Deviation	6.326E-003		
CV %	7.39		

Table 8. Variance Analysis Table for Air Permeability Values

Factor	F Value	P Value	% Contribution
MODEL	120.61	< 0.0001 Significant	-
A- Weft Fibre Type	222.52	< 0.0001	13.22
B- Weaving Pattern	15.71	< 0.0001	7.21
C- Weight	107.10	< 0.0001	61.30
D- Tickness	45.21	< 0.0001	3.58
E- Weft Yarn Count	20.87	< 0.0001	0.19
F- Weft Density	31.27	< 0.0001	3.05
AE	29.86	< 0.0001	3.15
AF	25.56	< 0.0001	1.59
BE	6.68	0.0030	0.69
CD	3.12	0.0847	0.58
CE	12.63	0.0010	1.97
CF	31.55	< 0.0001	0.90
DE	0.25	0.6164	8.748E-004
EF	13.14	0.0008	0.32
ABE	0.74	0.5720	0.17
ACE	8.06	0.0011	0.89
ADE	1.95	0.1546	0.046
AEF	1.42	0.2525	0.095
BCE	1.01	0.3740	0.050
BDE	0.85	0.4340	4.829E-003
BEF	1.80	0.1780	0.063
CDE	0.45	0.5051	2.957E-005
CEF	0.55	0.4637	1.480E-003
DEF	1.01	0.3199	0.022
R^2 Value	0.9909		
Standard Deviation	13.21		
CV %	6.77		

3.1.2. The Diagnosis of the Established Model

After interpreting the data acquired from the result of the experiment design, the appropriateness of the established experiment should be checked. When the errors are signed on the normal probability graphic, if there is a straight line then the errors are accepted sourced from the normal distribution. The appropriateness of the established model for the fabric stiffness, relative water vapor and air permeability was tested via normal % distribution and remnant value- scaled value graphics. When the Figure 1, Figure 3 and Figure 5 are examined it can be seen that data is close to the normal curve and errors spread as a straight line roughly. This conclusion means that the established models are enough and appropriate. When Figure 2, Figure 4 and Figure 6 are examined it can be seen that error values spread homogeneous and do not depend on the order of the test. Also, having no value number exceeding the bottom and upper control limits proves the reliability of the models.

The % distribution graphic of RWVP is given at Figure 1 and the remnant value-experiment number graphic of RWVP is given at Figure 2.

The % distribution graphic of fabric stiffness is given at Figure 3 and the remnant value-experiment number graphic of fabric stiffness is shown at Figure 4.

The % distribution graphic of air permeability is displayed at Figure 5 and the remnant value-experiment number graphic of air permeability is given at Figure 6.

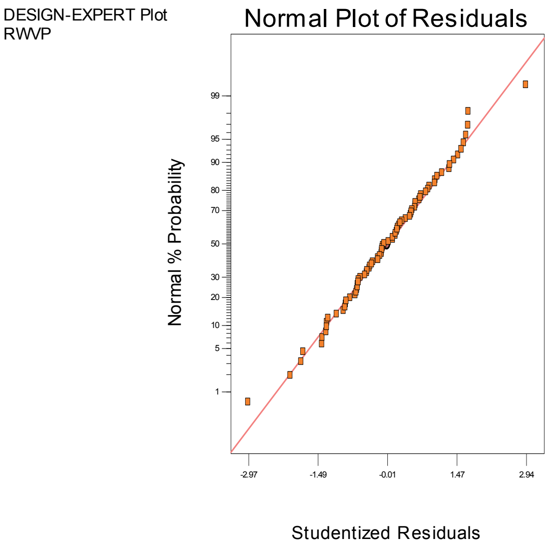

Figure 1. Normal % Distribution Curve for RWVP

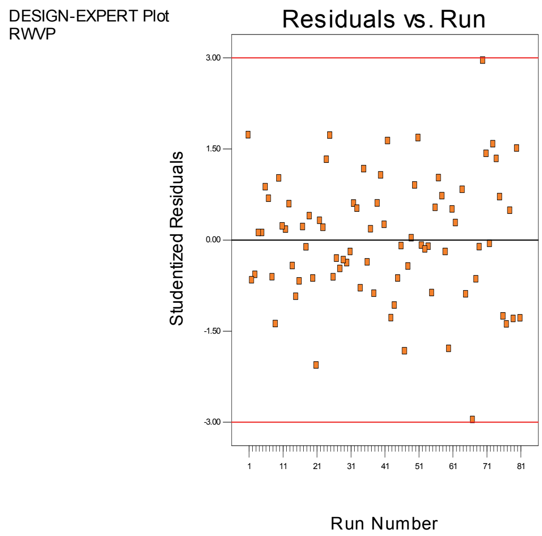

Figure 2. Remnant Value-Experiment Number Graphic for RWVP

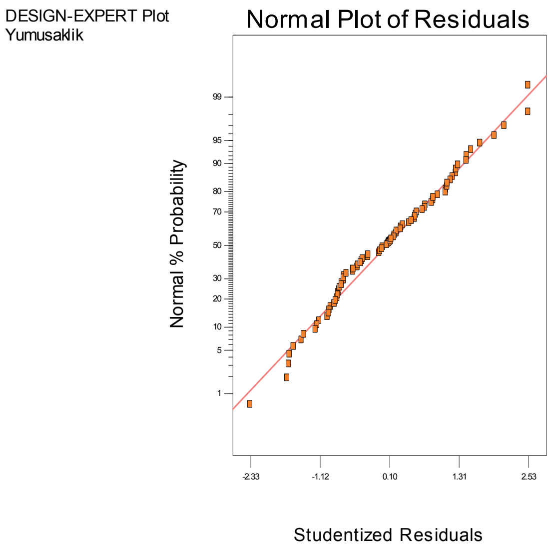

Figure 3. Normal % Distribution Curve for fabric stiffness

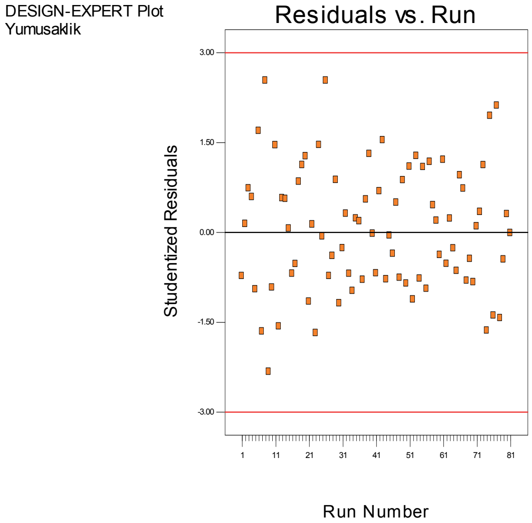

Figure 4. Remnant Value-Experiment Number Graphic for fabric stiffness

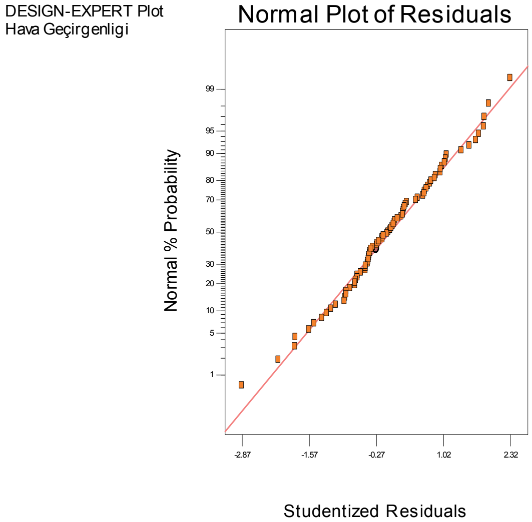

Figure 5. Normal % Distribution Curve for air permeability

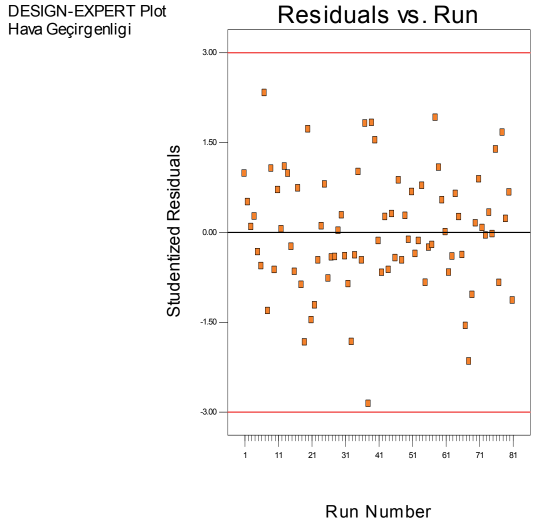

Figure 6. Remnant Value-Experiment Number Graphic for air permeability

3.2. Artificial Neural Network Models

While establishing Artificial Neural Network (ANN) Models, MATLAB®R2012a packet program was used.[16]. While establishing ANN models, the weft fiber type, weaving pattern, weight, thickness, weft yarn count and weft density values which were defined as effective on the air permeability, RWVP and stiffness specialties by statistical analyze. For the aim of predicting comfort properties, it was established ANN models separately with 6 input and 1 output for each comfort property. ANN Models were established with using feedforward and back propagation network [17,18]. While establishing ANN models %70 of 81 samples (57 items) were used for education, %15 (12 items) were used for cross validation and %15 (12 items) were used for test. MSE (Mean Square Error) was used to cross validation. In order to reach the optimum prediction model 10 different ANN models were established via using different network parameters. The topologies and regression values of the models are shown in Table 9.

Table 9. The Topologies and Regression Values of the Established ANN Models

Network Number	Network Structure				Air Permeability %R	Stiffness %R	RWVP %R
	Training Function	Transfer Function	Hidden Layer	Neuron Number			
1	Trainlm	Tansig	1	10	0,92780	0,91869	0,80393
2				20	0,91585	**0,96726**	0,81906
3				30	0,83791	0,94355	0,72472
4			2	10	0,91262	0,93138	0,81199
5				20	0,93988	0,93671	**0,83040**
6				30	0,81108	0,93043	0,65715
7		Logsig	1	10	0,91557	0,94565	0,69933
8				20	0,73612	0,93614	0,79970
9				30	**0,94491**	0,87529	0,77042
10			2	10	0,91373	0,90478	0,73016
11				20	0,92972	0,87253	0,65216
12				30	0,91745	0,90385	0,82441

When the Table 9 is examined among the established models the best result for air permeability is gained from the network9 which established in 6 inputs and 1 output as with the 0,94491 regression value. The model of the established network is given at Figure 7 and the regression graphic of the network is represented at Figure 8.

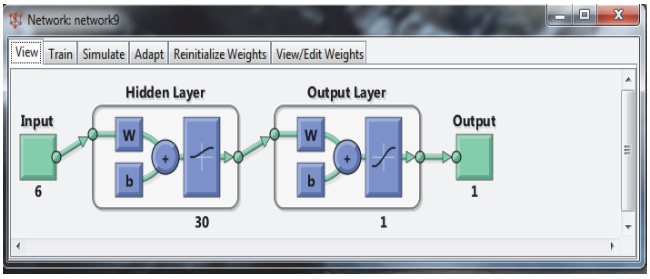

Figure 7. Structure of the Network9 Established for Air Permeability Values

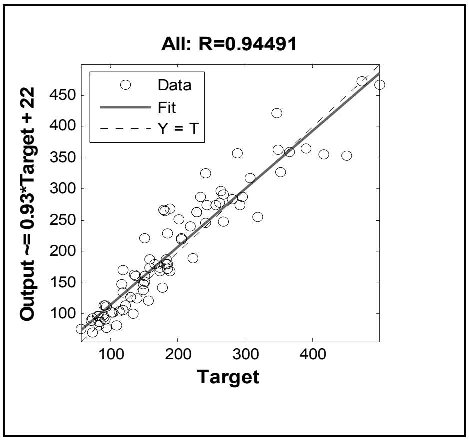

Figure 8. Regression Graphic of Network9 Established for Air Permeability Values

As seen at Figure 8, the general regression value of the network is R=0,94491. This value shows that the learning and guessing ability of the network is quite good.

It is observed that on Table 9 the best result for stiffness was gained in the model which established with the 6 input and 1 output in the network2 with 0,96726 regression value. This value shows that the learning and guessing ability of the network is quite good. The model of the established network is given at Figure 9 and the regression graphic is given at Figure 10.

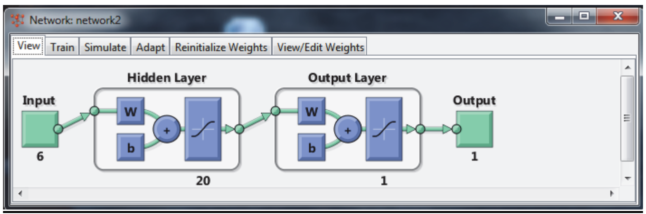

Figure 9. Structure of Network2 Established for Stiffness Values

When Table 9 is examined the best result for RWVP got in the model established with the 6 input and 1 output in the network2 with 0,83040 regression value. This value shows that the learning and guessing ability of the network is quite good. The model of the established network is given at Figure 11 and the regression values is given at Figure 12.

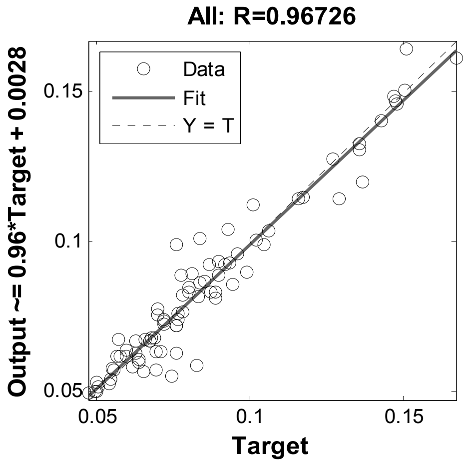

Figure 10. Regression Graphic of Network2 Established for Stiffness Values

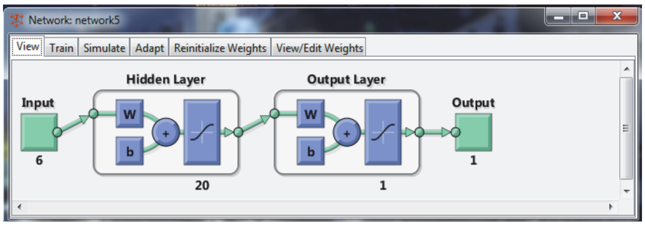

Figure 11. Structure of Network5 Established for RWVP Values

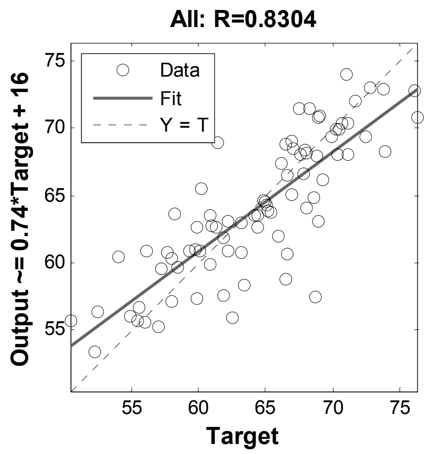

Figure 12. Regression Graphics of Network5 Established for RWVP Values

4. CONCLUSION

In the scope of the study, comfort specialties of the target fabrics were examined, the data were examined statistically and ANN Models were tried to be established in order to guess the comfort specialties. As a consequence of the statistical analysis, it was revealed that production parameters the effects of which were examined on the comfort specialties, such as weft yarn count, weft density, weaving pattern, fabric density, fabric weight and weft fiber type show meaningful effect on fabric stiffness, air permeability and relative water-vapor as parallel in literature. These results are parallel with the results of the Marmaralı and Oğlakçıoğlu (2013)`s studies. ANN Models trials were done as a result of the variance analysis parameters which were defined meaningful on the fabric comfort specialties. Among the ANN Models established in the concept of the study the best guessing results for the fabric stiffness were gathered at the network formed as ˜0,97 regression value, one hidden layer and 20 neurons. As for the relative water-vapor the values were gathered as follows ˜ 0,83 regression value, two hidden layer and 20 neurons. Among the ANN Models established in the concept of the study the best guessing results for air permeability were gathered at the network formed as ˜ 0,94 regression value, 1 hidden layer and 30 neurons. These results show that fabric stiffness, air permeability and relative water-vapor can be guessed in high correlation by using parameters such as fabric thickness, weight, weft yarn count, weft density and weaving pattern before manufacture. These findings support the studies of the Militky and others (2003), Oğulata(2006) and Oğulata & Mezarcıöz(2012).

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