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Prediction of Withdrawal Strength of Nail of Uludag Fir Wood by Using Artificial Neural Network (ANNs)

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Abstract
In this study, the effects of type of nails material and grain angle of wood on the withdrawal strength of nail have been researched. For this purpose specimens were firstly cut in different sections from Uludağ Fir (*Abies bornmülleriana* M.) wood. The tests of static nail strength were carried out according to the standards of TS EN 13446. Secondly, an artificial neural network system was built by using data obtained in an experimental study for the prediction of withdrawal nail strength. The comparison between the experimental data and predicted data was also carried out.
Key words: Fir, withdrawal strength, nail, artificial neural networks

Introduction

Various wood joint techniques are applied in furniture production. In our days, many new joint techniques which are suitable for machine production are used for binding the furniture parts. The nuts, screw nut, nails, bolts, and other special parts used for this reason are the equipments which provide mechanical bindings (Örs et al., 1999).

The maximum holding strength of a screw is determined in part by the panel's internal bond. The denser boards tend to have the higher screw holding strength (Eckelman, 1990). It was seen that dismountable joints were more successful than stable joint in "T" used for the production of frame construction furniture (Imirzi, 2000).

Örs et al. (1998) stated that the best result in terms of the ability of screw holding strength parallel and straight to the surface was observed in beech wood other than particleboard, medium-density board and werzalut.

In another study it was reported that the highest withdrawal strength was obtained face perpendicular of oriental beech to screw 20*35mm. The highest withdrawal strength was obtained when the face was parallel to nails such as 16*30 mm (Ozçifçi and Doğanay, 1999).

Yapıcı et al. (2009) stated that if the adhesive ratio, pres time and pres pressure used for the production of oriented strength board increase, the nail withdrawal strength increases as well. They also reported that the nail withdrawal strength values were changed between 124.60 and 334.81 N.

Artificial neural networks (ANNs) are computer algorithms whose structure and function are based on models. ANNs are currently being used in a variety of applications with great success in many of them (Vosniakos et. al., 2007). Artificial neural network modeling has been widely used in the field of wood recognition system (Tau et al. 2007; Marzuki et al., 2008) , in the modeling of product recovery for trees (Zhang et al., 2007), in the classifying of wood veneer defects (Packianather and Drake, 2000), in the calculation of wood thermal conductivity (Xu et al., 2007), in the predicting fracture toughness of wood (Samarasinghe et al., 2007), in the prediction of bending strength and stiffness in western hemlock (Shown et al., 2007), in the analysis of wood moisture (Stavros, 2007).

The goal of this study was to use ANNs as alternative was of modeling and determining how withdrawal strength of nail of Uludağ Fir wood was affected depending on different grain angles. Furthermore, a feed forward and backward propagation multilayer ANN model was advanced.

Material and Method

Wood Material

Test materials were prepared from Uludağ Fir which is widely used to the machinery industry in our country. The wood material was chosen randomly from the storage of a Karabuk merchant.

Nails

Two types of nails, 40-60 mm-long were used in this experimental design. The properties of them were shown in Table 1.

Table 1. Properties of nails

Type of Nail	Diameter of Nails (mm)	Diameter of Nail Head (mm)	Length (mm)
40	1.90 mm	4.70 mm	40
60	2.90 mm	7.50 mm	60

Preparing the experimental samples

Experimental samples were prepared from Uludag Fir with 100 x 100 x 50 mm size. Grain angles of prepared test samples were selected as 0, 15, 30, 45, 60, 75, and 90º (Figure 1).

After the preparation, test samples were conditioned to constant weight at 65±5% relative humidity and at a temperature of 20±2°C. Air-dried density, equilibrium humidity content, nail withdrawal strength values of test samples were determined by Turkish Standards Institution (TS EN 323, 1999; TS EN 322, 1999; TS EN 13446, 2005). In measurement of nail withdraw values a Zwick/Roell Z050 universal test device with a capacity of 5,000 kg and a measurement accuracy of 0.01 Newton was used. During testing testing, the loading mechanism had moved with a speed of 4 mm/min.

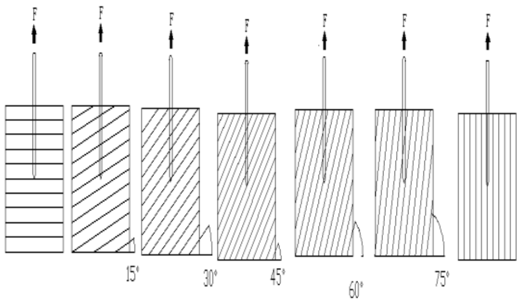

Figure 1. Experimental Samples

Statistic Procedure

Data for each test were statistically analyzed by using SPSS program. The analysis of variance (ANOVA) was used to test for significant difference between factors and levels. When ANOVA indicated a significant difference among factors, a comparison of means was carried out by employing a Duncan test.

Design of the Artificial Neural Networks

The ANN model was made by using the MATLAB Neural Network Toolbox. The developed ANN model depends on the experimental results. The input values are the type of nail and grain angle of test sample. The input data is applied after a normalization process between -1 and +1. The output value is the withdrawal strength of nails. The model has two layers as well as 8 neurons in the first hidden layer and 1 neuron in the second layer. The ANN architecture is shown in Figure 2.

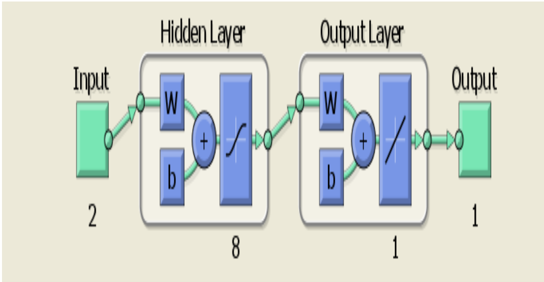

Figure 2. The design of ANN used for this study

In the solution of the problem, feed forward and backward propagation multilayer ANN was chosen to calculate errors and adjust the weights of neurons. Hyperbolic tangent sigmoid and linear transfer functions were selected as the activation function of the nodes in the hidden layers and output layer, respectively; traingdm, Levenberg Marquardt algorithm and mean square error were used to training function, activation function and performance function, respectively.

Result and Discussion

The average air-dry density of Uludağ-Fir samples is 0.41 g/cm^3. The average moisture content of samples is 11.56%.

The results of withdrawal strength values of nail both measured and predicted by using ANN are shown in Table 1.

Table 1. Measured and predicted values of nail strength

Experimental Conditions		Mean values of withdrawal strength of nails (N)	
		Exp.	Prediction
Grain Angle of Wood (°)	Length of Nail (mm)	Mean	Mean
90	40	217.05	222.19
	60	294.75	301.68
15	40	205.05	196.78
	60	320.93	251.50
30	40	229.61	190.65
	60	265.23	255.23
45	40	171.56	181.21
	60	248.33	255.71
60	40	194.05	175.74
	60	198.84	255.88
75	40	165.73	179.12
	60	259.32	259.69
0	40	112.14	109.73
	60	218.09	227.95

According to Table 1, the highest nail holding strength value (320.93 N) was obtained in case of grain angle of 15º by using a 60 mm long nail. The lowest nails holding strength value (112.14 N) was determined for the 0 º grain angle with 40 mm long nail. It was shown that the ANN model has predicted the withdrawal strength of nail with the average precision of 91.94 %.

The variance analysis was applied to data belonging to nails holding strength and they were shown in Table 2.

Table 2. The results of Variance analysis

Source	Type III Sum of Squares	Df	Mean Square	F	Sig. Level (P<0,05)
Intercept	12727102,68	1	12727102,68	2278,39	0,00
A	268921,60	6	44820,27	8,02	0,00
B	344704,67	1	344704,67	61,71	0,00
A*B	83578,74	6	13929,79	2,49	0,02
Error	1452360,36	260	5586,00		
Total	15428940,57	274			
A: Grain Angle (degree), B: Type of Nails					

According to the results of variance analysis the effects of grain angle, type of nails and each of them on withdrawal strength of nail were statistically significant. The interaction between factors was statistically identical ($p < 0.05$). The mean values of the variation sources that were found to be significant were compared using Duncan test and the results were summarized in Table 3.

Table 3. Duncan Test Results

Grain angle (degree)	Mean of Nail Strength (N)	HG
90	165.11	a
60	196.51	ab
45	206.99	b
75	212.53	b
30	247.42	c
0	255.90	c
15	270.23	c

The results of Duncan test in relation to the grain angle show that the highest withdrawal strength of nail (270.23 N) was obtained at 15º. The regression analysis with training, validation, test and all data were given in Figure 3. According to the regression analysis one may say that the ANN is very accurate to predict the performance of related to the data.

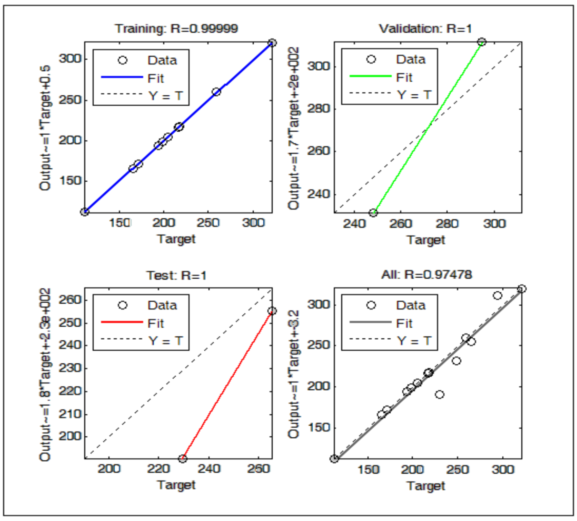

Figure 3. Regression analysis

Conclusion

Based on the above results one may conclude that the withdrawal nail strength was affected by both grain angle of test samples and type (length) of nail. This paper presents an Artificial Neural Networks (ANNs) application used for the prediction of withdrawal strength of nail in Uludağ fir. The comparison of ANN and experimental results for the withdrawal nail strength in the Uludağ Fir wood is shown in Figure 4.

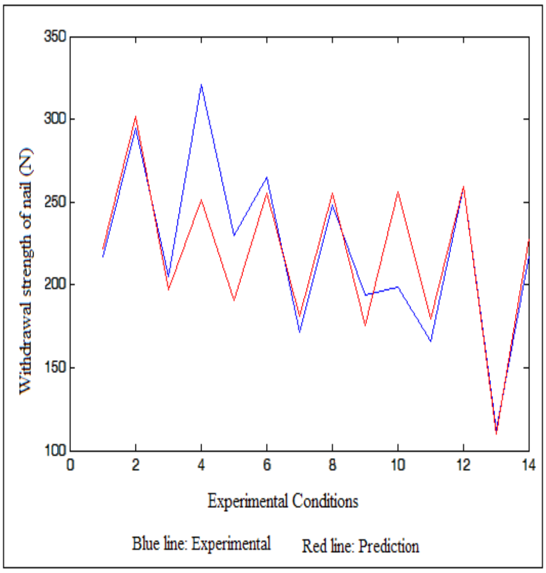

Figure 4. The comparison of the experimental and predicted values of withdrawal nail strength

It was shown above that the ANNs model has predicted the withdrawal nail strength with the average accuracy of 91.94 %. ANN can be used for the modeling of manufacturing design and optimization process in the woodworking application areas.

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