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PREDICTION OF SCREW AND NAIL WITHDRAWAL STRENGTH ON OSB (ORIENTED STRAND BOARD) PANELS WITH FUZZY CLASSIFIER

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Abstract

Oriented strand-board (OSB) is a fantastic development in the world of engineered wood products with its growth and performance. It is affected by different factors, so prediction of its behavior is so difficult. In this study, first, OSB panels were produced at different conditions (such as press time, press pressure and adhesive ratio). Second, nail and screw withdrawal strength values of produced panels were tested experimentally. Then, the results obtained by experiments were evaluated in multiple variance analysis, and homogeneousness of the groups was assessed by Duncan test. Finally, the input values and the corresponding results were utilized to build a fuzzy classifier by Matlab Simulink software. The developed fuzzy classifier model is able to predict the nail and screw withdrawal strength at the accuracy levels of 78.96 % and 89.26%, respectively. The model could be employed at the building construction and furniture manufacturing stages.

Keywords: Wood composite materials, Oriented strand board (OSB), Fuzzy logic classifier, nail withdrawal strength, screw withdrawal strength

1. Introduction

Oriented Strand board or Oriented Structural Board (OSB) is an engineered wood product in the form of panels made up of wood elements known as strands. The strands are deliberately formed within alignment or orientation, and are bonded with a thermosetting adhesive, generally phenol formaldehyde, under pressure and heat. The grain direction of the strands is mostly parallel to the flat surface [1]. OSB is really a second-generation panel that developed from the original product named waferboard that is made from square wafers [2]. OSB panels are used various applications such as building construction, furniture, roofing and flooring. OSB parts join with nut, nail, and screw at using area. Different wood joint techniques were applied on furniture production since the very old times of human history. In our day new joint techniques are used for join the parts of furniture. The nuts, screws, nails, bolts, and special joining parts used for this purpose. These techniques provide mechanical strength [3]. Dowel, mortise-tenon joint, some alternative joints and combinations of these joints are also used in furniture industry [4].

Screw withdrawal strength of beech, werzalut (mould pressed and coated elements), medium density fiberboard and particle board was researched and the highest screw withdrawal strength was achieved in beech wood and werzalut [5].The highest screw holding strength was achieved in particle boards with massive edges and plywood. It was found that the glue applied on the pilot holes increased the screw holding strength greatly [6].The best result was achieved in beech wood when particleboard, medium density board and werzalut were compared about the ability of screw withdrawal strength parallel and straight to the surfaces. Werzalut, medium density fiberboard and particle board follows the beech wood in this order [7].

The properties of wood composite materials are affected by the type of used wood, chips size, adhesive type and amount, pressing conditions, density of the panel and mat formation of it [8]. In short, all the factors are

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related with each other. Changing even one of these factors might be insufficient for desired panels. In order to be able to manufacture the panels for proper usage, it's important to know the effects of these factors on the panels' properties [9]. However, determining the effects of all these factors on the mechanical and physical properties one by one is time consuming and expensive for the researchers and manufacturers. So, it will be beneficial to use the developed models. Recently developed Fuzzy Logic is a powerful technology which allows to quickly incorporate engineering expertise into products.

Fuzzy logic has found wide application areas. Electrical home appliances, automobile electricity, daily used machines, production engineering, industrial technologies and automation are some of them [10]. Previous studies have attempted to develop customer satisfaction models with statistical regression, fuzzy regression, neural networks, quantification analysis, and fuzzy rule-based modeling. At the same time, various techniques have been attempted to model the fuzzy relationships between design attributes and customer satisfaction [11].

Yapici et al. [12] used fuzzy logic classifier model for prediction of modulus of rupture and modulus of elasticity of wood composite material, which is called flake board. The model agreed well with the experimental results at maximum errors of rupture modulus of 5% and elasticity modulus of 3%. Cha and Pearson [13] developed two dimensional finite element models to predict the elastic tensile properties of a 3-ply model on LVL (Laminated Veneer Lumber). The values of the predicted and experimental strains at maximum load (max. difference of 14.3%) as well as the predicted and experimental stresses (max. difference of 7.7%) were acceptably in harmony

In this study, the OSB panels were produced from Scots pine (Pinus slyvestris L.), which is widely used in wood composite panels production. Then, nail and screw withdrawal strength were measured by experiments designs. The results obtained from experiments were compared with the fuzzy logic classifier model for the accuracy.

2. Material and Methods

Scots pine (Pinus sylvestris L.) was used in the production of the oriented strand boards (OSB). The wood strand dimensions were approximately 80mm long, 20 mm wide and 0.7 mm thick. First, the wood strands were dried up to 3% moisture content before adhesive was sprayed on them. Then, adhesive material without wax, 47 % phenol formaldehyde, was applied in 3%-4.5 and 6 ratios based on the weight of oven dry wood strands. The press periods and press pressure were 3-5 and 7 minutes under the 35-40-45 kp/cm^2 respectively. The shelling ratio was 40% for core layer and 60% for face layer and density of boards was aimed as 0.70g/cm^3. Mats (56x56x 1.2cm) were formed. Totally, 27 OSB panels were produced at this study. All mats were pressed onto automatically controlled, heated press platens at 182±3ºC. After pressing, the boards were conditioned to constant weight at 65±5% relative humidity and at a temperature of 20±2°C. Air-dried density of test boards, equilibrium humidity amount, nail and screw withdrawal strength values were determined by Turkish Standards Institution [14, 15, 16].
In measurement of screw withdraw and nail withdraw values Zwick/Roell Z050 universal test device with capacity of 5000 kg and measurement capability of 0.01Newton in accuracy was used. In testing, loading mechanism was worked with a velocity of 5 mm/min. in order to complete the breaking process within 60-90 minutes beginning from the boarding time.

Data for each test were statistically analyzed. The analysis of variance (ANOVA) was used ($\alpha \leq 0.05$) to test for significant difference between factors. When the ANOVA indicated a significant difference among factors, the compared values were employed to Duncan test to identify which groups were significantly different from other groups.

3. Design of Fuzzy Logic System

In the fuzzy logic classifier; x is the input value, $\mu(x)$ is fuzzified output value, $\mu(u)$ is the result of inference operation and u is the output value. Fuzzifier unit converts definite data in the input of controller to the format of linguistic variables. Fuzzy knowledge base represents two basic data; database and rule base. When data base includes definition of each system variable using fuzzy set, rule base covers inspection rules that are necessary to obtain real output. Inference unit is a unit that performs fuzzy inference on fuzzy rules. This unit performs the operation resembling the way that people think. Defuzzification unit converts the fuzzy values obtained from the output of inference unit to numerical values. This operation is called as fuzzification. The simples fuzzy logic controller (classifier) is given in Figure1.

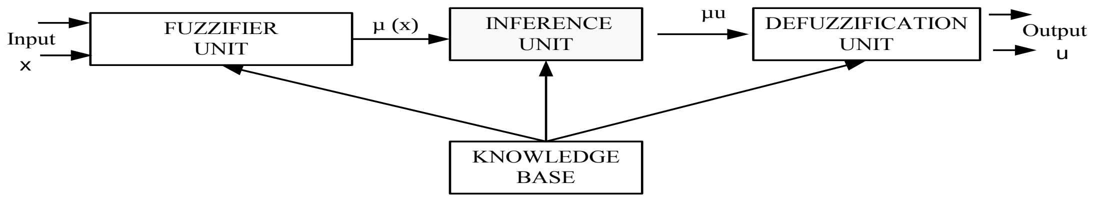

Figure 1. Fuzzy logic controller

In this study, rule base of fuzzy logic system was determined according to the input and output variables and their functions. These are 15 rules in the fuzzy logic classifier totally. Input variables are pressure, press time and adhesive ratio, in which were used in production of OSB panels. Input variables were called as little low, normal and little high are given in Figure2.

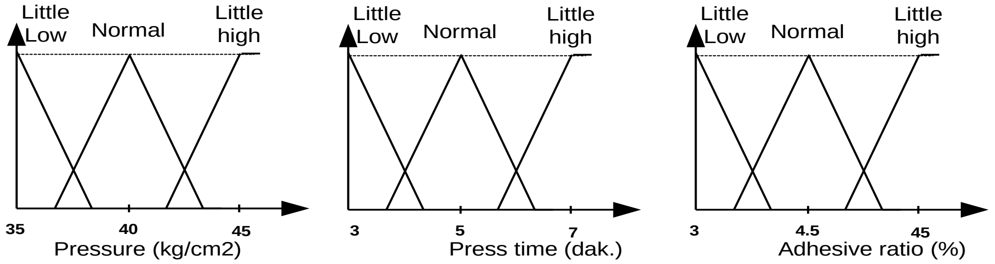

Figure 2. Input variables of fuzzy logic classifier

Output variables were determined according to nail and screw withdrawal strength values took from experimental results. And output variables were called as very low, low, normal, high and very high. The output variables defined for this study and the membership functions of them given in Figure3.

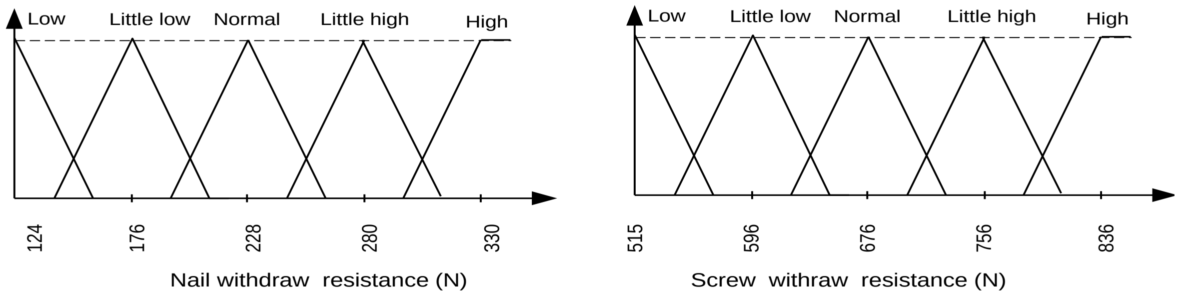

Figure 3. Output variables of fuzzy logic classifier for the nail and screw strength values

The classifier model was developed using MATLAB Simulink for predicting to nail and screw withdrawal strength values. Input variables were transferred from MATLAB working environment to the fuzzy logic classifier. Fuzzification was performed according to the number of membership and the type of membership function selected by the fuzzy logic classifier. The user could chance the number of the input and output variables by controller, and limit values of the membership function in the MATLAB fuzzy inference system editor can add rules to rule base or can change the existing rules. In the fuzzy inference system editor, the shape and the number of the membership functions of input and output variables can be changed. These features give flexibility to fuzzy logic diagnosis and provide clearer results (Figure4).

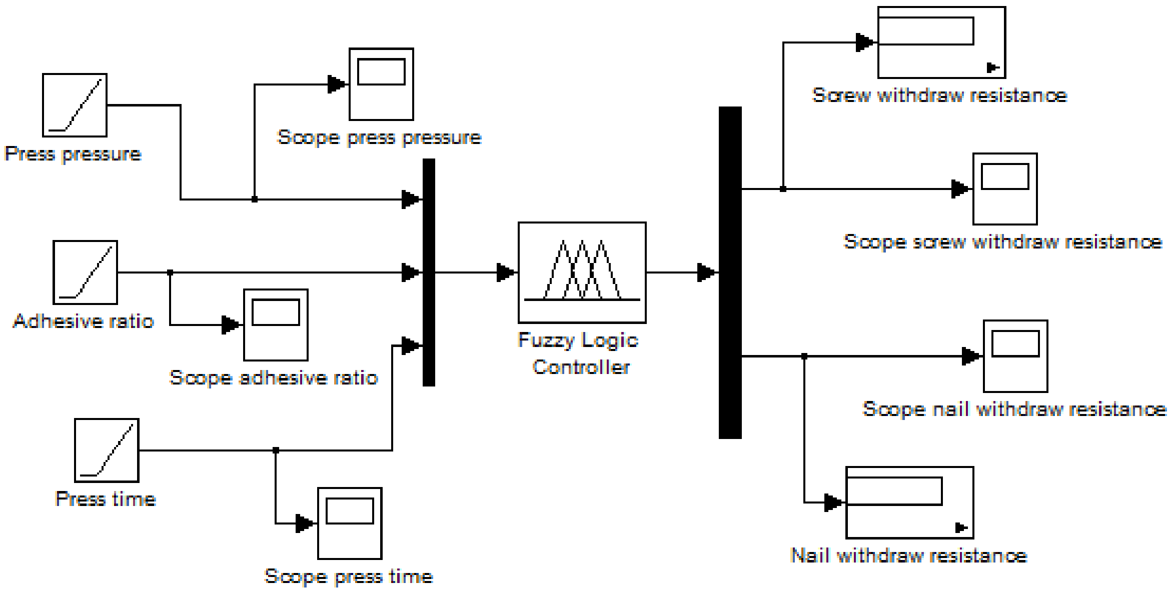

Figure 4. The model developed in MATLAB Simulink for fuzzy logic fault diagnosis

4. Result and Discussion

The average density and equilibrium moisture content of OSB panels were determined as 0.72 g/cm^3, 7.24 %, respectively. The variance analysis of nail and screw withdrawal strength based on manufacturing conditions of panels were conducted. Multiple variance analysis was used to determine the differences among the test samples. The results of variance according to the nail strength are given in Table1. Similarly, the variance analysis of screw withdrawal resistance was conducted. The results of variance analysis are given in Table 2. It was determined that there is a significant difference among the groups.

Table 1**.** Multiple variance analysis results of nail withdrawal strength

Source	Sum of square	Degrees of Freedom	Means of square	F-Value	Significant Level (P<0.05)
A	1078195.65	2	539097.82	164.55	0.000
B	353695.20	2	176847.60	53.98	0.000
C	13859.76	2	6929.88	2.11	0.122
A * B	18188.94	4	4547.23	1.38	0.237
A * C	8263.48	4	2065.87	0.63	0.641
B * C	5187.87	4	1296.96	0.39	0.812
A * B * C	7301.85	8	912.73	0.27	0.973
Error	1680597.83	513	3276.01		
Total	29651752.52	540			

A: Adhesive ratio (3-4.5-6 %), B: Pres time (3-5-7 min.), C: Press pressure (35-40-45kg/cm^2)

Table 2. Multiple variance analysis results of screw withdrawal strength

Source	Sum of square	Degrees of Freedom	Means of square	F-Value	Significant Level (P<0,05)
A	4494066.88	2	2247033.44	136.87	0.000
B	524578.84	2	262289.42	15.97	0.000
C	4790.80	2	2395.40	0.14	0.864
A * B	31488.99	4	7872.24	0.48	0.751
A * C	15277.12	4	3819.28	0.23	0.920
B * C	3668.72	4	917.18	0.05	0.994
A * B * C	17110.02	8	2138.75	0.13	0.998
Error	8421629.52	513	16416.43		
Total	274774167.32	540			

A: Adhesive ratio (3-4.5-6 %), B: Pres time (3-5-7 min.), C: Pres pressure (35-40-45kg/cm^2)

A multiple comparison of the means was done by employing Duncan test to identify which groups were significantly different from other group. The results are given in Table 3.

Table 3. Results of Duncan test

Experiments Conditions		Nail withdrawal strength		Screw withdrawal strength	
		Mean (N)	HG	Mean (N)	HG
Adhesive ratio (%)	3	163.39	A	570.91	a
	4.5	228.94	B	729.09	b
	6	272.07	C	786.69	c
Press Pressure (kg/cm^2)	35	215.78	A	692.58	a
	40	220.53	A	694.49	a
	45	228.09	A	699.63	a
Press time (minute)	3	195.00	A	658.47	a
	5	213.32	B	693.50	b
	7	256.08	C	734.73	c

HG: Homogenous groups

The effects of adhesive ratio and press time on nail and screw withdrawal strength were seen statistically meaningful at 95% significance level. It can be observed from the different homogenous groups in Table3. In addition, the results obtained by experiments and fuzzy classifier are compared and it is seen that the predicted values are satisfactory. Fuzzy logic classifier was predicted nail and screw withdrawal strength at average accuracies of 78.96% and 89.26% respectively (see Table 4).

Table 4. Measured and prediction results

Experiments Conditions			Nail withdrawal strength (N)			Screw withdrawal strength (N)		
Adhesive ratio (%)	Press time (min.)	Press Pressure (kg/cm^2)	Experimental	Prediction	Accuracy l (%)	Experimental	Prediction	Accuracy (%)
3	3	35	127.08	134.00	95.28	516.77	526.00	98.21
		40	124.60	154.00	76.40	531.77	636.00	80.44
		45	138.10	180.00	69.66	557.38	676.00	78.83
	5	35	153.06	134.00	87.55	565.30	526.00	93.05
		40	155.36	178.00	85.43	556.59	636.00	85.81
		45	170.08	210.00	76.53	577.07	716.00	76.09
	7	35	189.34	161.00	85.03	605.44	566.00	93.49
		40	200.64	228.00	86.54	616.07	636.00	96.92
		45	212.27	280.00	68.44	611.85	716.00	83.00
4.5	3	35	214.49	162.00	75.53	698.25	566.00	81.06
		40	207.85	280.00	65.36	691.99	676.00	97.69
		45	214.78	280.00	69.74	680.60	716.00	94.86
	5	35	221.29	161.00	72.76	741.46	566.00	76.34
		40	215.92	280.00	70.36	738.48	676.00	91.54
		45	221.62	298.00	65.71	740.22	716.00	96.73
	7	35	252.27	230.00	91.17	766.51	670.00	87.41
		40	262.10	280.00	93.51	745.76	676.00	90.65
		45	250.19	298.00	81.21	758.62	756.00	99.65
6	3	35	240.97	176.00	73.04	748.42	596.00	79.63
		40	244.42	280.00	85.68	754.05	716,00	94,95
		45	242.75	324.00	66.63	747.01	756.00	98.93
	5	35	251.11	176.00	70.09	757.79	636.00	83.93
		40	263.25	281.00	93.54	775.58	717.00	92.45
		45	268.23	324.00	79.50	789.09	778.00	98.59
	7	35	292.51	176.00	60.17	833.29	637.00	76.44
		40	310.64	281.00	90.46	840.17	716.00	85.22
		45	334.81	324.00	96.77	834.88	820.00	98.22
				Average accuracy: 78.96%			Average accuracy: 89.26%	

The changes of nail and screw withdrawal strength based on experiment conditions (adhesive ratio, press pressure and pres time) are showed in figure5.

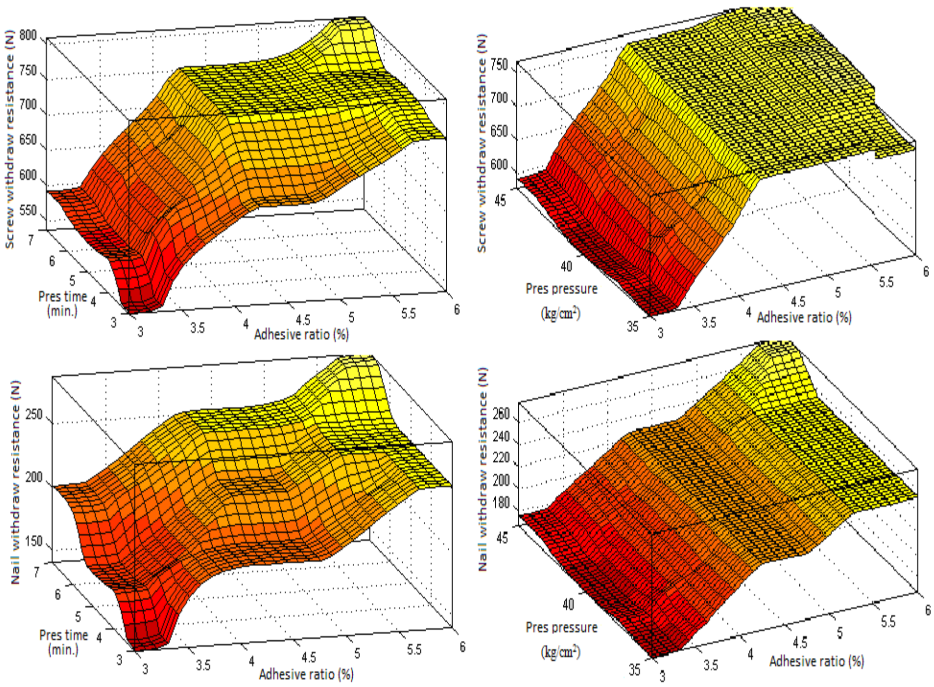

Figure 5. Changes on nail and screw withdrawal strength of OSB panels

5. Conclusion

In this study, developed Fuzzy Logic models can be used to success simulate the behavior of OSB panel which manufacturing by scotch pine. Obtained results from experimental study are used for a fuzzy classifier system. Their results are compared and it is showed that the prediction system has an average accuracy of 84.11% in considering both prediction averages of nail and screw withdrawal strength. These strengths values of the boards to be manufactured with any one manufacturing circumstance could be found in very short time by this prepared model. This model could easily be used to arrange manufacturing stage and for testing the correctness of values of these properties in wood composite panel industry. A little study has been devoted to understanding and modeling the spatial relationship between individual wood elements in wood composites. It is suggested that Fuzzy Logic programs can be used to produce for wood composites.

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