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MOISTURE CONTENT PREDICTION OF WOOD DRYING PROCESS USING FUZZY LOGIC

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ABSTRACT

The fuzzy logic method might be used with various applications, for example, timber production, air conditioners, washing machines, and molecular biology. Fuzzy logic systems are trusted. At the same time easy to use and flexible. Temperatures and relative humidity vary depending on the room where the wood is used. Moisture in wood-based products is one of the key points. Because it directly affects the usage area and production. In the present study, the effects of temperature and drying time on moisture content were modeled and predicted in the wood drying process. For this purpose, the wood test materials were prepared, and their moisture contents were measured. The fuzzy logic model was established by taking references of the observed values. With this fuzzy logic model, the moisture contents of the wood were predicted in relation to drying temperature and time. Then, experimental results were compared with modeling data. 97.16% accuracy was observed with the fuzzy logic model.

Keywords: fuzzy logic, moisture content, drying time

INTRODUCTION

The timber industry is an important part of the economy. In this industry, wood drying has a crucial role in wood processing. Wood drying process presents technical support for the efficient use of forest resources. (Zhao and Yu, 2016). Moisture is a critical issue in applications where wood is used. Various techniques are used to determine moisture. Wood materials, used in indoor and outdoor in wood products industry, are needed to be dried to certain moisture content depending on ambient temperature and relative humidity.

The wood drying process has a complex and nonlinear system with time-varying and uncertain characteristics (Zhao and Yu, 2016). The most important parameters of wood drying process in industrial plants are drying time and temperature.

Fuzzy logic presents a way for prediction, classification, and decision making, where issues can be identified by showing input variable to output variable. Fuzzy logic is a simple powerful problem-solving method with extensive capabilities (Jimoh, 2013). In this logic model, first formed by Zadeh, a subject can belong to one or more fuzzy set(s) with a gradation of membership (Cheung et al., 2005). The fuzzy logic model consists of processes. Three of these operations are fuzzification, rule evaluation, and defuzzification (Uraon and Kumar, 2016; URL1, 2016). Figure 1 illustrates the determined that artificial fuzzy logic system.

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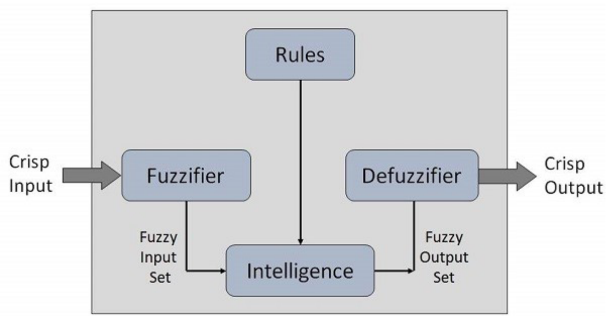

Fig. 1. Fuzzy logic system (URL2, 2017)

Many fuzzy logic models have been developed in the forest industry (Dos Santos et al., 2017). Previous studies determined that the artificial intelligence model might strongly help to make predictions in wood uses without requiring time-consuming and pricey comprehensive experimental inquiry (Bardak et al., 2016; Filiz et al., 2012a; 2012b; Tiryaki and Hamzaçebi, 2014; Tiryaki et al., 2015; Yapici et al., 2009). Fuzzy logic and data-mining are used in different industries in many applications (Bardak et al., 2018). But fuzzy logic studies in the forest industry are very limited.

In this paper, the effects of drying time and temperature parameters on the relative humidity during drying process are experimentally studied and modeled by means of fuzzy logic. Then, experimentally obtained results were compared with modeling outcomes.

MATERIALS AND METHODS

In this work, we used air dried wood species. These wood species chosen for this program is the *Fagus orientalis*, which is commonly utilized in the manufacturing. The specimens were dimensioned as 55×25×25 mm. Then, the samples were kept in the moisture conditioned room (20 ±2°C temperature and 65 ±5% relative humidity) until weight gain reach to equilibrium. After this process, the moisture content of 13% was achieved. Afterwards, wood samples were dried at different temperatures (50°C, 70°C, 90°C, 110°C) and time (0.5, 1.0, 1.5, 2.0, 2.5 hours) in a drying oven. Table 1 shows the experimental design of the study. 10 samples were prepared for each experiment. TS 2471 (1976) standards were used to determine moisture contents (MC). The data obtained from the study were used for both testing and model training.

Table 1. The experimental design of the study

Experiment no.	Drying temperature °C	Drying time hours	Number of samples
1	50	0.50	10
2		1.00	10
3		1.50	10
4		2.00	10
5		2.50	10
6	70	0.50	10
7		1.00	10
8		1.50	10
9		2.00	10
10		2.50	10
11	90	0.50	10
12		1.00	10
13		1.50	10
14		2.00	10
15		2.50	10
16	110	0.50	10
17		1.00	10
18		1.50	10
19		2.00	10
20		2.50	10

The study aims to calculate the effect of temperature and time on moisture content. The Labview programming language is used in the study. This programming language is widely used in scientific studies. In this model, there are two input variables (temperature, time) and one output variable (moisture content). Figure 2 gives the structure of the developed fuzzy logic model.

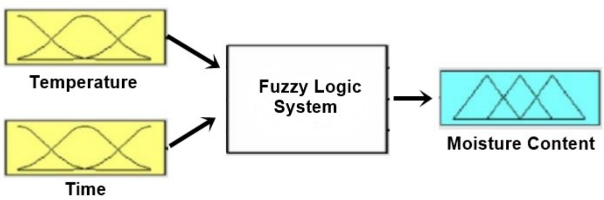

Fig. 2. Structure of the fuzzy logic model that determines the moisture content

The input and output parameters of the model used to determine the moisture content are shown in Figures 3, 4, 5.

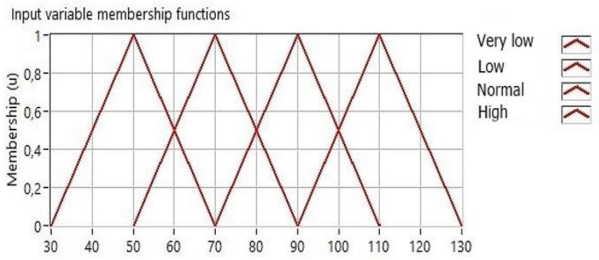

Fig. 3. Membership function for the temperature (input)

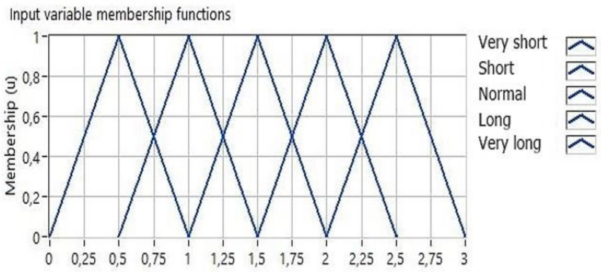

Fig. 4. Membership function for the time (input)

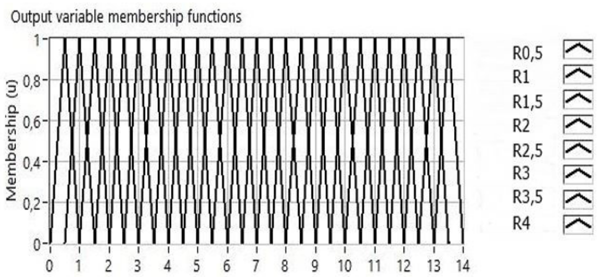

Fig. 5. Membership function for moisture content (output)

In the fuzzy logic model, 20 different rules were written. Some of the rules are as follows:

1. If 'drying time' is 'very short' and 'drying temperature' is 'very low' then 'moisture content' is 'R12'.
2. If 'drying time' is 'short' and 'drying temperature' is 'very low' then 'moisture content' is 'R11.5'.
3. If 'drying time' is 'normal' and 'drying temperature' is 'very low' then 'moisture content' is 'R11'.
4. If 'drying time' is 'long' and 'drying temperature' is 'very low' then 'moisture content' is 'R11'.
5. If 'drying time' is 'very long' and 'drying temperature' is 'very low' then 'moisture content' is 'R10.5'.

Relationship constituted between the inputs and outputs of the created rules is shown in Figure 6.

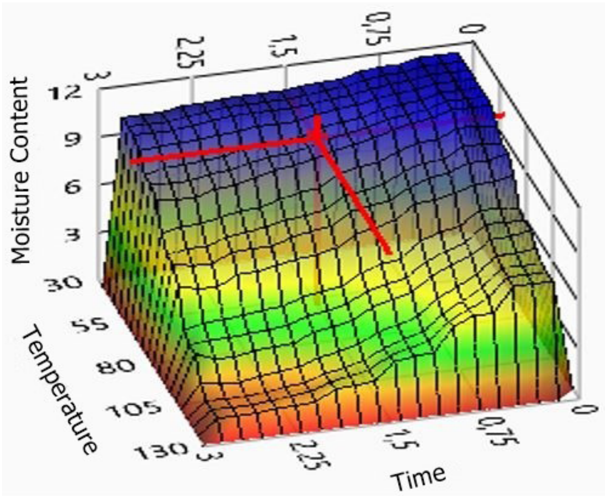

Fig. 6. The relationship chart between inputs and outputs

RESULTS AND DISCUSSION

In this study, the moisture content of beech samples was estimated by using a fuzzy logic model. The measured and predicted results for moisture content and Table 2 presents percentage error ratios.

Comparison of fuzzy logic model and the measurement results are shown in Figure 7.

Figure 7 shows similarities between the experimental output and the fuzzy logic output. When the results are examined, it is seen that the fuzzy logic model presents successful predictions. In the study,

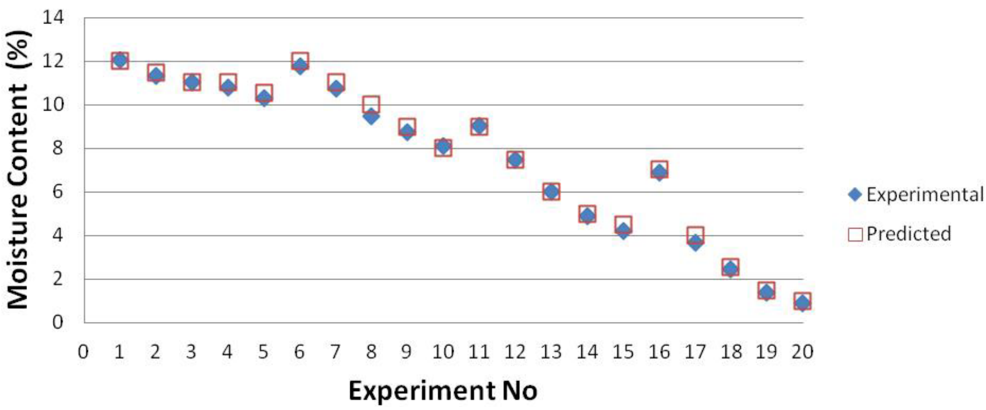

Fig. 7. Comparison of experimental and predicted values

Table 2. Measured values of experimental and predicted moisture content and their percentage errors using the fuzzy logic model, %

Experiment no.	Experimental	Predicted	Error
1	12.06	12.00	0.498
2	11.33	11.49	–1.431
3	11.01	11.02	–0.054
4	10.80	11.02	–1.999
5	10.32	10.54	–2.129
6	11.74	12.00	–2.215
7	10.75	11.02	–2.473
8	9.45	10.00	–5.820
9	8.74	8.98	–2.793
10	8.10	8.00	1.235
11	9.05	8.98	0.728
12	7.47	7.49	–0.295
13	5.99	6.00	–0.167
14	4.90	4.98	–1.717
15	4.23	4.51	–6.571
16	6.89	7.02	–1.827
17	3.69	4.00	–8.401
18	2.46	2.54	–3.239
19	1.39	1.46	–5.059
20	0.91	0.98	–8.146
Average error, %: 2.840			

the R^2 value was determined as 0.998. In the literature, it is emphasized that the model is satisfactory if the value of R is large than 0.7 (Sözen et al., 2018).

CONCLUSIONS

The results of experimental studies and fuzzy logic models were compatible with each other. The average accuracy rate of the model is % 97.16. The study showed that fuzzy logic can be used as a useful tool in the wood drying process. The drying process is an important part of the cost in the wood industry. Using the fuzzy logic model, it can more accurately determine the parameters in the drying process. In this way, costs can be reduced. An example of the use of fuzzy logic in the forest industry is given in the study. However, new fuzzy logic studies are needed to evaluate all factors affecting wood drying.

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