

## **Determination of moisture content profiles of spruce wood after high temperature process and air drying**

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**Abstract:** *Determination of moisture content profiles of spruce wood after high temperature process and air drying.* The results of moisture content of wood after the process of its drying under high temperature conditions and air drying are presented. Wood samples, namely spruce (*Picea abies* Karst.) from the northern part of Pomerania region in Poland, were subject of steam and air drying. The aim of experiments was to determine moisture content of wood in its cross sections using the moisture meter WRD-100. The samples of thickness 70 mm and length about 1050 mm were used. Wood moisture content was determined after drying process. The samples were machined on the modern narrow-kerf frame sawing machine PRW15M. Measurements of moisture content for steam dried and air dried samples, as a reference, allowed to reveal the effect of the drying process on moisture content of wood. It has been recognized that steam wood drying causes almost constant amount of moisture in treated material in comparison to air drying one.

*Keywords:* wood drying, high-temperature drying, wood moisture content

### INTRODUCTION

A good drying process is very much of the interest of lumber and timber industries. It may prevent the lumber from developing outer and inner cracks and several other defects. It increases the lumber strength, nails, screws and glue hold better, paint and finishes adhere well. The moisture content (MC) of lumber is an important aspect of lumber drying. To have good control on lumber drying, middle and large sizes timber industries dry lumber in kilns. The moisture content of the lumber before entering the kiln varies around 40% to 70%. In the drying process, the MC needs to be brought down to about 10 - 15%. The drying process in the kiln is done by controlling the Equilibrium Moisture Content (EMC), i.e. humidity in the kiln. To make the process faster, the EMC should be lower, and vice versa. This can be achieved by automatically (computerized) controlling the heater, fan and ventilation all together. Lumber which is dried too quickly, leaving the surface much drier than the inside, may develop cracks on the surface. If one surface is drier than the other, the lumber may bend. A good drying process should not develop these mal-forms, except reducing dimension. Therefore

a good process should dry the lumber evenly. Understanding this mechanism is extremely important to find an optimal drying time. While drying process of the surface of lumber is directly controlled by setting the EMC, drying the inside part very much depends on the surface and also the type of lumber, velocity of drying medium inside kiln, hence it is not easily controlled. For this reason high temperature drying process is applied using steam.

High temperature drying of wood is defined as a method of drying in the drying environment where the temperature is equal or higher than 100°C [1, 2]. During the drying intensification, which occurs at high temperature, affects the total time of duration of process in comparison with hot air drying, [3, 4]. The proper conduct of the drying process allows

faster extraction of water [5, 6]. The other benefits it is possible to mention a decrease in the equilibrium moisture content of wood or greater resistance to degradation [7, 8, 9, 10]. The disadvantages are a drop in the mechanical properties [11, 12, 13, 14] and the specific management of the drying process.

In terms of the development of industry and technology are places great emphasis on achieving maximum capacity and, therefore, the use of technology and equipment. The annual capacity of the kiln, it is subsequently possible to affect only the time of the drying process, high temperature drying method significantly reduced [3, 4], which creates a presumption in its future application.

From the perspective of the sawmill/plant management of the drying process is a substantial problem in the measurement of the humidity of the environment but in particular dried wood, which is itself due to the specific characteristics of the drying environment in the area above the boiling point of water and the boiling of the water content of the wood. Methods of measuring the moisture content of the wood known today because it is not possible to use, and their accuracy is not satisfactory. The drying process is so driven by time mode, where the experience of the previous drying is the drying time, which is expected to achieve the desired final moisture content.

The aim of this work is to determine the moisture content of wood after drying process in its cross section at the stage when the temperature of the drying environment is greater than 100°C and about 25°C.

## MATERIALS AND METHODS

The drying process was conducted in the experimental kiln of 0.55 m<sup>3</sup> load capacity, especially designed at the Gdansk University of Technology (GUT), Fig. 1. The heat was supplied to the kiln by both heat exchanger, supplied by exhaust gases from combustion chamber and fan's engine. The heat exchanger allowed to keep steam environment inside kiln. Steam circulation inside the kiln was forced by circulation fan with speed regulation up to 5,0 m/s. Fan and heat exchanger were located in the working area of the kiln separated from the drying area by the wall. The two chimneys on the roof of kiln controlled environment conditions inside. The temperature inside kiln was set about 100°C.

The control system is located outside the kiln. It includes 4 thermocouples to measure dry-bulb temperature inside the kiln and temperature inside wood in 3 locations. This system also includes 9 moisture content sensors used to measure the value of moisture in 8 places inside the wood and in 1 place inside the kiln.

Material used in the experiment was spruce wood (*Picea abies* Karst.) originating from the northern part of Pomerania region in Poland. From a beam with a length of 3,2 m were sampled with 70 × 70 × 1050 mm, Fig. 2. Before experiments all samples were measured. Results are presented in table 1. For the purposes of the experiment were selected samples without errors. Other samples were used to fill the area of the kiln.

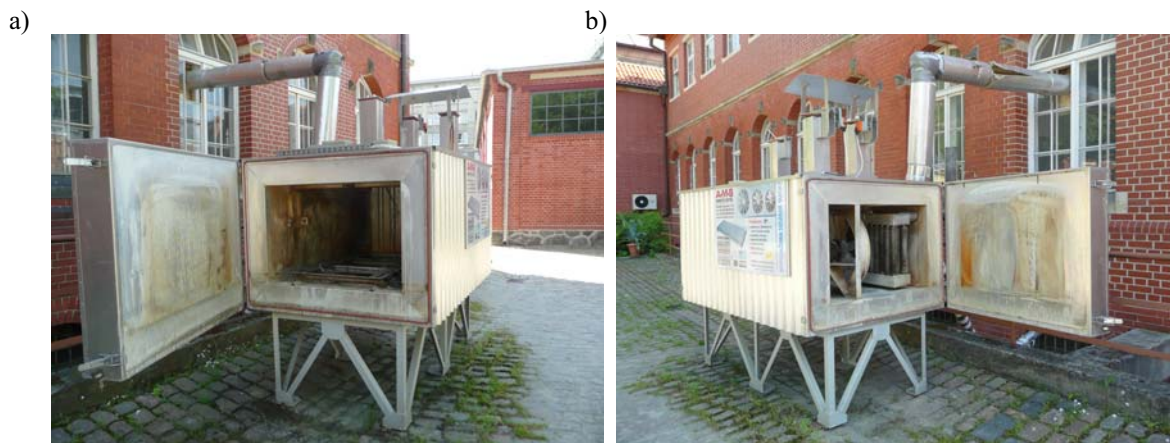


Fig. 1. Experimental kiln at GUT: a) front view - loading door, b) back view

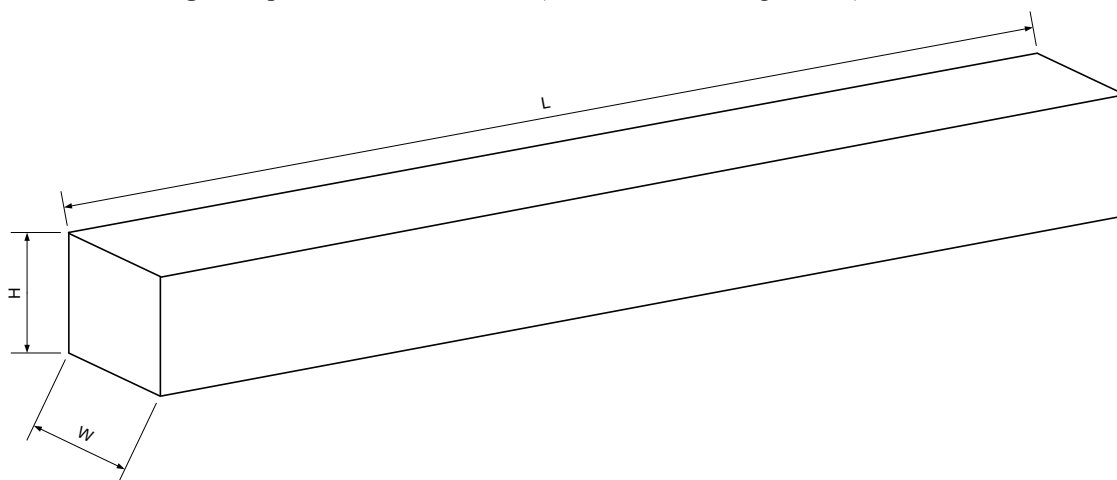


Fig. 2. The view of sample for moisture measurement

Tab. 1. Selected data of tested elements before drying process.

No of sample	Mass [g]	Average values [mm]			Density [kg/m <sup>3</sup> ]	Moisture content [%]	
		High	Width	Length			
Air dried	1	2382,9	69,23	69,20	1027,50	484,06	36,5
	2	2525,4	70,47	70,45	1071,00	475,17	38,2
	3	2225,0	69,47	69,45	1041,25	442,92	38,5
	4	2562,3	69,25	69,23	1034,00	516,86	35,1
	5	2610,0	69,43	69,30	1030,00	526,63	36,7
High temperature dried	1	2343,5	69,57	69,00	1012,00	482,43	38,0
	2	2492,0	69,55	70,28	1053,50	483,81	35,8
	3	2354,4	70,07	69,47	1053,75	459,04	38,8
	4	2393,0	68,48	68,25	1012,00	505,91	35,2
	5	2578,2	70,53	69,62	1018,00	515,78	38,7

The spruce lumber was dried with air and accelerated steam with an automatic control system applied. After drying process, the samples were checked, i. e. all dimensions, weight, density and moisture content and prepared to machining process. Before machining process each surface of sample was uniformed. After this step selected samples were cut for 6 lamellae. Inside each lamella moisture content was measured, Fig. 4.

To measure moisture content hygrometer type WRD 100 of Tanel Company was used, which is based on inductive method.

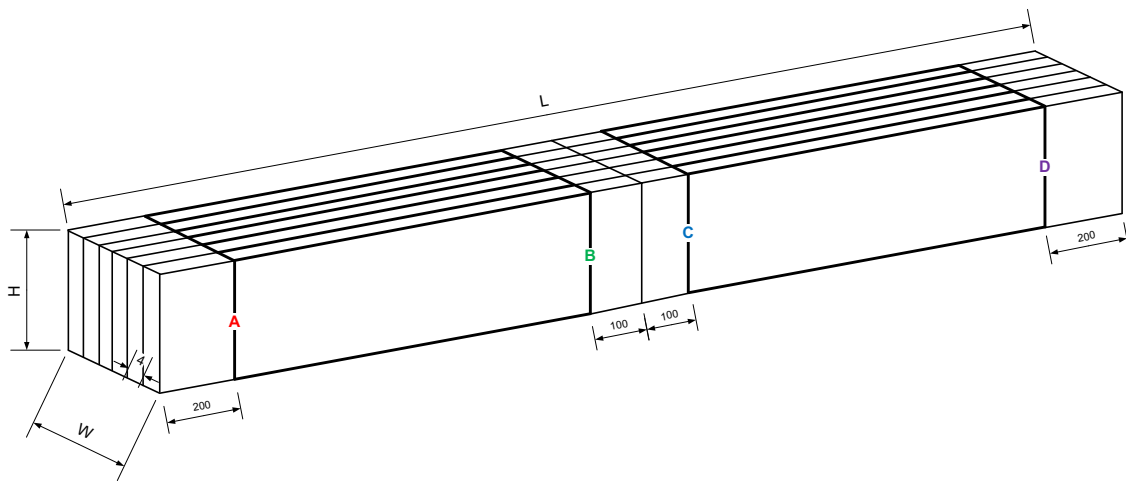


Fig. 3. The view of sample with A, B, C and D locations for moisture measurement

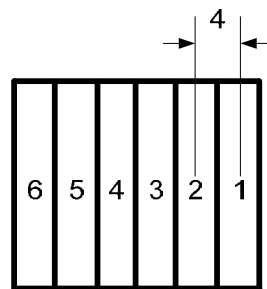


Fig. 4. The view of sample in cross section with points for moisture measurement

## RESULTS

The basic characteristics of the drying process are listed in Tab. 2. The average initial moisture content of the samples ranged between 35,1 to 38,8 %. Achieved the average final moisture content of samples during steam drying process was higher than required (12 %). The final moisture content of samples during air drying vary from 10,4 to 12,8 %. Measurements of moisture content were performed inside each slice after machining process, Fig. 3. Distance between measurements points was about 4 mm. There were 6 points of moisture measurement in each sample, Fig. 4.

Tab. 2. Selected data of tested elements after drying process

No of sample	Length [mm]	Average values of moisture content in A location [%]						
		no of point in sample						
		1	2	3	4	5	6	
Air dried	1	1004,50	11,8	11,2	11,8	11,5	11,6	11,4
	2	1028,75	11,9	11,6	11,5	11,8	10,4	12,0
	3	1035,25	11,7	11,6	11,4	11,2	11,1	11,2
	4	1028,25	11,3	12,0	10,5	10,3	10,4	11,6
	5	1023,25	11,0	10,5	11,1	10,5	10,6	11,5
High temperature	1	1005,25	13,2	12,8	12,8	13,1	12,8	12,1
	2	1007,00	12,8	12,8	13,1	12,6	12,4	12,5
	3	991,25	12,1	12,7	12,6	12,6	12,5	12,0
	4	996,25	12,4	12,5	12,3	12,3	12,7	12,8
	5	1011,75	12,3	12,4	12,6	12,2	12,5	12,3

No of sample	Length [mm]	Average values of moisture content in <b>B</b> location [%]						
		no of place in sample						
		1	2	3	4	5	6	
Air dried	1	1004,50	12,0	12,2	12,2	11,6	11,7	11,8
	2	1028,75	11,2	11,8	11,2	11,8	10,8	11,0
	3	1035,25	12,1	11,6	11,6	11,5	11,2	10,9
	4	1028,25	12,8	11,3	11,5	11,3	12,3	12,1
	5	1023,25	11,7	11,0	11,3	10,9	10,8	11,7
High temperature	1	1005,25	12,6	12,8	12,7	13,0	12,8	13,1
	2	1007,00	13,5	13,5	14,0	13,1	13,6	13,4
	3	991,25	13,3	13,2	13,5	13,0	13,0	13,3
	4	996,25	13,0	13,0	13,1	13,0	13,2	13,0
	5	1011,75	13,0	13,1	13,0	12,9	12,4	11,8

No of sample	Length [mm]	Average values of moisture content in <b>C</b> location [%]						
		no of place in sample						
		1	2	3	4	5	6	
Air dried	1	1004,50	12,3	12,3	12,2	12,1	12,0	11,6
	2	1028,75	11,2	11,1	11,1	11,1	11,0	11,5
	3	1035,25	11,4	11,5	11,1	10,9	11,1	11,4
	4	1028,25	12,8	11,1	11,5	11,1	11,1	11,4
	5	1023,25	11,6	10,9	11,6	11,4	10,8	9,8
High temperature	1	1005,25	13,2	12,3	12,3	12,1	12,3	13,0
	2	1007,00	13,7	13,6	13,3	13,2	13,0	13,2
	3	991,25	12,9	13,3	13,2	13,5	13,5	13,8
	4	996,25	13,0	13,0	12,4	13,1	12,9	13,1
	5	1011,75	13,1	13,0	13,0	12,7	12,7	12,0

No of sample	Length [mm]	Average values of moisture content in <b>D</b> location [%]						
		no of place in sample						
		1	2	3	4	5	6	
Air dried	1	1004,50	11,8	11,8	11,6	11,3	11,0	11,2
	2	1028,75	11,0	10,7	10,8	10,4	10,5	11,2
	3	1035,25	10,9	11,1	10,6	11,0	10,7	11,5
	4	1028,25	11,4	11,7	10,7	10,8	10,4	10,9
	5	1023,25	10,5	11,0	11,4	10,9	10,5	11,1
High temperature	1	1005,25	12,3	11,7	11,8	12,6	12,1	12,2
	2	1007,00	12,8	12,5	12,7	12,9	13,1	12,9
	3	991,25	12,9	12,0	12,7	12,8	12,8	12,6
	4	996,25	12,3	12,3	12,3	12,3	12,6	12,4
	5	1011,75	12,6	12,2	12,5	12,5	12,5	11,6

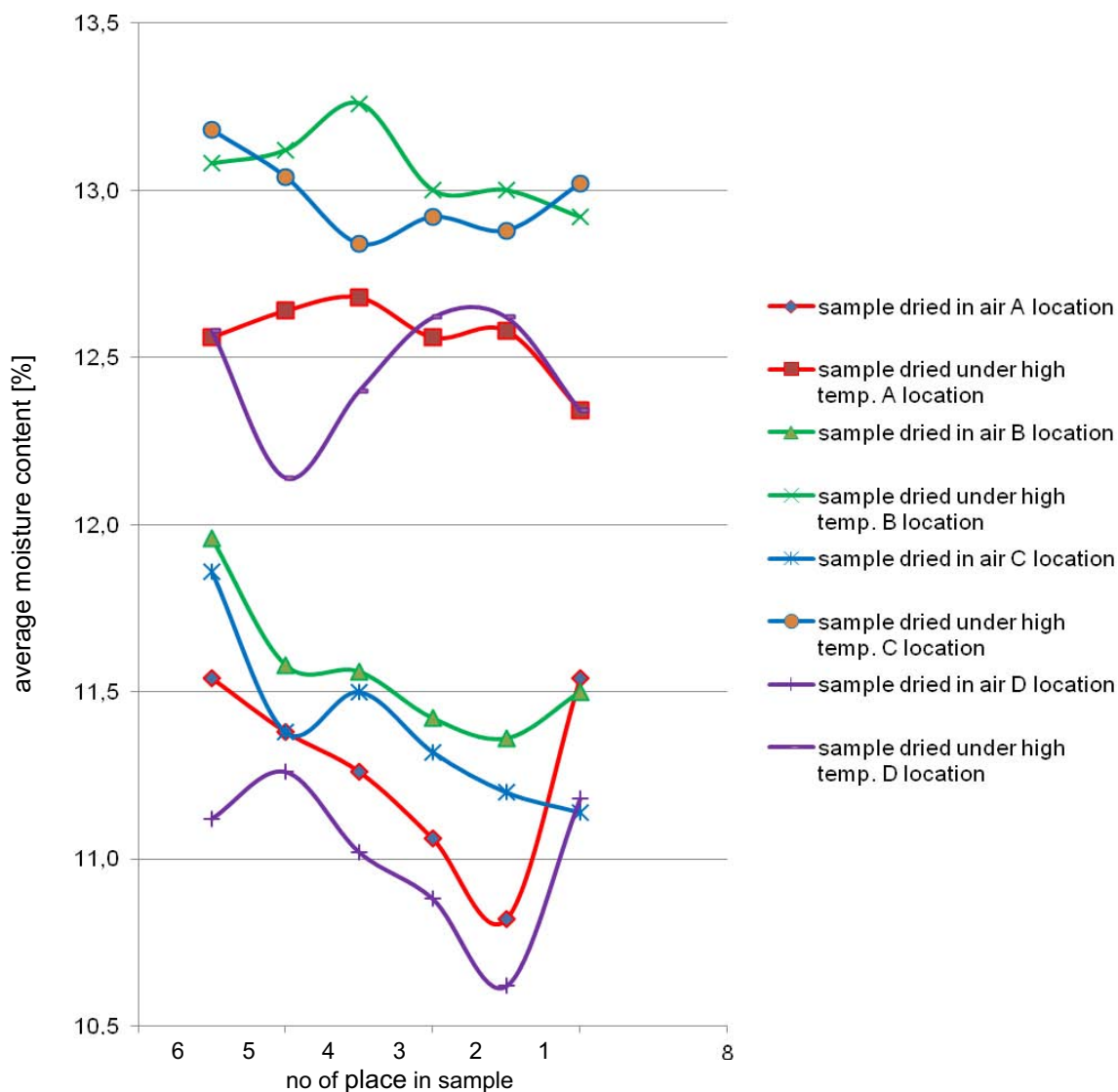


Fig. 5. The average moisture content in cross section of samples after drying

## CONCLUSIONS

The results obtained from tests show that drying under high temperature conditions affect the moisture content in wood. The difference in moisture content in samples dried in air is greater than in samples dried under high temperature using steam. The final average moisture content of samples after air drying vary from 10,8 to 12,0 %. In comparison the final average moisture content of samples after high temperature steam drying vary from 12,1 to 13,2 %. In the samples dried under high temperature moisture content is more uniform than in air dried samples, Fig. 5.

It is necessary to carry out further experiments to check impact of high temperature steam drying process on other type of wood.

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**Streszczenie:** *Określenie profili zawartości wilgotności w świerku po procesie suszenia wysokotemperaturowego i po suszeniu na powietrzu. Zaprezentowano wyniki wilgotności drewna po procesie suszenia w warunkach wysokiej temperatury z wykorzystaniem pary wodnej i po suszeniu drewna na powietrzu. Przedmiotem badań były próbki drewna świerku (*Picea abies* Karst.) pochodzące z północnej części regionu Pomorza w Polsce. Celem eksperymentów było określenie wilgotności w przekroju poprzecznym drewna przy użyciu miernika wilgotności WRD-100. Do badań wykorzystano próbki o wymiarach grubości 70 mm i długości około 1050 mm. Wilgotność drewna została ustalona po procesie suszenia w warunkach wysokotemperaturowych z wykorzystaniem pary wodnej i na powietrzu w warunkach naturalnych. Próbki zostały obrobione na z zastosowaniem nowoczesnej pilarki ramowej PRW15M. Pomiary zawartości wilgoci w drewnie suszonym wysokotemperaturowo i na powietrzu, jako poziomem odniesienia, umożliwiły pokazanie wpływu procesu suszenia na zawartość wilgoci w drewnie. Zastosowanie pary wodnej do suszenia drewna wpływa na równomierny rozkład zawartości wilgoci w próbce materiału w porównaniu do próbek suszonych na powietrzu.*

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