MOISTURE CONTENT GRADIENT FOR A 50,0 MM THICK FIR ELEMENTS IN THE CONDITIONS OF VACUUM DRYING

Goran Zlateski[1], Branko Rabadziski[2], Zoran Trposki[3], Vladimir Koljozov[4]

ABSTRACT

The aim of this research is the defining of moisture content gradient in fir elements after vacuum drying. The elements are 50,0 mm thick, 20,0 cm in width and 4,0 m in length. According to the drying schedule, the temperature of the wood and of the heating units in the kiln chamber during drying varies from 29 to 72 ^{0} C and from 25 to 45^0 C respectively. The elements are kiln dried from initial average moisture content (MCi) of 32,0 % to a final average moisture content (MCf) of 7,0% for 240 h. Moisture content gradient in the cross section of fir elements is – 1,35 %. The elements are used for manufacturing solid wood products.

Key words: fir, elements, vacuum drying, drying schedule, moisture gradient.

INTRODUCTION

In the conditions of wood drying, it is necessary to determinate the wood moisture content distribution in the cross – section of a piece of wood. The procedure for defining of the moisture content gradient is connected with the determining of both surface and core moisture content (MC). During the drying, a moisture gradient from the outer to the inner layers of the wood will be developed. How big will the MC gradient be depends on the severity of the drying process. If we have an adequate regime according to wood species and thickness, there is no condition for the development of a big difference of MC of the wood core and the wood surface. If the moisture gradient is too high at the end of the drying, this can lead to an increase in the stresses and instability in the wood, especially during subsequent machining, so that reducing the final moisture gradient is essential for the wood drying process.

MATERIAL AND METHODS

A total quantity of 3 m ^{3} fir elements were dried for this investigation. Their origin was from the Kožuv mountain, the Republic of Macedonia. The investigation was performed on material with the following dimensions: 50,0 mm thickness, 20,0 cm width and 4,0 length. The information on the temperature and moisture content of the wood was obtained with:

[1]Associate professor Goran Zlateski, Ph.D., Faculty of Design and Technologies of Furniture and Interior, Skopje, Macedonia, e – mail: zlateski@fdtme.ukim.edu.mk
[2]Full professor Branko Rabadziski, Ph.D., Faculty of Design and Technologies of Furniture and Interior, Skopje, Macedonia, e – mail: rabadziski@fdtme.ukim.edu.mk
[3]Full professor Zoran Trposki, Ph.D., Faculty of Design and Technologies of Furniture and Interior, Skopje, Macedonia, e – mail: trposki@fdtme.ukim.edu.mk
[4]Associate professor Vladimir Koljozov, Ph.D., Faculty of Design and Technologies of Furniture and Interior, Skopje, Macedonia, e – mail: koljozov@fdtme.ukim.edu.mk

_____

-   probes for determining moisture content gradient in the cross section of elements using oven dry method (Fig.1).
    -   three temperature probes consisting of a PT 100 sensor (Fig 2).
    -   three probes MC, that is, five pairs of electrodes planted in three elements which were previously chosen with highest initial moisture content (Fig 3).
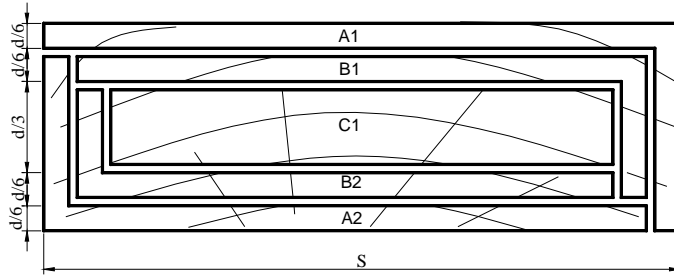

Fig.1: Slicing test (specimen production) for wood moisture gradient

Electrode positioning

The temperature probe was planted in the position shown in Fig. 2. For a correct reading of the temperature, it is necessary that the electrodes are planted in 1/2 of the board thicknesses.
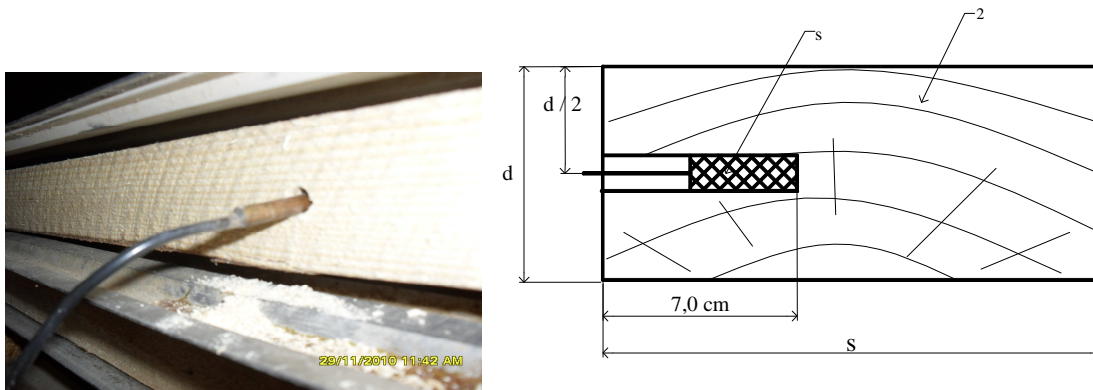

Fig.2: Wood temperature measuring
d – wood thickness, S – wood width

The electrodes for measuring moisture content of the elements and their position within the wood are shown in Fig.3.
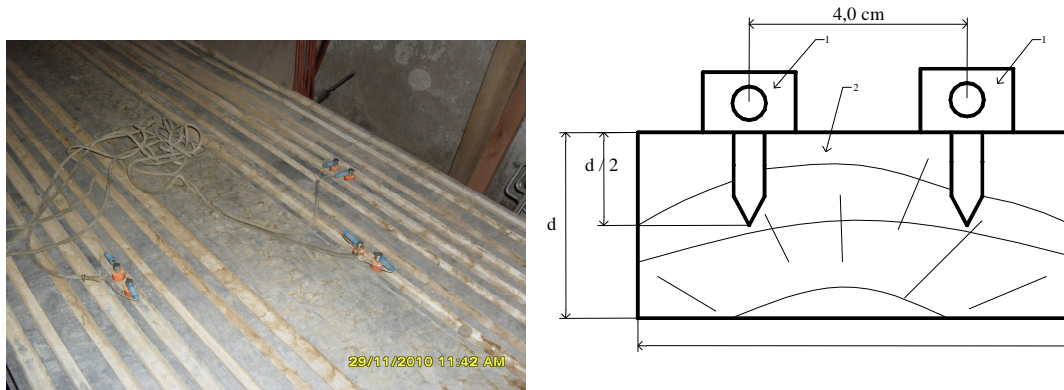

Fig. 3: Electrode for measuring of wood moisture content,
d – wood thickness, S – wood width

Drying regime

The drying regime is defined on the basis of: heating temperature, temperature of the wood and wood moisture content (MC) during all stages of the drying cycle.

The drying of the fir elements was performed in the vacuum kiln dryer type ES 3(Fig. 4) equipped with control and heating unit (Fig. 5) as well as an automatic system for drying control, manufactured by "ISVE" Italy.

Fig. 4: Vacuum dry kiln

Fig. 5: Control and heating unit of drying

RESULTS AND DISCUSSION

The drying regime of 50,0 mm thick fir elements is shown in Tab.1. This figure evidently shows that the temperature of the wood during the first 12 h rapidly increases from 17 ^{0} C to 49 ^{0} C and reaches its maximum of 60 until the end of drying for 24 h. In the same way, temperature of heating (heating units) increases from 25 to 55 ^{0} C for 12 h and to 65 ^{0} C for 24 h, which is the maximum value of heating. Initial average moisture content of the wood is 33,0 %, and during drying it decreases to a final MC of 10,0 %. The duration of the complete drying process is 168 h.

Tab.1: Drying regime of 50,0 mm thick fir elements

Temperature of heating [^{0}C]	Wood temperature [^{0}C]	Wood moisture content – sonde [%]			Average wood moisture content [%]	Time of drying [h]
29	25	30	29	28	29	0
39	25	29	28	28	28	24
45	33	28	27	27	27	48
55	35	27	26	26	26	72
57	38	25	23	23	24	96
66	42	22	19	19	20	120
67	43	18	16	16	17	144
69	44	11	10	10	10	168
72	45	8	6	6	7	192

Data from the investigation concerning the average moisture content of the core and the surface of the elements is presented in Tab.2.

Tab.2: Data of the surface and core moisture content of fir elements

Wood thickness [mm]	Layer –wood surface	Layer –wood core	Surface moisture content [%]	Core moisture content [%]
50	**A**		**6,55**	
	B		7,20	
	A+B		6,87	
		C		8,24

Based on the data shown in Tab. 2, it can be concluded that the moisture of the surface of the elements is 6,55% (layer A) and 7,20 % (layer B), respectively. Average moisture surface content (layers A+B) is 6,87 %. The moisture of the core (layer C) is 8,24%.

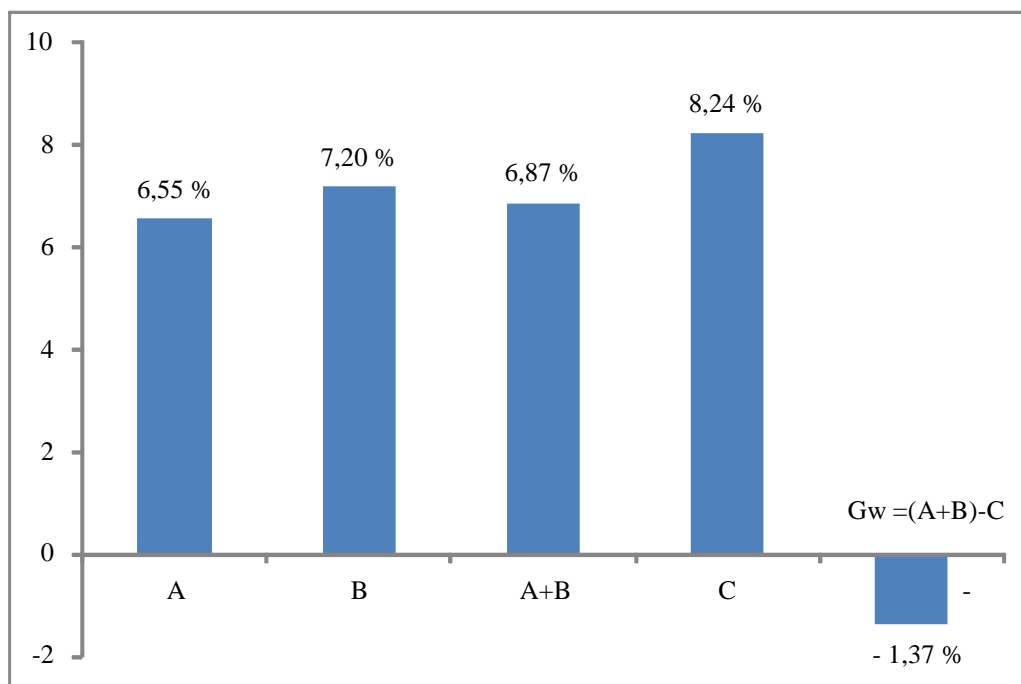For best access to obtained results, they are shown in Figure 5.

Fig.6: Wood moisture gradient for fir elements

From the histogram it can be concluded that in the process of vacuum drying of fir elements, a moisture content gradient of 1,37 % has been reached by the drying process. It means that obtained results for moisture content distribution in the cross – section of a piece of wood are in accordance with the production of solid wood construction details.

CONCLUSIONS

Investigations of moisture content gradient of 50,0 thick fir boards which appear in the vacuum drying process, give appropriate results for MC distribution in the cross – section of a piece of wood. The MC gradient as predicated occurrence is defined as the difference between the board's core moisture content (MC core) and the board's surface moisture content (MC surface). This provides moisture movement in the drying process. According to the drying regime, the MC gradient in the fir elements has been present after drying.

The investigation of the most important technological parameters, characteristics of the process of vacuum drying, has shown the following:

1. The elements were dried from their initial average moisture content of 29,0% to a final average moisture content of 7,0 % for 192 h.
2. Wood temperature in the drying process increases from 25 ^{0} C to 45 ^{0}
3. The plank's surface moisture content (layers A + B) is 6,87 %
4. The plank's core moisture content (layer C) is 8,24%.
5. The moisture content gradient is – 1,37 % which means that the MC of the surface is smaller than the MC of the core of the elements.

Due to many factors influencing the drying process, such as: origin and quality of the wood, type of kiln; the methods of drying behavior of the fir elements might be different from the ones discussed in this paper.

REFERENCES

1. Aquiar O., Perre P., 2000:The "flaying wood" test used to study variability of drying behavior of oak, COST action E 15, Advances in drying ofwood ,Sopron.
2. Carlsson P., Arfvidsson J., 1999 : Optimized wood drying, 6 thInternational IUFRO Wood Drying Conference, Stellenbosch.
3. Denig J., Wengert E., Simpson W. 2000: DryingHardwoodLumber,Madison.
4. Keey R., 1998: Understanding kiln – seasoning for the benefit of industry, Canterbury.
5. KollmanF., 1951: Technologie des holzes und der holzwerkstoffe, München.
6. Oliveira L., 2003: Analyzing industrial lumber drying data, Quality drying, the key to profitable manufacturing, International conference, Madison.
7. Рабациски Б., Г. Златески., 2000: Температурни режими за сушење на букова и дабова неокрајчена бичена граѓа, Јубилеен годишен зборник, Скопје.
8. Рабациски Б., Г. Златески., 2007: Хидротермичка обработка на дрвото I дел, Скопје.
9. Rasmussen E., 1961: Dry Kiln – Operator's manual, Madison.
10. Scaar C.,1972: Water in wood, Syracuse.
11. Simpson W., 1987: Vacuum drying northern red oak, Forest Products, Vol. 37, No.1, Madison.
12. Simpson W., 2000:DryingHardwoodLumber, Madison.
13. Welling J., 2000: Industrial needs and scientific expectations, COST action E -15, Advances in drying of wood, Sopron.
14. Златески Г., 2004: Проучување на режимите и квалитетот на контактно вакуумско сушење на пилански сортименти, Докторска дисертација, Скопје.