ICENS III INTERNATIONAL CONFERENCE ON ENGINEERING AND NATURAL SCIENCE 3 - 7 May 2017 BUDAPEST

Effects Of Paraffin Application, Heat Treatment, And Densification Process On Some Physical And Biological Properties Of Scotch Pine Wood

Mesut Yalcın[1], Halil İbrahim Sahin[1], Huseyin Pelit[2], Caglar Akcay[1]

Abstract

The aim of this study was to determine on the some physical and biological properties of paraffin applicated, heat treated, and densification process. In the study, three different process were applied: heat treatment at 180⁰C, hot paraffin application and densification at hot press temperatures. At the end of procedures, the physical properties such as anti-shrinkage efficiency and water absorption, as well as activity against Coriolus versicolor and Coniophora puteana wood destroying fungi were determined. The results shown that, while the anti-shrinkage efficiency was carried out higher than 80% until water immersion for *8 hours in paraffine applications, It was obtained lower than after this time. It can be seen that heat treatment and densification in paraffin-free specimens gave effective results on both fungal species. However, with paraffin application, efficacy against fungi has been variable. With the heat treatment application at 180⁰C, the weight loss was increased compared to the control samples, while the weight loss was the lowest value in densification samples with hot press.*

Keywords: *Heat treatment, Densification, Paraffine aplication, Fungal activitiy, Water absorption*

1. INTRODUCTION

Although wood materials have many important advantages in usage places, they have significant disadvantages. The major disadvantages in usage area are that they are not sufficiently resistant to biological factors in the natural form and that they can not adequately protect the dimensional stability in humidity environments. These disadvantages shorten the life span as they cause technical problems in the places of use.

Many methods have been developed in the past to gain the dimensional stability of wooden materials. In addition to the superficial or in-depth application of various water-repellent chemical substances, various modification methods are at the forefront of methods applied to provide dimensional stability. Heat treatment, acetylation, etc. are important modification methods applied in recent years.

Wooden materials can be destroyed when exposed to biological factors such as various fungi and insects at appropriate places of use. There are a variety of mechanical and chemical methods that have been developed and used against these factors for many years. Today, one of the most preferred methods is the preservation of various woods by impregnation with various preservatives. However, many of these chemical substances disrupt the natural order of nature and may even pose a threat to the environment and to life. For this reason, the use of some of these chemicals has been limited or even banned in recent years (Kartal et al. 2006).

Paraffin is a harmless chemical for plants and animals. In addition to having many uses, it is also used to impart water repellent activity to materials by virtue of having a hydrophobic structure. Today, they are used to protect wood from biodegradation by impregnating wood materials (Esteves, 2014).

High temperature applications can change the color of the wood material; improve its biological strength and dimensional stability. However, the mechanical properties of wood diminishes and changes the chemical structure of wood (Yalcin and Sahin 2015). In a study conducted, the effects of heat treatment on some physical, mechanical and chemical properties of redwood were investigated and significant reductions in all

[1] *Corresponding author : Duzce University, Forest Faculty Department of Forest Industry Engineering, Duzce, Turkey. mesutyalcin@duzce.edu.tr*

[2] *Duzce University, Faculty of Technology, Department of Wood Products Industrial Engineering, Duzce, Turkey*

the physical properties of redwood were determined depending on the heat treatment time and temperature (Ates et al., 2009). In a study using ash wood, the biological resistance of wood is also increased due to the increased heat treatment temperature (Yalcin and Sahin 2015).

2. MATERIAL AND METHOD

2.1. Wood samples

In this study, scotch pine (*Pinus sylvestris* L. sapwood was used for test samples. The wood samples were cut to 5 cm long, 2.5 cm wide, and 1.5 cm thickness according to the TS 5563 EN 113,1996 standards with minor modifications in sample size. All specimens were conditioned at 20 ^{0}C and 65 % RH for 3 weeks.

2.2. 2.2. Paraffin treatment, heat treatment and densification

The solid paraffin was heated to a temperature of 70 ^{0}C to make it liquid. The samples were weighed (W_{unP}) then placed in a desiccator and vacuum applied at 600 mmHG for 20 minutes. The liquid paraffin was added in the desiccator and waited for 10 minutes for impregnation. The surface of test samples were cleaned from the paraffin residues. After one week, the test samples were reweighed (WP) and the weight gain amounts (WPG) were determined according to the following formula.

$$\text{WPG (\%)} = [(W_P - W_{unP})/W_{unP}] \times 100 \quad (1)$$

After impregnation, the two groups of samples were heated to 180°C for 2 h. Impregnated samples were thermo-mechanically densified with a hydraulic press machine, the capability of pressure and temperature control. The densification process was carried out at target compression ratios of 20% with temperatures of 185°C. After densification processes the samples were taken from the press machine and cooled to room.

Table 1. Experimental groups and weight gain values

Group	Application	Process	Weight increase (%)
A Group	Without Wax	Control	-
B Group		Heat treatment at 180 °C	-
C Group		%25 densification at heat press	-
D Group		180 °C + %25 densification at heat press	-
E Group	Waxed	Control	83,42
F Group		Heat treatment at 180 °C	25,27
G Group		%25 densification at heat press	84,26
H Group		180 °C + %25 densification at heat press	25,95

2.3. Water absorption (WA) and Water Repellent Effectiveness (WRE)

Wood specimens were placed in glass containers filled with distilled water. The specimens were placed separately and horizontally in the containers with stainless steel mesh over the specimens. The water was replaced daily during the test. The specimens were first oven-dried at 103°C and then weighed. The specimens were weighed after 2, 4, 8, 24, 48, 72, and 168 h of immersion and water absorption (*WA*) was calculated as an index of bulking efficiency according to the formula below:

$$WA(\%) = [(W_2 - W_1)/W_1] \times 100 \quad (2)$$

where W_2 is the weight of the water-saturated specimen and W_1 is the weight of the oven-dried specimen. In addition to the WA values, the Water Repellent Effectiveness (WRE) values were calculated using following equation:

$$\text{WRE (\%)} = [(WA_1 - WA_2)/ WA_1] \times 100 \quad (3)$$

where WA_1 is water absorption of non-paraffine specimen and WA_2 is water absorption of paraffine specimen.

2.4. Decay Tests

Decay tests were carried out in Wood Preservation Laboratory of Duzce University according to EN 113 (1996). Test samples were dried at 60 °C for 24 h and weighed to determine their oven-dried weighets before decay test. The treated and untreated wood blocks were sterilized at 110 °C for 20 minute. The samples were then exposed to the white rot fungus *Corillous versicolor*, the brown rot fungi *Coniophora puteana* fungi cultered on 3.7% Malt Extract Agar (MEA) medium. All tests samples were transferred to the petri dishes and incubated at 24 + 2^0C with 75% relative humidity (RH) for 12 weeks. At the and of the exposure time, the samples were clened of the fungal mycelia and weighed their oven-dried weighets after decay test for calculate the percentage of mass.

3. RESULT AND DISCUSTION

3.1. Density and Water Absorption

The weight gain ratios resulting from paraffin treatment differed. A higher weight gain was observed, especially in the samples subjected to control and compression. In heat treatment applications, weight gains were lower than others (Table 1). This is due to the effect of heat, the paraffin, which is found in the wood after the heat treatment, becomes liquid again and moves away from the wood. In addition, there is also the effect of thermal degradation which is the result of heat treatment (Sahin 2013, Esteves et al 2014),

The density values and the water absorption values for different water absorption times are given in Table 2. Increases in water absorption rates were detected in all treatments due to the increase in the immersion time in the water. The highest water absorption rates of the paraffinized and non-paraffinized applications were determined in the hot press compaction experiments (groups C and G).

Table 2. Density and water absorption values of the experimental samples

Group	Density	Water absorption rate (%)						
		2 h	4h	8h	24h	48h	72h	168h
A Group	0,548	29,63	35,44	39,57	44,93	52,00	58,21	69,48
B Group	0,54	21,38	29,58	36,32	43,17	49,28	55,21	64,93
C Group	0,547	61,45	64,88	67,13	71,26	78,06	82,89	90,95
D Group	0,543	44,97	58,57	64,20	69,91	76,15	80,78	87,78
E Group	0,976	1,5	2	2,76	4,9	6,86	8,17	12,24
F Group	0,685	3,21	4,48	6,15	11,44	19,16	24,65	37,40
G Group	0,986	3,50	4,61	6,76	15,12	40,59	54,97	63,98
H Group	0,706	2,44	3,71	5,58	14,88	39,59	51,97	64,04

The heat treatment applied before the densification showed an effect of reducing the water absorption rate of the test specimens. In unwaxed test samples, the lowest water absorption rate was obtained in heat treatment (group B). Paraffin application to experimental specimens caused considerable decreases in water absorption rates while significant increases were seen in density values. Lesar and Humar (2010) treated beech (*Fagus sylvatica*) and Norway spruce (*Picea abies*) with 5 different fat solutions and found significant reductions in water absorption and fungal destruction

The water absorption rates of the paraffinized test samples in 2 hours of water ranged from 1.5 to 3.5% and these values were found to be 21.4 to 61.5% in the without paraffin control samples. The highest density values after the paraffin application were obtained in groups E and G without heat treatment (0,976 and 0,986 g / cm3). Esteves et al. (2014) reported that the paraffin treatment increased the density of the *Pinus pinaster*.

The water repellent efficacy value (SDI) refers to the reduction in water absorption rates of treated test samples according to control samples. For this purpose, the arithmetic mean values of SIE values of the test specimens suspended in water for various periods after different treatment procedures are given in Table 3.

Table 3. Water repellent activity values of the experimental specimens

Group	Water repellent activity						
	2h	4h	8h	24h	48h	72h	168h
E Group	94,94	94,36	93,03	89,09	86,81	85,96	82,38
F Group	84,99	84,84	83,07	73,51	61,12	55,35	42,39
G Group	94,30	92,89	89,94	78,79	48,01	33,69	29,65
H Group	94,57	93,67	91,30	78,71	48,01	35,67	27,04

Significant increases were observed in water-repellent activity values resulting from paraffin application. In particular, paraffin-treated test specimens have water-repellent activity values of more than 80% obtained during 2, 4 and 8 h of water retention. The highest water repellency activity values were obtained only in paraffin-treated test samples (group E). The water repellency activity values of these samples were obtained as 89.5% on average in all water waits. Paraffin application gave better results than heat treatment and compression processes. This has also been expressed in previous studies (Esteves et al., 2014). The lowest water repellent activity values were determined in the test samples with hot press compression (group G and H). Water retention efficiency values of the samples belonging to these groups were obtained by 29.7% and 27%, respectively, during long waiting periods. Significant reductions in the water repellent activity values of the samples belonging to groups G and H have been determined, especially after 24 hours of immersion in water. In addition, water repellent activity values of all experimental groups showed a decrease depending on the immersion time in water.

3.2. Fungi Test

Findings about the effects of paraffin impregnation, heat treatment and press applications on wood decaying fungi are seen in Table 4. According to the findings obtained, the highest weight losses were determined in the control samples in the unwaxed samples. It was determined that the highest weight losses were obtained in 170 °C heat treated and not densificated samples.

In general, paraffin administration has resulted in reductions in the mean weight loss caused by both fungi species (*Coriolus versicolor* and *Coniophora puteana*) That is, paraffin application increases the resistance of chambers to fungi. In some studies it has been reported that some impregnated chemicals used in conjunction with paraffin give effective results against wood-fungus fungi (Lesar et al., (2009).) In other studies, it has been reported that paraffin application reduced the moisture content of the wood and thus decreased the rot fungus (Lesar and Humar (2010). Paraffin application has been shown to give very effective results in destructive termites in woods (Scholz et al. (2010; Esteves, 2014).

It is seen that heat treatment application has little resistance to fungi alone. However, it has been found that the application of hot pressing together with the heat treatment significantly increases the resistance to fungi in both unwaxed and waxed samples.

Densification with hot press seems to increase resistance to fungi in waxed specimens. However, it has been determined that this resistance alone is sufficient for densification.

Table 4: Mean waight loss of samples

Heat treatment tempreature (^{0}C)	**Press tempreature (^{0}C)**	**Mean weight loss (%)**			
		without wax		**waxed**	
		Coriolus versicolor	***Coniophora puteana***	***Coriolus versicolor***	***Coniophora puteana***
Control		21.4	20.5	7.0	3.8
170	0	19.7	13.9	14.2	5.2
0	185	16.1	12	1.8	0.9
170	185	8.5	8.4	5.0	1.3

4. CONCLUSİON

The paraffin-impregnated Scotch pine woods caused significant increases in density and water repellency when compared to the untreated samples, while significant reductions in water absorption rates were found. The water absorption rates of only the wax treated Scotch pine woods gave better results than the densfication and heat treatments. The highest water absorption rates were obtained when the untreated scotch pine woods were densficated.

The paraffin application provided effective protection against both white rot and brown rot fungus. The alone heat treatment application has little effect on the durability of wood against fungi. However, if heat treatment and densification were applied together, the resistance against decay increased considerably.

REFERENCES

[1]. Ates S., Akyıldız M.H. and Ozdemir H. (2009). Effects of heat treatment on Calabrian pine (*Pinus brutia* Ten.) wood, *BioResources*, 4 (3): 1032-1043.

[2]. Esteves B., Nunes, L., Domingos, I. and Pereira, H. (2014). Improvement of termite resistance, dimensional stability and mechanical properties of pine wood by paraffin impregnation, *European Journal of Wood and Wood Products*, 72 (5): 609-615.

[3]. Kartal, NS, Engur O, Kose C.2006. Environmental Problems Of Wood Preservatives And Preservative Treated Wood Use. İstanbul Universitesi Orman Fakultesi Dergisi, B, 56(1).

[4]. Lesar B. and Humar M. (2010). Use of wax emulsions for improvement of wood durability and sorption properties, *European Journal of Wood and Wood Products*, 69: 231–238.

[5]. Scholz G, Militz H, Gasco´n-Garrido P, Ibiza-Palacios MS, Oliver-Villanueva JV, Peters BC, Fitzgerald CJ (2010) Improved termite resistance of wood by wax impregnation. Int Biodeterior Biodegrad 64:688–693

[6]. Sahin, H.İ. (2013). Isıl islemin dogal ve plantasyon ormanlarında yetisen disbudak (*Fraxinus angustifolia* Vahl.) odunlarının bazı teknolojik ozelliklerine etkisi, *Doktora Tezi*, Duzce Üniversitesi, Düzce (Turkish).

[7]. Yalcin, M. and Sahin H.I. (2015). Changes in the chemical structure and decay resistance of heat-treated narrow-leaved ash wood, *Maderas. Ciencia y tecnología,* 17(2): 435-446.