

## The Effects of Outdoor Conditions on the Combustion Properties of Scotch Pine (*Pinus Sylvestris* L.) Wood

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### ABSTRACT

The wooden material, which is a light and durable material, has also undesirable properties such as contagion from outdoor conditions and combustion properties. This research is conducted with the intent of determining the combustion properties of wood material left in outdoor conditions for one year. For this purpose, samples prepared from scotch pine (*Pinus sylvestris* L.) according to ASTM-E 160-50 are first impregnated with tanalith-E (T) and wolmanit-CB (W-CB) in compliance with ASTM-D 1413-76, and then are varnished with synthetic (St) and water based (wb) varnish according to ASTM-D 3023. The weight loss, the collapse time in combustion, the total combustion duration, the temperature values in the combustion levels are identified by subjecting pieces, which are left in outdoor air conditions, to combustion tests according to the principles specified in ASTM G7-05 standard by the end of the year. According to the results, the impregnation materials have decreased the collapse time by %7-26 in the combustion, increased the total combustion duration by %14-34, and the varnishes have raised the collapse times and reduced the total combustion durations.

**Keywords:** Combustion, wood, impregnation, varnish, gases analysis, outdoor conditions.

### 1.Introduction

The wooden material is a highly-preferred material because of its durability and naturalness. The wooden material can be preserved for centuries when appropriate conditions are provided. It is observed that various furniture made of wood, such as a bed, a cabinet, has

survived until today as undisturbed in the grave of the Egyptian Pharaoh Tutankhamen (Desroches, 1963).

Increasing the usage life of this precious material can only be achieved through protecting it against fire, chemical degradation, mechanical weathering, outdoor weather conditions and conservation from biological pests (Archer & Lebow, 2006) .

The wooden material is disfigured by outdoor weather conditions like humidity, sunlight, acid degradation, temperature and the wind. Sapwood samples of southern pine have an average life span of 1.8-3.6 years in open air conditions without projection, 45 years with copper oxide, 25 years with CCA, 55 years with coal tar creosote, and 29,6 years with copper naphthenate (Crawford *et al.*, 2002)

Nowadays, commercial protectors have been developed for the protection of wooden materials. The permanence of the protective materials has a high importance. In our day, greased preservative substances like creosote and pentachlorophenol, and waterborne salt preservative substances like chlorinated copper arsenate (CCA), amine-copper quaternary (ACQ), copper-chrome-boron (CCB), copper-potassium bichromate-boric acid (Wolmanit-CB) are applied as water solutions. There are many factors such as the amount of concentration, temperature and amount of pressure which affect the activity of these impregnation materials (Baysal *et al.*, 2007; Toker *et al.*, 2009; Percin, 2015)

Nowadays, chemicals such as borax, boric acid, ammonium, phosphorus and nitrogen are used to prevent the combustion of wooden material and to delay it. However, the biggest difficulties in these formulations are water erosion and leaking inconveniences (Rowell & Dietenberger, 2005).

Baysal *et al.* state that he has applied the Turkish pine and Poinciana wood, which are treated with a mixture of boric acid and borax mixture before varnishing procedure, with phrases of the combustion with flame, combustion without flame source and ember combustion phase according to ASTM 160-50 standard. The best results are obtained only in test samples impregnated with boric acid and borax mixture (BA + BX) with regard to combustion properties. (Baysal *et al.*, 2003).

The retention amount of *Abies Nordmanniana* fir impregnated with water-based preservatives and copper-based preservatives such as tanalith-E, wolmanit-CB and ACQ has shown an increase in comparison with concentration amounts (Cavdar, 2014).

Atar *et al.* (2015) have stated that after the impregnation of Scotch pine (*Pinus sylvestris* Lipsky) wood with boric acid and borax, it is coated with cellulosic, synthetic, polyurathane, waterborne, acrylic and acid hardening varnishes. Combustion temperature is highest in the Borax and waterborne in combustion with flame according to material and process type (Atar *et al.*, 2015)

The highest measured weight loss during combustion of Sapele tree impregnated with Tanalith-E, immersol aqua borax and boric acid is obtained in control samples impregnated with Tanalith-E. Tanalirh-E + water-based varnish has shown the highest values in the average combustion temperature. It is concluded that water-based varnishes accelerate combustion (Uysal *et al.*, 2011).

## 2. Material and Methods

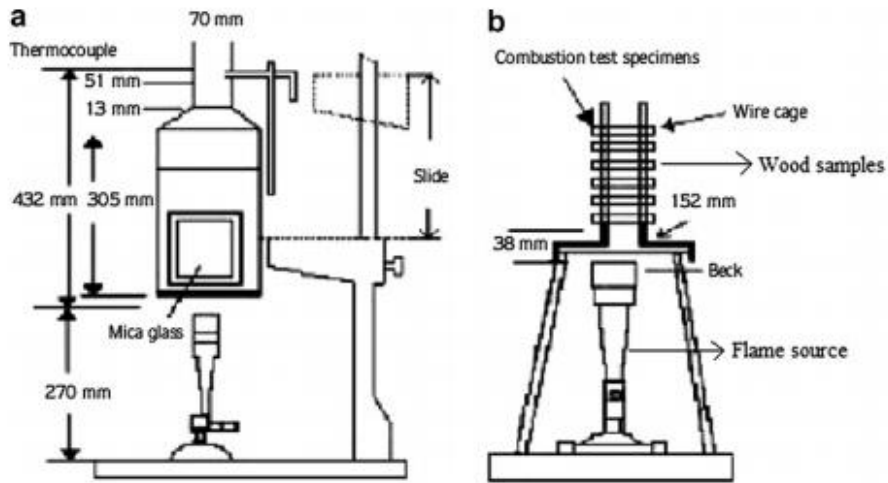
Scotch pine (*Pinus sylvestris* L.) samples are selected from Trabzon region with the coincident method. Impregnation material, Tanalith-E is supplied from Hemel and Wolmanit-CB is provided from Ramtaş-Emsan Korusan. Tanalith-E is a material which is used as water-based with copper triazole solution (Hemel, 2017). The combination of Wolmanit-CB contains 28 % copper sulphate, 48 % potassium bichromate, 24 % boric acid (Bozkurt *et al.*, 1993). Aqua Compact Lasur brand water-based varnish and Wood Art brand synthetic varnish are applied during the varnishing stage. Wolmanit-CB and Tanalith-E impregnation materials have been impregnated to the wood material according to ASTM-D 1413-76 principles (vacuum-pressure). The impregnated materials are left in an air recirculating room for 20 days for evaporation of the dissolvent agents. It is held at the relative humidity of  $65 \pm 3\%$  at  $20 \pm 2^\circ \text{C}$  to reach the constant moisture. Retention amounts (R) of impregnation materials are as follows.

$$R = \left[ \frac{G.C}{V} \right] \times 10^3 \text{ (kg/m}^3\text{)}, \quad (1)$$
$$G = T_1 - T_2$$

Here, G is the amount of impregnation solution absorbed by the sample,  $T_1$  is the specimen weight after the impregnation,  $T_2$  is the specimen weight before the impregnation. C is the concentration (%) of the impregnation solution and V is the volume of the samples. The retention amounts and solution concentrations of impregnation materials are shown in Table 1.

The principals specified in ASTM-D 3023 are followed in the varnishing of the acclimatised samples after impregnation. The instructions of the producing companies are complied with in the application of varnishes. After the implementation, samples are kept at room temperature.

The varnished samples are left in open air conditions for one year with respect to the principles stated in ASTM G7-05 standard. The samples are placed on the test stand with an angle of  $45^\circ$  with their surfaces facing south. The combustion characteristics of the samples received from the outside air are measured in the combustion testing device, which is shown in Figure 1, by following the ASTM E 160-50 principles. Before the combustion test, each sample group is weighed and a total of 24 pieces overlapping in 12 layers with 2 rows are stacked on top of the wire table in the machine. The fire source is placed in the center of the stack at the bottom. After combustion has occurred for 3 minutes while the fire source is open, it is switched off and combustion without flame source and combustion during ember combustion phase are carried out. Temperature changes ( $^\circ \text{C}$ ) are measured regularly from a thermometer for 15 seconds on the combustion with flame, and for 30 seconds on the Combustion without flame source and ember combustion phase.



**Figure 1.** Fire test apparatus (Temiz *et al.*, 2008)

For all parameters, multiple variance analysis (ANOVA) and least significant difference test (LSD) performed with SPSS 20 are used.

### 3. Results and Discussion

The retention amounts and solution concentrations are given in Table 1.

**Table 1.** Mean retention of the test samples used in the experiments.

Impregnation Material	Retention (kg/m <sup>3</sup> )	Concentration (%)
Tanalith-E	2,47	2,4
Wolmanit-CB	2,90	4

Studies showing that solution amount of impregnation materials increases the retention amount are available. The high concentration of Wolmanit-CB may have led to increase in the retention amount (Temiz *et al.*, 2008).

Results of variance analysis are given in Tab. 2. According to variance analysis, the impact of impregnation material and the type of varnish has been found to be significant except for TC' s double interaction (P<0.05).

The mean result values of the of the LSD test are given in Table 3. The graph of the change in combustion temperatures is given in Figure 2.

**Table 2.** Results of the analysis of variance for the temperature of combustion, illuminance, the duration of combustion and weight loss ratios

	Combustion With Flame(CWF)					Combustion Without Flame Source(CWOF)				
	F.D.	S.S.	S.M.	F.V	P.V*	F.D.	S.S.	S.M.	F.V	P.V*
im	2	766,500	383,250	34,359	0,000	2	256,500	128,250	8,679	0,002
vt	2	326,625	163,312	14,641	0,000	2	1771,875	885,938	59,951	0,000
im*vt	4	1617,375	404,344	36,250	0,000	4	1562,625	390,656	26,435	0,000
Error	18	200,778	11,154			18	266,000	14,778		
Total	26	2911,278				26	3857,000			

	Ember Combustion Phase(ECP)					Weight Loss (WL) (%)				
	F.D.	S.S.	S.M.	F.V	P.V*	F.D.	S.S.	S.M.	F.V	P.V*
im	2	26497,125	13248,563	66,409	0,000	2	1,165	0,582	9,526	0,002
vt	2	11127,375	5563,687	27,888	0,000	2	1,418	0,709	11,595	0,001
im*vt	4	10854,000	2713,500	13,602	0,000	4	12,273	3,068	50,190	0,000
Error	18	3591,000	199,500			18	1,100	0,061		
Total	26	52069,500				26	15,956			

	Total Time of Combustion (TC)					Demolition Time (DT)				
	F.D.	S.S.	S.M.	F.V	P.V*	F.D.	S.S.	S.M.	F.V	P.V*
im	2	142340,625	71170,312	72,582	0,000	2	1822753,125	911376563	37,299	0,000
vt	2	89184,375	44592,188	45,476	0,000	2	2103721,875	1051860,937	43,048	0,000
im*vt	4	6750,000	1687,500	1,721	*0,189	4	2011078,125	500769,531	20,576	0,000
Error	18	17650,000	980,556			18	439818,750	24434,375		
Total	26	255925,000				26	6377371,875			

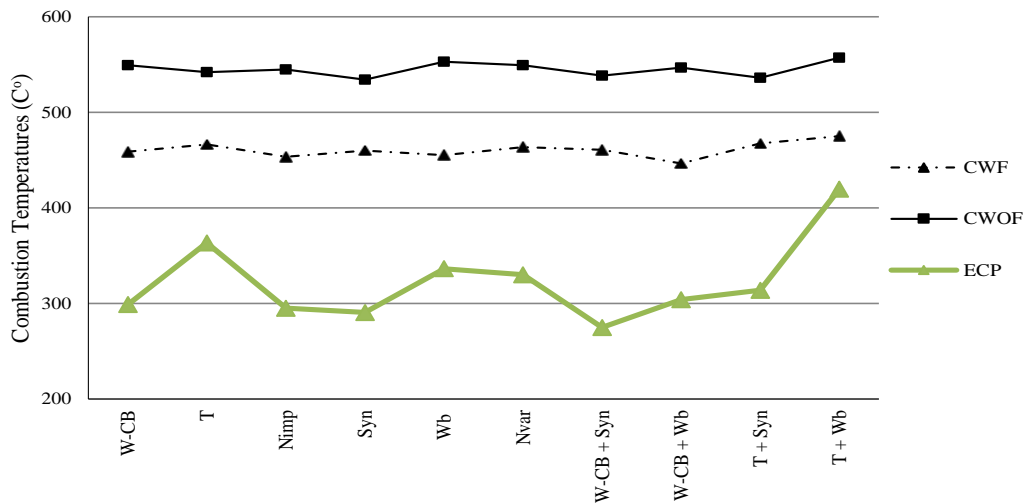
im: impregnating material, vt: types of varnish, F.D: Degrees of Freedom, S.S: Sum of Squares, S.M: Mean of Squares, F.V: F Value (<0.005)

**Table 3.** Mean values of the weight loss, combustion temperatures, combustion durations, and the groups resulting from the least significant difference (LSD) analysis

Factor	WL (%)	Temperature Values (C°)			Combustion Time (sec.)		
		CWF	CWOF	ECP	TC	DT	
Impregnation Materials (IM)	Wolmanit-CB (W-CB)	92,6	458,9	549,3	298,8	621,7	2146
	Tanalith-E (T)	92	466,4	541,8	363,3*	497,9	2514
	Nimp	92,5	453,4	544,8	295	670,4	1880
Varnish Types (VT)	Synthetic (Syn)	92,5	459,9	534,1	290,5	677,9*	2353
	Water-Based (Wb)	92,1	455,1	552,8*	336,3	557,9	1786
	Nvar	92,6	463,6	549,1	330,3	554,2	2401
IM+VT	W-CB+Syn	91,4	460,6	538,3	274,8	700,4	1940
	W-CB+Wb	92,6	446,4	546,6	304	587,9	1805
	T+Syn	92,8*	467,4	536,1	313,8	587,9	3099*
	T+Wb	91,2	474,9*	557,1	419,5	430,4	1794

Nimp: None impregnated Nvar: None varnished, WL: Weight Loss, CWF: Combustion With Flame, CWOF: Combustion Without Flame Source, ECP: Flame, Ember Combustion Phase, TC: Total Time of Combustion, DT: Demolition Time, \* : maximum values

The lowest weight loss has shown up in T+Wb, the highest has shown up in T+Syn. The highest combustion with flame temperature (CWF) has been observed in T+Wb, the lowest has observed in W-CB+Wb. In the combustion without flame source (CWO), Wb has resulted in the highest temperature, Syn has shown the lowest results. In the Ember Combustion Phase (ECP), the highest results are obtained in T+Wb, the lowest ones are obtained W-CB+Syn. The total combustion duration values (TC) are determined as highest in W-CB+Syn, as lowest in T+Wb. The demolition time (DT) values are found highest in T+Syn, lowest in Wb.



**Figure 2.** Combustion with flame, combustion without flame source and ember combustion phase temperature changes

#### 4. Conclusions

The impregnation materials have increased temperature values when used alone in proportion to the control samples. Wolmanit-CB has shown lower temperatures at combustion temperatures when compared with Tanalit-E. The varnish type has been more effective in the combustion without flame stage. Better results have been obtained from synthetic varnishes, one of varnish types. The combustion temperatures have increased in the water-based varnishes compared with control samples. Even though it has demolished early, Tanalith-E + synthetic varnish has continued to burn ember combustion phase. The Tanalit-E + water-based varnish duo has been extracted early while showing high temperatures.

The impregnation material and varnish choice affects the combustion properties of wooden material. Wolmanit-CB can be recommended as impregnation material, synthetic varnish can be recommended as a type of varnish for especially places which are exposed to outdoor weather conditions with the risk of burning.

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