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Ahşap koruyucuların sapsız meşe (Quercus Petreae L.) ağacının yanma özelliklerine etkileri

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The Effects of Wood Preservatives on the Combustion Characteristics of Sessile Oak (*Quercus Petreae* L.)

Araştırma Makalesi / Research Article

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ABSTRACT

This study carried out to determine the combustion properties of the sessile oak wood (*Quercus petraea* L.) which impregnated with wood preservative and subjected to surface treatments. For this purpose, the samples, which were prepared from sessile oak wood according to ASTM–E 160-50 combustion principles, impregnated with wolmanit-CB (WC) and tanalith-E (T) in accordance with ASTM-D 1413-76 and then synthetic (St) and Water-based (wb) varnishes were applied according to ASTM-D 3023. The combustion test was carried out in 3 stages, combustion with flame (CWF), self-combustion without flame source (CWOF) and ember combustion stage (ECP). It was aimed to determine the combustion temperature values in CWF, CWOF and ECP stage, weight loss, total combustion time and demolition time.

As a result, impregnation applications have increased the total combustion time to between 15-18% and reduced the demolition period. The exact opposite results were obtained for the varnish types, the total combustion time was reduced by 19-21% and the demolition time increased by 10-22%. In CWF stage, the highest temperature was obtained in water-based varnished samples (490 °C), the lowest in non-varnished samples (458 °C); in CWOF stage the highest temperature in water-based varnished samples (572 °C), the lowest in synthetic varnished samples (544 °C); and in ECP stage the highest temperature in non-varnished samples (306.5 °C), the lowest in the samples with the synthetic varnished (262.7 °C).

Anahtar Kelimeler: Combustion, wood, impregnation, varnish, Wolmanit-CB, Tanalith-E.

Ahşap Koruyucuların Sapsız Meşe (Quercus Petreae L.) Ağacının Yanma Özelliklerine Etkileri

ÖZ

Bu çalışma, ahşap koruyucu ile emprenye edilmiş, üst yüzey işlemleri uygulanmış sapsız meşe (*Quercus petraea* L.) odununun yanma özelliklerini belirlemek amacıyla yapılmıştır. Bu maksatla ASTM–E 160-50 'ye göre hazırlanan sapsız meşe örnekleri ASTM-D 1413-76 'ya göre tanalith-E ve wolmanit-CB ile emprenye edilmiş, ASTM-D 3023' e göre sentetik ve su bazlı vernik ile verniklenmiştir. Yanma deneyi, alev kaynaklı yanma (CWF), kendi kendine yanma (CWOF)ve kor halde yanma (ECP) olmak üzere 3 aşamada gerçekleştirilmiştir. Yanma deneyi ile ağırlık kaybı, toplam yanma süresi, yıkılma süresi ve CWF, CWOF ve ECP periyotlarındaki yanma sıcaklık değerleri belirlenmesi amaçlanmıştır.

Sonuç olarak; emprenye uygulamaları toplam yanma süresini %15-18 arasında arttırmış, yıkılma süresini azaltmıştır. Vernik çeşitlerin tam tersi sonuçlar elde edilmiş, toplam yanma süresi %19-21 arasında azalmış, yıkılma süresi %10-22 arasında artmıştır. Alev kaynaklı aşamasında yanma sıcaklığı en yüksek su bazlı vernikli (490 °C), en düşük vernik uygulanmayan örneklerde (458 °C), alev kaynağı olamadan kendi kendine yanmada en yüksek su bazlı vernikte (572 °C), en düşük sentetik vernik uygulanan örneklerde (544 °C), kor halde yanmada en yüksek sıcaklık vernik uygulanmayan örneklerde (306.5 °C), en düşük sentetik vernik uygulanan örneklerde (262.7 °C) elde edilmiştir.

Keywords: Yanma, ağaç, emprenye, vernik, Wolmanit-CB, Tanalith-E.

1. INTRODUCTION

Wood is a rapidly decreasing raw material source, which is a construction material that could insulate heat and electricity well and is esthetic, eco-friendly and light. Despite of all its positive aspects, being an inflammable matter restricts its areas of use.

Wood preservatives extends the serve life of the wooden material by protecting it from fire, mechanical weathering, weather conditions, biological hazards, physical and chemical degradation [1]. It is not only the protective properties of wood preservatives, physical, mechanical and chemical effects are also being investigated. For example in a study the compression strengths of impregnated wood with tanalith-E was investigated. The compression strength values were decrease with tanalith-E to control samples [2]. There are many ongoing researches to increase the resistance of wood especially against combustion and the environmental factors in the wood's place of use [3-6]. Water-based solutions prepared from water-borne salt like oil-based creosote, petrol solution

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pentachlorophenol and CCA, ACQ, CCB, CCP and CBA are commonly used wood preservatives [7]. That recent preservatives are eco-friendly and they are not harmful for human health, also matter considerably not just their resistance against environmental factors, their adsorption onto wooden material and their activity level. Environmental Protection Agency (EPA) suggested that label changing of arsenic, pentachlorophenol and creosote is convenient by taking assuasive precautions in 2008 [8].

Many different fire retardants developed in order to hinder the wooden material from combustion. Romans wet the wood with alum and vinegar and covered it with various materials [9]. Nowadays; boron, ammonium, phosphor and nitrogen compounds are used to prevent wooden material and its composites from combustion [10-19].

Normally, wood does not ignite by itself, but it can ignite with the help of a strong heat source and it creates a self-isolated coal layer during combustion [20]. In thermal analysis, pyrolysis of hemicellulose and cellulose occurre rapidly, it is founded that weight loss of hemicellulose is mainly between 220-315 °C and weight loss of cellulose is mainly between 315-400 °C [21]. Many different methods like thermo gravimetric analysis (TGA), cone calorimeter, fire spreading tests, smoke density tests and oxygen index tests are used in order to identify the combustion behaviors of the material [21, 22-26].

Application methods of impregnation materials affect combustion behaviors. While examining the combustion behaviors of Oriented Strand Board (OSB), treated with materials like potassium, carbonate, borax and wolmanit-CB, flaming fire is observed as 1180 secs in the samples in which wolmanit-CB is applied with brush method while flaming combustion observed as 587 secs in dipping method [27].

According to the control samples in thermal analysis of oriental beech wood impregnated with materials like Adolit KD-5, Wolmanit CX-8 and Tanalit-E with 0.25, 1 and 4.7 concentration, all impregnation materials decreased the maximum heat degradation while increased the amount of residual coal [28].

Various thermal behaviors are observed after the treating scots pine wood with fixed concentrated (4%) wood preservatives. Samples treated with Wolmanit-CB decreased the initial heat of weight loss during pyrolysis, the maximum pyrolysis heat and the weight loss after combustion in contrast with the control samples [29].

In this study, the effects of wood preservatives and varnish on combustion behaviors of oak wood examined. For this purpose, it was determined temperatures in the combustion stages, weight loss, total combustion and demolition times

2. MATERIAL AND METHOD

2.1. Material

The sessile oak wood (*Quercus petraea* L.), which is a widely used tree species in furniture production, was obtained from Trabzon province timber management completely randomly. The wood materials selected especially from those that did not suffer from damaged by pests and which does not included growth defect, fiber deterioration and knots.

Tanalith-E and Wolmanit-CB commercial wood protectors were used as impregnation material. Tanalith-E has a water-based copper triazole solution that does not contain chromium and arsenic [30]. Wolmanit-CB contains copper sulphate, potassium bichromate and boric acid in its composition [31]. Wolmanit-CB supplied from Emsan A.Ş. (Korusan) Tanalith-E from Hemel Impregnated Products.

Solvents of synthetic resin varnishes are known to be harmful to human health [32]. In the varnishing of the test specimens, water based varnish and synthetic varnish were applied according to the ASTM D-3023 principles [33]. Marshall-Wood Art and Jansen-Aqua Compact Lasur are used as synthetic and water based varnishes.

2.2. Method

2.2.1. Preparation of the test samples

Combustion test samples were prepared with dimensions of 13 x 13 x 76 mm (radial x tangent x length) according to the ASTM E 160-50 principles [34]. The samples were waited at 20 ± 2 °C before impregnation and at 65% relative humidity until reaching constant weight (12% moisture). Concentration amounts of impregnated materials affect the combustion values [29]. While the combustion properties of Wolmanit-CB and Tanalith-E measured at different concentrations, the combustion properties increased as the amounts of concentration increased, and concentration over 3% was suggested for Wolmanit-CB [35]. In this study, with the advice of the manufacturers, the concentration amounts of Tanalith-E and Wolmanit-CB, was determined as 2.4% and 4%. PH value measured 9.9 for Tanalith-E and 4.3 for Wolmanit-CB. Experiment samples were treated in a vacuum of 600 mm Hg for 30 minutes and at a pressure of 0.6 MPa for 60 minutes according to impregnation materials ASTM D 1413 76 [36] principles.

After the impregnation procedure was applied, the samples were kept until they reached the constant weight at a temperature of 20 ± 2 °C and 65% relative humidity so that they could be ready for surface treatment. The amount of varnish was determined by weighing with 0.01 sensitive scales according to the manufacturer's recommendations. The solid amount of the varnish types used in the study was determined as 47% in synthetic varnish and as 33% in water-based varnish according to TS 6035 EN ISO 3251 [37]. After the varnishing, the samples were kept for 15 days until they reached constant weight.

2.2.2. Combustion Experiments

The test pieces, which are ready after the varnishing, were performed combustion experiments in accordance with ASTM-E 160-50. Before the combustion, each test group weighed to be 24 pieces and placed on the wire stand. In Combustion With Flame (CWF) stage the pressure gauge was set at 0.5 kg/cm^2, was continued for 3 minutes, and the flame source was extinguished. After CWF stage self-Combustion Without Flame source (CWOF) and Ember Combustion Stage (ECP) were carried out. The temperature changes (°C) measured in thermometry on a regular basis for 15 seconds in CWF and 30 seconds in the other combustion stages. During the combustion test, temperatures of CWF, CWOF and ECP stage, weight loss, total time of combustion and demolition time were determined.

2.2.3. Analysis of The Data

Data of Experiments analyzed with SPSS 20.0. statistical evaluation program. While multiple variance analyses (UNIVARIATE) applied, differences between groups compared with the Duncan test.

3. RESULTS AND DISCUSSION

The retention amount of sessile oak wood is identified as 2.4 kg/m^3 for Tanalith-E while as 2.49 kg/m^3 for wolmanit-CB.

3.1. Weight Loss in Combustion

Results for variance analysis of weight loss after combustion given in Table 1.

Apart the impregnation material, all interactions turned to be significant. According to impregnation material and varnish type, the mean, maximum, minimum and standard deviation values of weight loss are as shown in Table 2.

3.2. Total Time of Combustion and Demolition Time

Results for variance analysis of the types of impregnation material and varnish related to the total time of combustion and demolition time of experimental stand are given in Table 3

Table 1. Results of variance analysis related to the changes in weight loss

Factor	Degree of freedom	Sum of squares	Average of squares	F Value	P
I	2	0.665	0.332	2.586	*0.103
V	2	0.957	0.479	3.723	0.044
I+V	4	29.622	7.406	57.596	0.000
Error	18	2.314	0.129		
Total	26	33.559			

Table 2. Average minimum, maximum, standard deviation weight loss values

Factor	Application	*M (%)*	*Max(%)*	*Min (%)*	*Sx*
Impregnation Material	*WC*	86.26	87.56	84.65	0.34
	T	85.92	87.64	83.99	0.41
	Ni	85.92	87.42	83.82	0.42
Varnish Type	*St*	86.03	87.42	84.65	0.31
	Wb	85.80	86.78	83.99	0.34
	Nv	86.26	87.64	83.82	0.49

Table 3. Variance analysis results related to the changes in total combustion and demolition time

	Factor	*Degree of freedom*	*Sum of squares*	*Average of squares*	*F Value*	*P*
Total time of combustion	*I*	2	379940.625	189970.313	23.256	0.000
	V	2	833287.500	416643.750	51.005	0.000
	I+V	4	771778.125	192944.531	23.620	0.000
	Error	18	147037.500	8168.750		
	Sum	26	2132043.750			
Demolition Time	*I*	2	7087.500	3543.750	2.719	*0.093
	V	2	146559.375	73279.688	56.234	0.000
	I+V	4	163012.500	40753.125	31.273	0.000
	Error	18	23456.250	1303.125		
	Sum	26	340115.625			

I: Impregnation Material, V: Varnish Type, P: $\alpha \leq 0.05$, *: insignificant

Except from the effect of impregnation material on demolition time, all interactions are significant. According to impregnation material and varnish type, the mean, maximum, minimum and standard deviation values of the combustion periods are as shown in Table 4.

Table 4. The mean, maximum, minimum and standard deviation of total combustion and demolition time

	Factor	Procedure	M (sn)	Max (sn)	Min (sn)	Sx
Total time of combustion	Impregnation Material	WC	1763	2265	1410	97.59
		T	1711	2310	1275	118.75
		Ni	1490	1600	1380	26.63
	Varnish Type	St	1512	1630	1380	30.65
		Wb	1550	1725	1275	51.82
		Nv	1902	2310	1380	120.06
Demolition time	Impregnation Material	WC	902	1005	825	20.58
		T	872	1005	735	30.43
		Ni	910	1170	660	57.24
	Varnish Type	St	988	1170	885	33.35
		Wb	887	1005	735	30.86
		Nv	808	875	660	24.98

WC: Wolmanit-CB, T: Tanalith-E, Ni: Unimpregnated, St: Synthetic varnish, Wb: Water based varnish, Nv: Unvarnished, M: Mean, Min: Minimum, Max: Maximum, Sx: Standard Error of Mean

Table 5. Results of variance analysis on temperature of combustion with flame

Factor	Degree of freedom	Sum of squares	Average of squares	F Value	P
I	2	199.500	99.750	2.997	*0.075
V	2	5301.375	2650.687	79.650	0.000
I+V	4	2586.000	646.500	19.426	0.000
Error	18	599.028	33.279		
Total	26	8685.903			

I: Impregnation Material, V: Varnish Type, P: $\alpha \leq 0.05$, *: insignificant

The highest total time of combustion was determined in the unvarnished samples (1902 secs) and the lowest in unimpregnated samples (1490 secs). The highest period of demolition time was determined in varnished samples (988 secs) and the lowest in unvarnished samples (808 secs).

Table 6. Mean minimum, maximum, standard deviation values of temperature of combustion with flame

Factor	Procedure	*M (ºC)*	*Max(ºC)*	*Min (ºC)*	*Sx*
Impregnation Material	WC	474	492	453	4.56
	T	468	505	429	8.53
	Ni	469	493	451	4.93
Varnish Type	St	463	470	453	1.92
	Wb	490	505	481	2.49
	Nv	458	482	429	6.09

WC: Wolmanit-CB, T: Tanalith-E, Ni: Unimpregnated, St: Synthetic varnish, Wb: Water based varnish, Nv: Unvarnished, M: Mean, Min: Minimum, Max: Maximum, Sx: Standard Error of Mean

3.3. Combustion Temperatures

3.3.1. Temperature of Combustion with Flame

The results of multiple variance analysis of the effect of impregnation material and varnish type on combustion with flame temperature are given in Table 5.

Except for of impregnation material, all interactions were found to be significant. According to impregnation material and varnish type, the mean, maximum, minimum and standard deviation values of the combustion with flame temperature are as shown in Table 6

The highest temperature in combustion with flame was determined in water-based varnish samples (490 °C) and the lowest (458 °C) in unvarnished samples. Wolmanit-CB kept temperature values highest in combustion with flame.

3.3.2. The temperature of self-combustion without flame source

The results of multiple variance analysis of the effect of impregnation material and varnish type on self-combustion without flame source temperature presented in Table 7.

Table 7. The results of variance analyses on the temperature of self-combustion without flame source

Factor	*Degree of freedom*	*Sum of squares*	*Average of squares*	*F Value*	*P*
I	*2*	136.500	68.250	1.586	*0.232
V	*2*	4041.375	2020.687	46.951	0.000
I+V	*4*	6280.500	1570.125	36.482	0.000
Error	*18*	774.694	43.039		
Total	*26*	11233.069			

I: Impregnation Material, V: Varnish Type, P: α≤0.05, *: insignificant

Table 8. Mean minimum, maximum, standard deviation values of the temperature of self-combustion without flame source

Factor	Procedure	*M (°C)*	*Max(°C)*	*Min (°C)*	*Sx*
	WC	557	573	540	3.73
Impregnation Material	T	552	599	504	10.66
	Ni	557	577	532	5.14
	St	544	552	532	2.28
Varnish Type	Wb	572	599	559	4.57
	Nv	549	577	504	8.59

WC: Wolmanit-CB, T: Tanalith-E, Ni: Unimpregnated, St: Synthetic varnish, Wb: Water based varnish, Nv: Unvarnished, M: Mean, Min: Minimum, Max: Maximum, Sx: Standard Error of Mean

Table 9. Results of variance analysis on the temperature of ember combustion stage

Factor	*Degree of freedom*	*Sum of squares*	*Average of squares*	*F value*	*P*
I	*2*	409.500	204.750	2.008	*0.163
V	*2*	8715.375	4357.687	42.740	0.000
I+V	*4*	15651.000	3912.750	38.376	0.000
Error	*18*	1835.250	101.958		
Total	*26*	26611.125			

I: Impregnation Material, V: Varnish Type, P: α≤0. 05, *: insignificant

Table 10. Mean minimum, maximum, standard deviation values of the temperature of ember combustion stage

Factor	Procedure	*M (°C)*	*Max(°C)*	*Min (°C)*	*Sx*
	WC	280.5	293	261	3.69
Impregnation Material	T	289	330	269	7.78
	Ni	288.5	376	235	17.02
	St	262.7	277	235	4.57
Varnish Type	Wb	288.7	330	257	8.33
	Nv	306.5	376.	271	12.58

WC: Wolmanit-CB, T: Tanalith-E, Ni: Unimpregnated, St: Synthetic varnish, Wb: Water based varnish, Nv:Unvarnished, M: Mean, Min: Minimum, Max: Maximum, Sx: Standard Error of Mean

Except from the effect of impregnation material, all interactions were found to be significant. According to impregnation material and varnish type, the mean, maximum, minimum and standard deviation values of the temperature self-combustion without flame source are as shown in Table 8.

The highest temperature in the combustion without flame source was determined in water-based varnished samples (572 °C) and the lowest in unvarnished samples (544 °C).

3.3.3. The Temperature of Ember Combustion Stage

The results of multiply variance analysis of the effect of impregnation material and varnish type on the temperature of ember combustion shown in Table 9.

Except from the effect of impregnation material, all interactions were found to be significant. The mean, maximum, minimum and standard deviation values of the temperature of ember combustion stage in terms of impregnation material and varnish type are as shown in Table 10.

The highest temperature of ember combustion stage was determined in water-based varnished samples (306.5 °C) and the lowest temperature is in synthetic varnished samples (262.7 °C).

The effects of the impregnation material and varnish types on the combustion temperature are shown in Figure 1.

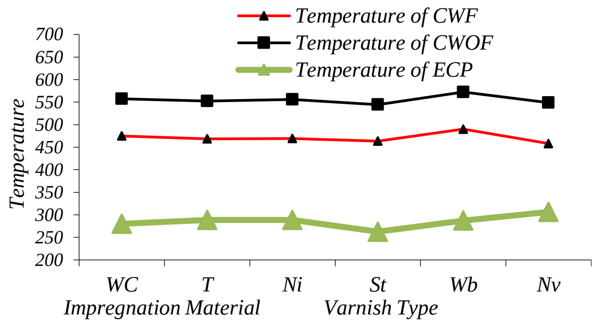

Figure 1. Impact of impregnation material and varnish type on combustion temperature

The impregnated materials showed close values at the combustion temperatures. Synthetic varnish showed minimum values on maximum and minimum combustion temperatures. Waterbased varnish increased temperatures at CWF and CWOF stage.

4. CONCLUSION

Varnish types affected weight loss and temperatures occurring during combustion. Water based varnish the most decreased the weight loss. The impregnation materials raised the total time of combustion between 15-18% and reduced the demolition time. The chemical structure of the impregnation materials and the small size of the test samples may have affected the combustion and destruction times. In future studies; wood preservatives can be tested on samples in different sizes by applying different concentrations and pressures.

The varnish types reduced the total time of combustion between 19-21% and raised the demolition time between 10-22% [3-6, 38]. Wolmanit-CB raised the average temperature values in combustion with flame and combustion without flame, kept the minimum combustion temperatures high. Tanalith-E increased the maximum combustion temperature value. Water based varnish raised the average, maximum and minimum temperature values. Wolmanit-CB increased the average temperatures in the combustion with flame and combustion without flame, while it reduced temperatures of ember combustion phrase. In the case of ember combustion phrase, varnish types reduced the combustion temperatures. During all combustion stages varnish types reduced temperatures and synthetic varnish type showed the lowest temperatures. Synthetic varnish may be recommended if varnish application is to be done in a place where there is a risk of fire.

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