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Impact Of Several Impregnation Materials And Varnishes On Gases Analysis Of Scotch Pine Left In The Weather Conditions

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ABSTRACT

The most objectionable environment for the wood material is outdoor conditions. This study is carried out to determine the amounts of oxygen, carbon monoxide, carbon dioxide and nitrogen oxide emitted by the combustion of wood materials, which are left in the outdoor conditions. For this purpose impregnation materials wolmanit-CB and tanalith-E, which are commonly used for wood protection, and synthetic and water-based varnishes as varnish types are studied. The results indicate that CO is emitted. It is confirmed that varnishes show a lowering effect and the impregnation materials shows an additive effect in the combustion caused by fire, combustion with flame and ember combustion phase. As a conclusion, it is observed that impregnation materials wolmanith-CB and tanalith-E and synthetic and water-based varnish types have an important effect on the gas values of wooden material occurring during the combustion.

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

1.Introduction

The wooden material is a combustible material due to its natural structure. While burning, the wood executes a very complex combustion reaction because of its chemical and physical structure. The wooden material does not burn directly but volatile gases form tar compounds and coal measure with the effect of a sufficiently strong fire source. During the combustion of wooden material, the rupture of internal chemical bonds, dehydration (water disposal), CO, CO_2 and carbon layer formation of carbonyl, carboxyl

and hydroperoxide groups are observed below 300 degrees (Rowell & Dietenberger, 2005)

Various researches have been conducted to improve the combustion performance of wooden and wood based materials. Liu et al have carried out the oxygen index analysis (LOI) to determine the combustion performance of ultra-low density fibreboard with boron, nitrogen- phosphor, silica and halogen based fire retardants. The LOI value of the fibreboard with %100 non-combustible material has increased to %31.2 and when compared with unprocessed fibreboard, it has increased by %102.6 (Liu *et al.*, 2016).
In order to improve the burning behavior of wooden materials; boron, nitrogen, phosphor, silica based compounds and halogen type fire retardants are used (Lee *et al.*, 2004; Keskin *et al.*, 2009; Ayan *et al.*, 2011; Kim *et al.*, 2012; Lu & Hamerton , 2012; Keskin *et al.*, 2013; Aydemir, 2016; Deveci *et al.*, 2017).

The oxygen index has an impact on the extinguishment and ignition during the combustion of wooden materials. The characteristics of the wood such as its moisture content, fibre direction and thickness are also effective in the combustion (White, 1979).

2.Materials and Methods

As a test material, sessile oak (*Quercus petreae L.)* wood was preferred because of its wide usage in woodworking, furniture and decoration works. The lumber, which was used in the preparation of test samples, was obtained from Trabzon timber enterprises by completely random method. In the selection of wood material, the requirements indicated in TS 4176 were followed by taking into consideration that the timber colour is natural, unrecorded, without knots, with smooth fibres, no reaction to wood, not affected by fungus and insect pests. The scotch pine (Pinus sylvestris L.), widely used in Turkey, is used as the wooden material. The wooden materials which are chosen in accordance with TS 345 standards. have been paid attention to be flawless, clean-cut fibrous, non-destructive, undamaged without a knot and internal corrosion. Randomly selected samples are conditioned at a temperature of 20 ± 2 ° C and %65 relative humidity until the constant moisture of %12 is reached prior to rough cutting. Tanalith-E and Wolmanit-CB which are used in the sector as a wood protector are selected as impregnation materials. Tanalith-E is a preservative which is applied with the vacuum-pressure system, doesn't contain chromium and arsenic and is composed of copper and organic biocides (triazole) which are effective against pests such as fungi and insects (Hemel, 2017). Wolmanit-CB comprises sulphate, potassium bichromate and boric acid content. (Bozkurt *et al.*, 1993) The studies which show that Wolmanit - CB is a late combusting material, but it can't stand long duration of fire are available (Berkel, 1972; Aslan & Ozkaya, 2004). Tanalith-E impregnation material has been supplied at a concentration ratio of %2.4, Wolmanit-CB has been provided at %4 concentration from the producing companies. Since it is not hazardous to human health, the water-based

varnish volatile and the synthetic varnish because it is widely used in the sector are preferred as varnish types.

The scotch pine (Pinus sylvestris L.) samples are cut in dimensions of 13x13x76 mm (radial x tangent x length). The vacuum-pressure method is employed in impregnation as stated in ASTM-D 1413-76.

Concentration amounts of impregnation material affect the combustion values. In another study, a concentration over %3 for Wolmanit-CB has been suggested according to oxygen index values measured during the combustion (Cavdar, 2014).
Retention amounts of impregnated Scotch pine samples have been determined as 2,9 kg/m^3 in the wolmanit-CB and as 2,47 kg/m^3 in Tanalith-E. Impregnated specimens have been left in a setting with air circulation for 20 days in another study. The samples are varnished by following the manufacturer's instructions according to ASTM-D 3023 principals.
The varnished samples are left in open air conditions for one year according to ASTM G7-05.

The samples obtained from outdoor air conditions are combusted according to ASTM-E 160-50 principles. The combustion is executed in three stages: combustion with flame source (CWF), combustion without flame source (CWOF) and ember combustion phase (ECP). The CWF) process is sustained for 3 minutes by centring the flame source under the pile. Following the extinguishment of the flame source, the CWOF and ECP processes are carried out.

The measurements of the gas emerged during the combustion stages are performed in respectively 15 secs, 30 secs and 30 sec. The measurement of O_2 (%), CO (%), CO_2 (ppm) and NOx (ppm) gases is carried out with the SIGMA Flue gas analyser shown in Figure 1., positioned on the upper side of the combustion device flue.

Figure 1. SIGMA 74172 NSU gas analyser.

The statistical evaluation of the results is conducted with SPSS 20.0 statistical package software. The results are statistically tested with the one-way analysis of variance. The effect of impregnation materials and varnish type on gas values of samples is increased with two-way analysis of variance.

3.Results and Discussion

The retention amounts and solution concentrations are given in Table 1. The variance analysis results of impregnation material and varnish types on gas analyses are presented in Table 1.

Table 1. The variance analysis results of the gas analysis during combustion with flame source, combustion without flame source and ember combustion phase

Source of Variance	O_2 (%)														
	Combustion with Flame Source(CWF)					*Combustion Without Flame Source(CWOF)*					*Ember Combustion Phase(ECP)*				
	FD	SS	SM	FV	PV	FD	SS	SM	FV	PV	FD	SS	SM	FV	PV
IM	2	49,74	24,873	23,66	0,00	2	2,52	1,26	15,30	0,00	2	921,695	460,847	26,33	0,00
VT	2	40,96	20,480	23,59	0,00	2	2,74	1,37	16,63	0,00	2	1416,771	708,385	40,47	0,00
IM+VT	4	120,18	30,046	34,62	0,00	4	14,75	3,68	44,78	0,00	4	1914,441	478,610	24,34	0,00
Error	18	15,62	0,868			18	1,48	0,08			18	315,030	17,502		
Total	26	226,51				26	21,50				26	4567,936			
Source of Variance	CO (ppm)														
	CWF					CWOF					ECP				
	FD	SS	SM	FV	PV	FD	SS	SM	FV	PV	FD	SS	SM	FV	PV
IM	2	47,08	23,544	28,71	0,00	2	2,33	1,16	15,20	0,00	2	71,91	35,95	35,68	0,00
VT	2	38,34	19,171	23,38	0,00	2	2,55	1,27	16,63	0,00	2	2,74	1,37	1,36	*0,28
IM+VT	4	113,82	28,455	34,70	0,00	2	13,74	3,43	44,82	0,00	2	170,17	4254	42,22	0,00
Error	18	14,75	0,820			18	1,38	0,07			18	18,13	1,00		
Total	26	214,01				26	20,01				26	262,96			
Source of Variance	CO (ppm)														
	CWF					CWOF					ECP				
	FD	SS	SM	FV	PV	FD	SS	SM	FV	PV	FD	SS	SM	FV	PV
IM	2	221548240	110774120	72,20	0,00	2	16453053	8226526,	36,74	0,00	2	117337030	58668515	25,92	0,00
VT	2	4349815	21749087	14,17	0,00	2	9876753	4938376	22,05	0,00	2	70241804	35120902	15,51	0,00
IM+VT	4	107747043	26936760	17,55	0,00	4	28079945	7019986	31,35	0,00	4	36241600,	90604000	40,03	0,00
Error	18	27614330	1534129			18	4030352	223909			18	40740358	2263353		
Total	26	400407789				26	58440114				26	590735195			
Source of Variance	NOx (ppm)														
	CWF					CWOF					ECP				
	FD	SS	SM	FV	PV	FD	SS	SM	FV	PV	FD	SS	SM	FV	PV
IM	2	501,85	250,92	42,41	0,00	2	224,33	112,16	3,34	*0,05	2	6207	3103,50	32,04	0,00
VT	2	561,48	280,74	47,45	0,00	2	2410,01	1205,00	35,93	0,00	2	5391	2695,76	27,83	0,00
IM+VT	4	440,55	110,13	18,61	0,00	4	802,89	200,72	5,98	0,00	4	11933	2983,28	30,80	0,00
Error	18	106,49	5,91			18	603,57	33,53			18	1743	96,83		
Total	26	1610,38				26	4040,81				26	25274			

IM: Impregnation materials, VT: Varnish type, FD: Degrees of Freedom, SS: Sum of Squares, SM: Mean of Squares, FV: F Value (<0.005), CWF: Combustion with Flame, CWOF: Combustion Without Flame Source, ECP: Ember Combustion Phase

According to variance analysis, the impact of impregnation material and the varnish type is found significant except for varnish type on CO variance analysis and impregnation material on NO variance analysis ($P<0.05$).

The oxygen, carbon dioxide, carbon monoxide and nitrogen oxides amounts occurred in the combustion stages are given in Table 2, and the graph belong to this is given Figure 2. and Figure 3.

Table 2. Mean values of the gas analyses and the groups resulting from the least significant difference (LSD) analysis

Factor		*Combustion with Flame Source (CWF)*				*Combustion Without Flame Source(CWOF)*				*Ember Combustion Phase(ECP)*			
		O_2 (%)	CO_2 (%)	CO (ppm)	NO (ppm)	O_2 (%)	CO_2 (%)	CO (ppm)	NO (ppm)	O_2 (%)	CO_2 (%)	CO (ppm)	NO (ppm)
IM	WC	17,6	3,1	9957,4	11,7	1,3	19,1	30490,2	15,5	12,7	9,7	18279,7	53,8
	T	14,6	6,1	15116,7	4	0,6	19,7	31679,1	22,5	25,4	12,9	17009,2	89,2
	Nimp	14,9	5,8	8418,7	14,2	1,2	19,2	29787,7	19,8	13,2	9,2	13361,3	62
VT	Syn	16,5	4,2	9397,4	16,4	0,6	19,7	31342,2	8,5	11,8	10,6	14755,8	57,5
	Wb	16,7	4,1	12321,8	6,2	1,3	19	29869,5	17,8	27,4	10,9	15430,1	59,3
	Nvar	14	6,7	11773,6	7,3	1,1	19,2	30745,4	31,5	12,2	10,1	18464,3	88,3
IM+VT	WC+Syn	15,9	4,9	11096	25,2	0,5	19,8	30652	6,7	13,5	8,9	11502	43,6
	WC+Wb	19,3	1,5	9730	5,1	0,9	19,4	30918	16	14,1	8,3	15862	76,3
	T+Syn	19,2	1,6	9523	3,9	0,9	19,5	31676	11,9	9,9	12,4	18594	62,6
	T+Wb	12,7	7,9	18180	4,3	0,4	19,9	31678	12,1	32,3	17,6	16217	65

IM: Impregnation materials, VT: Varnish type, WC: Wolmanit-CB, T: Tanalith-E, Nimp: Non-impregnated, Syn: Syntetic varnish, Wb: Water based varnish, Nvar: Non-varnished

The oxygen amount in combustion with flame source is highest in WC + Wb, is lowest at T + Wb; in the combustion without flame source, the highest value is in W and Wb, the lowest is in T + Wb; in ember combustion phase, it is found highest in T + Wb and the lowest in T + Syn. O2 values in the combustion with flame source and in the combustion without flame source with Wolmanit-CB are high. Due to the boric acid in the Wolmanit-CB content, a higher O2 amount may have delayed the combustion and ignition of the wood (Wang & Winandy, 2004).

The wooden specimens treated with Wolamanit-CB CCB requires more oxygen to combust in comparison with samples treated with ACQ and Tab-E since CCB contains boric acid.

The carbon dioxide amount is measured highest at T + Wb in the combustion with flame source, lowest in WC + Wb; in the combustion without flame source, the highest value is in T + Wb, the lowest is in Wb; in ember combustion phrase, the highest is found in T + Wb and the lowest is found in WC + Wb. In the combustion with flame source, varnish types have increased the O2 amount between %17 and %19, and have reduced the CO2 values by %37-38.

The carbon monoxide amount is highest in T + Wb in the combustion with flame source, the lowest in Nimp; in the combustion without flame source the highest value is measured in T, the lowest is measured in Nimp; in ember combustion phrase the highest value is observed in T + Syn.

The nitrous oxide amount is found highest in WC + Syn and lowest in T + Syn in the combustion with flame source; in the combustion without flame source, the highest value is in T, lowest in Nvar; In ember combustion state, it is found highest in T, lowest in WC + Syn. Wolmanit-CB has reduced NOx values during all combustion processes.

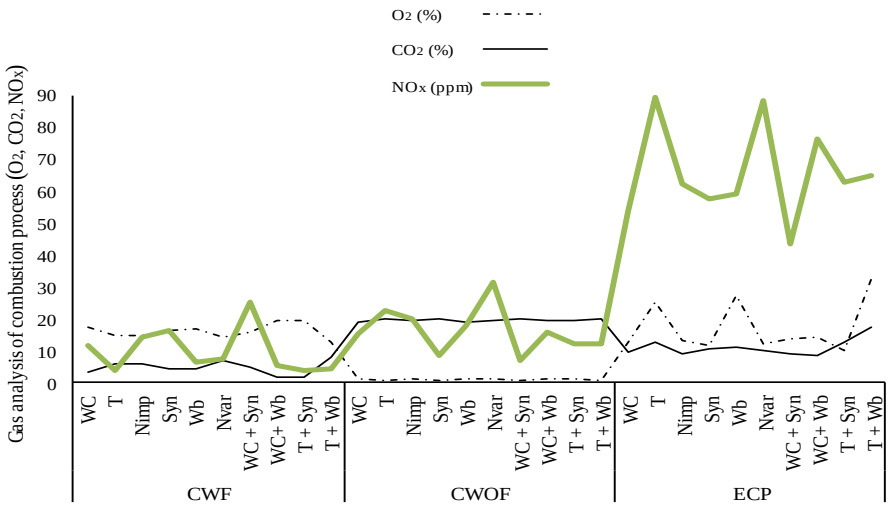

Figure 2. O_2, CO_2 and NO_x amounts emerged in the combustion with flame source, combustion without flame source and ember combustion phase in scotch pine wood.

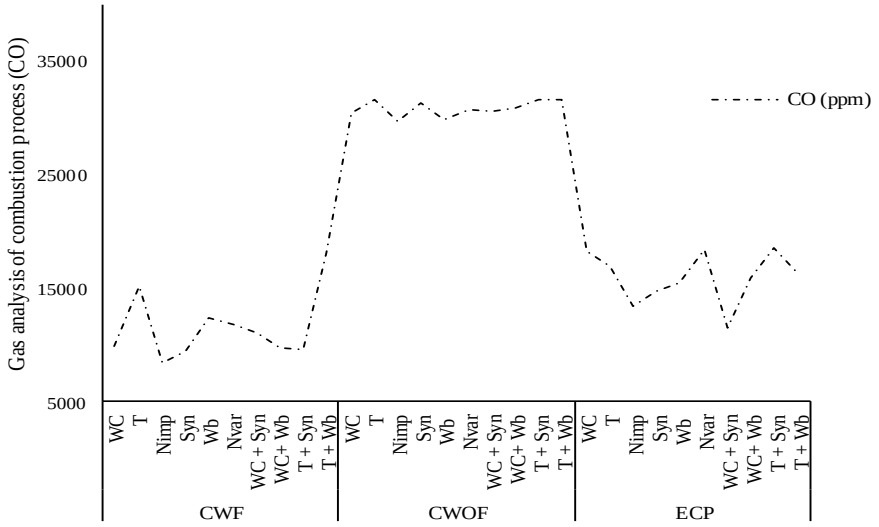

Figure 3. The CO amounts emerged in combustion with flame source, combustion without flame source and ember combustion phase.

4.Conclusions

In this study, the oxygen, carbon dioxide, carbon monoxide and nitrogen oxides amounts, which are formed during the combustion of the scotch pine wood samples exposed to the outdoor weather conditions, are investigated. The gas amount formed in the combustion has been affected by the impregnation materials and varnish types. In the first stage of the combustion, the varnish types and oxygen amounts have come out high and slow combustion has occurred. In Combustion with Flame source, the O_2 amount is high in Wolmanit-CB, and later combustion is fast. Wolmanit-CB impregnation materials have increased CO values in the combustion.

It can be figured that impregnation substances have increased the toxicity effect especially in places where there is a fire risk. Wolmanit-CB may be suggested as fire-retardant impregnation material [18].

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