Mugla Journal of Science and Technology

THE EFFECT OF BORIC ACID MODIFICATION ON THE COMBUSTION PROPERTIES OF WATER-BASED VARNISH

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Received: 11.11.2016, Accepted: 05.12.2016
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Abstract

In this research, the effects of boric acid (H_3BO_3) solution on the combustion properties of water based varnish was investigated. For this purpose, water-based varnish which was modified with 5% boric acid at varied amount (10%, 20%, and 30%) was applied on the experiment samples made from scots pine (Pinus sylvestris L.) and beech (Fagus orientalis L.). Afterwards, the combustion properties of the water based varnish was determined according to ASTM-E 69 standard principles. During combustion tests, released amount of oxygen (%), carbon monoxide (ppm), nitrogen oxide (ppm) gases, mass loss of the samples (%) and combustion temperature(°C) values weredeterminate. According to the research outcome, when increase the boric acid value in the water based varnish the resistance properties against to fire increases. In addition it may also be suggested that, in the selection of the furniture and decoration parts likely to be exposed to higher temperatures, beech wood is better than pine wood.
Keywords: Boric Acid, Modification, Wooden Material, Water Based Varnish, Combustion Test

BORİK ASİT MODİFİKASYONUNUN SU BAZLI VERNİĞİN YANMA DİRENCİNE ETKİSİ

Özet

Bu araştırmada, borik asit (H3BO3) çözeltisinin su bazlı verniğin yanma direnci üzerindeki etkisi araştırılmıştır. Bu maksatla, sarıçam (Pinus sylvestris L.) ve kayın (Fagus orientalis L.)'dan hazırlanan örneklere, farklı oranlarda (%10, %20, %30) %5'lik borik asitle modifiye edilmiş su bazlı vernik uygulanmıştır. Daha sonra örnekler, ASTM-E 69-15 esaslarına göre yanma deneyine maruz bırakılmıştır. Yanma deneyi sonrasında, ağırlık kaybı (%), açığa çıkan oksijen (%), karbon monoksit (ppm) ve azot oksit (ppm) gazları ile sıcaklık değerleri (ºC) tespit edilmiştir. Araştırma sonucuna göre, su bazlı vernik içindeki borik asit karışım oranının artışı, yanmaya karşı olan direnci artırmıştır. Ayrıca, yüksek ısıya maruz kalması muhtemel mobilya dekorasyon elemanlarında kullanılacak ağaç malzeme seçiminde, sarıçama kıyasla kayının tercih edilmesi önerilebilir.
Anahtar Kelimeler: Borik Asit, Modifikasyon, Ağaç Malzeme, Su Bazlı Vernik, Yanma Deneyi.

1 Introduction

Wood is a material which an indispensable part of our lives has been used since ancient times. The lightness and the resistance to mechanical and physical impacts are the most important characteristic features of the wood material. Modification of wood can be described as the enrichment of features of wood and production of a new type material which does not cause harm to nature after finishing life cycle [1]. Although wood material has superior properties such as lightness, durability, aesthetic appearance, it contains some undesired features. Dimensional changes caused by different climate conditions, vulnerability to biological threats and changes in the color and texture that occurs outdoor restrict the potential applications of wood.

Another one of these factors is flammability of wood. From this point of view, chemical impregnation with various chemicals is extremely essential in order to improve the combustion resistance of products obtained from the wood material [1], [2].Because forming of volatile and flammable substances which occurs at high temperatures was prevented in the impregnated wood, flammability properties of wood decreases. The spread of fire can be prevented by this way [3]. This situation is one of the undesired properties of wood. While other undesired properties only cause financial losses, the burning feature of wood also can be cause vital losses. Flame and gases can lead to death of people [4].

Water-based varnishes and paints are gaining importance day by day in parallel with the technological developments in the furniture and wood products industry. In 1970, with "Clean Air Act", drawn up and signed by the United States Environmental Protection Agency, the reduction and limiting of volatile organic compounds were aimed. In parallel with this development, usage and development of water-based varnishes increased. In this context, it is aimed not only to provide a protective feature in the wood material with this varnishes, but also to develop the aesthetic and technological properties. In terms of technological characteristics, water-based paints and varnishes are healthier compared with solvent-based surface protectors. However, unfortunately, the vast majority of paints and varnishes used in Turkey are solvent-based [5]. In a previous study, it was reported that the Scots pine samples impregnated with a mixture of Borax and boric acid gave better combustion results than other samples [6]. In another study, the combustion properties of Douglas samples which impregnated with boron compounds and Polyethylene Glycol 400 was investigated. As the result of the study, it was found that the combustion resistance of boron compounds are higher than Polyethylene Glycol 400 [7].In the performed another study, an alternative surface protective varnish obtained by mixing water-based varnish with boric acid and hardness value of surfaces coated with this varnish was investigated. As a result, it was found that the boric acid has an increasing effect on the hardness value of surface coated with varnish [8]. Boron and boron-based chemicals is commonly used today with the properties of fire-retardancy, oxidation deterrence and corrosion inhibitor [9]. Yapıcı et al. investigated the combustion properties of beech samples impregnated and coated with different materials. According to these results, impregnate enrichment in the water-based varnishes have a positive effect on combustion properties compared with other varnishes. In addition, it was stated that water-based varnishes positively affect the formation of gases resulting from combustion. Boron and boron-based compounds with fire-retardant feature are used in the numerous study and these earned a reputation as a very effective fire retardant [10].

In this study, water-based varnish which modified with 5% boric acid at varied amount (10 %, 20 %, and 30%) was applied on the samples made of Scots pine (Pinus sylvestris L.) and beech (Fagus orientalis L.). Then, combustion properties of this samples was investigated.

2 Material and Methods

2.1 Material

2.1.1 Wood material

For using in experiments, Scots pine (Pinus Sylvestris L.)and oriental beech (Fagus orientalis L.) samples, which are commonly used in furniture and wood working industry, was prepared. Samples was chosen randomly from timber suppliers of Karabuk, Turkey. A special emphasis was put on the selection of the wood material. Accordingly, detect-free, whole, knotless, normally grown (without zone line, reaction wood, insect damage, or fungal infection) wood materials were selected. Blending process was carried out to represent control samples for other groups. The oversized test samples were climatized until they reached constant weight (for 12% air-dry moisture content) at 20 ±2 °C and 65±3 relative humidity in a climate room. Following the climatization, they were cut with the dimension of 9x19x1016 mm according to ASTM E-69-15 [11]. For the experiments; 24 pieces of pine, 24 pieces of beech and 6 pieces of control samples for each wood type were prepared.

2.1.2 Water-Based Varnish

Water-based varnish modified with Boric acid was applied to the obtained samples. Water-based varnishes were prepared with modification using 5% boric acid at varied amount (10 %, 20 %, 30 %). Varnishes were applied to samples according to ASTM-D 3023-98 [12].

2.2 Methods

2.2.1 Air-Dry Density

Upon conducting the experiments the moisture contents (the moisture content deviation from 12 percent) of the specimens were measured according to TS 2471 [13] and density values was measured according to TS 2472 [14]. Samples were conditioned at 20 ± 2 °C and % 65 ± 3 relative humidity until they reach constant weight. Afterwards, the dimensions of wood materials were measured with a compass of ±0.001 mm sensitivity and volumes were determined by a stereo-metric method. The air-dry (δ12) densities of samples were calculated by the following equation:

$$\delta_{12} = \frac{M_{12}}{V_{12}}\ {}^{g}/_{cm^3} \qquad (1)$$

where M_{12} is the air dry weight (g) and V_{12} is the volume of the sample.

2.3 Oven-Dry Density

Over dry densities of wood materials used for the preparation of treatment samples were determined according to TS 2472 [14]. Accordingly, air dried samples were oven dried up to 103 ± 2ºC until they reach constant weights. Then, the samples were cooled in a desiccator containing calcium chloride and weighed in an analytic balance of 0.01 sensitivity. Afterwards, the dimensions of wood materials were measured by a compass of 0.01 sensitivity and volumes were determined by a stereo-metric method. The oven-dry (δ12) densities of samples were calculated by the following equation:

$$\delta_0 = \frac{M_0}{V_0}\ {}^{g}/_{cm^3} \qquad (2)$$

Where M_0 is the oven-dry weight (g) and V_0 is the volume of the sample.

2.4 Non-Volatile Matter Content of Varnish

The aim of determining of Non-Volatile Matter Content of Varnish is to detect of layer properties of varnishes for forming uniform varnish layer. Non-volatile matter content (NV) was determined with Ø 75 ± 5 mm concave glass according to TS 6035 EN ISO 3251 [15]. It can be calculated by the equation

$$NV = \frac{m_2 - m_0}{m_{1-m_0}} x100 \qquad (3)$$

where m_0 is the empty cap weight (g), m_1 represents the cap weight with test sample (g), and m_2 is the cap weight with the remnant (g).

2.5 Execution of Combustion Tests

The combustion tests was executed according to the ASTM E-69-02 [11] standard. A digital weighing scales with the precision of 0.01 g was used for ascertain of mass reduction of specimens. Butane gas was preferred to make an ignition flame. The flow of gas was fixed to a flame high of 25 cm, and the 1000 °C heat temperature. The distance between the end of the samples and the tip of gas pipe were adjusted as 2.54 cm. Samples were hanged inside of the fire tube with the help of metal pegs. During the test, reduction of samples mass, values of fire temperature and emission of released carbon monoxide, nitric oxide and oxygen (CO, NO and O_2) gases were determined every 30 seconds. Tests were realized under a flue where the current of air was drawn with natural draft. The flame source was used first 4 minutes of the test and then the flame source was closed and taken out from test cabinet. The test was continued 6 minutes without flame source. In total, the test lasted 10 minutes.

2.6 Dry-Film Thickness of Varnishes

Dry-film thickness of varnishes is an important factor in the comparative tests. The thickness of the varnish layers was measured with a comparator which has a sensitivity of 5 µm.

2.7 Statistical Analyses

An open-source statistical analysis software package was used evaluate data statistically. Multivariate analysis of variance (MANOVA) was carried between processed and unprocessed (control) groups. Duncan test results and mean values were compared when significant differences were detected within obtained data.

3 RESULTS

3.1 Density Values

The oven-dry and air-dry densities of samples was determined. The average oven-dry density and air-dry density of Scots pine samples was found as 0,47 g/cm3 and 0,51 g/cm3, respectively.

The average oven-dry density and air-dry density of beech samples were found as 0,66 g/cm3 and 0,72 g/cm3, respectively.

3.2 Non-Volatile Matter Content and Layer Thickness

The non-volatile matter content of non-modified, 10%, 20% and 30% boric acid modified water-based varnishes were found as 26.2%, 27.2%, 27.4% and 29%, respectively. The thickness of varnish layer was measured with a compass of ±0.001 mm sensitivity. 83 µm thickness found on Scots pine samples while 87 µm thickness found on beech samples.

3.3 Combustion Tests

The average mass reduction values obtained during combustion tests were given in Table 1.

Table 1. Weight-Loss Values (%)

Time	Scots Pine					Beech				
	Control	0%	10%	20%	30%	Control	0%	10%	20%	30%
1	2,23	1,32	0,79	0,48	1,13	1,24	1,60	0,53	0,83	0,98
2	5,12	2,25	1,79	1,39	1,95	3,12	2,63	1,56	1,42	2,20
3	8,46	5,92	4,09	4,28	4,49	5,94	5,44	3,94	4,03	6,22
4	13,56	9,16	7,43	7,75	7,79	10,95	9,85	8,40	8,03	10,61
5	22,47	13,78	11,47	11,61	11,94	18,92	13,80	13,04	13,26	13,52
6	28,42	18,16	15,84	16,31	15,84	23,48	19,01	17,03	17,60	17,19
7	37,12	24,39	21,37	21,71	21,86	33,27	24,18	23,42	22,20	21,46
8	45,16	31,68	30,58	30,30	27,15	41,57	29,46	27,71	27,39	26,85
9	52,41	35,30	37,39	33,63	30,67	47,15	33,41	32,57	33,60	30,46
10	60,85	36,63	38,76	35,21	35,80	54,29	36,71	36,96	35,35	31,75
11	72,64	43,05	41,77	38,63	37,45	66,95	38,88	38,34	37,70	32,03
12	77,14	47,61	45,44	43,03	38,97	73,42	40,98	39,25	38,06	33,15
13	81,68	53,03	52,36	49,60	42,71	78,52	43,08	41,56	40,00	34,30
14	83,42	58,04	59,41	56,18	48,81	82,46	46,96	44,98	41,32	35,48
15	85,16	66,06	68,20	62,82	53,48	85,01	51,22	45,80	44,68	37,64
16	89,43	74,15	74,27	69,30	57,35	88,16	53,55	46,22	48,44	38,88
17	93,46	81,61	79,68	75,88	63,81	91,74	57,53	50,36	50,24	41,12
18	96,78	87,23	84,63	81,47	69,33	95,47	60,21	53,99	52,20	43,23
19	97,15	94,55	92,56	86,86	74,74	96,54	66,58	56,00	53,70	45,44
20	98,26	97,55	95,24	92,51	78,00	97,56	70,53	58,50	55,28	46,80

According to Table 1, while the highest average mass reduction was observed in Scots pine control samples with % 45,16, the lowest was observed in beech samples coated with 30% boric acid modified water-based varnish with 26,85%. The highest average mass reduction was observed in Scots pine control samples with 98.28% and the lowest mass reduction was observed in beech samples coated with 30% boric acid modified water-based varnish with 46,80% when combustion process finished. The average temperature values obtained during combustion tests, were given in Table 2.

Table 2. Temperature Values (°C)

Time	Scots Pine					Beech				
	Control	0%	10%	20%	30%	Control	0%	10%	20%	30%
1	81	61	87	93	81	79	75	82	80	66
2	100	80	108	112	98	102	92	102	97	84
3	126	101	132	135	119	136	113	126	120	108
4	153	123	155	158	140	161	136	154	145	135
5	178	145	177	180	161	210	159	181	171	163
6	202	167	200	202	182	246	179	204	196	188
7	226	192	224	225	204	281	197	226	213	203
8	253	213	245	243	223	309	214	235	223	210
9	291	227	257	251	232	366	224	237	226	211
10	368	236	260	256	232	474	223	228	221	206
11	464	250	271	267	237	534	223	222	219	200
12	535	270	295	286	247	612	230	220	220	193
13	546	299	333	319	261	634	241	225	221	186
14	526	347	401	376	283	594	262	231	226	180
15	478	403	481	450	315	543	282	237	232	174
16	401	457	543	524	353	459	304	255	239	169
17	343	500	573	563	394	399	324	264	261	164
18	310	511	557	562	427	346	328	256	287	159
19	273	479	507	536	438	309	307	236	305	154
20	238	439	449	481	425	291	280	220	303	150

According to Table 2, while the highest average temperature value was observed in beech control samples with 634 °C, the lowest average temperature value was observed in beech samples coated with 30% boric acid modified water-based varnish with 211°C during combustion tests. The average % O_2 values obtained during combustion tests were given in Table 3.

Table 3. O_2 Values (%)

Time	Scots Pine					Beech				
	Control	0%	10%	20%	30%	Control	0%	10%	20%	30%
1	20,50	20,77	20,40	20,49	20,53	20,67	20,62	20,53	20,39	20,28
2	19,59	20,14	19,93	20,11	20,00	20,03	20,27	20,51	20,31	20,16
3	18,81	19,86	19,77	19,99	19,75	19,16	20,11	20,05	19,74	19,68
4	18,17	19,69	19,61	19,82	19,22	18,44	19,87	19,57	18,73	19,01
5	17,65	19,31	19,43	19,19	18,50	17,73	19,59	18,79	17,99	18,20
6	17,50	18,74	19,38	18,51	17,90	17,12	19,41	17,97	17,18	17,29
7	17,39	18,42	19,20	17,76	17,20	16,91	19,20	17,39	16,61	16,41
8	17,35	17,96	18,82	17,11	16,56	16,81	18,97	16,91	16,50	15,78
9	17,28	17,84	18,41	16,64	16,27	16,72	18,64	16,71	16,54	15,60
10	17,25	17,81	17,82	16,22	15,97	16,47	18,51	16,81	16,84	15,58
11	17,24	18,32	17,39	16,07	15,91	16,34	18,30	17,02	17,36	15,76
12	17,77	18,68	17,14	16,08	16,03	16,96	17,86	17,48	17,79	16,04
13	18,48	18,73	16,92	16,09	16,18	17,81	17,53	18,17	18,20	16,55
14	19,07	18,94	16,75	16,13	16,34	18,56	17,40	18,74	18,52	17,05
15	20,02	18,93	16,86	16,27	16,50	19,12	17,44	19,13	18,59	17,43
16	20,59	19,18	17,03	16,35	16,59	19,76	17,55	19,32	18,63	17,79
17	20,77	19,58	17,39	16,54	16,66	20,07	17,66	19,44	18,63	18,11
18	20,83	20,21	17,83	16,62	16,66	20,24	17,84	19,53	18,72	18,47
19	20,82	20,39	18,29	16,76	16,73	20,37	18,05	19,59	18,85	18,66
20	20,85	20,46	18,86	16,83	16,89	20,51	18,10	19,64	18,96	18,73

According to Table 3, while the highest average % O_2 value was observed in beech samples coated with unmodified water-based varnish with ratio of 18.05%, the lowest average O_2 value was observed in beech samples coated with 30% boric acid modified water-based varnish with ratio of 15.58%. The average CO values obtained during combustion tests were given in Table 4.

Table 4. CO (ppm) Values

Time	Scots Pine					Beech				
	Control	0%	10%	20%	30%	Control	0%	10%	20%	30%
1	25	32	46	53	52	34	40	51	51	53
2	86	51	63	70	70	74	56	70	63	75
3	126	74	75	85	77	119	81	82	101	96
4	150	88	86	99	96	157	96	89	138	110
5	169	99	97	117	129	186	118	117	191	122
6	206	105	109	155	158	216	125	159	252	140
7	288	113	123	193	198	285	142	200	305	167
8	368	122	134	223	239	424	159	244	354	202
9	431	144	166	267	262	528	183	308	424	264
10	475	162	190	315	296	645	215	356	479	345
11	394	189	210	359	339	686	247	383	500	404
12	283	221	239	404	378	654	279	415	508	472
13	237	255	280	439	405	607	323	424	486	518
14	226	292	294	444	445	571	362	400	460	537
15	206	320	304	433	463	525	386	376	435	534
16	172	378	317	394	450	449	399	353	418	510
17	129	353	280	341	444	375	406	324	401	483
18	84	301	249	316	422	296	381	301	389	459
19	47	270	226	289	395	218	350	282	376	439
20	31	233	187	276	376	135	316	259	351	415

According to Table 4, while the highest average CO value was observed in beech control samples with 687 ppm, the lowest average temperature value was observed in Scots pine samples coated with 10% boric acid modified water-based varnish with 317 ppm. The average NO values obtained during combustion tests were given in Table 5.

Table 5. NO Values (ppm)

Time	Scots Pine					Beech				
	Control	0%	10%	20%	30%	Control	0%	10%	20%	30%
1	2	0	10	10	9	1	8	7	9	9
2	4	0	13	15	13	2	12	11	12	13
3	7	1	13	16	21	7	18	23	23	21
4	11	1	18	16	31	13	27	38	31	31
5	15	4	27	22	40	20	35	46	44	41
6	17	7	36	29	46	26	37	52	53	50
7	17	15	41	32	48	29	41	51	54	57
8	17	22	45	37	48	29	43	48	55	60
9	18	29	46	41	48	30	43	45	52	58
10	20	36	44	42	47	34	41	41	46	54
11	23	37	43	42	47	36	41	37	43	50
12	21	40	42	44	50	34	39	35	37	45
13	17	41	40	46	55	30	39	33	31	41
14	13	40	40	47	60	23	38	31	27	35
15	7	42	40	49	65	17	38	32	25	31
16	3	44	38	53	66	12	35	31	24	28
17	2	47	37	51	61	8	30	30	22	25
18	1	40	31	46	54	5	23	28	20	22
19	1	32	28	40	48	3	16	25	16	20
20	1	25	23	33	38	2	10	22	11	17

* Flame-induced combustion

According to Table 5. while the highest average NO value was observed in Scots pine samples coated with 30% boric acid modified water-based varnish with 66 ppm, the lowest average NO value was observed in Scots pine control samples with 23 ppm. The average chimney temperature values obtained during combustion tests were given in Table 6.

Table 6. Chimney Temperature Values (°C)

Time	Scots Pine					Beech				
	Control	0%	10%	20%	30%	Control	0%	10%	20%	30%
1*	56	45	50	52	37	56	36	47	46	50
2*	81	65	69	71	45	81	52	56	64	62
3*	102	87	88	91	54	109	70	67	55	74
4*	121	102	110	112	64	138	88	75	66	81
5*	137	110	121	122	73	162	104	82	78	88
6*	149	124	127	139	79	180	115	89	85	92
7*	159	134	136	148	89	192	123	98	93	98
8*	169	144	147	156	97	205	131	102	97	101
9	181	155	152	159	101	219	140	103	98	102
10	191	160	163	161	101	238	152	109	96	100
11	191	162	166	161	99	228	146	103	101	103
12	188	169	166	169	103	211	155	102	102	100
13	182	174	169	173	109	192	163	104	102	107
14	169	172	173	177	118	177	153	106	104	105
15	152	171	176	180	131	164	145	109	108	103
16	137	166	179	182	136	145	128	108	102	105
17	123	156	180	187	152	129	116	102	100	103
18	113	143	178	186	164	116	104	98	100	101
19	93	133	175	186	168	104	97	91	97	99
20	76	124	173	185	163	92	89	85	97	98

According to Table 6. while the highest average chimney temperature value was observed in beech control samples with 238 °C, the lowest average temperature value was observed in beech samples coated with 30% boric acid modified water-based varnish with 107 °C during combustion tests. Obtained values from tests were investigated by variance analysis. The Duncan test was applied in order to determine which of the difference obtained from variance analysis were ($p \leq 0.05$) significant. The Duncan test result shown as different homogenous group in table 7.s

Table 7. Duncan Test Results

Factor	Weight-Loss		Temperature		O_2		CO		NO		Chimney temperature	
	Mean	HG	Mean	HG	Mean	HG	Mean	HG	Mean	HG	Mean	HG
Beech-30%	27,47	a	165	a	18,90	a	317	c	35	c	94	a
Beech-20%	31,27	ab	210	b	19,20	b	334	c	33	bc	90	a
Beech-10%	32,00	ab	207	b	18,36	b	260	b	32	bc	92	a
Beech-0%	35,28	ab	220	bc	17,47	b	233	b	31	b	115	b
Scots Pine-30%	36,16	bc	253	cd	17,31	a	280	b	33	bc	104	ab
Scots Pine-20%	40,94	c	311	e	18,49	a	263	b	45	d	150	cd
Scots Pine-10%	43,15	c	313	e	18,65	b	184	a	36	c	145	c
Scots Pine-0%	44,07	c	275	d	18,67	b	190	a	25	b	135	bc
Beech-Control	54,78	d	354	f	18,25	b	359	d	18	ab	157	d
Scots Pine-Control	57,55	d	305	de	17,63	c	207	a	11	a	139	bc

4 Discussion

As a result, it was found that the beech samples were more resistant to mass reduction during combustion compared with Scots pine samples. In terms of mass reduction, the highest values (%) were observed in control samples of Scots pine. The mass reduction values of Scots pine samples decreased up to 1%, 3%, 6% and %21 in the unmodified and 10%, 20%, 30% boric acid modified water-based varnishes, respectively. According to test results, it can be said that boric acid solution significantly reduces the rate of weight loss.

The highest mass reduction values (%) were observed in control samples of Beech. The mass reduction values of beech samples decreased up to 28%, 40%, 43% and %52 in the unmodified and 10%, 20%, 30% boric asid modified water-based varnishes, respectively. The highest combustion temperature values were observed in control samples of Beech. It was found that the Scots pine burned at a higher temperature compared with beech samples. These high temperature values can be related to the resin content of pine samples. In terms of O_2, the highest values (%) were observed samples coated with 30% boric acid modified water-based varnishes in both wood type. When control groups take into consideration, the CO values of beech samples found higher (up to 31%) compared to Scots pine. In terms of NO values, the results of beech samples found higher (up to 36%) compared to Scots pine. For all that, it can be said that as the ratio of boric acid of the boric acid-varnish solution increase, the CO and NO values of combustion tests increases.

The highest chimney temperature values were observed in control samples of Beech. When the varnished samples were examined, the highest values were observed Scots pine samples.

As a result; it can be said that the boric acid is an important fire-retardant and boric acid modified water-based varnishes can be used in places where high temperature resistance is necessary. In the similar studies, it was reported that the boron compounds provide resistance to combustion [16]. In another study, it was stated that samples coated with boric acid modified varnishes provide better results in all combustion parameters compared unvarnished control samples. In parallel with these results, it was reported that pine samples have worse combustion properties because of the resin content [17]. In similar studies realized on samples coated with boron impregnated varnishes, it was stated that the amount of boric acid effects the NO and CO values of combustion, positively [10]. As a result of the study, it can be said that obtained results are parallel with literature. The varnishes and paints which contain combustible and flammable substances accelerate the spread of fire, especially in the wooden structures. Borons are excellent fire retardants for this structures when applied at adequate retentions to cellulosic fibers. [18]. According to results of this study, it

can be said that in the constructions which at higher risk of fire, can be preferred coated beech wood with 30% boric acid modified water based varnish.

Also, with the using of boron compounds in an alternative industry will be put boron to good use. Also alternative boron markets will be emerged for our country which also has 75% of boron reserves of the world. In the parallel of this study, the abiotic properties of boron and boron compounds is another workable subject which supported in literature [19].

5 Acknowledgment

This study was presented as an oral presentation at the II. International Furniture Congress (IFC 2016), 13-15 October 2016, Muğla, Turkey.

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