Technology, 13(4), 273-279, (2010)

TECHNOLOGY

COMBUSTION PROPERTIES OF POPLAR OF FINISHING PROCESSED

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Abstract

In this study, it has been investigated that the effects of finishing materials that are Polyurethane, cellulosic, synthetic, polyester and acid hardening varnish on combustion properties of Poplar. Combustion test was performed according to the procedure of ASTM-E 69 standards. During the test, mass reduction, temperature and released gas (CO, NO, O_2) were determined in every 30 seconds. Cellulosic varnish was found to be the most successful varnish according to the mass reduction. According to the results, all of the varnishes used to in this study showed a low resistance against fire and high temperatures. Since it diminishes combustion, it is advisable to use fire retardant chemicals with varnishes in the furniture and building construction.

Key Words: Poplar , Combustion, Varnish, Coating

1. Introduction

Wood has many good properties from the point of view of processing, physical and mechanical properties, aesthetic, environmental and health aspects. In many countries the wood is widely used as building material, in some areas as main construction and decoration material.

Massive constructions and furnitures, coated only with paint and varnish, have surface protection only for two years. So, varnishing and painting after the impregnation is important for long-term utilization against biotic and abiotic effects photochemical degradation, dimensional changes, biological factors and fire [1].

Wood continues to play an important role as a structural material in today's high-tech society. As lumber and in reconstituted products, wood is commonly used for house siding, trim, decks, fences, and countless other exterior and interior applications. When wood is exposed to the elements, particularly sunlight and moisture, special precautions must be taken in structural design as well as in the selection and application of the finish[2].

Painting and varnishing with water-repellent chemicals after impregnating with boron compounds makes the wood more resistant to environmental conditions [3]. Impregnating with the solution of copper, chrome and salt makes wood more resistant to environmental effects[4].

At the same time Uysal et al. have obtained laminated wood produced from Uludağ fir for out ply, and different veneer materials for core ply were used and bonded with PVAc. The combustion test was applied to the test samples. The highest mass reduction and concentration of O_2 were observed in white mulberry and the highest heat increase in Scotch pine used in core ply [5].

Uysal and Kurt have studied impregnation of the Spruce fir (*Picea orientalis* L.) with boron compounds and the test samples were applied to the combustion test. Borax- boric acid % 10 solutions was found to be the most successful fire retardant chemical in spruce fir[6].

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Since there has not been many studies, combustion properties of Poplar of finishing processed, the aim of this study was to compare the effects of finishing varnishes (polyurethane, cellulosic, synthetic, acid hardening and polyester varnish).

2. Material and Method

2.1 Wood Species

Poplar (*populus nigra*) was chosen randomly from timber suppliers of Ankara, Turkey. Blending process was made represent control simples on other groups. A special emphasis was put on the selection of the wood material. Accordingly, non-deficient, whole, knotless, normally grown (without zone line, reaction wood, decay, insect or fungal infection) wood materials were selected.

2.2 Varnished Materials

Cellulosic, synthetic, polyurethane, Polyester, Acid hardening varnishes were used according to the producer's instructions. The type, selection, preparation and surface application system of the varnish to be used and the post-application processes as recommended by the manufacturers and the techniques used are very important to make varnish layers durable against various effects and to ensure the desired properties. Therefore, materials used in the experiments (tests) were stored appropriately until their usage to prevent loss of properties. Varnishes were checked to confirm they had the properties specified in their descriptions and they were used after seeing that they were appropriate for the tests (viscosity control). The technical specifications of the conventional varnishes are given in Table 1.

Table 1. Some technical properties of the conventional varnishes.

Technical Properties	Varnish Type				
	Synthetic	Cellulosic	Polyurethane	Polyester	Acid hardening
Density (g/cm3)	0.94-0.95	0.94-0.96	0.95-0.96	-	0.94-0.96
Viscosity (second/DIN CUP 4 mm/20°)	18	20	16	18	18
Amount applied (gram/m²) 100	100	125	120	300-600	110
Nozzle gap (mm)	-	1.8	1.8-2	1.8	
Air pressure (bar)	-	3	2	3	2
Drying type	Physical	Physical	Chemical	Chemical	Chemical
Drying time (20°)	6-8 hour	20-30 minute	2-3 hour	4 hour	2-3 hour

2.3 Preparation of Test Samples

The oversized test samples were acclimatized until they were stable at 20 ± 2 ^{o}C and 65 ± 3 % relative humidity in climate room. Later on they were cut with the dimensions of 9x19x1016 mm^3 according to the procedure of ASTM E – 69 [7] and finished with Synthetic, Polyurethane, Cellulosic, Polyester and acid hardening. 10 samples were manufactured for each test sample 60 test samples were prepared in total.

2.4 Execution Test

The combustion test was carried out according to the principles of the ASTME –69. But some changes were made in the stand. For this purpose, a digital balance having 0.01 g sensitiveness has been used for determination of mass reduction of materials when they are burnt. Butane gas was used to make an ignition flame. The gas flow is standard as the high of flame is 25 cm, the temperature must be 1000 ^{o}C.

The distance between the bottoms of the test samples, which were hanged inside of the fire tube and the top of the gas pipe must be adjusted as 2.54 cm. During the test, mass reduction, temperature and released gas (CO, NO, O_2) were determined in every 30 seconds. The test was made under a chimney where the flow of air blown was drawn with natural draft. At the beginning of combustion test flame source was used for 4 minutes then flame source was taken away and it was continued 6 minutes. Totally 10 minutes, the test was lasted.

Testo 350 M and XL flue gas analyser was used for measuring concentration of the released gasses (CO, NO, O_2), and temperature variation. The probe was inserted into the first hole from the top of the fire tube.

2.5 Statistical Procedure

By using untreated control samples and 5 finished materials as parameters, a total of 120 samples (5 x 2 0 + 2 0) were prepared using 20 samples for each parameter.

3. Result and Discussion

The averages of density are given in Table 2. The air dry density (0. 400gr/cm^3) was obtained in Poplar wood. The oven dry density (0.360gr/cm^3) was obtained in Poplar wood samples.

Table 2. Average values of density (gr/cm^3).

Oven dry density g/cm^3	Air dry density g/cm^3
0.360	0.400

Dry film thicknesses and solid amounts of varnish types are given in Table 3.

Tablo 3. Dry film thicknesses of varnish types

Varnish Type	Synthetic Varnish	Polyester Varnish	Cellulosic Varnish	Acid hardening Varnish	Polyurethane Varnish
Solid Amounts	% 51	% 91	% 23	% 46	% 36
Dry film Thickness	91 µm	141 µm	81 µm	88 µm	109 µm

Dry film thicknesses were determined. The thickness of the varnish layers were measured with a comparator, which has a sensitivity of 5 µm. The highest dry film thickness of 141 µm was obtained with polyester varnish samples The lowest dry film thickness of 81 µm was obtained with cellulosic varnish samples.

The solid amounts of the varnish were measured. The highest solid amount of % 91 was obtained with polyester varnish samples. The lowest solid amount of % 23 was obtained with cellulosic varnish samples.

Tablo 4. Average of Mass Reduction(%)

Measured of time	Control	Polyurethane	Acid Hardening	Cellulosic	Synthetic	Polyester
1	4.69	7.84	6.67	23.60	16.05	15.11
2	52.09	24.81	23.96	41.12	35.04	38.52
3	65.70	43.55	42.51	62.68	57.39	58.41
4	80.91	65.28	60.85	78.32	73.65	82.95
5	85.44	82.51	83.14	83.31	84.38	89.99
6	90.10	84.67	86.24	86.55	86.97	91.60
7	90.63	85.41	88.30	88.62	87.48	91.82
8	90.73	85.95	88.35	88.92	87.73	91.97
9	91.95	86.32	88.39	89.26	87.84	92.10
10	92.35	87.13	88.40	89.71	88.05	92.21
11	92.35	87.29	88.53	89.79	88.14	92.25
12	92.37	87.30	88.54	89.83	90.45	92.25
13	92.37	87.31	88.56	89.83	90.46	92.26
14	92.37	87.35	88.57	89.83	90.46	92.27
15	92.37	87.36	88.59	89.83	90.46	92.28
16	92.37	87.65	89.52	89.83	90.46	92.28
17	92.37	87.65	88.67	89.83	90.46	92.28
18	92.37	87.65	88.67	89.83	90.46	92.28
19	92.37	87.65	88.67	89.83	90.46	92.28
20	92.37	87.66	88.67	89.83	90.46	92.28

The highest mass reduction was (%92.39) observed in Acid Hardening varnish samples, the lowest value (%73.72) from the cellulosic varnish samples. The results connected with these values are shown in Table 4.

Tablo 5. Average of O_2 amounts(%)

Measured of time	Control	Polyurethane	Acid Hardening	Cellulosic	Synthetic	Polyester
1	17.38	17.39	11.97	9.57	14.78	16.58
2	9.24	7.75	4.31	3.28	5.20	9.48
3	8.51	6.20	4.06	2.51	3.68	8.14
4	10.27	5.14	3.83	4.48	3.78	11.23
5	13.15	10.79	11.21	10.54	10.24	12.26
6	15.74	14.76	16.36	16.99	15.69	15.39
7	17.70	16.69	17.42	17.17	16.19	15.91
8	19.11	18.39	18.64	17.09	16.60	16.39
9	19.65	19.34	19.08	17.60	18.48	17.98
10	20.44	20.46	20.64	18.13	20.48	19.58
11	19.71	20.53	20.70	18.65	20.69	20.03
12	20.63	20.70	20.75	19.01	20.79	20.50
13	20.71	20.70	20.77	19.04	20.84	20.67
14	20.81	20.72	20.82	19.13	20.86	20.76
15	20.90	20.74	20.84	19.16	20.87	20.80
16	20.90	20.80	20.86	19.19	20.88	20.84
17	20.90	20.81	20.87	19.23	20.88	20.88
18	20.90	20.82	20.88	19.25	20.89	20.90
19	20.90	20.83	20.89	19.26	20.90	20.90
20	20.90	20.85	20.89	19.28	20.90	20.90

The highest reduction of O_2 concentration (%50.36) was measured in Cellulosic varnish samples, the lowest change of O_2-concentration (%16.59) in combustion of Polyurethane samples**.** The results connected with these values are shown in Table 5.

Table 6. Average of Temperature Values(^{0}C)

Measured of time	Control	Polyurethane	Acid Hardening	Cellulosic	Synthetic	Polyester
1	282.08	229.00	296.06	232.18	215.10	182.68
2	521.36	420.62	536.14	441.90	387.10	430.18
3	517.98	476.70	574.94	471.16	433.78	475.22
4	510.58	516.84	603.24	526.02	455.24	432.10
5	432.72	389.74	437.04	409.24	378.82	354.98
6	344.78	340.12	345.70	330.70	328.38	314.60
7	276.46	279.98	279.28	253.10	290.64	289.72
8	224.38	236.80	234.20	206.82	250.58	269.40
9	181.32	195.80	180.78	167.56	211.02	220.74
10	148.56	164.44	156.10	150.44	166.60	190.32
11	130.82	145.70	135.28	125.48	143.88	172.76
12	115.60	126.34	122.02	109.30	122.18	147.76
13	104.42	115.84	110.08	96.88	111.94	131.18
14	95.22	102.72	98.78	85.88	96.96	118.44
15	88.52	93.16	93.06	77.84	89.28	108.20
16	81.66	86.74	85.44	72.52	80.92	98.60
17	75.70	81.74	80.24	66.86	74.60	92.44
18	70.66	76.98	75.76	63.10	70.44	86.26
19	65.34	73.04	71.06	59.56	65.94	80.58
20	61.37	69.56	68.52	56.88	62.78	76.20

The highest temperature (229.18 ^{0}C) variation was observed in the experiment of Acid Hardening varnish and the lowest (200.17 ^{0}C) in Cellulosic varnish samples. The results connected with these values are shown in Table 6.

Table 7. Variation of CO (ppm)

Measured of time	Control	Polyurethane	Acid Hardening	Cellulosic	Synthetic	Polyester
1	4064.00	402.00	1005.60	944.60	844.20	428.00
2	5317.80	7139.20	10000.00	10000.00	10000.00	8277.20
3	7151.60	8334.40	10000.00	10000.00	10000.00	10000.00
4	8394.80	7211.00	10000.00	10000.00	10000.00	5112.20
5	7260.80	4362.00	8380.00	5952.40	10000.00	3814.60

6	6505.20	3366.60	8146.60	4684.00	10000.00	1473.80
7	4063.00	1798.20	6856.40	3285.60	8218.60	1476.40
8	3078.40	1402.20	6391.00	3109.00	8143.00	1430.20
9	1365.40	1080.40	1898.20	1343.40	4575.40	1257.40
10	632.00	414.40	868.80	1020.00	4366.60	1322.40
11	520.80	310.80	732.40	541.60	1216.40	1193.60
12	418.20	224.80	467.40	308.80	643.20	1011.60
13	358.00	177.80	361.80	224.60	419.80	569.80
14	315.20	144.00	269.20	144.20	302.60	483.80
15	225.40	122.60	210.80	128.80	251.00	299.00
16	173.20	97.60	163.00	124.00	189.60	236.20
17	125.80	89.40	135.60	110.40	170.20	167.40
18	91.40	83.60	120.40	93.80	165.00	124.40
19	64.00	79.40	105.80	87.00	149.20	103.80
20	52.20	73.20	88.60	81.60	140.40	84.60

The highest increase in CO concentration was (3989.76 ppm) observed in the experiment Synthetic varnish samples and the lowest in (1845.68 ppm) those of Polyurethane samples. Due to fire resource, at the five measured was stage of the combustion test, linear increase was observed in temperature variation. The temperature decreased when the fire source got away from the fire tube, all of the samples. The results connected with these values are shown in Table 7.

Table 8. Variation of NO (ppm)

Measured of time	Control	Polyurethane	Acid Hardening	Cellulosic	Synthetic	Polyester
1	33.40	106.80	110.90	81.00	64.20	57.200
2	56.00	185.80	234.00	172.40	130.00	117.800
3	64.00	146.40	180.40	147.20	157.20	110.60
4	69.80	126.20	170.80	140.40	178.00	105.00
5	48.00	87.00	95.20	64.60	110.80	84.20
6	31.00	61.00	65.40	30.60	80.20	72.20
7	21.00	50.40	49.80	24.80	67.80	65.60
8	12.80	31.60	34.40	27.80	56.60	61.40
9	8.20	26.40	25.60	20.00	39.00	53.20
10	4.00	16.80	16.60	16.00	26.00	45.80
11	3.20	14.80	15.40	11.20	21.60	42.60
12	2.60	13.60	13.80	9.00	18.60	39.20
13	2.60	13.00	12.60	8.60	16.80	37.20
14	2.40	12.60	11.80	7.60	15.20	36.00
15	2.20	12.20	11.00	7.20	14.00	33.00
16	2.00	11.80	10.80	6.80	13.00	34.40
17	1.80	11.20	10.00	6.20	12.80	34.00
18	1.20	11.00	9.80	5.80	12.40	34.00
19	1.20	10.60	9.00	5.60	11.60	32.80
20	1.20	10.40	9.00	5.80	11.00	32.00

In this study, the highest increase in NO concentration was observed in the experiment of (56.41 ppm) Polyester varnish samples and the lowest in those of (18.43 ppm) control samples. The results connected with these values are shown in Table 8.

4. Conclusion

According to Table 4, in the mass reduction values that were finished with all varnish samples give the highest increase when compared to massive control samples. It has been observed that while finished with synthetic varnish samples increases mass reduction values % 13.34 in average, finished with polyester varnish increases % 11.9 average, finished with acid hardening varnish increases % 2.66 average, finished with polyurethane varnish increases % 4.07 average and finished with cellulosic varnish increases % 22.33 average. Sample wood materials that were not finished gave the lowest mass reduction values.

When the fire-retardant product is subjected to an ignition source, the cellulose chars but does not combust. The cross-linked ammonia groups appear to prevent oxygen from igniting the cellulose molecule. In addition, vapor is also generated when the cellulose product is contacted with an ignition source [9].

According to Table 5, in the O_2 consumption values that were finished with varnishes samples give the highest decrease when compared to massive control samples. It has been observed that while finished with

polyster varnish samples decreases O_2 consumption values % 17.5 in average, finished with polyurethane varnish decreases % 17.22 average, finished with acid hardening varnish decreases % 16.78 average, finished with Synthetic varnish decreases % 16.68 average and finished with cellulosic varnish increases % 15.42 average. Sample wood materials that were not finished gave the lowest mass reduction values.

Due to fire resource, at the first stage of the combustion test, linear increase was observed in temperature variation. The temperature decreased when the fire source got away from the fire tube, all of the samples. This situation, varnish effect increase or speed of burning phenomenon since the fire source got away from the fire tube.

According to Table 6, in the temperature variation that was finished with acid hardening varnish samples give the highest increase when compared to massive control samples. It has been observed that while finished with synthetic varnish samples decreases temperature values % 6.77 in average, finished with acid hardening varnish increases % 5.87 average, finished with polyester varnish decreases % 1.32 average, finished with polyurethane varnish decreases % 2.48 average and finished with cellulosic varnish decreases % 7.53 average. Sample wood materials that were not finished gave the lowest mass reduction values

The highest CO ratio was observed in finished with Synthetic varnish samples (3989.76 ppm); the lowest in finished with Polyurethane samples (1845.68 ppm). As well known, there are two forms of reaction between C_2 and O_2 during combustion. Combustion ratio of a sample is directly connected to the sum of the amount of CO and CO_2 emissions. Because the combustion tests are made in an open environment, there is not a lack of O_2 and poor mixing

According to Table 7, in the CO ratio values that were finished with Polyurethane varnish samples give the lowest value when compared to massive control samples. It has been observed that while finished with polyester varnish samples increases CO ratio values % 22.54 in average, finished with synthetic varnish samples increases CO ratio values % 59.02 in average, finished with cellulosic varnish samples increases CO ratio values % 3.99 in average, finished with acid hardening varnish samples increases CO ratio values % 31.93 in average, finished with polyurethane varnish samples decreases CO ratio values % 26.43 in average.

According to Table 8, in the NO ratio values that were finished with all varnishes samples give increase when compared to massive control samples. It has been observed that while finished with polyster varnish samples decreases NO consumption values % 56.41 in average, finished with polyurethane varnish increases % 47.98 average, finished with acid hardening varnish increases % 54.81 average, finished with Synthetic varnish increase % 52.84 average and finished with cellulosic varnish increases % 39.93 average.

Consequently, cellulosic varnish was found to be the most successful varnish according to the CO amounts and mass reduction. Finished with cellulosic varnish can be used as a furniture industry according to the use of area and its purpose (construction, yatch, etc) where the fire resistance is required. According to the results, all of the varnishes used to in this study showed a low resistance against fire and high temperatures. Since it diminishes combustion, it is advisable to use fire retardant chemicals with varnishes in the furniture and building construction.

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