28th ICWST

International Conference on Wood Science and Technology

IMPLEMENTATION OF WOOD SCIENCE IN WOODWORKING SECTOR

PROCEEDINGS

Zagreb, 7th – 8th of December 2017

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Improvement of Fire Performance of Impregnated Wood with Copper Based Chemicals

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ABSTRACT

Copper is among the most commonly used substances in impregnating industry due to its high toxicity against fungi at last 50 years. Copper-azole (CuA) and ammonical copper quaternary (ACQ) are the most widely used, because it is highly effective against fungi and insects. However, their fire resistance properties are not good. The aim of this work is to examine and improve the resistance of CuA and ACQ against fire. For this purpose CuA and ACQ were prepared with 2.4% solution by Firetex. These prepared solutions were impregnated with the full cell method. According to Mini Fire Tube (MFT) test results, 99,99% weight loss was observed in the control samples, while 17,15% and 16,63% weight loss were observed in CuA and ACQ prepared with FireTex, respectively. CuA impregnated samples maximum temperature increased to 479.88 ºC, while the maximum temperature in the solution CuA with firetex was 97.78 ºC.

Keywords: Copper azole, Ammonical copper quaternary, Ffire test, Firetex

1. INTRODUCTION

Nowadays, reducing environmental pollution and the idea of better protection of human health are increasing the demand for biodegradable materials. In this context, the use of wood and wood based materials is increasing day by day comparing to alternative materials (Öztürk 2003). Wood material has very good physical and mechanical properties and is a renewable resource (Salca and Hiziroglu, 2014). Wooden material is widely used in many areas because of its important advantages. Mainly, wooden material is used for the structural applications and used in the indoor environment for the aesthetic and furniture purposes.

Since wood is an organic material and exposed to many harmful biotic and abiotic factors such as fungi, insects, termites, outdoor conditions (water damage, UV radiation) and fire. In order to protect the wood material from these harmful effects and to increase the period of use, some applications require that wood is additionally protected (Baysal *et al.*, 2017; Le Van and Winandy, 1990). The most common way of preserving wood from deterioration is by treatment with protective chemicals that penetrate into the wood and thereby prolong the service life of wood and wood products (Poncsák *et al*., 2006; Ajuong and Pinion 2010; Ahmed and Moren, 2012).

Many protective preservatives contain copper as an active component against fungal attack, and copper compounds are very effective against many fungi species (Mourant *et al.,* 2008). It is also relatively easy to form copper-based water solutions, and to determine and analyze their penetration into the wood (Archer and Preston, 2006).

Except for impregnated materials with fire retardant properties such as boron compounds, many preservatives with flame-burning properties such as copper and chromium can adversely affect the burning performance of the wood material. It has been pointed out in different studies that the flammability of wood materials is increased when it is impregnated with paraffin, styrene, methyl methacrylate and isocyanate, materials that increase dimensional stability and improve water repellent efficiency (Baysal, 1994 and Atar and Peker, 1998). There are not enough studies that thoroughly examine the burning performance of the impregnated wood material. However, impregnated wood is widely used in the interior of buildings and creates a potential hazard to humans in case of fire (Gao *et al.* 2005). So it is important to have knowledge of the thermal degradation and combustion performance of the impregnated wood material and to take the necessary precautions (White and Dietenberger, 2001; Lowden and Hull, 2013; Jiang *et al,* 2015).

Different studies have shown that fire retardant chemicals have some negative effects on the physical and mechanical properties of wood materials (Laufenberg, *et al.,* 1986; Laks and Palardy, 1990; Baysal, *et al.,* 2006; Ustaömer, 2008 *et al.,* 2017). Fire retardants should improve their fire properties without harming the properties of the material to be produced in use. An effective fire retardant must have a low ignition speed, reduce the intensity of burning, cause low-speed and high-quality smoke, and not to be toxic. Features and appearance must be acceptable for a given area of use, and should not significantly affect product cost (Aydin *et al.,* 2016).

Firetex, obtained by converting limestone-bearing rocks into water, is an industrial additive or chemical-free compound (Kesik, *et al.,* 2015).

In this work we investigated the influence of Firetex is on improvement of the resistance of copper impregnated materials to fire. For this purpose ACQ and CuA impregnated materials prepared with Firetex and it is investigated.

2. MATERIAL AND METHOD

2.1. Materials

Fir (*Abies nordmanniana* subsp. *bornmulleriana*) specimens were prepared from sapwood blocks with dimensions of 5x10x100 mm (height x width x longitudinal). These well-selected specimens were nondeficient, proper, knot-free, normally grown wood material (without reaction wood and without decay, insect and fungal attack) according to the principles of TS 2470.

The samples were treated with copper azole (Tanalith E-3492) and ammonium copper quate (ACQ) at concentration of 2.4 % and Firetex (FT) at concentration of 100%. In this study, according to the report of Istanbul University Department of Pharmacology and Toxicology, Firetex that is natural, not harmful for human health and environment; in the test results of Gazi University Faculty of Technical Education, it is applicable for short period, medium period and vacuum impregnated methods; it has been also reported in the test results of Balıkesir University Basic Sciences Application and Research Center that Firetex which is not including any industrial additive or chemical is acquired transformation to water of rocks having the feature of limestone in nature, in addition it has been the standard of raw water according to the ICP AES analysis (Kesik *et al.,* 2015). The ICP AES analysis results of Firetex made by Balıkesir University were shown in *Table 1* below.

Table 1. ICP AES analysis results of Firetex (Kesik et al., 2015)

Parameters	Ba	Cd	Ni	Mg	Fe	Pb	Cu	Zn	Mn	Cr	Co	Hg	As
Results	0,368 mg/L	<1 µg/L	0,012 mg/L	4,25 mg/L	<5 µg/L	<5 µg/L	<1 µg/L	<10 µg/L	<1 µg/L	<2 µg/L	<0,5 µg/L	<5 µg/L	<0,5 µg/L

2.2. Methods

5 control samples, 5 test samples impregnated with CuA, ACQ and Firetex, totally 30 samples were prepared. Before the experiment, the test samples were dried until they were stable at 20±2◦C, 60±5% relative humidity and 12% moisture gradient in climate room.

2.2.1. Impregnation of Wood

Five different solutions were used for impregnation of wood. For this purpose, CuA and ACQ was dissolved in the 2.4 % and 2.4 % of water and Firetex, whereas 100% Firetex was used.

Table 2. Variation and short naming

Name	Content
C	Control samples
FT	Impregnated with Firetex
DWACQ	ACQ dissolved in water
FTACQ	ACQ dissolved in Firetex
DWCuA	CuA dissolved in water
FTCuA	CuA dissolved in Firetex

Wood samples were dried in an oven at the temperature of 103 ºC until the constant weight. Oven dried samples were treated with dilute solutions in an impregnation chamber according to full cell process. In this process, first samples left under vacuum at 650 mm/Hg for 30 min, then 6 bar pressure for 60 min. After impregnation, retention and weight percent gain (WPG) of the treated samples was determined by Eq.1 and Eq.2.:

R(kg/m3)=((GxC)/V)x10 (1)

Where;
G is the difference between sample weight after impregnation and sample weight before impregnation (kg), C is the concentration (%), and V is the sample volume (m^3).

WPG(%)=((M2-M1)/M1)x100 (2)

Where;
M2 is the weight after treatment, and M1 is the weight before treatment

2.2.2. MFT – Mini Fire Tube Method

The MFT (Mini Fire Tube) method is an adopted and a modified ASTM E69 method. Profile tube made of aluminium (2 x 2 cm) with stand is placed on the laboratory weight. The source of heat is a gas burner with adjustable flame height (preferred height is 1 cm), mounted on a tripod. Measurement of exhausted gases temperature at the outlet of the pipe was made by using a type K thermocouple display for the temperature range 50-1200 ^{0}C.

The samples left loosely arranged after the protection procedure for a period of 7 days in order to dry. Before the test, the samples should be pre-drilled with the holes for suspension in the tube.

The performance test of the effect of protective system carried out according to the methods similar to the ASTM E69 method. After the placing the sample in the tube, on the hook and placing it on a laboratory balance, the balance was tarred. During sample combustion the display show the result of proper mass loss. A burner was placed with the height of the flame ca. 1 cm under a suspended sample. The duration of the flame on the sample was regulated and should amount to 6 minutes. The mass loss and the value of action gas temperature at the outlet of pipe shall be recorded at intervals of 2 seconds.

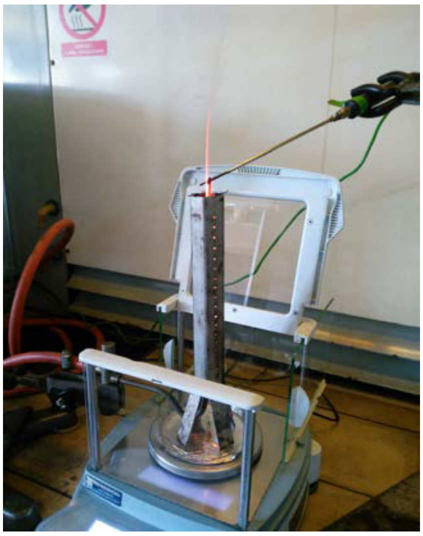

Figure 1. The appearance of test machine and the sample burning

Mass loss
The main evaluation criterion was the mass loss of the test samples which was calculated according to Eq. 3,

$$\Delta m=((m1-m2)/m1)x100 \quad (3)$$

Where;
Δm: mass loss (%), m1: sample's weight before the test (g), m2: sample's weight after the test (g),

3. RESULTS AND DISCUSSION

The weight percent gain (WPG%) and retention (kg/m^3) values in the wood samples after impregnation were given in *Figure 2*. The weight percent gain of Firetex treated samples after impregnation process was determined as 124.86% and for the samples treated with Firetex added ACQ and CuA materials also had a weight gain of 122.37% and 124.67% respectively. The use of vacuum and pressure in the impregnation process increased the gain. When the retention values of the copper treated specimens were examined, it was found as 17.92 kg/m^3 for ACQ prepared with pure water, 18.30 kg/m^3 for ACQ prepared with Firetex, 17.69 kg / m^3 for CuA prepared with pure water, and 20.67 kg/m^3 CuA prepared with Firetex. Thus, the use of Firetex has increased the retention values of the examples. This is due to the fact that Firetex material increases the weight of the samples more than pure water after the impregnation process. In the study done by Ozcan *et al.* (2016) retention was obtained at a rate of 36.1 kg/m^3 with a 24 hour immersion process using 100% Firetex and 52.8 kg/m^3 with a 7 day perforation process.

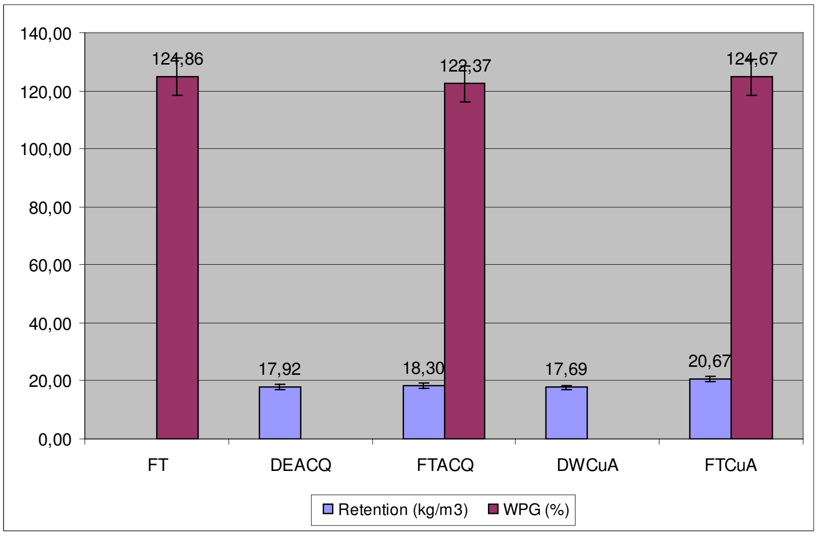

Figure 2.Retentions (kg/m3) and weight per cent gain (%) of samples

The weight loss values of the samples after the combustion test are shown in *Figure 3* and the maximum temperature values reached in the test case are given in *Figure 4*.

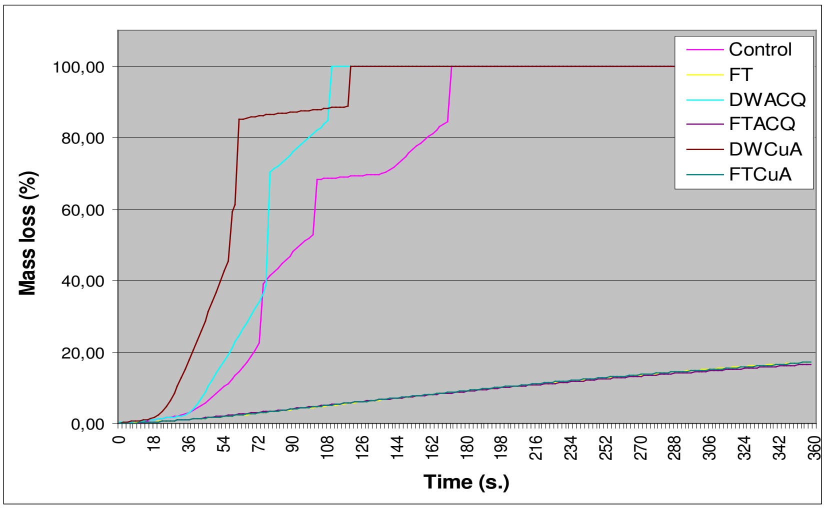

Figure 3. Mass loss course during the test

When the weight loss values measured in 2 seconds during the testing are examined, it is seen that the control, ACQ and CuA impregnated samples have weight loss values as 100%. The samples impregnated with ACQ reached 100% weight loss at 106 seconds, the samples impregnated with CuA reached at 110 seconds, and the control samples reached at 170 seconds. The ACQ and CuA preservatives showed no resistance to burning, on the contrary they seem to facilitate the burning of the wood and reach a maximum loss of weight in a short time. However, with Firetex usage, resistance to burning has increased at a significant level. At the end of 360 seconds, Firetex impregnated specimens presented 18% weight loss. The use of Firetex in the preparation of ACQ and CuA increased resistance to burning of these materials. In previous studies, Firetex has shown to be an effective substance against burning (Kesik *et al.,* 2015; Ozcan *et al.,* 2016). In the control experiments made by Kesik *et al.* (2016), they achieved a loss of up to 40% in the impregnated samples with Firetex while burning completely with a loss of 98% weight after 600 seconds of testing. In addition, while 159.60 ppm CO emission was occurred in control samples, 80.17 ppm CO emulsion was measured in Firetex impregnated samples.

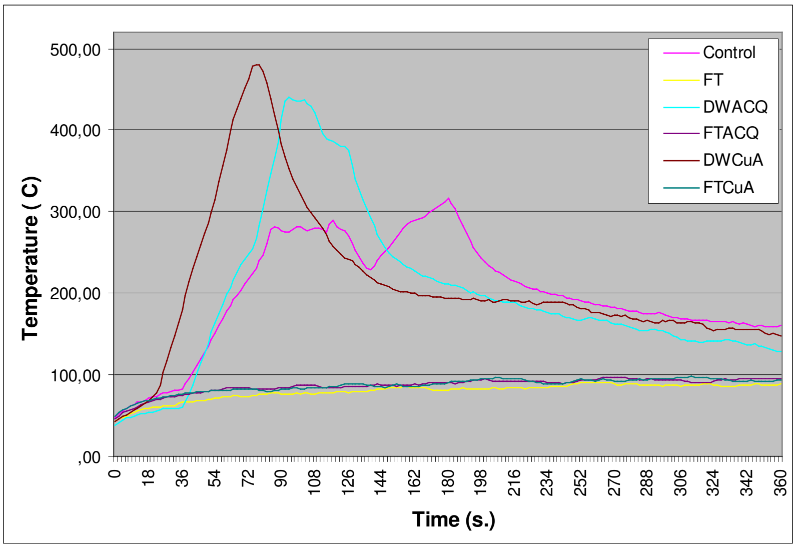

Figure 4. Maximum temperature of wood during the test

Figure 4 shows the maximum temperature values reached during the testing. The loss of weight values given in *Figure 3* related to the maximum temperatures of the samples. That is, the maximum temperature was reached during burning in ACQ and CuA impregnated samples with reaching maximum loss of weight in a short time. The specimens impregnated with CuA were removed after 78 seconds from the start of combustion and reached maximum temperature to 479.63 °C. The samples impregnated with ACQ reached 437.03 °C after 94 seconds and the control samples reached maximum temperature of 310.73 °C after 182 seconds. Firetex treated samples presented minimum weight losses and the maximum temperature reached remained below 100 °C. The similar situation is valid for the three variants prepared with Firetex.

4. CONCLUSION

According to results, after taking the flame source from the fire tube, the highest mass reduction (100 %) was observed in the non-impregnated control and impregnated with ACQ, CuA samples, the lowest in the impregnated with Firetex (17.15 %).

According to *Figure 4*, the highest temperature was observed in the impregnated with CuA samples (479.63 ^{0}C). It been has observed that impregnated by full cell method fir samples impregnated with Firetex samples decreases ^{0}C consumption values 80 % in average.

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