Research Journal of Recent Sciences ISSN 2277-2502
Vol. **2(12),** 80-82, December **(2013)** *Res.J.Recent Sci.*

Fire Safety Properties of Heat Treated Wood

Müllerová Jana
Faculty of Special Engineering, University of Zilina, 1. mája 32, 010 08 Žilina, SLOVAKIA

Available online at: www.isca.in, www.isca.me
Received 12th November 2013, revised 18th November 2013, accepted 27th November 2013

Abstract

Thermal modification of spruce and pine wood has positive impact on its both indoor and outdoor use. Many tests had been done to measure fire safety properties. Heat treated spruce samples reduce the smoke released comparing to untreated sample. Heat treated pine shows opposite effect. Heat treated soft wood has decreased ignition time and heat release when burning. Slightly decreased heat conductivity was measured.

Keywords: Fire safety, heat treatment, thermowood, pine, spruce, ignition, smoke.

Introduction

Smoke is the major cause of fire deaths according global fire statistics. Not direct contact with fire but the smoke is the fatal for victims of fire. Gormsen states that soot in the respiratory tract was found in about 90% of consequent 169 cases of fire deaths[1]. Decreasing the smoke emission is therefore key for fire safety increasing. Wood constructions, floorings and furniture, generally, release less smoke comparing to common plastic and other materials. Heat treated wood timbers and board properties differ from normally dried wood also in sense of fire safety.

Wood Thermal Characteristic

Wood combustion is defined as a process of Thermic decomposition of basic components bounds, when the chemical content is being changed and much volatile matters as well as much solid matters are released[2]. Wood is characterized by main three components. Typically, Hemicelluloses, Celluloses and Lignin represent 90 - 97% of wood structure. The rest are organic and inorganic matters – the most flammable substances. Their content is up to 10% of wood volume.

Table 1 shows approximate temperatures of wood component degradation. Hemicelluloses are the less heat radiation resistant components of wood. They are pyrolised by temperature of 170-240°C. Celluloses degrade by 250-300°C. Highest stability belongs to lignin. It is decomposed in two stages. Firstly, alkyl bounds then active lignin pyrolysis starts by 350°C[3]. Behaviour of heated lignin is well described in details by Kačíková.[4] However, first of all some organic and inorganic substances are pyrolised by wood warmed over 100C for a longer time. These matters can include water, oily substances, wax etc. Therefore they can cause esthetical problems on the surface, when stains and spots are unwanted. Thermal conductivity and mechanical properties of wooden materials are, however, depended on temperature; this topic is described in details by Nazmul et al.[5], Kumar et al[6].

Table-1
Temperature interval for wood compound pyrolysis

Temperature interval (°C)	Wood component
100	Organic and inorganic matters
150	
170	Hemicelluloses
240	
250	Celluloses
300	
320	Lignin alkyl bounds
350	
350	Lignin active pyrolysis
390	

Wood heat treatment process

The sense of thermal modification is to decrease the volume of flammable substances present in wood. The volatile and vapor substances sublimes by the higher temperature. The procedure has to be very careful in order not to degrade the wood unwanted way. The tests showed up that thermo modification is more progressive in inert environment rather than in oxidizing environment[7,8]. The procedure is made in gas (air or nitrogen) or liquid (vegetable oil) environment. The wood can be heated for over 180°C for several hours. All the three factors (environment, temperature, duration) have certain impact on results.

Thermal modification of the wooden materials as boards and timbers during the manufacturing is an extra step before their final use. The mostly used wood species for ThermoWood production are spruce (47%) and pine (47%). Other minor species are Aspen, Birch and others. But totaly less then 7% of official production in 2012[9]. Patented ThermoWood® has been produced since 2000 in Finland, Sweden, Japan and another countries having licensed partners in Scandinavian countries and other European, American and Asian countries. The production programs of thermo-wood vary in temperature, time and environment. Wood is treated in three phases. First phase, temperature increase rapidly over 100°C then steadily to 130°C. The moisture content drops to almost zero. This phase is processed in the steam atmosphere. During the second phase the wood is heated up to 185ºC- 215ºC. The duration of this phase depends on the final use requirements. Controlled cooling and moisturizing is the next phase. ThermoWood Association uses water spray system to reach 4 -7 %.[8] The same effect can be reached after 2 days in normal atmosphere[9].

Fire resistance tests

Fire resistance test were done by VTV, Finland. Fire resistance properties of ThermoWood were tested on spruce and pine samples according to ISO 5660 using Cone Calorimetric method. The samples were heat treated for 5, 8 or 10 hours at temperatures of for the Cone Calorimetric tests. The heat of 50 kW/m^2 was applied on pine sample, 25 kW/m^2 was applied on spruce. Average density of pine and spruce samples was 500 kg/m^3 and 425 kg/m^3 [10]. Control samples of spruce and pine were normal kiln dried softwood samples (up to 65°C).

Single Burning Item test (EN 13823) was taken at VTV[9] to measure the heat resistance of thermo wood. Rate of Heat Release (RTR) was measured. The sample wings had following dimensions: height 1.5 m, width 0.5 (1.0) m, thickness 21(25) for untreated (heat treated) sample. Gas burner released heat of max.40 kW/m^2 on the sample tested.

The emissions were measured according to the KET 3300495 test method. They were measured from heat-treated pine boards (50 x 150mm) in VTT chemical labs. Four hour heat treatment was applied[9]. The tests had been made several weeks after production of heat treated samples[10].

Results and Discussion

The topic of heat treated wood fire assessment is well described by Martinka et al.[12] Generally, many measurements are required to find out the exact properties of samples tested.

Heat treated pine sample RTR level is 10 kW greater comparing to untreated sample. The ignition time of pine heat treated sample was 30% shorter. Spruce sample test shows that heat treatment decreases its ignition time for more than half comparing the untreated samples.

Table 2 includes untreated samples of spruce and pine wood (0h). Spruce samples were heat radiated 50 kW/m^2 and pine samples by 25 kW/m^2 in Cone Calorimeter. Spruce sample treated for 8 hours had an ignition time of 97s. Ignition time of untreated spruce sample of the same size (50x150mm) was 193s. Similarly, with pine samples it took around 50% time comparing to untreated pine samples.

Table-2
ThermWood association - Cone Calorimeter measurements (average values)

Sample treated (230 °C)	Ignition time (s)	RHR (60s) (kW/m$^{2)}$	Smoke (m^2/kg)
Spruce (0h)	193	113	72
Spruce (8h)	97	112	21
Pine (0h)	22	150 – 200	25 –100
Pine (5h)	12	137	180
Pine (8h)	13	136	147
Pine (10h)	16	160	120

Smoke release by treated spruce sample was 21 comparing to 72 m^2/kg of untreated sample. It is at 71% lower smoke emission. Pine samples show different results. Heat treated pine samples have significantly increased values of smoke release comparing to untreated pine samples.

Wood typically contains 3 – 10 % of organic and inorganic matters. Volatile organic compounds (VOC) emissions measured by VTT team are represented by table 3. Total amount of VOC (TVOC) rapidly decreased from 1486 to 235 µg/m^2 h by heat treatment. It dropped by 84% from original amount of TVOC. Almost all the identified VOC compounds volatalize by heat treatment. Camphene, hexanal, limonene decrease to zero, and alpha-pinene almost zero. The presence of furfural causes the typical smoked-like smell of Thermo wood. Acetic acid volume increased rapidly by heat treatment procedure from 5 to 110 µg/m^{2}h. VOC in table 3 present 50% of total VOC volume. The rest of compounds remain unidentified. Thermal conductivity reduction up to 25% was proofed by VTT tests.

Table-3
VTT- Volatile organic compounds emission from pine sample

Emissions VOC (µg/m^{2}h)	Acetic acid	Alpha-pinene	Camphene	Furfural	Hexanal	Limonene	TVOC
Untreated sample	5	674	232	2	43	191	1486
Heat treated (180°C)	78	312	32	29	8	153	828
Heat treated (230°C)	110	24	0	10	0	1	235

Conclusion

Proper Thermic modification of the wooden material changes the natural properties of the wood. It improves biologic resistance and also esthetic properties. On the other hand it decreases the flexibility of the material and other mechanical properties. The main disadvantage is connected to worse mechanical properties of themal modified wood as fortress, impact strength and hardness. This effect might be unwanted by manufacturers when flexibility of board is required for some reasons. Assorted properties of heat-treated wood are shown in table 4.

Table-4
Properties of heat modified wood comparing to normal wood

+	-
Reduced smoke emission (spruce)	Ignition time decreased
Reduced hygroscopy	Impact strength reduced
Improved durability	Bending strength reduced
Improved dimensional stability	Splitting strength reduced
Decay resistance	Fortress Reduced
Resin removed	
Biologic degradation resistance	
Improved accoustic properties	
Consistent colour	

Positives are on the left side, negatives on the right side of the table.. From fire protection point of view reduced smoke emission is probably the most wanted property of heat treated wood (ThermoWood®). Cone calorimetric test showed that heat treated spruce sample had significantly lower smoke release comparing to untreated sample. On the other hand, heat treated pine sample had the opposite effect. Much decreased ignition time is also unwanted effect as well as greater RTR. Heat treated wood has many important properties different to normal wood. Extra measurements focused on smoke release and emissions need to be done to enable accurate fire risk assessment.

References

1. Gormsen H, Jeppesen N and Lund A., The causes of death in fire victims. *Forensic Sci Int*. **24(2)**, 107-111, (**1984**)

2. Osvald A. and Osvaldová L., Retardácia horenia smrekového dreva, Zvolen: *TU Zvolen*. (**2003**)

3. Bučko J., Osvald A., Rozklad dreva teplom a ohňom, Zvolen: *TU Zvolen* (**1998**)

4. Kačíková D., Kačík F., Vplyv termického pôsobenia na zmeny lignínu smrekového dreva. *Acta Fac. Xylologiae*, **51(2),** 71–78, (**2009**)

5. Nazmul A.D.M., Md. Nazrul I., Khandkar-Siddikur R., and Md. Rabiul A., Comparative study on physical and mechanical properties of plywood produced from eucalyptus (Eucalyptus camaldulensis Dehn.) and simul veneers (Bombax ceiba L.), *Res. J. Recent Sci*., **1(9)**, 54-58, (**2012**)

6. Kumar A., Chauhan R.R. and Kumar P., Effective thermal conductivity of cucurbit as a function of temperature by thermal probe method, *Res. J. Recent Sci*., 1(10), 33-36 (**2012**)

7. Candelier K., Dumarçay S., Pétrissans A., Desharnais L., Gérardin P. and Pétrissans M.,Comparison of chemical composition and decay durability of heat treated wood under different inert atmospheres: Nitrogen or vacuum, *Polymer Deg. Stabil.* , **98(2).** 677–681, (**2013**)

8. Zachar M. and Skrovný R., Influence of heat on thermal degradation of spruce wood, *Acta Fac. Xylologiae*, **49(1)**, 61-68 (**2007**)

9. Thermowood Association. ThermoWood production statistics. Helsinki: ITWA (**2013**)

10. Reinprecht L. and Vidholdová Z.: Termodrevo. Ostrava: SPBI (**2011**)
11. Thermowood Association. ThermoWood handbook. Helsinki: ITWA (**2003**)

11. Martinka J., Hroncová E., Chrebet T., Balog K., Fire risk assessment of thermally modified spruce wood, *Acta Fac. Xylologiae*, **55(2),** 117-128 (**2013**)