Annals of Warsaw University of Life Sciences – SGGW
Forestry and Wood Technology No 72, 2010: 192-195
(Ann. WULS-SGGW, For and Wood Technology. 72, 2010)

Analysis of the heat release rate from wood with applied fire protection by selected flame retardant agents

MARZENA PÓŁKA, MAREK KONECKI
Department of Combustion and Fire Theory – The Main School of Fire Service, Warsaw – SGSP

Abstract: *Analysis of the heat emission rate from wood with applied fire protection by selected flame retardant agents*. From the very beginning of our civilisation wood – a flammable material has been in use as a basic construction material. The spectrum of fire retarding impregnating formulations and their increasingly widespread application impose carrying out of research relating to their impact on flammable properties of different wood types. This paper comprises a comparative analysis of the efficacy of selected fire protection formulations, implemented by testing the rate of heat emission from selected wood samples at external heat exposure equal to 30kW/m^2. The applied thermal exposure simulates heat and flow conditions, which take place in the incipient stage of the fire.

Keywords: fire hazards, flame retardant for wooden, heat release rate.

INTRODUCTION

From the very beginning of our civilisation wood – a flammable material has been in use as a basic construction material. Light framework construction widespread in Poland and worldwide offers an excellent option for buildings of mineral materials, which are relatively difficult in the construction process, and also quite costly. Buildings of brick and concrete also comprise elements made of wood. The examples cover roof truss systems, staircases, architectural elements in the form of flooring, wall panelling, ceilings or furniture. Wooden elements may lead to a fire risk in a structure, hence prevention and physical protection methods of wooden elements in buildings are highly recommended. Chemical wood protection methods still tend to remain the most effective methods of fire proof wood protection. Wooden elements, protected with flame retardants, are less susceptible to inflammation, and consequently need a bigger thermal flux or longer time of its action.

At present the Polish market offers several dozens of various flame retardants (antipyrenes). They are available as salt granulates, liquid agents ready for surface and deep application, paints, varnishes or fire resistant mass. The action of antipyrenes varies, yet in the majority of cases it is based on protecting wood from fire, house fungi, mould and insects. In their recommendations the producers present the general designation of their formulations, their chemical composition, application method and output. However, in many cases there is insufficient information related to effectiveness. Frequently the customers tend to ask themselves – what should be borne in mind when buying a flame retardant and whether the price is adequate to the effectiveness?

The spectrum of fire retarding impregnating formulations and their increasingly widespread application impose carrying out of research relating to their impact on flammable properties of different wood types [1-7]. This paper comprises a comparative analysis of the efficacy of selected fire protection formulations, implemented by testing the rate of heat emission from selected wood samples at external heat exposure equal to 30kW/m2. The applied thermal exposure simulates heat and flow conditions, which take place in the incipient stage of the fire.

DESCRIPTION OF RESEARCH MATERIAL AND OF ANTIPYRENES

The tests were carried out on dried seasoned oak wood samples with a density not exceeding 0.80 g/cm3. Flame retardant modification comprised two-fold application of the antipyrene, the volume and procedures of which are specified by the producer of formulations applied in our research. Choice of the application method (brush or spray) of flame retardants arises from the most common practical application of the formulations in construction industry.

The following flame retardants available on the market have been applied for flame retardant modification of oak wood samples:

- Fobos,
- Uniepal,
- Prevento,
- Ogniochron.

TEST METHOD - CONE CALORIMETER METHOD ACCORDING TO ISO 5660

To perform analysis of heat and smoke release rates for wood samples a cone calorimeter manufactured by FTT (Fire Testing Technology) from Great Britain was used (it is available at Combustion Institute of the Main School of Fire Service. The tests were performed according to the ISO 5660:2002 standard [8].

Although the theoretical base of the cone calorimeter has been known for a few dozen years, the first standardized method of determining fire properties was developed in the middle of 90'. In 1917 Thornton [9] proved that significant number of organic fluids and gases exposed to heat fluxes release constant amount of heat per unit of mass of oxygen used for complete combustion of a flammable substance. Huggett [10] verified this dependence for the solid bodies and found that heat released during combustion of solid bodies is proportional to the amount of oxygen required to burn a unit of mass of a flammable material. In case of most flammable materials to which one can include wood, plastics, organic fluids and other flammable materials, this dependence defines that for every kg of consumed oxygen during combustion time 13,1 MJ of heat is released. Deviations from average value reach (on average) ±5% for different materials. Thus, 13,l MJ of the released heat was assumed as a constant unless more precise data are available.

RESULTS

Results of testing for wood samples not modified by flame retardants and with added flame retardants (an average obtained from 3 measurements) were shown in table 1.

ANALYSIS OF THE RESULTS OF EXAMINATION OF THE THERMOKINETIC AND THERMOPHYSICAL PROPERTIES OF STUDIED MATERIALS – CONCLUSIONS

Basing on the performed research of materials produced from unmodified oak samples and those modified by flame retardants, the following presumptions can be made:

- Flame retardants introduced to tested wood effectively reduced the heat release rate as compared to the unmodified wood material.
- The lowest values of HRR_{max} were obtained for oak + ogniochron (brush) at the applied heat exposure.

- Average heat release rates for the modified materials were by 10–20% smaller than HRR_{av} of the unmodified material. The lowest HRR_{av} value was obtained for oak +prewento (brush)
- When applied by a brush at 30 kW/m^2 on oak they reduced the time to ignition of the flammable gaseous phase very slightly ca. 2.3 times. This proves that products of thermal decomposition and combustion obtained from oak = prevento inhibit the moment of igniting gaseous phase. Prevento in tested wood acts as an antipyrene mainly in gaseous phase.

Tab 1. Results of testing for wood samples not modified by flame retardants and with added flame retardants (an average obtained from 3 measurements) at 30 kW/m^2

Samples	**The way applied of flame retardant**	**HRRmax [kW/m^2]**	**HRRśr [kW/m^2]**	**MLRśr [g/s]**	**t ignition [s]**	**SEAśr [m^2/kg]**	**TSR [m^2/m^2]**
Unmodified oak sample	-	193,91	73,41	0,052	68	16,76	60,93
Fobos	brush	236,13	68,50	0,041	107	78,33	254,92
	spray	185,54	77,67	0,050	114	51,23	165,75
Uniepal	brush		62,95	0,045	72	45,23	171,13
	spray	224,82	87,67	0,071	77	47,89	176,49
Prevento	brush	208,12	55,89	0,035	146	27,67	113,05
	spray	215,27	99,98	0,074	144	32,29	98,31
Ognioochron	brush	181,40	61,40	0,040	109	49,44	177,52

- Introduction of the applied flame retardant at the density of external heat flux equal to 30 kW/m^2 extended the time to ignition for the unmodified oak. This implies that products of decomposition and combustion released from those modified samples effectively inhibit the moment of ignition of the gaseous phase, and the mechanism of operation is active primarily in the gaseous phase. Thermal decomposition products of the modified oak samples dilute the flammable gaseous phase and undergo chain-radical reactions that reduce the energy of the radicals responsible for propagation of the flame combustion. At 50 kW/m^2, the best combustion inhibitor operating in the gaseous phase of Ep 561 was melamine, since in its case the time to ignition was longer than for other flame retardants (next were: UEp 561 + Roflam P and UEp 561 + Roplast FN-1.
- While considering Total Smoke Release (TSR) it can be asserted that the applied flame retardant increases the smoke release rate at the tested heat exposure. The lowest value of TSR was observed for oak +prevento (spray) among the tested modified oak samples.
- The lowest value of SEA_{av} and TSR was obtained for unmodified wood samples. It means that the applied flame retardants increase smoke generation during the fire as compared to unmodified oak.
- As to emission of CO from 1kg of a material it was found that the lowest CO value was for oak + uniepal (spray).
- As regards CO_2, it was observed that at 30 kW/m^2 oak + uniepapal (spray) indicated the lowest CO_2 emission as compared to the other investigated materials produced from oak.
- The application of the applied flame retardants using a brush led to obtaining lower HHR_{av} values as compared to the application of the same agent onto an oak wood ample but with spraying. This dependence has been observed for all samples impregnated with flame retardants.

- Uniepal applied by spraying on an oak wood sample generated the lowest emission of CO and among the retardants and thermal exposure.
- The highest level of CO among flame retardants applied in testing was generated by Ogniochron, while the biggest volume of CO_2 was generated by Fobos applied by rush on oak samples.

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Streszczenie: *Analiza szybkości wydzielania ciepła z drewna zabezpieczonego ogniochronnie wybranymi środkami ogniochronnymi.* Drewno – materiał palny, już od początku naszej cywilizacji było stosowane jako podstawowy materiał budowlany. Spektrum impregnatów przeciwogniowych oraz ich coraz powszechniejsze zastosowania, zmuszają do prowadzenia badań dotyczących ich wpływu na właściwości palne różnych rodzajów drewna. Niniejsza praca jest analizą porównawczą skuteczności wybranych środków ogniochronnych, zrealizowanym poprzez badanie szybkości wydzielania ciepła z wybranych próbek drewna przy zewnętrznej ekspozycji ciepła 30kW/m2. zastosowana ekspozycja cieplna symuluje warunki cieplno – przepływowe zachodzące w i fazie rozwoju pożaru.

Badania przeprowadzono w ramach POIG.01.01.02-10-106/09-01

Corresponding author:

Marzena Półka
Szkoła Główna Służby Pożarniczej
Zakład Spalania i Teorii Pożarów
ul. Słowackiego 52/54, 01-629 Warszawa
mpolka@sgsp.edu.pl