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Assessment of Fire Risk of Selected Agglomerated Wooden Materials

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Abstract

In the submitted paper, the fire risk of the oriented strand boards (OSB) and chipboards is assessed. Fire risk of these materials was assessed on the basis of heat flux density effect on the ignition time of tested materials with thickness of 12, 15 and 18 mm. The dependence of initiation time on the heat flux density was determined by the apparatus (cone heater) according to the ISO 5657:1997 through the modified testing procedure. The testing procedure modification consists of specimen heat flux exposure without any secondary initiator use. The minimal heat flux density at which ignition occurred was 43 kW / m^2 for the OSB boards, and 40 kW / m^2 for the chipboards. The obtained data show that the ignition time of assessed wooden materials decreases exponentially with increasing heat flux density. Obtained data imply also a fact that the influence of studied materials thickness on the ignition time decreases with increasing heat flux density. Measured data imply an independence of minimal heat flux density on studied materials thickness, as well.

Keywords: assessment of material fire risk, heat flux density, fire propagation dynamics, ignition of material, fire technical characteristic of materials.

Introduction

To assess material fire risk, it is essential to measure the heat release rate and chemical composition of combustion products[1].

The question of assessment of the heat release rate from materials was dealt in details, for example in Babrauskas's work[2]. The mass loss of selected lignocelluloses' materials when exposed to radiant heat was determined for example by Osvaldová, Makovický[3], Zachar and Skrovný[4]. The results from those cited authors' show an exponential dependence of the mass loss on a studied materials distance from the infrared radiation source.

The effect of external conditions on chemical composition of combustion products or thermal decomposition was studied e.g. by Martinka et al.[5] and Bubeníková, Veľková[6]. From data presented by Martinka et al.[5] it is clear that the highest yield of toxic combustion products (carbon oxide) is produced in the initiation phase of wooden materials.

The time to initiation of materials depending on the heat flux density is very suitable parameter for comparison of material regarding the fire propagation dynamics[7].

The time of initiation is a time interval from exposing material to the constant temperature or to the constant heat flux density to the material ignition[8].

The ignition time of selected natural or synthetic polymers was studied by several authors, for example Tereňová[9] and Martinka et al.[10]. According to Martinka et al.[10], also the parameters of the oxidation atmosphere (prevailingly the flow rate and oxygen concentration in it), except temperature or heat flux density respectively, have a significant effect on the polymers ignition time[10].

The minimal heat flux density for material ignition depends on material chemical composition and physical characteristics. Physical properties can be divided according to characteristics joined with material itself and on environmental parameters. Among the most significant physical characteristics of material belong its geometry (shape, dimensions, and form), volume mass (density), moisture content, surface quality, thermal conductivity, mechanical properties, and mutual orientation between exposed sample surface and radiant heat source[11]. Thermal conductivity and mechanical properties of materials are, however, depended on temperature; this topic is described in details by Nazmul et al.[12], Kumar et al.[13] and many others authors[14-16]. Besides material physical characteristics and chemical composition, also the presence of fire retarders has significant effect on initiation process of material. This problem is described in details by Muralidhara and Sreenivansan[17].

Among the most important environmental parameters that are variable under normal conditions, belong air flow rate. The air flow rate decreases minimal heat flux density down to certain limit. This effect is caused by mechanism of how the air flow rate affects the minimal heat flux. At relative small air flow rates, the increasing flow rate influence positively the decrease of minimal heat flux density due faster and more complex mixing of thermal decomposition products with air oxygen. At high air flow rates, it evokes increasing of thermal exhaust rate from reactive burning zone that is demonstrated in increasing of critical thermal flux density. Under fire conditions, a variability of flow rates is higher in comparison with normal conditions; in this case the critical heat flux can also be affected by decreased oxygen concentration (growth of critical thermal flux value) and increased temperature of oxidation atmosphere (decline of critical thermal flux value).

The effect of external environmental parameters on burning process of wooden materials was studied in details by Ladomerský and Hroncová[18].

The goal of this paper is to determine the minimal thermal flux density necessary for ignition of OSB boards and chipboards with thickness of 12, 15 and 18 mm as well as determination of heat flux density effect on time to initiation.

Material and Methods

The time to initiation dependence of chipboards and OSB boards on heat flux density was determined on the apparatus according to ISO 5657:1997, by a modified testing procedure. The modification consisted of specimen exposure by radiant heat flux, without any secondary initiator use.

Before the experiment itself, the minimal heat flux was determined at which ignition of OSB boards and chipboards, without any secondary initiator use, appeared. It was found that the prolongation of exposure time interval of OSB boards and chipboards affects a decline of minimal heat flux only within the time interval of 300 s approximately. After decreasing the critical heat flux density for 300 s time interval the ignition did not take place even at 3600 s exposure. At heat flux lower than minimal heat flux density required for ignition, the rate of thermal degradation of material did not reach a critical value necessary for reaching the flammability lower concentration limit of originated decomposition products. Due to thermal flux from the heater, the material was subjected to thermal decomposition but it did not ignite.

Specimens of OSB boards and chipboards were thermally exposed by prescribed minimal heat flux for 300 s time interval. Minimal heat flux density needed for ignition was 43 kW / m^2 for OSB boards and 40 kW / m^2 for chipboards. Ignition times of chipboards were determined at 40, 41, 42, 43, 44, 45, 46, 47, 48, 49 a 50 kW / m^2 heat flux values for chipboards and 43, 44, 45, 46, 47, 48, 49 a 50 kW / m^2 heat flux values for OSB boards. Each measurement was repeated five times minimally. Recorded extreme values were excluded from data set and replaced by values gained from repeated measurements.

Specimen dimensions and configurations met the ISO 5657:1997 requirements, flat dimension was 165 x 165 mm. Thickness of studied materials was 12, 15 and 18 mm. Absolute moisture content of used boards was 6 % volume. Density of OSB boards was from 560 up to 580 kg / m^3; and that of chipboards was from 660 up to 680 kg / m^2.

Studied specimens are shown on the figure 1.

Results and Discussion

Minimal heat flux density necessary for ignition of OSB boards was determined at 43 kW / m^2; and that for chipboards at 40 kW / m^2 while tested board thicknesses did not affect the minimal heat flux density. This fact, however, might be caused by narrow interval of tested chipboard and OSB board thicknesses. Determined values of minimal heat flux density causing ignition of tested materials were approximately 50 % higher when compared with data related to wooden materials referred by Lawson and Simms[19] and Merryweather and Spearpoint[20]. Mentioned difference was caused by the test procedure modification. Cited authors determined values of minimal heat flux density of selected wooden materials by the procedure according to the ISO 5657:1997, it means with the use of secondary initiation source. Data on minimal heat flux and ignition time dependence of tested materials in the submitted paper were gained, on the other hand, by modified testing procedure, without the use of any secondary initiation source.

Integrated effect of OSB board thicknesses and heat flux density on the initiation time is shown on figure 2; and effect of chipboard thicknesses and heat flux density on the initiation time is shown on figure 3[7].

Figure-1
Studied OSB board and chipboard specimens

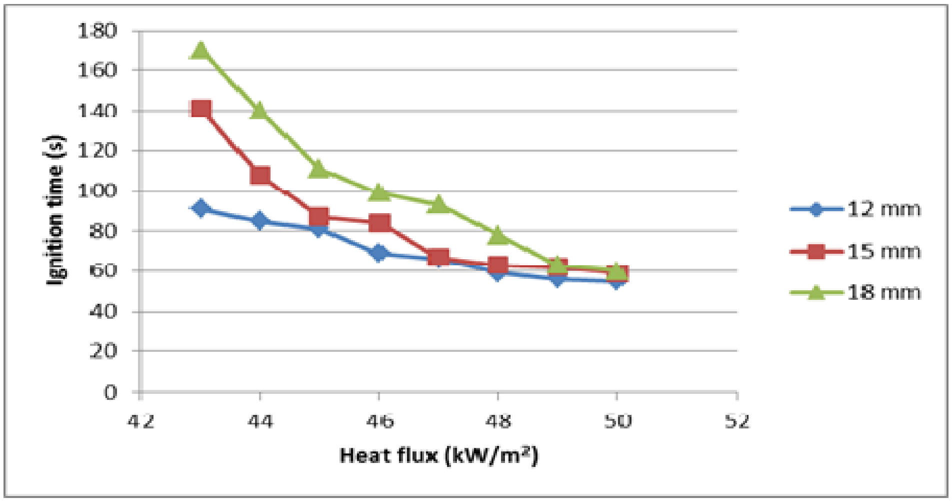

Figure-2
Ignition time dependence on OSB board thicknesses and heat flux density

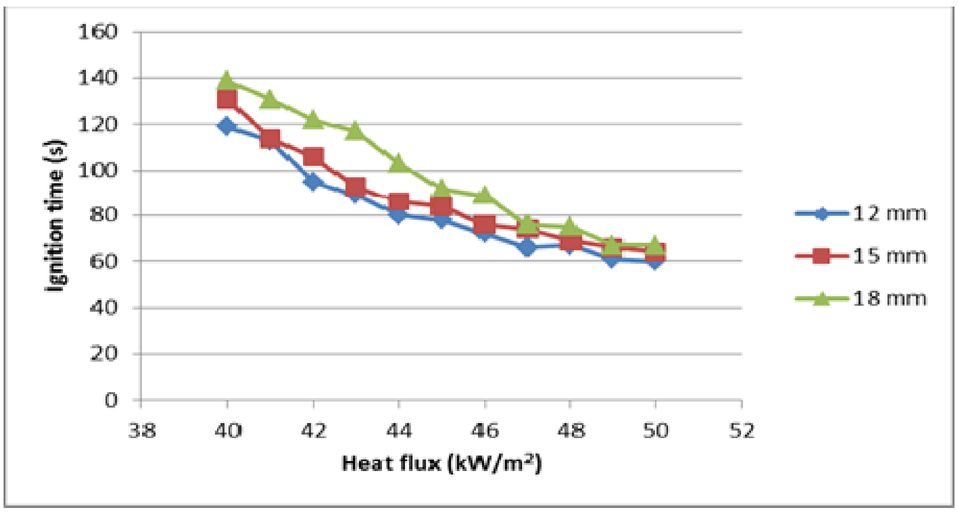

Figure-3
Ignition time dependence on chipboard thicknesses and heat flux density

From visual analysis of figures 2 and 3 follows that effect of OSB board as well as chipboard thickness declines with growing heat flux. For the 50 kW / m^2 heat flux density the effect of board thickness was negligible. This trend was caused by effect of heat flux density on thermal material thickness[21].

Thermally thick material is defined as a material whose surface temperature on the opposite side of exposed surface at the ignition time is coming near to the ambient environment temperature. Thermally thin material is defined as a material whose surface temperature on the opposite side of exposed surface at the ignition time is coming near to the exposed surface temperature. From these definitions it is clear that terms “the thermally thick material” and “the thermally thin material” are relative ones in a considerable rate. Thermal thickness relativity follows from its dependence on heat flux. At relative low heat flux density the transfer of heat from the material surface towards its inside occurs. It means that all material is overheated and heat is absorbed in material. The ability of material to accumulate heat in a volume unit is physically represented by thermal inertia that can be mathematically expressed as a sum of the thermal conductivity coefficient, density and thermal capacity coefficient. During increasing of heat flux density, the surface temperature is growing rapidly faster that temperature inside the material, thus the same material with the same dimensions and the same thermal inertia can be either thermally thin material for certain heat flux and also thermally thick material for higher heat flux. Thermal thickness of material thus depends mainly on its thermal inertia, material thickness, thermal conductivity coefficient, heat flux density and moisture content.

Water content in a material absorb certain heat necessary to water evaporation, but on the other hand, at high heat flux values it can cause extremely fast water evaporation and consequent creation of cracks enabling faster penetration of thermal degradation products.

Based on determined average ignition time difference between OSB boards with thickness of 12 mm (91 s) and 18 mm (170 s), respectively, at critical heat flux density (43 kW / m^2), it cannot be said that 12 mm thick OSB board is a thermally thin material at critical heat flux density, because the temperature measured on unexposed side, even in this case, does not exceed 40°C, while with increasing heat flux and increasing OSB board thickness, the temperature on unexposed side decreased at the ignition time. The same conclusion is also valid for chipboards, where average ignition time at critical heat flux density (40 kW / m^2) was 119 s for 12 mm thickness; and 139 s for 18 mm thickness, while temperature on unexposed side did not exceeded 40 °C at the ignition time.

To determine thickness influence on ignition time of OSB boards and chipboards in studied thickness interval and heat flux density interval, the one-factor variance analysis (ANOVA) was used. Based on calculated criteria for OSB boards $F = 2.4493 < F_{0.05\ crit} = 3.4668$, the zero hypothesis on equality of variances of ignition times for OSB boards with different thickness was confirmed on the significant level $\alpha = 0.05$. Thus, from the one-factor variance analysis follows that OSB board thickness has no significant effect on ignition time thereof under studied conditions. Similarly, based on calculated criteria for chipboards $F = 1.4324 < F_{0.05\ crit} = 3.158$, the zero hypothesis on equality of variances of ignition times for chipboards with different thickness was confirmed on the significant level $\alpha = 0.05$. Finally, from the one-factor variance analysis follows that chipboard thickness has no significant effect on time ignition thereof under studied conditions.

Conclusion

From data measured it is clear, that influence of thickness of chipboards and OSB boards on ignition time during exposure by radiant heat flux declines with increasing heat flux density. For OSB boards, board thickness has a negligible effect on ignition time from heat flux density value of 50 kW / m^2. This value represents 115% of minimal heat flux density value that caused ignition of tested OSB boards. For chipboards, board thickness has a negligible effect on ignition time, similarly like for OSB boards, from heat flux density value of 50 kW / m^2. This value is 125% of minimal heat flux density value that caused ignition of tested chipboards. Stated conclusion is valid, however, only for studied thicknesses (12, 15, and 18 mm).

Temperature on unexposed side of OSB boards or chipboards did not reach even 40°C (at none studied thicknesses 12, 15 and 18 mm and at none studied heat flux densities 40 up to 50 kW / m^2). The minimal heat flux density necessary for ignition of OSB boards was 43 kW / m^2 and that of chipboards 40 kW / m^2, thus those materials can be considered to be thermally thick materials for purpose of combustion initiative parameters assessment.

Obtained data also indicate independence of minimal heat flux density on material thickness. This statement was proved on for thicknesses of 12, 15 and 18 mm. To generalize it, further experiments will be necessary to carry out.

Further research should be focused on determination of minimal thickness of studied materials at which these materials begin to behave as thermally thin materials at minimal heat flux density required for their ignition. It should also be focused on determination of material thermal thickness impact on amount of main fire emissions (carbon oxide and carbon dioxide) and on correlation thereof with heat release rate from wooden materials, in similarly way as was determined by Xu et al.[15] for synthetic polymers.

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