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The study of time to ignition of woods under external heat flux by piloted ignition and autoignition

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Abstract: *The study of time to ignition of woods under external heat flux by piloted ignition and autoignition.* A typical room fire starts when a building material (i.e wood, plastics) is exposed to an external heat (ignition) source. Due to the heating, the surface temperature of the solid object starts to rise. Provided the net heat flux into the material is sufficiently high, the surface temperature eventually reaches a level at which pyrolysis begins and material decomposes into volatiles. The ignition of combustible materials is an important aspect of the processes taking place in a fire. In this work, an experimental study of the time to ignition of wood by autoignition and piloted ignition has been carried out. A study of the autoignition and piloted ignition (spark igniter) of wood by a radiant cone heater from Cone Calorimeter was conducted. Insulated samples were exposed horizontally to incident heat flux: 20, 30 and 50 kW/m^2. The times to piloted ignition and were measured and compared with the times to autioignition of beech, pine and oak wood. The study found that for smallest incident heat flux (20 kW/m^{-1}) the time to autoignition is prominently diverges from the piloted ignition time. The biggest differences, first observed for beech wood (difference – 241 sec). The study found that for high incident heat flux (50 kW/m^2) differences of the time to ignite the samples by piloted ignition and autoignition are insignificant, especially for pine and oak.

Keywords: ignition, piloted ignition, autoignition, wood, cone calorimeter

INTRODUCTION

Wood is a common building materials and can constitute the bulk of the fuel load in structures (McAllister 2001). The ignition of building materials is an important aspect of the processes taking place in an fire. An accurate prediction of fire risk requires an adequate description of the initiation and development of a fire (Bilbao et al. 2001, Mastral et al. 2001). Ignition may be defined as that process by which a rapid, exothermic reaction is initiated, which then propagates and causes material involved to undergo change ,producing temperature greatly in excess of ambient (Shi and Chew 2013). More specifically, the ignition of a solid materials can be viewed as a three-step process: as wood is subjected to a heat flux, it undergoes decomposition. The wood decomposes generating fuel gases flowing to the surrounding while leaving a residual char matrix over the virgin wood (Boonmee and Quintiere 2005). The next, fuel vapor mixes with fresh air to dorm a combustible mixture, and the flammable mixture reaches the pilot to the point where chemical reaction reaches the "thermal runway" (Boonmee and Quintiere 2005, Mindykowski et al. 2011). Ignition tends to mean two different things: (1) kindled ignition where a material is ignited by an external heat source such as flame, sparks (piloted ignition) or hot surface (autoignition, spontaneous ignition). Ignition by piloted ignition occurs when the rate of pyrolysis is sufficient to allow the establishment of a diffusion flame, when a spark or small pilot flame is introduced into the boundary layer close to the irradiated surface (Silcock 1995). Autoignition requires very high intensities to occur. Compared with piloted ignition, process of autoignition is closer to the development of real fire. Generally, the time to ignition is dependent on the power of the radiation source and the method of its starting. There is a number of reviews concerning the ignition of wood.Combustible materials (include woods) showed different fire behaviors under piloted ignition and autoignition conditions (Shi and Chew 2013). From statistical analysis of experimental results, Mellinek noticed that minimum rate of volatile emission can be used to predict ignition, which is about 5,1 g/m^{2}s for piloted ignition and 7,7 g/m^{2}s for autoignition. Atteya (Atteya 1983) performed a comprehensive set of ignition measurements on eight wood species (Shi and Chew 2013). Kanuary has found the minimum surface temperature of wood under radiative heating mode for autoignition is 600^{0}C and for piloted ignition 300 – 410^{0}C. With convective heating the spontaneous ignition, occurred at 490^{0}C and with piloted ignition 450^{0}C. Dimitrakopoulos used the standard cone colorimeter methods to determine the ignition time and the moisture of extinction of selected Mediterranean forest fuels in order to develop a relative flammability classification. Schemel et al. described a calorimetric study of pine needle beds. Mindykowski et al. conducted experiments in the FM Global Fire Propagation Apparatus (FPA) to investigate the piloted ignition of litters composed of oven dried maritime pine (MP) needles and kermes oak leaves. For the fuel beds considered they found that the inverse of the ignition time is linearly dependent on the imposed heat flux, as observed for thermally- thin solids (Consalvi et al. 2001). Quintiere gained an approximate solution of ignition time by solving integral equations. It was assumed that ignition is based on critical temperature of surface under external heat flux. The ignition time was found to be related with thermal inertia, ignition temperature, and external heat flux (Quintiere 1992). Further work by Atreya, Carpentier & Harkleroad examined the effect of sample orientation on piloted ignition and flame spread on wood (Spearpoint and Quintiere 2001).

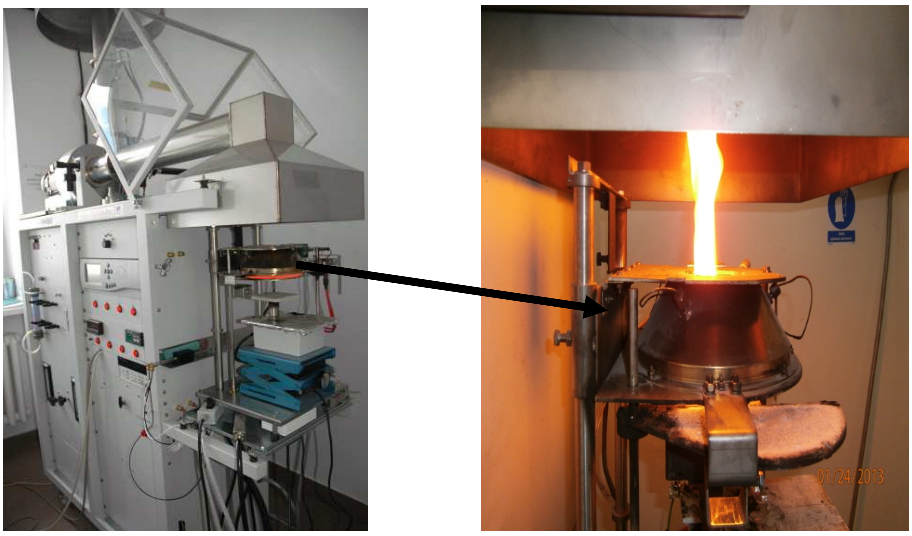
MATERIALS AND METHODS

The three kinds of wood species: beech, oak and pine used in this study are shown in table 1. The dimensions of the samples were 100 x 100 mm. The thickness of the test specimens was 10 mm.

Table 1. Description of the test materials

Wood	Grain orientation	Average density [kg/m^{-1}]	Average moisture content [%]
Beech	along	610,4	9,6
Oak	along	643,8	9,2
Pine	along	475,7	9,4

The experiments were carried out on a cone calorimeter (fig.1) provided by Fire Testing Technology (FTT) Ltd. All the experiments were conducted placing the specimens in a sample holder in a horizontal position. The back of the samples was insulated with low-conductivity material to reduce heat losses to the sample holder. The spark igniter and cone heater to the cone calorimeter was used to induce ignition. The materials were tested in the horizontal orientation, at an external heat flux 20, 30 and 50 kW/m^2. A sample was considered ignited when visible flame was observed. Time at ignition was considered as the time do ignition. This was defined as the minimum exposure time required for the specimen to ignite and sustain flaming combustion.



a) b)

Fig.1. Experimental set-up of the cone calorimeter. a) Cone calorimeter, b) cone heater

RESULTS AND DISCUSSION

The time to autoignition was measured and compared with the time to piloted ignition. Summary of time to ignition as shown in tab. 2.

Table 2. Time [s] to autoignition and piloted ignition

Species	**Autoignition or piloted ignition**	**External heat flux [kW/m^2]**		
		20 kW/m^2	**30 kW/m^2**	**50 kW/m^2**
		Time to autoignition or piloted ignition		
Beech	autoignition	865	194	46
	piloted ignition	624	64	29
Oak	autoignition	621	240	40
	piloted ignition	451	81	36
Pine	autoignition	509	59	20
	piloted ignition	302	50	25

Definition of time to ignition is as the time to existence of flaming on or over the surface of the specimen for periods of over 10 s (ISO 5660) and is very important parameter for evaluating flammability of building materials. Regardless of the intensity of the heat flux to ignite the longest time for a beech wood. For smallest incident heat flux (20 kW/m^{-1}) the time to autoignition is prominently diverges from the piloted ignition time. The biggest differences, first observed for beech wood (difference – 241 sec). The longer time to autoignition is a result of the absence of a piloted heat source (igniter spark) to promote the ignition process. The time to autoignition with low incident heat flux still follows the trend of the time to autoignition for the high heat flux and time to piloted ignition. The study found that for high incident heat flux (50 kW/m^2) differences of the time to ignite the samples by piloted ignition and autoignition are insignificant, especially for pine and oak.

CONCLUSIONS

Three species of wood samples, namely pine, beech and oak, were studied experimentally under external heat flux – 20, 30 and 50 kW/m^2 by autoignition and piloted ignition (in presence spark). Understanding piloted ignition and autoignition is a key component of under- standing fire spread, both in structural and wildland fires (McAllister 2013): The ignition of wood depends on many factors including the species, grain orientation, moisture content, exposure conditions and the inherent variability of wood as a natural material. The ignition is some inverse function of the incident heat flux. The higher the incident heat flux is the shorter is the ignition time. The study found that the heat flux – 20 kW/m^2 is sufficient to ignite the wood species tested regardless of the type of ignition. At high heat flux (50 kW/m^2) differences in the time to ignition by autoignition and piloted ignition were insignificant.

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Streszczenie: *Badanie czasu do zapalenia poprzez samozpałon i zapłon wybranych gatunków drewna.* Zapoczątkowanie pożaru odbywa się poprzez niekontrolowane zapalenie materiałów budowlanych, elementów wyposażenia wnętrz. Źródłem ciepła może być bodziec: ciągły – działający w dłuższym czasie (np. gorąca powierzchnia grzejnika elektrycznego, papieros) lub bodziec punktowy połączony z bodźcem ciągłem (np. przegrzany kabel elektryczny z iskrą elektryczną). Pierwszy ze sposobów zapoczątkowania spalania nazywa się samozapłonem, a drugi zapłonem pilotowym. W odniesieniu do bezpieczeństwa pożarowego rodzaj zapalenia ma istotne znaczenie gdyż wpływa na szybkość tworzenia się zagrożeń pożarowych podczas pożaru, w szczególności w I fazie jego rozwoju. W artykule przedstawiono wyniki badań czasu do zapalenia poprzez zapłon i samozapłon wybranych gatunków drewna (sosnowego, bukowego i dębowego). Do badań eksperymentalnych wykorzystano kalorymetr stożkowy. Na próbki umieszczone poziomo w stosunku do radiatora oddziaływano strumienia ciepła o natężeniu 20, 30 i 50 kW/m^2. Zapłon inicjowano iskrą elektryczną. Badania dowiodły, że w przypadku niższych wartości strumienia ciepła (20 i 30 kW/m^2) różnice w czasach do zapalenia poprzez zapłon i samozapłon były znaczne. Dla strumienia ciepła – 50 kW/m^2 różnice były niewielkie.

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