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Short contribution – Fire Management

Spontaneous ignition of vertically positioned wood samples under time-dependent heat flux

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Abstract

Dynamic heating regimes are observed during structural and wildland fires. Most experiments to date use static/constant heating regimes, whereas ignition characteristics under time-dependent heat flux has been poorly studied. Existing apparatuses have limitations to study this effect, such as heating conditions and sample size/position. In this study, we conduct experiments on a custom-made apparatus to investigate the spontaneous ignition and convection cooling effect on this ignition of different vertically positioned wood species subjected to both static and dynamic heat fluxes. All experiments were conducted on cypress wood. Temperature, mass and ignition time were recorded during the experiment. Samples were exposed to 30 kW/m^2 static heat flux and increasing heat flux. Preliminary results showed that for static heat flux two out of four samples were ignited at 100 sec and 78 sec with mass consumption 9.5% and 8% respectively. Two other samples were smouldered intensively during the heating period without flaming ignition observed. Their consumed mass was 28 and 31 % after 5 minutes. For increasing heat flux, ignition occurred at 743±7 sec with mass consumption 20.7±0.8 % for all four samples. Infrared video showed that flaming ignition for increasing heat flux started after the phase when the wood sample surface cracked into rectangular areas. This led to the heating of a deeper section of the sample, thus generating more pyrolysis gases, which was indirectly confirmed by the two times greater temperature at 3 mm depth for increasing heat flux. The next step of the proposed research will be to investigate the convective cooling on spontaneous ignition using various types of wood species. Different static and dynamic heating regimes will be used and their influence on the ignition process will be evaluated.

Keywords: spontaneous ignition, wood samples, time-dependent heat flux, ignition time

1. Introduction

Flame spread is an important parameter in the assessment of fire hazards. Ignition and combustion are dependent on the type of the heat flux, whether it is static or variable. The majority of previous research has used static heat flux, despite dynamic heating regimes being commonly observed during structural and wildland fires.

Dynamic fluxes have been tested (Peterson *et al.* 2015; Vermesi *et al.* 2016; Zhai *et al.* 2017) but these studies have generally been limited. Many only use one regime that is simulated to be either increasing, decreasing or parabolic. Most studies use a cone calorimeter or flame propagation apparatus, which have limitations, such as heating conditions and sample size/position (DiDomizio *et al.* 2016; Vermesi *et al.* 2016). Furthermore, the majority of the experiments are conducted for horizontally located samples, which are heated from above in contrast to “classical” fire where the flame propagates horizontally heating the fuel from the side. Chen et al. (2014) demonstrated that ignition time is strongly dependent on sample orientation.

To increase the realism of ignition experiments we experimentally test spontaneous ignition of vertically positioned wood samples subjected to both static and dynamic heat fluxes.

2. Methods

The experiment was conducted using a custom-made Radiative Heat Flux Apparatus (Fig. 1).

The apparatus consists of: 1) radiative panel, 2) linear stage, 3) shutter and PC control system. The radiative panel contains infrared short wave quartz lamps producing radiative heat flux. The radiative panel was installed on a 1.5 m linear stage that allows the panel to move forward or backward, simulating variable heat flux. An infrared camera (FLIR T1050sc) was used to measure temperatures on the exposed surface with frequency 30 Hz and resolution 1024 x 768. An DSLR camera (Canon EOS 600D) was used to film the experiment. Square cypress wood samples with a depth of 19 mm and width of 65 mm were used. Wood boards were cut into 65 mm square samples.

Figure 1 - Radiative Heat Flux Apparatus

One thermocouple was imbedded at a depth of 3 mm from the exposed surface, two thermocouples - 10 mm from the exposed surface and one on the back side of the sample. Samples were dried to a constant mass state using an oven at 104 °C for 48 hours (Kuznetsov and Fil'kov 2011). To avoid the influence of heterogenous wood surface properties (texture, colour etc.) on heat flux absorption, the exposed surface of the sample was coated with lampblack (Kuznetsov and Fil'kov 2011) (fig. 2a). To investigate the influence of convection cooling effect on the ignition time two sample holders were made. One with blocked sides and bottom (fig. 2b) and second without.

a ***b***

Figure 2 - a) Original (left) and blackened (right) sample; b) sample holder to block convection cooling

The sample holder was constructed of two layers of 7.5 mm thick cement board. To prevent the heat loss along the edges of the sample internal layer of 25 mm silica boards was used as an insulation. The entire sample holder was positioned on the scale. Five repetitions were conducted for each condition.

At the first stage, the samples were exposed to 30 kW/m^2 static heat flux during 5 min and increasing heat flux 12.5 min duration. The length of time for the increasing regime was chosen to approximate the integral of the heating function. For the dynamic regime, heat flux was increased by moving the radiative panel with a constant speed of 0.4 mm/sec.

3. Results and discussion

Preliminary results showed that for static heat flux 30 kW/m^2, two out of four samples were ignited at 100 sec and 78 sec with mass consumption of 9.5% and 8 % respectively. Two other samples smouldered intensively during the heating period without flaming ignition. Their consumed mass was 28 % and 31 % after 5 minutes. For increasing heat flux all four samples were ignited at 743±7 sec with mass consumption of 20.7±0.8 %. Infrared video showed that flaming ignition for increasing heat flux started after the phase when the wood sample surface cracked into rectangular areas. This led to the heating of a deeper section of the sample, thus generating more pyrolysis gases, which was indirectly confirmed by the two times greater temperature at 3 mm depth for increasing heat flux. For static heat flux, the average temperature at the time of ignition was 112 °C and for the increasing regime it was 219 °C.

The next step of the proposed research will be to investigate the effects of convective cooling and wood type on spontaneous ignition. Different static and dynamic heating regimes will be used and their influence on the ignition will be evaluated. Further investigation is also required to determine why some samples were not ignited in flaming mode under considered static heat flux.

4. References

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