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DETERMINING THRESHOLD CONDITIONS FOR EXTREME FIRE BEHAVIOUR

Memo on experimental design

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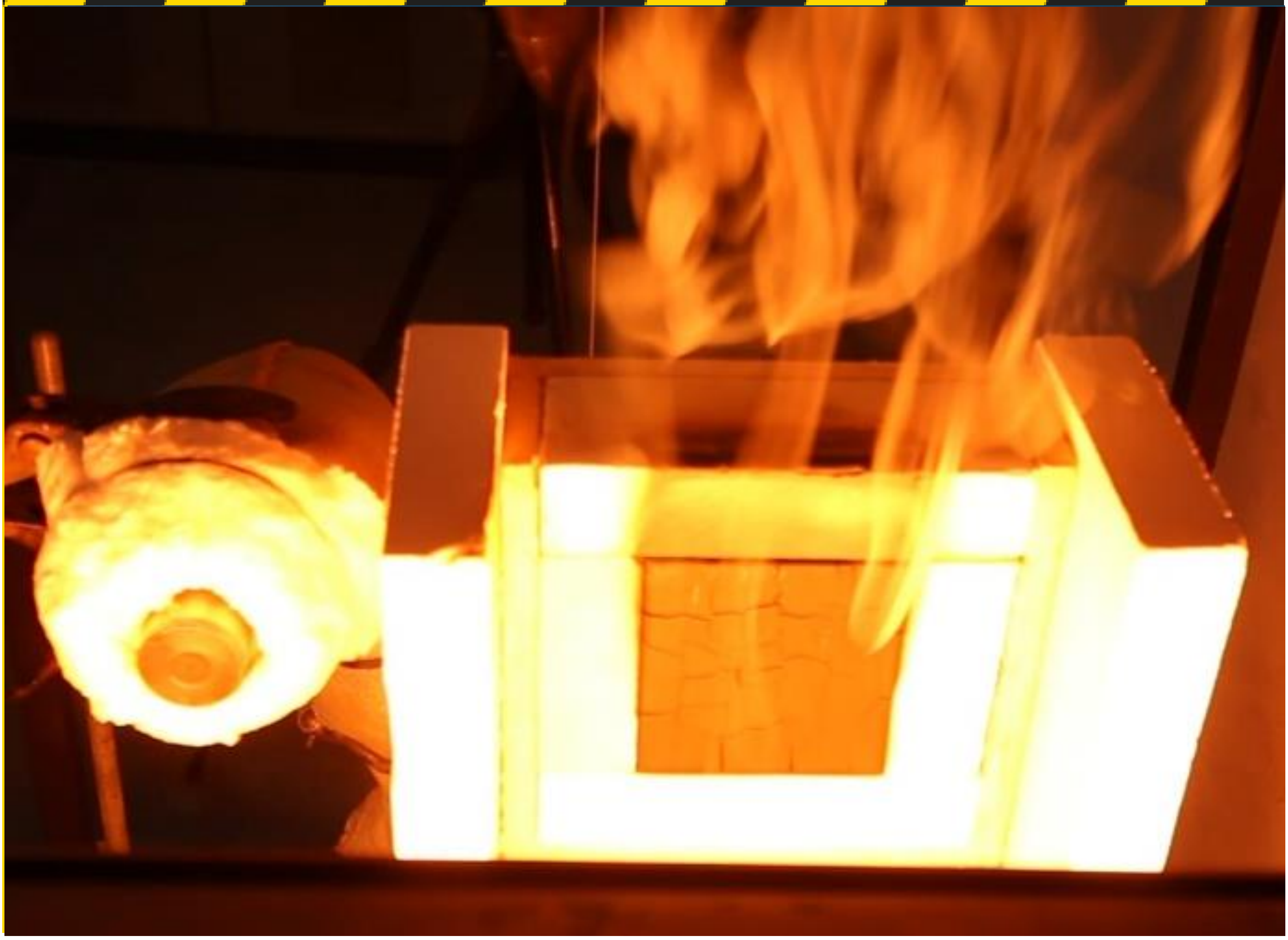

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TABLE OF CONTENTS

INTRODUCTION

Flame spread is an important process in the propagation of bushfires. The likelihood of ignition and combustion rates of fuels are dependent on the type and nature of the heat flux. The majority of previous research has used static heat flux, whereby a consistent heating source is used to ignite samples in a laboratory setting. This is despite the highly dynamic heating regimes typically observed during structural and wildland fires.

Dynamic fluxes have been tested (Vermesi et al. 2016; Peterson et al. 2015; 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, Mulherin, and Weckman 2016; Vermesi et al. 2016). Furthermore, the majority of the past experiments have been conducted on horizontally oriented samples heated from above - in contrast to "classical" fire where the flame propagates horizontally, heating the fuel from the side. Chen et al. (2014) have shown that ignition time is strongly dependent on sample orientation.

We have developed a novel system to better represent the dynamic heat fluxes of real fires in a laboratory setting. In this, we are able experimentally test the spontaneous ignition of vertically positioned wood samples subjected to both static and dynamic heat fluxes.

METHODS

A custom-made Radiative Heat Flux Apparatus (Fig. 1) was developed as part of this project. This has been used for some preliminary heat flux experiments.

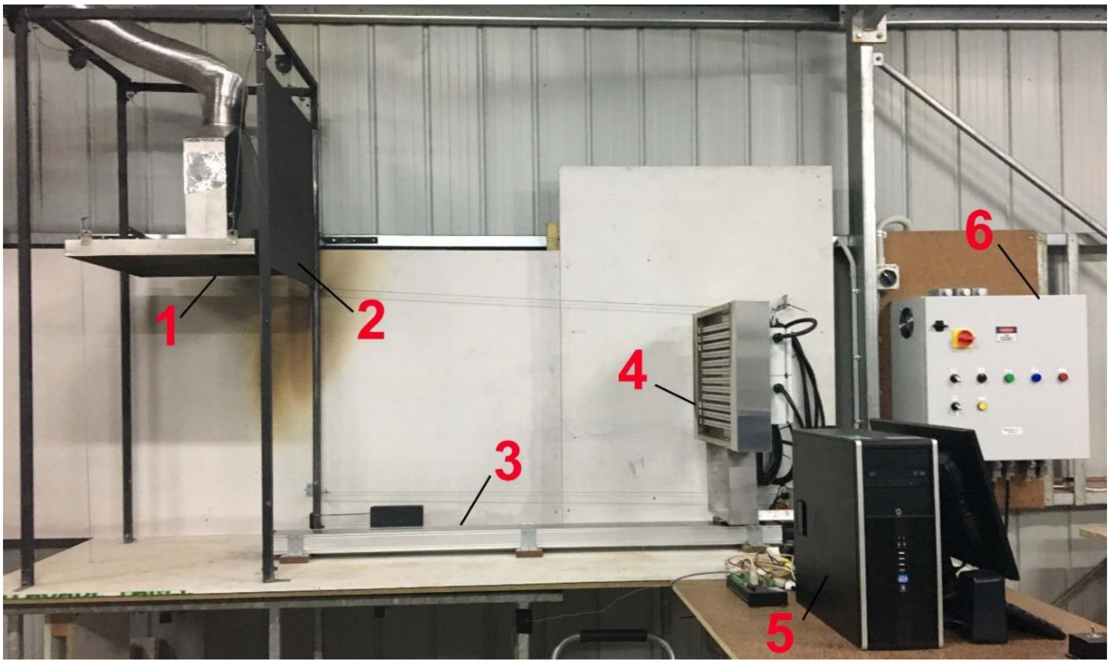

Figure 1 - Radiative Heat Flux Apparatus

The apparatus consists of: 1) an exhaust system, 2) a shutter, 3) a linear stage, 4) a radiative panel, 5) a control system and 6) a power control box. The shutter protects the sample from radiation prior to the experiment. The shutter has two positions, open and closed. A remote control operates the shutter and opens it within 1 s. The radiative panel is installed on the 1.5 m linear stage to allow the panel to be moved forward or backward, simulating variable heat flux. A programmable step motor controller PCL601USB (Anaheim Automation, Inc.) is used to change movement speed within the range of 0.001-0.3 m/s. The radiative panel produces radiative heat flux using 12 shortwave infrared quartz lamps. Each lamp has the following characteristics: draws 2400 W power, has peak wavelengths of 1.2-1.4 μm, has a maximum surface power 150 kW/m^2 and filament temperature of 1800-2200°C. The control system allows the operator to control the conditions of the experiment. The power control box controls the radiant heat flux produced by the lamps.

Two CR1000 dataloggers (Campbell Scientific, Inc.) with frequency of 1 Hz are used to measure thermal characteristics of materials under the study. To measure heat flux, a water-cooled heat flux sensor SBG01-100 (Hukseflux Thermal Sensors B.V.) is used. It was factory calibrated for a heat flux of 100 kW/m2 (± 6.4 %) and has a response time of less than 0.25 s. The system is designed for samples being tested with Type K glass braided insulated thermocouples (OMEGA Engineering Inc.) with stripped leads and diameter of 0.25 mm in accordance to Australian Standard (AS) 1530.4:2014. (Australian Standard 2014). These are used to measure temperatures inside samples and on their surfaces. An infrared camera (FLIR T1050sc) is used to measure temperatures on the exposed surface at a resolution of 1024 x 768 and a frequency of 30 Hz. A DSLR camera (Canon EOS

600D) is used to film the experiments.

The samples being tested are square cypress wood samples with height and width of 65 mm and a depth of 19 mm. One thermocouple is embedded at a depth of 3 mm from the exposed surface, two at a depth of 10 mm and one on the back side of the sample. Before testing samples are 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 is 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 have been designed, one with blocked sides and bottom (fig. 2b) and a second without.

a ***b***

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

The sample holder is constructed of two layers of 7.5 mm thick cement board. To prevent heat loss along the edges of the sample, an internal layer of 25 mm silica boards is used as an insulation. The entire sample holder is positioned on a scale during experimentation to record mass loss.

In preliminary experiments, samples have been exposed to 30 kW/m^2 static heat flux for 5 min and an increasing heat flux for a duration of 12.5 min. The length of time for the increasing regime was chosen to approximate the integral of the heating function. For the dynamic regime, the heat flux was increased by moving the radiative panel closer to the sample with a constant speed of 0.4 mm/sec.

In a second stage of experimentation influence of convective cooling on the autoignition of samples will be tested, as well as additional heating regimes.

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