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Ignition of Mulch by Firebrands in Wildland/Urban Interface (WUI) Fires[1]

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INTRODUCTION

Firebrands are produced as trees and structures burn in wildland/urban interface (WUI) fires. These firebrands are entrained in the atmosphere and may be carried by winds over long distances. Hot firebrands may ignite fuels far removed from the fire, resulting in fire spread. This process is commonly referred to as spotting.

It is believed that firebrand showers created in WUI fires may ignite vegetation and mulch located near homes and structures. This, in turn, may lead to ignition of homes and structures due to burning vegetation and mulch. Understanding these ignition events due to firebrands is important to mitigate fire spread in communities (Pagni, 1993).

Unfortunately, ignition due to spotting is one of the most difficult aspects to understand in these fires (Babrauskas, 2003). As a result, the ignition of fuels due to firebrand impact has been investigated, but a limited number of laboratory studies are available in the open literature (Babrauskas, 2003).

The goal of this study is to understand how lofted firebrands created by WUI fires ignite the impacted fuel bed. This paper describes an apparatus that has been constructed to investigate the ignition propensity of the materials due to the impingement of firebrands. This apparatus has been used to determine the ignition propensity of structural materials due to firebrand impact (Manzello *et al*., 2004; Manzello *et al*., 2005 a,b,c). The apparatus was designed to be implemented into the Fire Emulator / Detector Evaluator (FE/DE). The Fire Emulator / Detector Evaluator, or FE/DE, was used here as a wind tunnel to investigate the influence of an air flow on the ignitability of fuel beds.

Shredded hardwood mulch was used as the test fuel bed for these experiments. Such mulch is commonly used in the United States of America. The moisture content of this material was varied. The total number of firebrands deposited upon the fuel beds was varied to assess the influence of multiple firebrand contact on ignition propensity. Ignition regime maps were generated for the material tested as a function of impacting firebrand size, number of deposited firebrands, air flow, and material moisture content.

EXPERIMENTAL DESCRIPTION

Figure 1 is a schematic of the experimental apparatus used for the firebrand impact studies. The firebrand ignition apparatus consists of four butane burners and a firebrand mounting probe. The butane flow rate is controlled by a metering valve coupled to a solenoid valve. The firebrand, or in the case of multiple firebrand impact, firebrands, are held into position and the air pressure is activated, which moves the actuator and clamps the firebrand(s) into position.

The experimental apparatus was designed to simultaneously release and deposit multiple firebrands. Up to 4 firebrands were loaded into the firebrand ignition apparatus. Further details of the apparatus are given elsewhere (Manzello *et al*., 2004; Manzello *et al*., 2005 a,b,c)

The firebrand ignition apparatus was installed in the duct of the FE/DE. The FE/DE is described elsewhere (Grosshandler, 1997; Cleary *et al*., 2000) and was used here as an air flow source for the experiments. The FE / DE allowed for air flow rates up to 3 m/s and these velocities were verified through laser doppler velocimetry (LDV) measurements.

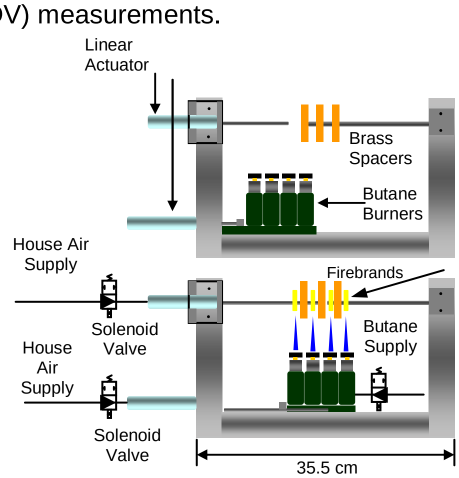

Fig. 1 Schematic of the firebrand ignition and release apparatus.

Firebrands were simulated by machining wood into sections of uniform geometry. Both the size and shape are important factors as it is these properties that determine the lofting characteristics and burn time of the firebrands (Tarifa *et al*., 1967; Woycheese, 2001).

Firebrands were simulated as disks of two different sizes. The first size used was 25 mm in diameter with a thickness of 8 mm. The second size used was 50 mm in diameter and 6 mm thick. Disks are believed to be a representative shape that can easily be generated in WUI fires (Woycheese, 2001). Disks of this size range are capable of being lofted over long distances (Woycheese, 2001)

Ponderosa Pine (*pinus ponderosa*) was selected as the wood type for these experiments since it is abundant in the Western United States and it is here that WUI fires are most prevalent. Prior to machining the disks, the ponderosa pine planks were stored in a conditioning room at 21 °C, 50 % relative humidity. After the disks were machined, they were stored in the conditioning room prior to the experiments.

Shredded hardwood mulch beds were used as test fuel beds for the ignition experiments. The impact of burning firebrands on shredded hardwood mulch beds was designed to simulate the showering of firebrands into mulch beds near homes and structures. The shredded hardwood mulch beds were contained in aluminum foil pans of 23 cm long by 23 cm wide by 5.1 cm deep. The moisture was varied from 0 % to 11 %. The moisture content was determined by oven drying the samples. It was found that three hours of oven drying at 104 °C was sufficient to remove all the moisture in the shredded hardwood mulch beds.

The firebrand ignition process and release onto the target fuel beds was captured using a CCD camera coupled to a zoom lens as well as digital still photography.

RESULTS AND DISCUSSION

The firebrands were released onto the target fuel beds in both a flaming state and a glowing state. It has been suggested that firebrands fall at or near their terminal settling velocity. When firebrands contact ignitable fuel beds, they are *most likely* in a state of glowing combustion, not open flaming (Waterman and Takata, 1969; Tarifa *et al*., 1967). It is possible for firebrands to remain in a flaming state under an air flow and therefore it is reasonable to assume that some firebrands may still be flaming upon impact. As a result, the ignition propensity of the shredded hardwood mulch beds was assessed based upon *both* glowing and flaming firebrand impact.

Experiments were performed for single firebrand impact (both flaming and glowing) to investigate whether it was possible to ignite fuel beds under such conditions. Figure 2 displays a characteristic image of a glowing firebrand which was released onto the shredded hardwood mulch beds. The results obtained for single glowing firebrand impact into shredded hardwood mulch beds is displayed in table 1. Each result was based on identical, five repeat experiments. The acronym NI denotes no ignition. For the firebrand sizes tested and the experimental combination tested, it was not possible to ignite shredded hardwood mulch beds from single glowing firebrand impact. After the firebrand impacted the shredded hardwood mulch bed, one or two pieces of mulch would smolder and the smolder front would not propagate further in the bed.

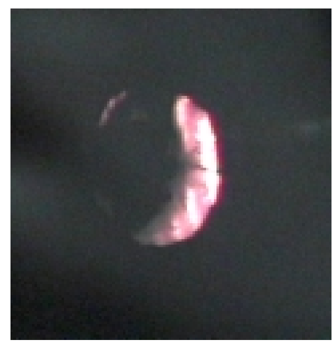

Fig. 2 Glowing firebrand, d_0 = 25 mm

Table 2 displays the results for single flaming firebrand impact onto shredded hardwood mulch beds. To produce flaming firebrands, the firebrands were ignited and then allowed to free burn for 30 s prior to release into the samples. The acronym FI denotes flaming ignition. From these tables, it was possible to produce flaming ignition for single firebrand impact when the firebrands were released in a flaming state onto dried shredded mulch beds. When the shredded hardwood mulch beds were held at 11 % moisture, it was not possible to sustain a flaming ignition. The shredded hardwood mulch would ignite (by flaming) for 5 s and quickly self extinguish. These results demonstrate that moisture content is important in order to begin an ignition event in this material. The ignition process due to a single flaming firebrand impacting onto a dried shredded hardwood mulch bed is shown in figure 3.

Table 1 Glowing firebrand ignition data for single firebrand impact onto shredded hardwood mulch.

Size (mm)	Hardwood Mulch (dry)	Hardwood Mulch (11 %)
25	NI	NI
50	NI	NI

0.5 m/s

Size (mm)	Hardwood Mulch (dry)	Hardwood Mulch (11 %)
25	NI	NI
50	NI	NI

1.0 m/s

Fig. 3 Single flaming firebrand which produced flaming ignition in dried shredded hardwood mulch bed, d_0 = 50 mm.

Table 2 Flaming firebrand ignition data for single firebrand impact onto shredded hardwood mulch beds.

Size (mm)	Hardwood Mulch (dry)	Hardwood Mulch (11 %)
25	FI	NI
50	FI	NI

0.5 m/s

Size (mm)	Hardwood Mulch (dry)	Hardwood Mulch (11 %)
25	FI	NI
50	FI	NI

1.0 m/s

The single firebrand results suggest that a shower of firebrands is required to ignite shredded hardwood mulch beds. Therefore, based upon these findings, the flux of firebrands is clearly an important parameter which must be considered.

Consequently, the experiments were repeated, but now multiple firebrands were deposited upon shredded hardwood mulch beds. Single flaming firebrands were able to ignite dried shredded hardwood mulch beds, thus multiple flaming firebrand experiments were not conducted for dried shredded hardwood mulch.

Table 3 displays results obtained for multiple glowing firebrand impact upon shredded hardwood mulch beds. From the table, the deposition of four 25 mm glowing firebrands did not produce an ignition event under the conditions tested. For the 50 mm glowing firebrands, smoldering ignition was observed to occur when four firebrands were deposited onto dried shredded hardwood mulch beds under an all air flows tested. When four 50 mm firebrands were deposited onto dried shredded hardwood mulch beds, smoldering was observed followed by a transition to flaming combustion under an air flow of 1.0 m/s. Four glowing firebrands were unable to ignite shredded hardwood mulch with a moisture content of 11 %. Figure 4 displays an image of transition to flaming combustion that occurred in dried shredded hardwood mulch, due to glowing firebrand impact.

Fig. 4 Transition to flaming combustion in dried shredded hardwood mulch bed. Four (d_0 = 50 mm) glowing firebrand were deposited.

Table 4 displays results for multiple flaming firebrand impact onto shredded hardwood mulch beds. As mentioned, single flaming firebrands were able to ignite dried shredded hardwood beds, but were unable to ignite shredded hardwood mulch beds at 11 % moisture. A flux of four flaming 50 mm firebrands was unable to ignite shredded hardwood mulch at 11 % moisture.

Table 3 Glowing firebrand ignition data for multiple (four) firebrand impact into shredded hardwood mulch beds.

Size (mm)	Hardwood Mulch (dry)	Hardwood Mulch (11 %)
25	NI	NI
50	SI	NI

0.5 m/s

Size (mm)	Hardwood Mulch (dry)	Hardwood Mulch (11 %)
25	NI	NI
50	SI To FI	NI

1.0 m/s

Table 4 Flaming firebrand ignition data for multiple (four) firebrand impact into shredded hardwood mulch beds.

Size (mm)	Hardwood Mulch (dry)	Hardwood Mulch (11 %)
25	FI	NI
50	FI	NI

0.5 m/s

Size (mm)	Hardwood Mulch (dry)	Hardwood Mulch (11 %)
25	FI	NI
50	FI	NI

1.0 m/s

The following conclusions were drawn from the shredded hardwood mulch bed experiments. Glowing firebrands were able to ignited shredded hardwood mulch beds only if a flux of four 50 mm fire brands was applied and the mulch beds were dried. Single flaming firebrands were able to ignite dried shredded hardwood mulch beds. It was not possible to sustain ignition for shredded hardwood mulch beds held at 11 % moisture.

CONCLUSIONS

This paper has described the ignition propensity of materials due to the impingement of firebrands. Firebrands were simulated by machining wood (*pinus ponderosa*) into small disks of uniform geometry and the size of the firebrands was varied. Firebrands were suspended and ignited within the test cell of the FE/DE apparatus. The Fire Emulator / Detector Evaluator (FE/DE) was used to investigate the influence of an air flow on the ignition propensity of a fuel bed.

Shredded hardwood mulch a used as the test fuel beds for the ignition experiments. The moisture content of the shredded hardwood mulch was varied. The total number of firebrands deposited upon the fuel beds was varied to assess the influence of multiple firebrand contact on ignition propensity. Ignition regime maps were generated as a function of impacting firebrand size, number of deposited firebrands, air flow, and material moisture content. The sizes of the firebrands, degree of the air flow, and moisture content of the shredded hardwood mulch beds were important parameters in determining ignition. It is desired that these results, in conjunction with other literature studies, will be used to validate firebrand ignition models.

ACKNOWLEDGEMENTS

The support of Dr. William Mell, Dr. Ronald Rehm, Mr. Alexander Maranghides and Dr. William Grosshandler of BFRL-NIST is appreciated.

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