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Investigating Conifer Tree Flame Spread Under an Applied Wind Field

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Abstract

The most well-known type of large outdoor fires are wildland fires that spread into developed, urban areas, known as wildland-urban interface (WUI) fires. More than a decade ago, the state of California in the USA identified the need to develop an approach to harden communities to WUI fires exposure. The term harden simply indicates to make infrastructure in communities more ignition resistant. The premise has its roots in the development of standards and codes developed to mitigate urban fire disasters that were observed in the USA, such as the 1871 Great Chicago Fire or 1904 Baltimore Fire. The urban fire codes and standards provide the basis for fire resistant construction in many countries throughout the world. In the USA, the concept of WUI fire building codes and standards is far newer, due to the more recent WUI fire problem in this country. It is important to note that the exposure conditions used in these test methods are best guess estimates of what exposure conditions would be in a WUI fire and were developed with the best available information at that time. For these reasons, it is not surprising WUI communities will continue to be lost in the future. The lack of physical understanding is a major barrier to developing computational methods to be able to predict and understand how WUI fires spread well as develop sorely needed scientifically-based building codes and standards need to ensure resilience to these threats. There has been little in the way of quantification of firebrand production from vegetative fuel sources. Three ignition sources were utilized. The first considered a custom propane burner, the second made use of firebrand showers using a custom firebrand generator, and the third utilized one tree to ignite another tree. In this short paper, some results are presented using the firebrand generator igntion method for one conifer tree species, Douglas-fir.

1. Introduction

The large outdoor fire problem is a global issue that shows no signs of stopping in the future. The most well-known type of large outdoor fires are wildland fires that spread into developed, urban areas, known as wildland-urban interface (WUI) fires. In the USA, the size of areas burned in 2020 is simply staggering. In California, the August Complex fire itself consumed more than 1 million acres. WUI fires continue to occur throughout the Americas, Australia, Europe, and in Asia. Studies have linked climate change to increased wildland fire hazards [Abatzoglou, and Williams, 2016]. Significant WUI fires were observed in South Korea in 2019 [Lee and Lee, 2020] and in Australia in 2019 and 2020 [Deb et al., 2020]. It is important to distinguish WUI fires from wildland fires [Mell et al., 2010]; WUI fires include the combustion of both vegetative fuels and entire communities whereas wildland fires include the combustion of vegetative fuels and occur in uninhabited areas. Estimates place at least 70,000 communities, nearly 46 million structures at risk from WUI fires, which amounts to nearly 120 million people in the USA [Manzello *et al*., 2018].

More than a decade ago, the state of California in the USA identified the need to develop an approach to harden communities to WUI fires exposure. The term harden simply indicates to make infrastructure in communities more ignition resistant. The premise has its roots in the development of standards and codes developed to mitigate urban fire disasters that were observed in the USA, such as the 1871 Great Chicago Fire or 1904 Baltimore Fire. The urban fire codes and standards provide the basis for fire resistant construction in many countries throughout the world. In the USA, the concept of WUI fire building codes and standards is far newer, due to the more recent WUI fire problem in this country. Developing test standards for outdoor fire exposures presents significant challenges. Based on post-fire studies of ignition vulnerabilities in WUI fires, standard test methods were devised by the office of the State Fire Marshal (SFM) in California to address ignition vulnerabilities to exterior walls, exterior windows, horizontal projections such as eaves, decking assemblies, and the use of ignition resistant materials. It is important to note that the exposure conditions used in these test methods are best guess estimates of what exposure conditions would be in a WUI fire and were developed with the best available information at that time. For these reasons, it is not surprising WUI communities will continue to be lost in the future. To put in it lightly, the science is not there and is dangerous to even reside in many places in California or other areas prone to WUI fires. The international standards organization (ISO) has just begun to address the large outdoor fire problem, as WUI fires are occurring all over the globe [Manzello, 2020].

An important missing piece to better grasp WUI fire spread processes are firebrands. Firebrands are new far smaller combustible fragments from the original fire source. Firebrands signifies any hot object in flight that are capable to ignite other fuel types. Firebrands are produced or generated from the combustion of vegetative and structural fuels. Firebrand processes include generation, transport, deposition, and ignition of various fuel types, leading to fire spread processes at distances far removed from the original fire source. There has been little in the way of quantification of firebrand production from vegetative fuel sources [Manzello *et al*., 2020]. The lack of physical understanding is a major barrier to developing computational methods to be able to predict and understand how WUI fires spread well as develop sorely needed scientifically-based building codes and standards need to ensure resilience to these threats. In this study, discrete fuel packages, manifested as conifer trees, were spaced apart, and the flame spread processes through these fuel packages were observed under an applied wind field. The experiments were conducted using wind facilities at the National Research Institute of Fire and Disaster (NRIFD) in Japan. Three ignition sources were utilized. The first considered a custom propane burner, the second made use of firebrand showers using a custom firebrand generator, and the third utilized one tree to ignite another tree. In this short conference paper, some results are presented using the firebrand generator igntion method for one conifer tree species.

2. Experimental Description

There was interest to see if firebrand showers alone could result in tree ignition and combustion. For these experiments, the reduced-scale firebrand generator was used to generate firebrand showers (see **Figure 1**). The firebrand generator has the ability to produce continuous firebrand showers. In this experimental series, Japanese cypress chips were used to produce firebrands. For a detailed description of the firebrand generator technology and procedures, please see Suzuki and Manzello (2017). A brief description is provided here.

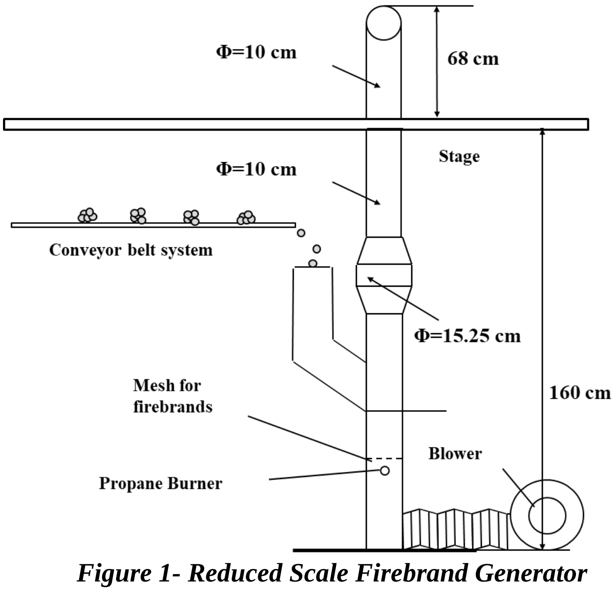

Figure 1- Reduced Scale Firebrand Generator

The reduced-scale continuous-feed firebrand generator consisted of two parts; the main body and continuous feeding component. The capability of a smaller-sized firebrand generator to develop continuous firebrand showers has been described [Suzuki and Manzello 2011]. Japanese Cypress wood chips, which represent firebrands generated from *structures*, and Douglas-fir wood pieces, which represent firebrands generated from *vegetation*, were used to produce firebrands. The Japanese Cypress wood chips had dimensions of 28 mm ±7.5 mm (L) by 18 mm ± 6.3 mm (W) by 3 mm ± 0.8 mm (H) (average ± standard deviation), respectively, before combustion. These were provided from a supplier and filtered to remove really small wood chips by using a 1

cm mesh. Douglas-fir wood pieces were machined to dimensions of 7.9 mm (H) by 7.9 mm (W) by 12.7 mm (L). Similar to the authors' prior full-scale studies, firebrands made from Japanese Cypress wood chips have approximately double the projected areas at a certain mass, compared to firebrands generated from Douglas-fir wood pieces as also seen in [Suzuki and Manzello, 2017]. The difference of wind speeds on characteristics was not observed. In this case, a tree was placed at Δx = 500 mm, from the exit of firebrand generator, similar to prior work that exposed structural fuels to firebrand showers **[**Suzuki and Manzello 2017].
In this short paper, the confier tree species used was Douglas-fir. These trees were collected a tree farm in Japan. The trees were not being grown for inside use. Nearly all the previous confier tree research in laboratory settings used conifers that were collected from Christmas Tree farms in order to have a full, uniform tree for easy comparison. Rather, in these experiments, it was of interest to determine if a tree growing in a more natural state may be ignited by wind-driven firebrand showers.

3. Results and Discussion

Figure 2 displays the results for the interaction of firebrand showers and a Douglas-fire tree of 1.5 m in height. In this experiment, the applied wind speed was 4 m/s. The firebrand generator was fed with Japanese Cypress wood chips to simulate an attack from a near-by adjacent structure. It is interesting to observe that even conifer trees with an open shape may be ignited from firebrand showers. As will be presented at the conference, the authors have recently investigated conifer tree ignition processes under and applied wind field for Nobel-fir conifers [Manzello and Suzuki 2021]. For both species, ignition was possible from firebrand showers. Perhaps the most striking feature is that combustion dynamics are vastly different under an applied wind.

Figure 2- Douglas-fir tree ignited by the firebrand generator under a 4 m/s wind

4. Summary

An important missing piece to better grasp WUI fire spread processes are firebrands. Firebrands are new far smaller combustible fragments from the original fire source. There has been little in the way of quantification of firebrand production from vegetative fuel sources. In this study, discrete fuel packages, manifested as conifer trees, were spaced apart, and the flame spread processes through these fuel packages were observed under an applied wind field. The experiments were conducted using wind facilities at the National Research Institute of Fire and Disaster (NRIFD) in Japan. Three ignition sources were utilized. The first considered a custom propane burner, the second made use of firebrand showers using a custom firebrand generator, and the third utilized one tree to ignite another tree. In this short paper, some results were presented using the firebrand generator igntion method for one conifer tree species, Douglas-fir. Results indicated that it was possible to ignite Douglas-fir trees using wind-driven firebrand showers. Once ignited, the combustion dynamics of a real-scale tree combusting under wind were markedly different than all the studies performed under no-wind conditions.

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