Experimental Study of Firebrand Transport

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1. Introduction

The NIST Firebrand Generator (NIST Dragon) has been used to quantify the vulnerability of structures to ignition by firebrand attack. The Firebrand Generator is also a useful device to study firebrand transport, and has been used to validate firebrand transport models. During this series of firebrand transport experiments, the Firebrand Generator was fed with wood cubes of uniform size. The glowing firebrands generated from the combustion of these wood cubes were collected in an array of water-filled pans that were arranged to collect the bulk of the lofted firebrands. The pan arrangement was determined from repeated preliminary studies. These experiments were performed over a range of wind speeds (up to 9 m/s) to determine the lofting distance of the firebrands generated. The major change in these experiments from prior work was that, for a given wind speed, the firebrand size and mass was determined at each pan location. In the past, it was only possible to determine the number distribution; specifically the number of firebrands at each spatial location was counted (not resolved at every pan but only across a given row of pans). Statistical analysis indicated that a normal distribution was able to capture the number/mass percentage versus horizontal distance. This study will provide even greater fidelity measurements to validate firebrand transport models, and provide further insights into the operation of the Firebrand Generator.

2. Experimental description

The wood cubes, 2.1 kg in total mass, were deposited into the Firebrand Generator. After the wood cubes were loaded, the top section of the Firebrand Generator was coupled to the main body of the apparatus. The blower was then switched to provide a low flow for ignition. The two propane burners were then ignited individually and simultaneously inserted into the side of the Firebrand Generator. This sequence of events was selected in order to generate a continuous flow of glowing firebrands for up to 4 minutes duration.

The Firebrand Generator was installed inside the Fire Research Wind Tunnel Facility at BRI. To track the evolution of the size and mass distribution of firebrands produced, a series of water-filled pans was placed downstream of the Firebrand Generator. A total of 277 rectangular pans were arranged in 40 rows and filled with water to quench burning firebrands. Each pan was 49.5 cm long and 29.5 cm wide. The arrangement and width of the pans was not random; rather it was based on scoping experiments to determine locations where the firebrands would most likely land. In comparison with [1], the Firebrand Generator was raised by 0.5 m off the ground, and the test section was extended by 9.85 m to accommodate more collection pans.

After each test, the firebrands were filtered from the water using a series of fine mesh, and then dried in an oven at 104 °C for eight hours. The mass of each firebrand was measured by a precision balance with 0.001 g resolution. Repeat measurements of known calibration masses were measured by the balance which was used for the firebrand mass analysis. The standard uncertainty in the firebrand mass was approximately ± 1%.

Image analysis software was used to determine the projected area of a firebrand by converting the pixel area using an appropriate scale factor (MATROX image analysis software) [2]. It was assumed that deposited firebrands would rest flat on the ground and the projected areas with the maximum dimension and the second maximum dimension of three dimensions were measured (for cylindrical and flat shaped firebrands respectively) [2]. Images of well-defined shapes (*e.g.* circular objects) were used to determine the ability of the image analysis method to calculate the projected area [2]. Based on repeat measurements of different areas, the standard uncertainty in determining the projected area was ± 10 %.

A precision caliper with 1/1000 mm resolution was used to measure the height of each firebrand in the direction perpendicular to the projected area. For all the analyses in this study, the projected area and height were the maximum values for each firebrand. About 15,000 collected firebrands were sized and weighed.

3. Results and Discussions

The total mass of firebrands generated was measured as a function of wind speed. When the wind speed was increased from 0 m/s to 9 m/s, the total firebrand mass was measured as 93 g, 57 g and 63 g, respectively, and corresponded to 4.4% (at 0 m/s), 2.7% (at 6 m/s) and 3.0% (at 9 m/s) of the total wood pieces loaded. From video records, a significant number of firebrands were lofted outside the measurement location (downstream) at 6 m/s and 9 m/s. In addition, it is possible that several firebrands were also burned completely before reaching the pans at the higher velocities. The reduction in mass at 6 m/s and 9 m/s must have been due to a combination of these effects. It is interesting to observe that no significant change was observed in the total mass of firebrands collected as the wind speed was increased from 6 m/s to 9 m/s. Yet, as shown in **Fig. 1**, the percentage of firebrands with the lowest mass was the largest under 9 m/s wind speed, whereas the 0 m/s situation held the largest percentage of largest mass firebrands.

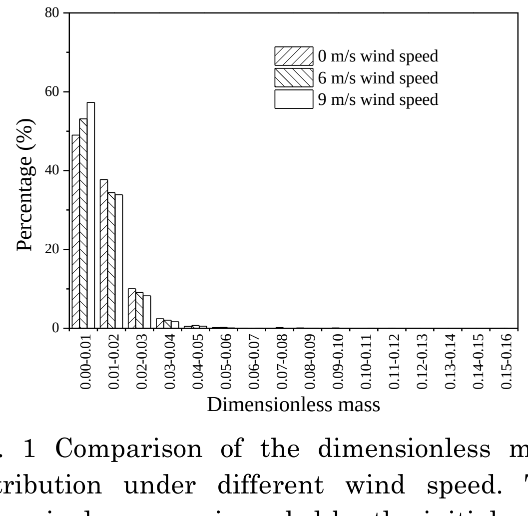

Fig. 1 Comparison of the dimensionless mass distribution under different wind speed. The dimensionless mass is scaled by the initial wood piece mass, i.e. 1.44 g.

The average mass of each firebrand produced was 17 mg ±12 mg (0 m/s; average ± standard deviation), 15 mg ± 14 mg (6 m/s), and 15 mg ± 11 mg (9 m/s). The average projected area of each firebrand produced was 0.37 ± 0.17 cm^2 (0 m/s), 0.33 ± 0.18 cm^2 (6 m/s), and 0.34 ± 0.16 cm^2 (9 m/s). The height of each firebrand produced was 0.35 ± 0.29 cm (0 m/s), 0.33 ± 0.16 cm (6 m/s), and 0.33 ± 0.12 cm (9 m/s). It is interesting to observe that little or no change was also observed in the average mass, and projected area of each firebrand generated as the wind speed increased from 6 m/s to 9 m/s.

In this study, the wind speed determined the maximum distance that the firebrand traveled, as well as the landing range of the maximum number/mass percentage. As shown in **Fig. 2**, the firebrands were collected as far as 3.3 m, 7.3 m, and 11.8 m under the effect of 0 m/s, 6 m/s and 9 m/s wind speed, respectively. The landing regimes of maximum number percentage are 0.8 -1.3 m, 1.3-1.8 m, and 2.8-3.3 m for 0 m/s, 6 m/s and 9 m/s wind speed, respectively. It is of great interest to note that the profile of the number/mass percentage versus distance scattered smoothly as the wind speed increases.

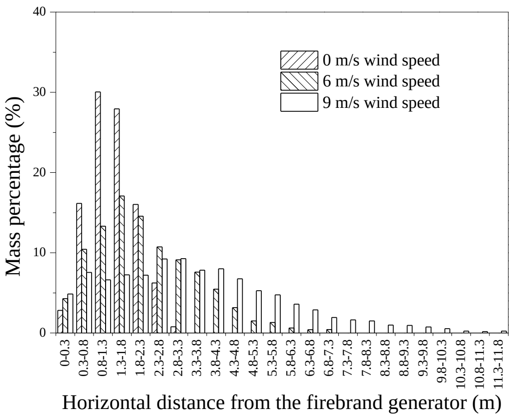

Fig. 2 Comparison of the mass percentage versus distance under different wind speeds.

In order to mathematically quantify the wind effect, the Gaussian function (*i.e.* normal distribution) was tested for depicting the number/mass percentage versus distance.

4. Summary

This paper presents a systematic study on the character of firebrands produced from the Firebrand Generator loaded with cube wood pieces under the effect of different wind speeds.

5. References

1. S. L. Manzello et al., Fire Safety J. 43 (4) (2008) 258-268
2. S. Suzuki; S. L. Manzello; M. Lage; G. Laing, Int. J. Wildland Fire 21 (8) (2012) 961-968.