DETERMINING TEMPORAL EVOLUTION OF MASS LOSS PROFILES FROM MOCK-UPS OF STRUCTURAL COMPONENTS

Samuel L. Manzello[1] and Sayaka Suzuki[2]
[1]National Institute of Standards and Technology (NIST), USA
[2]National Research Institute of Fire and Disaster (NRIFD), Japan

1. INTRODUCTION

Wildland fires that spread into urban areas, termed Wildland-Urban Interface (WUI) fires, are becoming more and more common across multiple locations of the world. The 2018 WUI fires in the US state of California demonstrated the shear destruction that WUI fires are capable of by destroying more than 18,800 structures and resulting in multiple fatalities [1]. In 2020, the situation grew even worse, with multiple fires reported all over the Western US. WUI fires are one example of large outdoor fires. In Japan, urban fires have been the main large outdoor fire problem for centuries.

An important component in rapid spread of large outdoor fires is the production or generation of new, far smaller combustible fragments from the original fire source referred to as firebrands. 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. While the term ember has been used to sometimes indicate the same connotation as firebrand, these terms are in fact slightly different. For WUI fires, the production of firebrands occurs from the combustion dynamics of vegetative and man-made fuel elements, such as homes. In the case of urban fires, the main culprit in firebrand production are homes.

The authors have shown that mock-ups of full-scale roofing assemblies may provide insights into firebrand generation from actual, full-scale roofing assemblies [2-3]. Here, the work has been extended to begin to understand more details of the combustion process of mock-ups of full-scale assemblies. The wind effect was explored on the temporal evolution of mass loss profiles for mock-ups of full-scale roofing assemblies.

2. EXPERIMENTAL DESCRIPTION

A series of experiments with mock-ups of full-scale roofing assemblies was performed in a wind facility in the National Research Institute of Fire and Disaster (NRIFD). NRIFD's wind facility has a 4 m diameter fan. The flow field was measured to be within ± 10 % (two standard deviations) over a cross-section of 2.0 m by 2.0 m. Experiments were performed within this cross-section.

Mock-ups used in this study were roofing assemblies, constructed with oriented strand board and wood studs, with the dimensions of 0.61 m (W) x 0.61 m (H). As a first step, specific roofing treatments, such as roof tiles, were not applied. The mock-up assembly is half the height and width of the full-scale roofing assemblies (1.2 m by 1.2 m). The roofing angle was fixed at 25° (**see Figure 1**). The entire mock-up roofing assembly was placed on top of a load cell. Care was taken to protect the load cell from the heat generated from the combustion process. The assemblies were placed on top of gypsum board custom cut and sized to shield the load cells from the combustion process. The load cell was calibrated using a series of known mass samples prior to the experiments.

Experiments were performed in the following manner. Mock-up assemblies were ignited by a T-shaped burner with heat release rate (HRR) of 32 kW ± 10 % (two standard deviations) for 10 min. The reason to ignite under no wind was to provide consistent flame contact area for the assembly ignition for all experimental cases, independent of the wind speed. These afforded repeatable ignition conditions.

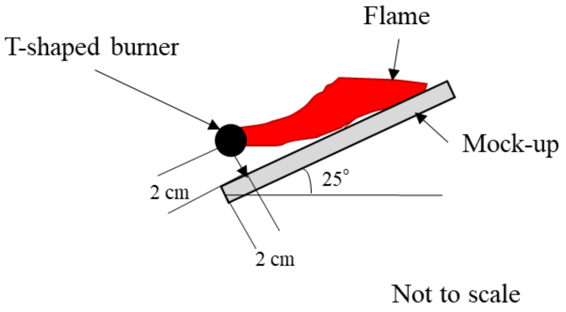

Figure 1 Schematic of the mock-up roofing assemblies used for the experiments. Side view is shown. Oriented strand board (OSB) was used as base sheathing.

After the burner was turned off, a desired wind speed (6 m/s or 8 m/s) was applied. Experiments were stopped when the combustion of the assemblies was completed, or the assemblies were not able to support themselves anymore.

3. RESULTS AND DISCUSSIONS

Experiments were conducted for wind speeds of 6 m/s and 8 m/s. **Figure 2** displays the temporal evolution of mass loss for roofing assembly mock-ups at 6 m/s and 8 m/s. It is natural to assume that as the wind load was applied, this would result in artificial load on the mock-up assembly and this would influence the measured mass loss. To reduce this affect, the wind was turned on with the mock-up roofing assembly in place to determine the degree of actual offset. This offset was then subtracted from the measured mass loss profiles. The standard uncertainty in the temporal evolution of mass loss was approximately ± 5 % (two standard deviations).

The results are interesting as increases in attendant wind speed produce a faster reduction in the measured mass loss from the mock-up roofing assemblies. It is now possible to couple the temporal evolution of mass loss profiles to the measured size and mass distributions of firebrands liberated from the mock-up assemblies.

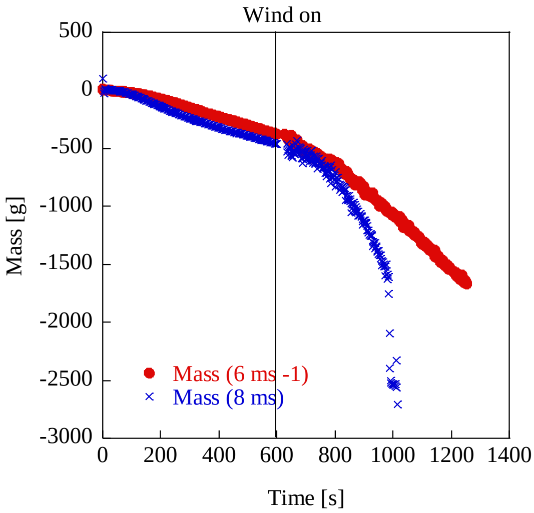

Figure 2 The temporal evolution of mass loss determined for mock-up roofing assemblies combusting under wind.

4. PRACTICAL IMPLICATIONS

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. Developing test standards for outdoor fire exposures presents significant challenges.

The main ignition mechanisms of structures from large outdoor fire exposures are due to direct flaming combustion contact, radiant heat, and firebrand exposure. Direct flaming combustion contact refers to the situation where a structural component is in direct contact with flaming combustion from an adjacent combusting fuel source. Radiant heat is a form of electromagnetic radiation that is emitted from sufficiently hot materials. Due to the combustion of fuels in large outdoor fires, any fuel type in close proximity to these combustion processes will experience radiant heat that may lead to ignition of these adjacent fuels.

Firebrand exposure is a dominant mechanism to structure ignition in large outdoor fires but global test methods for firebrands are lacking and are underway in ISO TC92/WG14 [4]. ISO TC92 has approved the development of an ISO standard firebrand generator for firebrand shower exposure. A current missing piece are simplified test methods that afford the ability to rank and rate building materials and vegetation for firebrand production.

5. SUMMARY

The wind effect was explored on the temporal evolution of mass loss profiles for mock-ups of full-scale roofing assemblies. The new experimental measurements have elucidated the influence of wind on the temporal evolution of mass loss for simplified structural components. Coupling these measurements with those of firebrand production from mock-ups of roofing assemblies are important to not only better understand the firebrand generation processes from structural fuels, but are also needed to develop new standard test methods to rank and rate building materials for the propensity for firebrand production.

5. REFERENCES

[1] Shulze, S., *et al.* (2020) Natural Hazards,104-901-905.

[2] Suzuki, S., Manzello, S.L. (2021) J. of Cleaner Production. 130: 135-140.

[3] Suzuki, S., and Manzello, S.L. (2020) Fuel 267:117154.

[4] ISO TC92/WG214 (Large Outdoor Fires and The Built Environment Working Group) https://www.iso.org/committee/50492.html (accessed on Feb 15, 2021).