FINDINGS

Validation of firebrand model in fire dynamic simulator with tree burning experimental data, and quantifying firebrand landing and heat flux on structures.

Physics-based simulation of firebrand and heat flux on structures in the context of AS3959

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Is it feasible to model firebrand and heat load on structures in the wildland-urban interface (WUI) using a physics-based model?

Introduction

Quantifying the firebrand and heat flux on structures is essential to determine the wildfire risks and prepare plans to mitigate the hazard. We endeavour to use a physics-based model, Fire Dynamic Simulator (FDS) to map firebrand and heat flux to determine the vulnerability of structures in the wildland-urban interface(WUI).

- We have validated FDS' tree burning and firebrand transporting sub-models against the experiment conducted in no wind condition at the National Institute of Standards and Technology (NIST).
- Subsequently, the input number, direction, and velocities of firebrands of validation were used to quantify firebrand and heat flux on a designed house in different wind velocities.

Modelling

Tree burning:

Firebrand data of the Douglas fir tree burning experiment were analyzed and divided into 30 mass classes to use as inputs to the model. The domain size is taken as 8 m×8 m×10 m to capture the complete flame and to include devices to replicate all the firebrand collection pans. The height (2.6 m) and the girth (1.5 m) of the cone shape model tree were chosen the same as the original tree. Thermo-physical parameters of the vegetation were taken from Moinuddin et al[1]. Fig. 1 illustrates tree burning and firebrand distribution at different times of the simulation. The grid convergence was appraised in terms of mass loss rate (MLR) and grid convergence index (GCI). An inverse analysis was carried out inputting multiplications (4, 5, 6, etc.) of the experimental firebrand collection (70) and different firebrand initial velocities to map the mass distribution of the simulation and the experiment.

Firebrand landing and heat flux on a structure:
The structure is designed with proper architectural features using Pyrosim software. Wind fields of U_{10}=3 m/s, 6 m/s and, 12.5 m/s are added with synthetic eddy method (SEM) [2] to the simulation. The buoyancy for firebrand transporting is generated by a burning tree. Firebrands' initial velocity and input number were taken from the validation of Douglas fir tree burning.

Results and Discussion

Peaks aligned MLR and HRR results of tree burning simulations are presented for 100 mm, 75 mm, 50 mm and, 37.5 mm grid sizes in Fig. 2(a) and (b). With decreasing grid size, results gradually converged and 50 mm is taken as the reasonably grid size. The GCI of 75 mm/50 mm is about 4%. The FDS' particle model was examined for these grid sizes and found the firebrand mass distribution difference was -6% to +5% for 100 mm – 37.5 mm grids compared to the 50 mm grid. Fig. 2(c) is the MLR comparison of the experiment and the simulation with an 8.5% difference of total mass loss. The firebrand mass distribution contour map is shown in Fig 2. (d) where the tree base is on (0,0) coordinates. Results show that firebrands should eject with 70 cm/s vertical and 210 cm/s horizontal velocities to reach collection pans. The experimental firebrand collection is about 18±4 g and inputting 5 times of this collection could obtain 18.9 g of firebrand mass in simulation while successfully validating the FDS' tree burning and firebrand transporting sub-models.

Fig. 3 is the firebrand mass distribution contour map around the tree and the house. Increasing wind velocity shows landing firebrands more towards the house. However, firebrands did not land on the house because of the low height of the tree and low fire-induced buoyancy. According to Fig. 4, radiative heat flux is higher at the ground level of the house close to the fire. Lowest heat flux is at the door corner and the magnitude of heat flux is decreasing with increasing the distance between the fire and each strategic location of the house. Most of the time lower wind velocity shows higher radiative heat flux at the ground level while medium wind velocity shows higher heat flux at the top level of the house.

Conclusion and future studies

- The physics-based model FDS has been validated against the measurements from a single tree burning and firebrand distribution experiment conducted by NIST.
- Firebrand and heat flux will be examined further in the future by simulating a cluster of taller trees (100 m wide) to quantify the heat flux and firebrand hazard on structures.
- Outcomes are expected to add to the prevailing AS3959 standard for the better counter the wildfire risk and improve the standards of building construction in bushfire-prone areas.

References

[1]. Moinuddin, K. and D. Sutherland, *Modelling of tree fires and fires transitioning from the forest floor to the canopy with a physics-based model.* Mathematics and Computers in Simulation, 2019.

[2]. Jarrin, N., et al., *A synthetic-eddy-method for generating inflow conditions for large-eddy simulations.* International Journal of Heat and Fluid Flow, 2006. **27**(4): p. 585-593.

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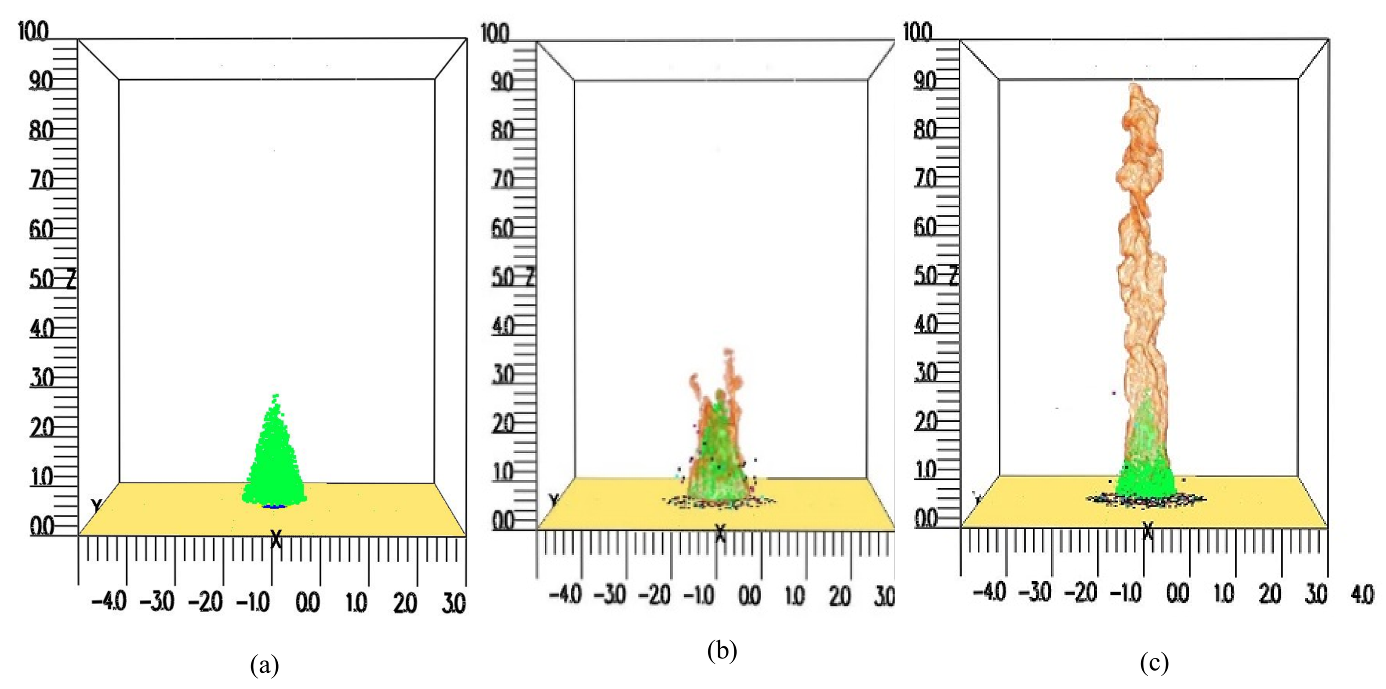

Fig. 1. Graphical representation of Douglas fir tree burning and firebrand distribution at (a) zero second (b) 14 seconds and, (c) 35 seconds.

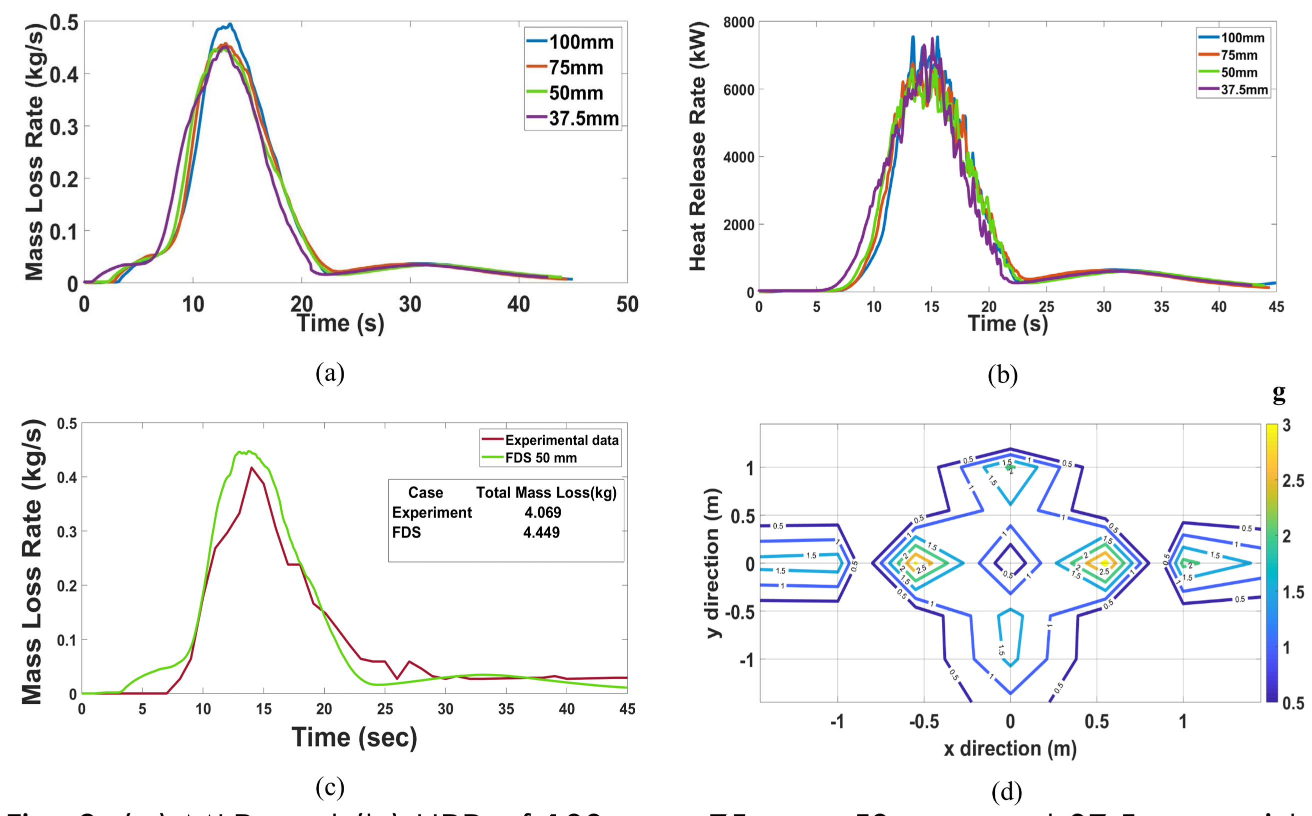

Fig. 2. (a) MLR and (b) HRR of 100 mm, 75 mm, 50 mm and 37.5 mm grid sizes. The MLR comparison of experiment and 50 mm grid is shown in (c). The contour map of firebrand mass distribution is presented in (d).

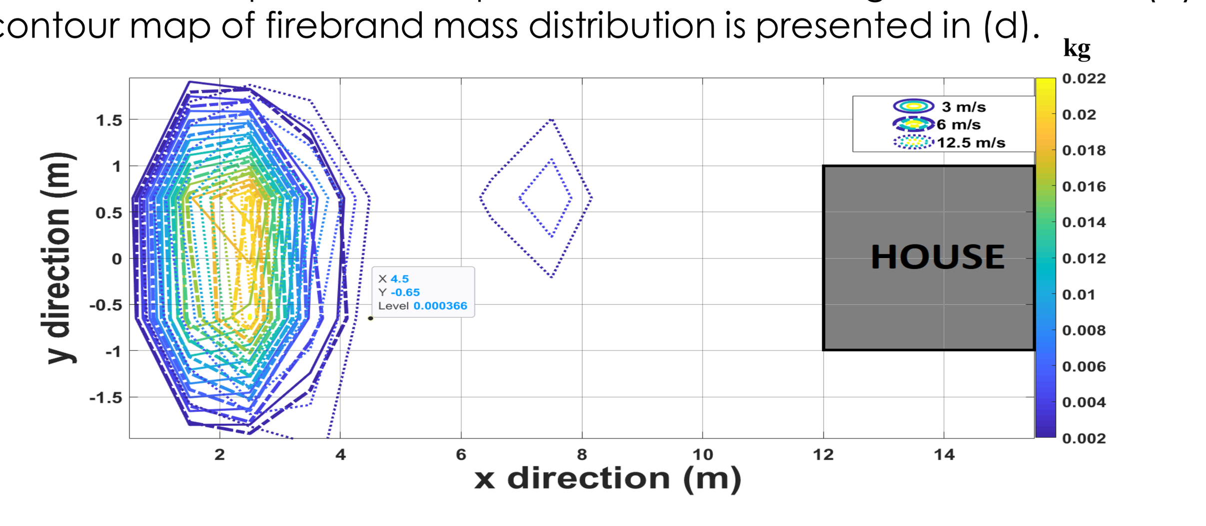

Fig. 3. The domain size is 40 m ×10 m×10 m and the contour map illustrates firebrands landing is increasing with the increase of wind velocity. The tree base is at (2, 0) coordinate.

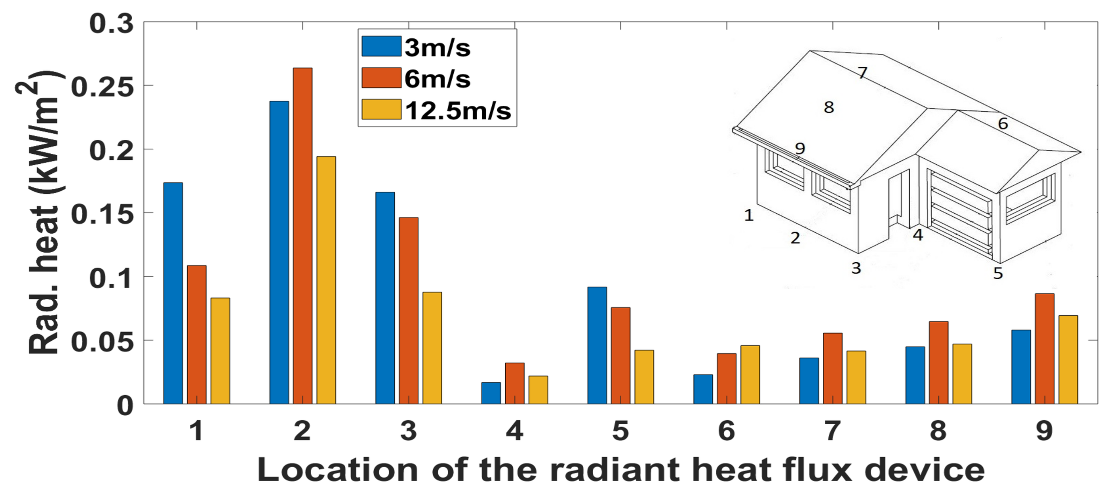

Fig. 4. Radiative heat flux on the house at 3 m/s, 6 m/s and, 12.5 m/s wind velocities. Each strategic location such as wall corners, door corners, gutter, and rooftops is numbered from 1 to 9.

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