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Effect of Packing Ratio on Fire Spread across Discrete Fuel Beds: An Experimental Analysis

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Abstract : In the wild, the vegetation layer with exceptionally complex fuel composition and heterogeneous spatial distribution strongly affects the rate of fire spread (ROS) and fire intensity. Clarifying the influence of fuel bed structure on fire spread behavior is of great significance to wildland fire management and prediction. The packing ratio is one of the key physical parameters describing the property of the fuel bed. There is a threshold value of the packing ratio for ROS, but little is known about the controlling mechanism. In this study, to address this deficiency, a series of fire spread experiments were performed across a discrete fuel bed composed of some regularly arranged laser-cut cardboards, with constant wind speed and different packing ratios (0.0125-0.0375). The experiment aims to explore the relative importance of the internal and surface heat transfer with packing ratio. The dependence of the measured ROS on the packing ratio was almost consistent with the previous researches. The data of the radiative and total heat fluxes show that the internal heat transfer and surface heat transfer are both enhanced with increasing packing ratio (referred to as 'Stage 1'). The trend agrees well with the variation of the flame length. The results extracted from the video show that the flame length markedly increases with increasing packing ratio in Stage 1. Combustion intensity is suggested to be increased, which, in turn, enhances the heat radiation. The heat flux data shows that the surface heat transfer appears to be more important than the internal heat transfer (fuel preheating inside the fuel bed) in Stage 1. On the contrary, the internal heat transfer dominates the fuel preheating mechanism when the packing ratio further increases (referred to as 'Stage 2') because the surface heat flux keeps almost stable with the packing ratio in Stage 2. As for the heat convection, the flow velocity was measured using Pitot tubes both inside and on the upper surface of the fuel bed during the fire spread. Based on the gas velocity distribution ahead of the flame front, it is found that the airflow inside the fuel bed is restricted in Stage 2, which can reduce the internal heat convection in theory. However, the analysis indicates not the influence of inside flow on convection and combustion, but the decreased internal radiation of per unit fuel is responsible for the decrease of ROS.

Keywords : discrete fuel bed, fire spread, packing ratio, wildfire
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