A Novel Approach to Predicting Upward Flame Spread over Polymers

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With their expanding use in a variety applications within aircraft cabins, especially with the continuing drive towards lighter and cheaper materials, synthetic polymers pose an increasing fire safety risk. Unfortunately, despite these mounting challenges, widely practiced test standards, which are used to indicate some level of fire resistance, are often severely limited in their ability to predict material behavior outside of test conditions. One aspect of flammability that is of particular interest is upward, concurrent flame spread over a material's surface – a process that is almost always present in the early stages of a fire and is a key determinant of its initial growth [1]. The governing physics of this problem have been extensively studied for decades, revealing a positive feedback cycle between the energy released by the flame, some of which is invariably sent back into the sample, and the material's response to this external heat transfer (pyrolysis and production of flammable vapors).

In this work, the existing understanding of flame spread dynamics is enhanced through an extensive study of the heat transfer from flames spreading vertically upwards across 5 cm wide, 15 cm tall samples of two commonly used polymers, which present distinctly different burning behaviors [2, 3]. These experiments have provided highly spatially resolved measurements of flame to surface heat flux and material burning rate at the critical length scale of interest, with a level of accuracy and detail unmatched by previous empirical or computational studies. Peak flame heat flux was measured on the order of 35 - 40 kW m^{-2} for each material studied.

Using these measurements, an analytical expression was developed that describes a flame's heat feedback profile (both in the continuous flame region and the thermal plume above) solely as a function of material burning rate. This expression can be used to predict flame spread, with accuracy beyond that of current models, by coupling it with a powerful solid phase pyrolysis solver, ThermaKin2D, which computes the transient rate of gaseous fuel production of constituents of a pyrolyzing solid in response to an external heat flux, based on fundamental physical and chemical properties. It is expected that this will enable highly accurate simulations of flame spread dynamics with reasonable computational time. Current work is aimed at generalizing this analytical flame heat feedback expression to describe the behavior of a range of different polymers.

References

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