

Modeling Solid-Phase Pyrolysis using Emmons' Burning Rate Solution – Application to FDS

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Abstract

Current numerical codes (such as FDS developed by NIST) use a one-dimensional heat conduction equation for the material temperature in the direction normal to the solid surface to model solid pyrolysis. To correctly estimate the burning rate \dot{m}_f'' , the grid size needs to be about 1 cm. However, due to computational costs, typical grid sizes are 10 to 50 cm when modeling room fires in FDS. These grid sizes are too large to correctly estimate solid phase pyrolysis. As a result, current numerical codes are efficient with the gas phase but cannot describe the interaction between the hot gases and the solid fuel. Detailed codes use Arrhenius type expressions to model the fuel degradation; however, this makes the code too cumbersome, thereby reducing its practical application to real world problems. The classical solution developed by Emmons [1] to model flame spread relies on the assumption that the mass burning rate is proportional to the shear stress at the surface. The constant of proportionality is the B-number (also called as the mass transfer number defined by Spalding (1950) [2]) for a forced-flow flame spread. In other words, $\dot{m}_f'' = C \frac{\tau_o}{U_\infty}$, where $\tau_o = \mu \left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial y} \right)^{y=0}$, and $C = B$, for a two dimensional geometry. The constant of proportionality, C , is dependent on material properties and the flow-field.

This work shows that C can be determined using a simplified boundary condition based on images of the stand-off distance of a flame following the methodology outlined by Torero *et al.* [3]. This study promotes an alternate method for determination of the burning rate using the relationship between the shear stress at the surface, τ_o and the burning rate. Experimental results obtained by burning vertical PMMA slabs are compared with both the numerical FDS solver developed by NIST and using the classical theory mentioned above. The main advantage of this method is that the solution of the burning rate \dot{m}_f'' can be obtained without solving the energy equation in the solid phase.

References

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