EXPERIMENTAL VALIDATION OF A MODEL FOR THE PILOTED IGNITION OF THERMOPLASTIC POLYMERS

A. Galgano

Dipartimento di Ingegneria Chimica, dei Materiali e della Produzione Industriale, Università degli Studi di Napoli "Federico II", P.le V. Tecchio, 80125 Napoli, Italy.

Tel:+39-081-7682232; e-mail: agalgano@unina.it

ABSTRACT

Piloted ignition of solid fuels is a subject of paramount importance from both the scientific and the practical point of view as it represents the initiation of unwanted fires or the desired start-up of gasification and incineration plants. Mathematical models are particularly attractive tools due to the expensive costs to design and implement experiments, especially on a real scale. Poly (methyl methacrylate) (PMMA) is a typical non-charring fuel and so its decomposition and ignition behavior under thermal irradiance has been extensively investigated in fire science. A significant number of one-dimensional solid-phase models specific for the ignition of this material is available, based on different approximations, where the description of the gas-phase processes is replaced by empirical ignition criteria. More comprehensive models for PMMA are also available which couple the description of the solid- and gas-phase processes. These are more suitable for the study of ignition as, in principle, they do not require empirical criteria. One-dimensional models represent an attractive compromise between simple solid-phase models and complex multidimensional models that couple the two phases.

In this study, a comprehensive one-dimensional solid-gas model is developed for the study of piloted ignition of polymeric materials exposed to thermal irradiance. The mathematical description of the electrical spark as igniter is the most critical issue, with the simplest approach (heating spark model) consisting of a planar source, periodically activated, giving rise to the addition of exceedingly high and unrealistic amounts of direct and indirect (from exothermic pre-ignition combustion) heat to the system. The second approach (non-heating spark model), thanks to a laborious iterative procedure, cuts off direct and indirect spark heating and with this also the prediction of possible flashing phenomena. The third approach, that is, the chemical spark model, still preserving the simplicity of a non-iterative numerical implementation, makes the reaction to occur at the temperature of the spark which does not affect direct heating. Limited effects of the indirect heating are retained, permitting for this model the prediction of possible flashing. For the typical heating conditions of the cone calorimeter (25-75kW/m^2), the chemical spark model predicts ignition times slightly longer than those of the non-heating spark model. On the other hand, the predicted ignition times of the heating spark model are typically shorter by about 20-12% (in addition to the unrealistic prediction of the gas-phase thermal field).

The chemical spark model is applied to investigate the behavior of clear and black PMMA as the intensity of the external irradiance is varied from 25 to 150kW/m^2. The agreement between predicted and measured ignition time is good.

A local sensitivity analysis is also carried out for a radiative heat flux intensity of 50kW/m^2 showing a high sensitivity for the activation energies of the decomposition and combustion kinetics, the surface emissivity, the polymer specific heat, the spark temperature, the position of the igniter and the enthalpy of the combustion reaction.