IGNITION OF PYROPHORIC POWDERS: AN ENTRY-LEVEL MODEL

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Chemically prepared metal nanopowders are normally pyrophoric, i.e. liable to ignite spontaneously on exposure to air because of high reactivity and developed specific surface. In order to prevent accidents during their further processing, such powders are passivated (covered with a thin oxide film) in processes that last for dozen hours, which seriously restricts the mass production of nanopowders. On the other side, reliable theoretical models for spontaneous self-ignition of finely dispersed powders at room temperature have not been suggested so far. A deeper insight into the mechanism of the phenomenon would shed new light on the critical conditions for self-inflammation and thus would provide some clues for optimization of the passivation process. The available models of ignition based on account of the retarding action of diffusion barriers seem inapplicable since, in terms of the above models, room-temperature inflammation is impossible at all because of low diffusivity of the oxide barrier.

In this work, we formulated and analyzed an entry-level model for ignition of pyrophoric powders. A planar infinitely long layer of porous condensed matter is in contact with gaseous oxidant at ambient temperature $T_0$. The reaction of a porous solid with gas reactant is infiltration-controlled and yields a condensed combustion product. It is assumed that the temperatures of solid and gas in pores are the same (single-temperature model). Heat withdrawal from the reaction zone is assumed to proceed over the solid skeleton, and heat sink into the environment is neglected. Analysis of such a model in terms of the ignition theory gave the following results.

Depending on the width of the reaction zone, the ignition may get started in either one or two stages. The duration of each stage was evaluated using approximate methods of combustion theory. In order to find out critical conditions for spontaneous inflammation, our model must be supplemented by either (i) the kinetic equations of combustion or (ii) the condition for formation of protective layer on the particles of solid reagent. Derived were parametric limits for the applicability of the model, and the influence of sample length on the ignition process was also explored.