Technical Program and Abstracts

St. Petersburg, Russia
October 4-8, 2010

7th International Colloquium on Pulsed and Continuous Detonations

Aluminum particle ignition model with regard for mechanical stresses at metal–oxide layer interface

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The oxide layer on aluminum particle surface is known to influence particle oxidation and ignition when it is injected into a hot oxidizing gas. On the one hand, the oxide layer protects the metal core from direct contact with the oxidizing gas but is considered to be permeable to diffusion fluxes which can result in gradual metal oxidation or run-away to ignition. On the other hand, due to different physical properties of pure aluminum (Al) and aluminum oxide (Al_2O_3), particle heating is accompanied with the development of internal thermal stress which can attain a critical value thus leading to the formation of microcracks in the oxide layer. As a result, the protecting properties of the oxide layer reduce drastically and the direct contact of pure metal with the oxidizing gas in the microcracks can facilitate particle oxidation and ignition. For better understanding the comparative role played by these processes at different initial conditions, there is a need in properly grounded models. In this paper, the mathematical model of partly-oxidized, spherical aluminum particle heating in high-temperature inert gaseous atmosphere has been formulated and solved.

The model takes into account (*i*) the layered structure of the particle with a pure metal core and the surface oxide layer of finite thickness, and (*ii*) different (temperature dependent) physical properties of Al and Al_2O_3. It has been shown that under certain conditions (in terms of particle size, oxide layer thickness, gas temperature, and pressure), the thermal stress arising in the particle can exceed the critical value required for the incipience of microcracks. For small particles, the corresponding critical temperature of the oxidizing gas was shown to decrease with the thickness of the oxide layer.