Modeling of propellant combustion with nano-aluminum particles

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ABSTRACT :

Aluminum particles are commonly used in solid propellants to increase performance of solid rockets. It has been reported of increasing the burn rate of solid rocket propellant with addition of nano-aluminum particles. This specific behavior has been investigated by many contributors by using mainly experimental approaches. However, the cause for this burning rate increase has not been clearly identified.

Some authors [1] suggested that the characteristics of the nano-aluminum particles could store internal energy which is released during the combustion. This hypothesis was refuted by several research teams [2]. To quantify the effects of nano-aluminum particles on the propellant combustion, a recent model [3] was developed taking into account a strategy of homogenization of small particles in the binder. The combustion of nano-aluminum particles was modeled following a global approach because the physical mechanisms are not well understood at the present time. In fact, nano-aluminum particles have lower ignition temperature, faster burning rate and consequently shorter burning time due to their specific-surface area compared with micron-aluminum particles. The modeling of nano-aluminum particles in combustion in solid rocket motor remains a quite challenging task.

The purpose of this paper is to present a model to describe a composite propellant in combustion with nano-aluminum particles. This model is based on a one-dimensional approach including radiative effects in the energy balance. After discussion on the hypothesis of the model in the frame of the continuum theory, we focused on the problem of modeling the combustion of nano-aluminum particles in gas propellant environment. The propellant combustion model was built following the idea developed in [4] based on low gas activation energy. The full model, including nano-aluminum particles, was then applied to the combustion of two composite HTPB propellants burned at ONERA. The first one contains a micro-sized aluminium particles and the second a bimodal nano/micro-sized aluminium particles. Results are analyzed in terms of flux entering into the energetic materials in order to give an explanation on physical mechanisms regarding the increasing of the burn rate.

Reference

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