Self-Organizing of the Reactionary Zones of the Energetic Materials and Concept of the Smart Solid Micro-Propulsion System

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Abstract

For more than ten years, micro-propulsion has been an active world-wide field of research. The cheap, reliable, and versatile clusters of micro-spacecraft have more advantages than a conventional spacecraft in fabrication, launch, and operation. A micro-propulsion system is required in micro-spacecraft for high-accuracy station keeping, attitude control, drag compensation and orbit adjustment of micro-spacecraft. The level of thrust and the precise impulse required for micro-satellite maneuvers cannot be achieved with conventional solid propulsion systems.

Because in the combustion chambers of micro-propulsion systems of the small-sized orbital maneuvering vehicles (maneuvering stages of rockets, Fig. 1), the scale factor has the significant influence, the micro/nano-structures arising in energetic material (EM) reactionary zones has a significant influence on physical and chemical processes and on controllability of processes of ignition and combustion.

The analysis of experimental data shows that in a number of cases, the macro-scale phenomena at the EM combustion are result of self-synchronization of the magneto-dipole micro-structures in the reactionary zones. As noted by Novozhilov, B.V. [1], the solid propellant burning surface represents the oscillatory system with infinite number of freedom degrees. Such composite systems cannot be understood, analyzing their parts separately.

For the first time the representation regarding excitation of magneto-dipole micro-structures in the liquid-viscous layer of a burning EM was suggested in papers [2, 3]. The magneto-dipole micro/nano- structures generated in the heated liquid-viscous layer (Fig. 2) of burning EM cause the formation of the cellular-pulsating micro-structures in this layer, on the burning surface and over the burning surface of the EM, and also for excitation of periodic toroidal vortex micro-structures over the burning surface. Excitation of these micro-structures displays a fundamental relationship of energy and the burning substance.

Magneto-dipole self-organizing in reactionary zones of the EM is induced under the influence of a thermo-electric field in the liquid-viscous layer and as a result of separation of electrical charges because of distinction in diffusion coefficients and mobility of charged particles in the flame.

In the paper the new hypothesis of excitation of some anomalies of burning that connected with collective interaction of the self-organizing magneto-dipole micro-structures in the reactionary zones of the EM is suggested. The hypothesis of self-synchronization of the magneto-dipole micro/nano- structures in the EM reactionary zones is supported by the experimental data provided by Japanese research team. This data has been obtained during study of oscillation and synchronization in the simple experimental system containing a set of paraffin candles.

Research of self-organizing and self-synchronization of the micro/nano- structures in the reactionary zones opens a new possibility for development of the smart solid propellants that allow variable thrust at minimal cost.

The new possibilities for effective control by combustion processes opens in connection with possibility of initiation of self-organizing of the reactionary zone by use of the electric fields and electric discharges. Self-organizing of the reactionary zones of the EM is essentially new level of self-organizing which is determined by achievement of critical spacial concentration the micro/nano - structures - by a bifurcation point.

The idea of using electric fields to manipulate propellant burning rates is not new. In fact, this concept was proposed at least as far back as the 1960's. In general, the application of electric fields to a combusting solid propellant has shown to increase the burning rate of the propellant, and even under certain conditions can decrease the burning rate as well [4]. In particular, application of an electric field, changes the burning surface roughness [4, 5], i.e. modifies the process of excitation of the micro/nano- structures in the reactionary zones.

Use of the electric fields and electric discharges for control by the magneto-dipole micro-structures in the reactionary zones gives possibility for control by local curvature of the burning cells surface and to control by origin of vortex micro-structures over the burning surface roughness and to change localization of zones of a heat release over the burning surface. As a result of local change of the burning cells surface curvature, the stability conditions of burning process also will change. There is a limiting value of local curvature of the burning surface in each cell, above which self-sustained combustion is impossible.

The concept of the smart solid micro-propulsion system includes integration of the propellant reactionary zones both into the control system by combustion mode, and into the general control system of the small-sized orbital maneuvering vehicle (maneuvering upper stage). In case of use of the electrically controlled solid propellants, the phenomenon of spontaneous excitation of the micro/nano- structures in the reactionary zones will influence also on the processes of ignition, combustion and extinguishing.

Fig. 1. Solid Divert and Attitude Control System of the Orbital Maneuvering Vehicle.

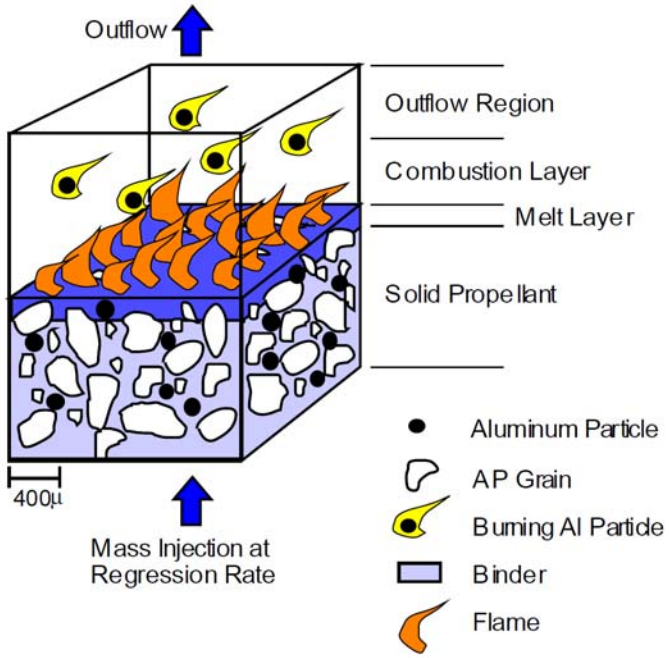

Fig. 2. Solid Rocket Propellant Melt Layer.

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