Dedicated to the memory of Ulian Gaikovich Pirumov

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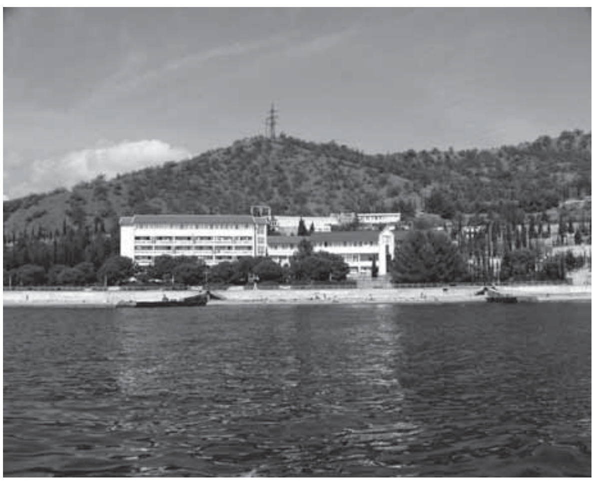

HOW TO DISPOSE METAL PARTICLES IN THE PROPELLANT GRAIN

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Using the dispersed metal in solid propellants to increase the temperature of combustion products leads to such a problem as the specific impulse loss due to the incomplete combustion of metal particles in the exhaust products. A redistribution of metal loaded into the propellant grain is one of the methods to decrease the specific impulse loss. This paper reports on the ways to obtain the optimum metal particle disposition for the case-bounded propellant grain of tube cross-sectional type from the maximum combustion efficiency point of view and to identify main parameters affecting the combustion efficiency. Three different approaches to analyze the metal combustion efficiency are discussed. They are zero-dimensional, two dimensional equilibrium and two-dimensional non-equilibrium ones.

The influence of the dynamic non-equilibrium of two-phase flow on the optimum metal particles disposition in the propellant grain of tube cross-sectional type is investigated.

The analytical correlation for the optimum disposition of metal particles in the case-bounded propellant grain of tube cross-sectional type under the assumption of equilibrium two-phase flow is deduced. For one-dimensional approach it is

$$\theta(\xi) = \frac{2}{3}\ln(1/\xi)\Big/\int\limits_0^1 f(\delta,\Phi)\,d\delta,$$

and for two-dimensional approach it is

$$\theta(\xi) = \frac{4}{3\pi}\,\mathrm{arcosh}(1/\xi)\Big/\int\limits_0^1 f(\delta,\Phi)\,d\delta,$$

where θ — burning-to-residence time ratio for particle, δ — dimensionless particle size, Φ — mass flux ratio, ξ — dimensionless initial position of metal particle on the propellant surface, $f(\delta,\Phi) = \delta^{0,5}[1+\Phi(\delta^3-1)]^{-0,9}$ — burn rate function for particle.

Analysis of the dimensionless system of equations describing a motion of burning particle in the channel of circular cross section with taking into account the velocity lag shows the optimum disposition of metal particles in the propellant grain depends on five parameters: the relative length of the channel; the particle relaxation time; the molar metal to oxidizer flux ratio at the propellant grain surface; particle combustion to residence time ratio and Reynolds number of particle. The increase of the particle relaxation time and the decrease of the particle Reynolds number and the relative channel length are preferable from the combustion efficiency point of view in the case of non-equilibrium flows.