THERMODYNAMIC MODEL OF PROPELLANT POWDER COMBUSTION TAKING INTO ACCOUNT ITS COMPRESSIBILITY

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Abstract: In most standard models of propellant combustion widely used in solving internal ballistics problems for barrel systems and solid-fuel engines, the propellant is considered incompressible. This assumption is justified by the characteristic pressure range in these problems. However, for certain applications in explosion safety and energy systems, nonclassical combustion regimes of propellants such as convective burning and low-speed detonation are of interest. These regimes are characterized by elevated pressures at which the compressibility of the energetic material becomes significant. This study focuses on modeling propellant combustion in a manometric bomb using the Baer–Nunziato equations. This two-phase model accounts for the compressibility of both gaseous and condensed phases as well as pressure nonequilibrium between the phases. Three modifications to the conventional propellant combustion model are proposed: (i) adjustment of the thermal effect of propellant combustion on the internal energy of the condensed phase; (ii) an additional term in the equation for the change in relative thickness of the burning layer accounting for propellant compressibility; and (iii) a correction procedure for the combustion law coefficient to ensure consistency between the impulse of burnt gas pressure and experimental data. These modifications were validated by analyzing combustion of a charge of single-channel pyroxylin propellant in a manometric bomb.

Keywords: grained propellant; thermodynamic model; geometric burning law; Baer–Nunziato equations; compressibility

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Figure Captions

Figure 1 Schematic representation of combustion of a gunpowder particle in the form of a sphere (*a*) and a cylinder with a channel (*b*)

Figure 2 Combustion of a single-channel pyroxylin powder charge in a manometric bomb: *1* — authors' calculations performed using the model (37)–(42), (21), (24), (29), and (44) assuming $\mathcal{F} = 0$ which corresponds to incompressible powder; and *2* — calculations [30]

Figure 3 Combustion of a single-channel pyroxylin powder charge in a manometric bomb: *1* — $\overline{\alpha}$; *2* — $\overline{\rho}$; *3* — p; and *4* — z. The calculation was performed using the model (37)–(42), (21), (24), (29), (44) with a finite value of μ_C

Figure 4 Influence of the equation of state of the condensed phase on the gas pressure curve in the calculation of gunpowder combustion in a manometric bomb: *1* — $P_0 \sim 10^8$ Pa; *2* — $\sim 10^9$; *3* — $P_0 \sim 10^{10}$ Pa; and *4* — incompressible

Figure 5 Influence of the correction of the coefficient in the gunpowder combustion law within the compressible model on the gas pressure curve during the simulation of gunpowder combustion in a manometric bomb: *1* — incompressible; *2* — compressible; and *3* — correction

Table Caption

Physicochemical properties of gunpowder [30]

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