PULSE NOZZLE SETUP WITH A CHARGE OF HIGH-DENSITY COMPOSITE PROPELLANT BURNING IN THE LOW-VELOCITY DETONATION MODE

A. A. Sulimov, B. S. Ermolaev, V. E. Khrapovskii, and A. V. Roman'kov

N. N. Semenov Institute of Chemical Physics, Russian Academy of Sciences, 4 Kosygin Str., Moscow 119991, Russian Federation

Abstract: The results of investigation concerning application of low-velocity detonation (LVD) in high-density block charges for developing small-size nonexplosive rocket motors with high thrust and short operation time (1–2 ms) are considered. Firings are carried out in the laboratory nozzle setup consisting of the cylindrical chamber and nozzle block with a nozzle-diffuser. The propellant charges are prepared by pressing to a porosity of 2%–4% of the mixture of ammonium perchlorate (AP) with polymethylmethacrylate (PMMA) 85/15 or three-component mixture of these compounds with 15% of RDX additive. Low-velocity detonation was induced in the charge by the igniter with the subsequent acceleration of the burning wave in a booster charge, that is, a pellet of pressed RDX. Properties of the pellet were selected so that the acceleration of burning at its butt end resulted in LVD with the velocity of 1.4–2 km/s. The same process was obtained in the propellant charge. The investigation conducted shows that the pressed mixture charges provide a steady work of the nozzle setup with a high specific impulse of the thrust. In firings of the base configuration with the loading density of 0.65 g/cm^3, the specific impulse was 222 s for mixture PMMA/AP 15/85 and 236 s for the mixture with the RDX additive. The key factors affecting specific impulse are the length of the afterburning cavity and the expansion ratio of the nozzle. As the expansion ratio increased to 10, the specific impulse exceeded 250 s. The most part of chemical energy releases in a dense cloud of burning particles produced behind the LVD wave front. Pressure measurements conducted with the use of high-frequency piezoelectric gauges show that pressure in the LVD wave propagating along the charge is typically 1–1.2 GPa. After the LVD wave passes from the charge into the afterburning cavity, the peak pressure reduces to 300–400 MPa. A high pressure inherent in the LVD has positive aspects: it reduces the burning time and raises the specific impulse.

Keywords: low-velocity detonation; high-density composite propellant, ammonium perchlorate

Acknowledgments

The work was supported by the Russian Foundation for Basic Research (grant No. 16-08-00299).

References

1. *Energeticheskie kondensirovannye sistemy. Kratkiy entsiklopedicheskiy slovar'* [Energetic condensed systems. Brief encyclopedic dictionary]. 1999. Moscow: Yanus-K. 485 p.
2. Afanasenkov, A. N. 1970. Issledovanie nekotorykh detonatsionnykh svoystv promyshlennykh VV [Investigation of some detonation properties of industrial HE]. *Vzryvnoe delo* [Explosion Technology]. Moscow: Nedra. 68/25:93–100.
3. Lempert, D. B., G. N. Nechiporenko, G. P. Dolganova, and L. N. Stessik. 1998. Dependence of specific impulse of the optimized MSRP of composition (binder + metal + oxidizer) on character of the metal and oxidizer. *Chem. Phys. Rep.* 17(7):114– 120.

Received January 16, 2018

Contributors

Sulimov Alexey A. (b. 1937) — Doctor of Science in physics and mathematics, professor, chief research scientist, N. N. Semenov Institute of Chemical Physics, Russian Academy of Sciences, 4 Kosygin Str., Moscow 119991, Russian Federation; aasul@chph.ras.ru

Ermolaev Boris S. (b. 1940) — Candidate of Science in physics and mathematics, head of laboratory, N. N. Semenov Institute of Chemical Physics, Russian Academy of Sciences, 4 Kosygin Str., Moscow 119991, Russian Federation; boris.ermolaev@yahoo.com

Khrapovskii Vladimir E. (b. 1945) — Candidate of Science in physics and mathematics, senior research scientist, N. N. Semenov Institute of Chemical Physics, Russian Academy of Sciences, 4 Kosygin Str., Moscow 119991, Russian Federation; khrapovskii@chph.ras.ru

Roman'kov Alexander V. (b. 1947) — Candidate of Science in physics and mathematics, senior research scientist, N. N. Semenov Institute of Chemical Physics, Russian Academy of Sciences, 4 Kosygin Str., Moscow 119991, Russian Federation; romankov@mail.ru