

EXPERIMENTAL STUDIES OF SMALL SAMPLES BENCH ROCKET ENGINE WITH A CONTINUOUSLY-DETONATION COMBUSTORS

S. M. Frolov^{1,2,3}, V. S. Aksenov^{1,2,3}, P. A. Gusev^{1,2}, V. S. Ivanov^{1,2}, S. N. Medvedev^{1,2},
and I. O. Shamshin^{1,2,3}

¹Noncommercial Partnership Center of Pulse Detonation Combustion, 4 Kosygin Str.,
Moscow 119991, Russian Federation

²N. N. Semenov Institute of Chemical Physics, Russian Academy of Sciences, 4 Kosygin
Str., Moscow 119991, Russian Federation

³National Research Nuclear University MEPhI, 31 Kashirskoe Sh., Moscow 115409,
Russian Federation

Abstract: A test bench for fire tests of demonstration samples of rocket engines of a new type with continuous-detonation combustion has been created. Demonstration tests with small-scale samples of rocket engines with annular combustors 50 and 100 mm in outer diameter with an annular gap of 5 mm, operating on hydrogen–oxygen mixture, proved experimentally for the first time that a thermodynamic Zel’dovich cycle with continuous detonation combustion of hydrogen–oxygen mixture is, respectively, 6%–7% and 7%–8% more efficient than the thermodynamic cycle with continuous constant-pressure combustion of the same mixture under similar conditions. In a series of demonstration tests with the 100-millimeter-diameter combustor using methane–oxygen mixture with an overall equivalence ratio from 0.95 to 1.4, only modes with continuous-detonation combustion were obtained whereas the mode with continuous combustion was not observed. In view of the fact that the pressure in the combustion chambers was relatively low so far (less than 3 atm) and the design of the combustion chambers and nozzles was unoptimized, the values of specific impulse were relatively low (up to 160 s).

Keywords: continuous-detonation combustion; test bench; rocket engine; hydrogen–oxygen; methane–oxygen; Zel’dovich cycle; energy efficiency

Acknowledgments

The work was supported by the Russian Ministry of Education and Science under the State Contract No. 14.609.21.0002 (Contract ID RFMEFI60914X0002) “Development of technologies for the use of liquefied natural gas (methane, propane, butane) as fuel for rocket and space technology and the creation of a new generation of stand demonstrator rocket engine” under the Federal Target Program “Research and development in priority areas of scientific and technological complex of Russia for 2014–2020” and by the Russian Academy of Sciences through the Program No. 26 “Combustion and Explosion.”

References

1. Zel'dovich, Ya. B. 1940. K voprosu ob energeticheskom ispol'zovanii detonatsionnogo goreniya [To the question of energy use of detonation combustion]. *Zh. Tekhn. Fiz.* [J. Tech. Phys.], 10(17):1455–1461.
2. Bykovskii, F. A., and S. A. Zhdan. 2013. *Nepreryvnaya spinovaya detonatsiya* [Continuous spin detonation]. Novosibirsk: Siberian Branch of the Russian Academy of Sciences Publ. 423 p.
3. Roy, G. D., S. M. Frolov, A. A. Borisov, and D. W. Netzer. 2004. Pulse detonation propulsion: Challenges, current status, and future perspective. *Prog. Energy Combust. Sci.* 30(6):545–672.
4. Heiser, W. H., and D. T. Pratt. 2002. Thermodynamic cycle analysis of pulse detonation engines. *J. Propul. Power* 18(1):68–76.
5. Frolov, S. M., A. E. Barykin, and A. A. Borisov. 2004. Termodinamicheskiy tsikl s detonatsionnym szhiganien topliva [Thermodynamic cycle with detonative burning of fuel]. *Khim. Fiz.* 23(3):17–25.
6. Chvanov, V. K., S. M. Frolov, and L. E. Sternin. 2012. Zhidkostnyy detonatsionnyy raketnyy dvigatel' [Liquid propellant detonation rocket engine]. *Trudy NPO Energomash im. Akademika V. P. Glushko* [Transactions of R&D Enterprise Energomash named after academician V. P. Glushko]. Moscow: NPO Energomash im. Akademika V. P. Glushko. 29:4–14.
7. Frolov, S. M., V. S. Aksenov, P. A. Gusev, V. S. Ivanov, S. N. Medvedev, and I. O. Shamshin. 2014. Experimental proof of energy efficiency of thermodynamic Zel'dovich cycle. *Dokl. Akad. Nauk* 459(2):207–211.

Received November 1, 2014

Contributors

Frolov Sergey M. (b. 1959) — Doctor of Science in physics and mathematics, head of department, N. N. Semenov Institute of Chemical Physics, Russian Academy of Sciences, 4 Kosygin Str., Moscow 119991, Russian Federation; scientific head, Noncommercial Partnership Center of Pulse Detonation Combustion, 4 Kosygin Str., Moscow 119991, Russian Federation; professor, National Research Nuclear University MEPhI, 31 Kashirskoe Sh., Moscow 115409, Russian Federation; smfrol@chph.ras.ru

Aksenov Victor S. (b. 1952) — 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; designer, Noncommercial Partnership Center of Pulse Detonation Combustion, 4 Kosygin Str., Moscow 119991, Russian Federation; associate professor, National Research Nuclear University MEPhI, 31 Kashirskoe Sh., Moscow 115409, Russian Federation; v.aksenov@mail.ru

Gusev Pavel A. (b. 1942) — Candidate of Science in physics and mathematics, research scientist, N. N. Semenov Institute of Chemical Physics, Russian Academy of Sciences, 4 Kosygin Str., Moscow 119991, Russian Federation; engineer, Noncommercial Partnership Center of Pulse Detonation Combustion, 4 Kosygin Str., Moscow 119991, Russian Federation; gusevpa@yandex.ru

Ivanov Vladislav S. (b. 1986) — 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; specialist, Noncommercial Partnership Center of Pulse Detonation Combustion, 4 Kosygin Str., Moscow 119991, Russian Federation; ivanov.vls@gmail.com

Medvedev Sergey N. (b. 1985) — 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; specialist, Noncommercial Partnership Center of Pulse Detonation Combustion, 4 Kosygin Str., Moscow 119991, Russian Federation; medvedevs@chph.ras.ru medvedev@idgcenter.ru

Shamshin Igor O. (b. 1975) — 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; specialist, Noncommercial Partnership Center of Pulse Detonation Combustion, 4 Kosygin Str., Moscow 119991, Russian Federation; associate professor, National Research Nuclear University MEPhI, 31 Kashirskoe Sh., Moscow 115409, Russian Federation; shamshin@idgcenter.ru