

It is also seen that the transverse velocity component is considerably smaller than the axial one with the latter exceeding the local sound velocity.

4 CONCLUDING REMARKS

The possibility of arranging a cyclic operation in the detonation mode of the CDC with a wide annular gap (23 mm) comparable to the height of the blades of the last stage GTE compressor and with separate delivery of fuel and oxidizer has been demonstrated computationally based on 3D URANS simulations coupled with the Particle method modeling micromixing and turbulence–chemistry interaction. A 15 percent gain in total pressure has been obtained in the CDC. A proposed design of the upstream isolator was shown to provide almost complete damping of pressure disturbances propagating upstream from the CDC towards the compressor.

Further efforts will be directed towards transition from hydrogen to liquid hydrocarbon fuel and the design of a downstream isolator protecting the turbine from pressure disturbances generated in the CDC.

ACKNOWLEDGMENTS

This work was partly supported by the Russian Academy of Sciences (Program #26 “Combustion and Explosion”), Russian Foundation for Basic Research (grant 15-08-00782), and Russian Science Foundation (grant 14-13-00082).

REFERENCES

1. Zel'dovich, Ya. B. 1940. On utilizing detonative combustion in power engineering. *Sov. J. Techn. Phys.* 10(17):1453–1461.
2. Voitsekhovskii, B. V. 1959. Stationary detonation. *Dokl. USSR Acad. Sci.* 129:1254–1256.
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. Frolov, S. M., ed. 2006. *Pulse detonation engines*. Moscow: TORUS PRESS. 592 p.
5. Bykovskii, F. A., S. A. Zhdan, and E. F. Vedernikov. 2006. Continuous spin detonation of fuel–air mixtures. *Combust. Expl. Shock Waves* 42(4):1–9.
6. Bykovskii, F. A., S. A. Zhdan, and E. F. Vedernikov. 2010. Continuous spin detonation of a hydrogen–air mixture with addition of air into the products and the mixing region. *Combust. Expl. Shock Waves* 46(1):52–59.
7. Davidenko, D. M., I. Gokalp, and A. N. Kudryavtsev. 2008. Numerical study of the continuous detonation wave rocket engine. AIAA Paper No. 2008-2680.

8. Hishida, M., T. Fujiwara, and P. Wolanski. 2009. Fundamentals of rotating detonations. *Shock Waves* 19(1):1–10.
9. Shao, Y.-T., M. Liu, and J.-P. Wang. 2010. Numerical investigation of rotating detonation engine propulsive performance. *Combust. Sci. Technol.* 182:1586–1597.
10. Kindracki, J., P. Wolanski, and Z. Gut. 2011. Experimental research on the rotating detonation in gaseous fuels–oxygen mixtures. *Shock Waves* 21(2):75–84.
11. Frolov, S. M., A. V. Dubrovskii, and V. S. Ivanov. 2012. Three-dimensional numerical simulation of the operation of the rotating detonation chamber. *Russ. J. Phys. Chem. B* 6(2):276–288.
12. Tchvanov, V. K., S. M. Frolov, and E. L. Sternin. 2012. Liquid-fueled rocket detonation engine. *Trans. NPO Energomash* 29:4–14.
13. Schwer, D., and K. Kailasanath. 2013. Fluid dynamics of rotating detonation engines with hydrogen and hydrocarbon fuels. *Proc. Combust. Inst.* 34(2):1991–1998.
14. Frolov, S. M., A. V. Dubrovskii, and V. S. Ivanov. 2013. Three-dimensional numerical simulation of operation process in rotating detonation engine. *Progress in propulsion physics*. Eds. L. DeLuca, C. Bonnal, O. Haidn, and S. Frolov. EUCASS advances in aerospace sciences book ser. EDP Sciences–TORUS PRESS. 4:467–488.
15. Frolov, S. M., A. V. Dubrovskii, and V. S. Ivanov. 2013. Three-dimensional numerical simulation of the operation of a rotating-detonation chamber with separate supply of fuel and oxidizer. *Russ. J. Phys. Chem. B* 7(1):35–43.
16. Frolov, S. M., A. V. Dubrovskii, and V. S. Ivanov. 2013 (submitted). The way of arranging the operation process in the continuous detonation chamber for gas turbine engine and the device for its implementation. Patent of Russian Federation.
17. Pope, S. B. 1985. PDF methods for turbulent reacting flows. *Prog. Energy Combust. Sci.* 11:119–192.
18. Frolov, S. M., and V. S. Ivanov. 2010. Combined flame tracking–particle method for numerical simulation of deflagration-to-detonation transition. *Deflagrative and detonative combustion*. Eds. G. Roy and S. Frolov. Moscow: TORUS PRESS. 133–156.
19. Ivanov, V. S., and S. M. Frolov. 2011. Numerical simulation of the operation process and thrust performance of an air-breathing pulse detonation engine in supersonic flight conditions. *Russ. J. Phys. Chem. B* 5:597–609.
20. Frolov, S. M., V. S. Ivanov, B. Basara, and M. Suffa. 2013. Numerical simulation of flame propagation and localized preflame autoignition in enclosures. *J. Loss Prevention Proc. Ind.* 26:302–309.
21. Basevich, V. Ya., and S. M. Frolov. 2007. Kinetics of blue flames in the gas-phase oxidation and combustion of hydrocarbons and their derivatives. *Russ. Chem. Rev.* 76(9):867–884.
22. Frolov, S. M., S. N. Medvedev, V. Ya. Basevich, and F. S. Frolov. 2013. Self-ignition of hydrocarbon–hydrogen–air mixtures. *Int. J. Hydrogen Energy* 38:4177–4184.