INFLUENCE OF TURBULENCE ON COMBUSTION OF HYDROGEN–AIR MIXTURES OF DIFFERENT COMPOSITION

A. D. Kiverin, K. S. Melnikova, and I. S. Yakovenko

Joint Institute for High Temperatures of the Russian Academy of Sciences, 13-2 Izhorskaya Str., Moscow 125412, Russian Federation

Abstract: The results of mathematical modeling of combustion of hydrogen–air mixtures of different compositions in a closed vessel are presented. Two settings were considered: laminar and turbulent combustion. The paper provides an analysis of scenarios of combustion evolution at various turbulence intensities. It was shown that depending on the intensity of turbulent flows either the increase of combustion or its extinction can be observed. The values of the critical pulsation velocity for combustion extinction for mixtures of different compositions are given.

Keywords: combustion of hydrogen; mathematical modeling; flame stability; turbulent combustion

DOI: 10.30826/CE23160404 **EDN:** EDREBE

Figure Captions

Figure 1 The statement of the problem

Figure 2 Effects of turbulence on the temperature distribution inside a vessel with 8% hydrogen–air mixture at $t = 12$ ms: (*a*) $u' = 0$ m/s; (*b*) 2.05; and (*c*) $u' = 6.6$ m/s

Figure 3 Effects of turbulence on the pressure rise for hydrogen–air mixture with 8% hydrogen content: signs — calculations; and curves — approximations

Figure 4 Effects of turbulence on the pressure rise for hydrogen–air mixture with hydrogen content 6% (*a*) and 15% (*b*): signs — calculations; and curves — approximations

Table Caption

The critical velocities of turbulent pulsations at which combustion of hydrogen–air mixture is extinguished

References

1. Broughton, J. M., P. Kuan, D. A. Petti, and E. L. Tolman. 1989. A scenario of the Three Mile Island Unit 2 accident. *Nucl. Technol.* 87(1):34–53. doi: 10.13182/NT89-A27637.
2. Al-Khishali, K. J., D. Bradley, and S. F. Hall. 1983. Turbulent combustion of near-limit hydrogen–air mixtures. *Combust. Flame* 54:61–70. doi: 10.1016/0010-2180(83)90022-6.
3. Karpov, V., and E. Severin. 1980. Effects of molecular-transport coefficients on the rate of turbulent combustion. *Combust. Explo. Shock Waves* 16(1):41–46.
4. Yakovenko, I., A. Kiverin, and K. Melnikova. 2022. Computational fluid dynamics model for analysis of the turbulent limits of hydrogen combustion. *Fluids* 7(11). 11 p. doi: 10.3390/fluids7110343.
5. McGrattan, K., R. McDermott, S. Hostikka, C. G. Weinschenk, and G. P. Forney. 2013. Fire Dynamics Simulator Technical Reference Guide Volume 1: Mathematical model. Gaithersburg, MD: U.S. Department of Commerce, National Institute of Standards and Technology. Technical Report NIST Special Publication 1018-1. 175 p. doi: 10.6028/NIST.SP.1018.
6. Semenov, E. S. 1965. Measurement of turbulence characteristics in a closed volume with artificial turbulence. *Combust. Explo. Shock Waves* 1:57–62. doi: 10.1007/BF00757231.
7. Hertzberg, M. 1981. Flammability limits and pressure development in H_2–air mixtures. *Workshop on the Impact of Hydrogen on Water Reactor Safety Proceedings*. 3:13–65.
8. Ronney, P. D. 1990. Near-limit flame structures at low Lewis number. *Combust. Flame* 82:1–14. doi: 10.1016/0010-2180(90)90074-2.
9. Basevich, V. Ya., A. A. Belyaev, S. M. Frolov, and F. S. Frolov. 2017. Pryamoe chislennoe modelirovanie turbulentnogo goreniya gazov v dvumernom priblizhenii [Direct numerical simulation of turbulent combustion of hydrogen–air mixtures of various compositions in a two-dimensional approximation]. *Goren. Vzryv (Mosk.) — Combustion and Explosion* 10(1):4–10.

Received November 20, 2023

Contributors

Kiverin Alexey D. (b. 1985) — Doctor of Science in physics and mathematics, leading research scientist, Joint Institute for High Temperatures of the Russian Academy of Sciences, 13-2 Izhorskaya Str., Moscow 125412, Russian Federation; alexeykiverin@gmail.com

Melnikova Ksenia S. (b. 1992) — Candidate of Science in physics and mathematics, research scientist, Joint Institute for High Temperatures of the Russian Academy of Sciences, 13-2 Izhorskaya Str., Moscow 125412, Russian Federation; mkss-ks@yandex.ru

Yakovenko Ivan S. (b. 1989) — Candidate of Science in physics and mathematics, senior research scientist, Joint Institute for High Temperatures of the Russian Academy of Sciences, 13-2 Izhorskaya Str., Moscow 125412, Russian Federation; yakovenko.ivan@bk.ru