CHARACTERISTICS OF MICROEXPLOSIVE DISPERSION OF GEL FUEL PARTICLES IGNITED IN A HIGH-TEMPERATURE AIR MEDIUM*

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Abstract: An experimental study of the characteristics of the processes occurring during the ignition and combustion of single particles (10 mg) of typical gel fuel in a high-temperature air environment was carried out using a software and hardware complex consisting of a high-speed video camera, LED spotlight. The group of fuel compositions is prepared on the basis of oil-filled cryogels without and with 30 %(wt.) addition of solid finely dispersed components (coal particles, Si, and Cu). Polyvinyl alcohol (PVA) was used as an organic polymer thickener (10 %(wt.) in an aqueous solution). Fuel compositions are characterized by microexplosive dispersion of particles under conditions of intense heating. By varying air temperature in the range of 600–1000 °C, the velocities of movement of fine fragments after microexplosive dispersion of a droplet of fuel melt were determined.

Keywords: gel fuel; particle; high-temperature air medium; ignition and combustion; dispersion

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References

1. Padwal, M. B., B. Natan, and D. P. Mishra. 2021. Gel propellants. *Prog. Energ. Combust.* 83:100885. doi: 10.1016/j.pecs.2020.100885.
2. Ciezki, H. K., and K. W. Naumann. 2016. Some aspects on safety and environmental impact of the German green gel propulsion technology. *Propell. Explos. Pyrot.* 41(3):539–547. doi: 10.1002/prep.201600039.
3. Baek, G., and C. Kim. 2011. Rheological properties of Carbopol containing nanoparticles. *J. Rheol.* 55(2):313–330. doi: 10.1122/1.3538092.
4. Varma, M., and R. Pein. 2009. Optimisation of processing conditions for gel propellant production. *Int. J. Energetic Materials Chemical Propulsion* 8(6):501–513. doi: 10.1615/IntJEnergeticMaterialsChemProp.v8.i6.30.
5. Fakhri, S., J. G. Lee, and R. A. Yetter. 2010. Effect of nozzle geometry on the atomization and spray characteristics of gelled-propellant simulants formed by two impinging jets. *Atomization Spray.* 20(12):1033–1046. doi: 10.1615/atomizspr.v20.i12.20.
6. Glushkov, D. O., A. G. Nigay, V. A. Yanovsky and O. S. Yashutina. 2019. Effects of the initial gel fuel temperature on the ignition mechanism and characteristics of oil-filled cryogel droplets in the high-temperature oxidizer medium. *Energ. Fuel.* 33(11):11812–11820. doi: 10.1021/acs.energyfuels.9b02300.
7. Glushkov, D. O., G. V. Kuznetsov, A. G. Nigay, V. A. Yanovsky, and O. S. Yashutina. 2020. Ignition mechanism and characteristics of gel fuels based on oil-free and oil-filled cryogels with fine coal particles. *Powder Technol.* 360:65–79. doi: 10.1016/j.powtec.2019.09.081.
8. Vershinina, K. Y., G. S. Nyashina, V. V. Dorokhov, and N. E. Shlegel. 2019. The prospects of burning coal and oil processing waste in slurry, gel, and solid state. *Appl. Therm. Eng.* 156:51–62. doi: 10.1016/j.applthermaleng.2019.04.035.
9. Dreizin, E. L. 2009. Metal-based reactive nanomaterials. *Prog. Energ. Combust.* 35(2):141–167. doi: 10.1016/j.pecs.2008.09.001.
10. Maggi, F., S. Dossi, C. Paravan, *et al.* 2015. Activated aluminum powders for space propulsion. *Powder Technol.*

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270(Part A):46–52. doi: 10.1016/j.powtec.2014.09.048.

11. Sundaram, D., V. Yang, and R. A. Yetter. 2017. Metal-based nanoenergetic materials: Synthesis, properties, and applications. *Prog. Energ. Combust.* 61:293–365. doi: 10.1016/j.pecs. 2017.02.002.
12. Pinchuk, V. A., and A. V. Kuzmin. 2020. The effect of the addition of TiO_2 nanoparticles to coal–water fuel on its thermophysical properties and combustion parameters. *Fuel* 267:117220. doi: 10.1016/j.fuel.2020.117220.
13. Glushkov, D. O., K. K. Paushkina, A. O. Pleshko, V. S. Vysokomorny. 2022. Characteristics of micro-explosive dispersion of gel fuel particles ignited in a high-temperature air medium. *Fuel* 313:123024. doi: 10.1016/j.fuel.2021.123024.
14. Vershinina, K. Y., D. O. Glushkov, A. G. Nigay, V. A. Yanovsky and O. S. Yashutina. 2019. Oil-filled cryogels: New approach for storage and utilization of liquid combustible wastes. *Ind. Eng. Chem. Res.* 58(16):6830–6840. doi: 10.1021/acs.iecr.9b00580.
15. Glushkov, D. O., A. O. Pleshko, and O. S. Yashutina. 2020. Influence of heating intensity and size of gel fuel droplets on ignition characteristics. *Int. J. Heat Mass Tran*. 156:119895. doi: 10.1016/j.ijheatmasstransfer. 2020.119895.
16. Glushkov, D. O., D. V. Feoktistov, G. V. Kuznetsov, K. A. Batishcheva, T. Kudelova and K. K. Paushkina. 2020. Conditions and characteristics of droplets breakup for industrial waste-derived fuel suspensions ignited in high-temperature air. *Fuel* 265:116915. doi: 10.1016/j.fuel.2019.116915.
17. Pinchuk, V. A., and T. A. Sharabura. 2015. Physical and chemical transformations under the thermal action on coal–water fuel made of low-grade coal. *Metall. Min. Ind.* 7(6):623–628.
18. Pinchuk, V. 2018. The main regularities of ignition and combustion of coal-water fuels produced from fat, non-baking coal and anthracite. *Int. J. Engineering Research Africa* 38:67–78. doi: 10.4028/www.scientific.net/JERA.38.67.
19. GOST 20799-88. 2005. Masla industrial'nye. Tekhnicheskie usloviya [Industrial oils. Specifications]. Moscow: Standardinforn. 7 p.
20. Gazpromneft motor oils. 2022. Pasport bezopasnosti khimicheskoy produktsii. Industrial'noe maslo bez dobavok I-40A [The material safety data sheet of chemical products. Industrial oil without additives I-40A]. 46 p. Available at: https://gazpromneft-oil.ru/en#/product/1609/tab/certificate (accessed June 28, 2022).
21. Glushkov, D. O., G. V. Kuznetsov, A. G. Nigay, and V. A. Yanovsky. 2020. Influence of gellant and drag-reducing agent on the ignition characteristics of typical liquid hydrocarbon fuels. *Acta Astronaut.* 177:66–79. doi: 10.1016/j.actaastro.2020.07.018.

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