Control of combustion and detonation by *in situ* blending of fuel with hydrogen peroxide

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Flammability and detonability of air mixtures (both gas-phase and heterogeneous) of hydrocarbon fuels (*n*-heptane, *iso*-octane, and *n*-tetradecane) with hydrogen peroxide (HP) was studied theoretically. The listed hydrocarbons approximately represent jet propulsion (JP) fuel. (It is known that JP kerosene can be considered to be made up of approximately 79% high *n*-alkanes, 10% cycloalkanes and 11% aromatics). The following results have been obtained:

(1) Three approximate approaches to determine the total pressure and gas-phase composition in water – HP two-phase systems depending on solution composition and temperature are presented. Chemical composition is assumed to vary (e.g., due to HP decomposition) slowly as compared with the rate of physical relaxation processes. Although the approaches are based on different prerequisites, all of them are in a good agreement with each other in terms of predictions of total pressure, activity coefficients and equilibrium gas-phase composition. The approaches have been generalized on three- and four-component systems containing low-volatility (nonsolvable JP fuel) and high-volatility (air) components.

(2) The flame velocity in suspensions of *n*-heptane droplets in air with addition of HP vapor increases with the concentration of HP vapor in the mixture. Addition of HP vapor to *n*-heptane–air mixture allows to significantly increase the energy density of the burning material due to increase of the amount of fuel required for complete burnout in the unit volume.

(3) Droplets of HP burn with a considerable temperature rise only at elevated pressures (> 5 bar) and at relatively large droplet size (> 30 μm). Combustion of fine HP droplets at atmospheric pressure shows low exothermicity.

(4) Hybrid combustion of hydrocarbon fuel and HP shows a variety of phenomena. Three modes of hybrid combustion have been studied, namely, (1) combustion of a hydrocarbon droplet in air mixed with HP vapor, (2) combustion of a HP droplet in air mixed with hydrocarbon vapor, and (3) combustion of a hydrocarbon droplet in hot exhaust gas (with no free oxygen) mixed with HP vapor. Such a study provides valuable information on the reactivity of the two liquid fuels injected simultaneously into a combustion chamber. It has been proved, that hybrid combustion is more efficient than combustion of single components in air.

(5) It has been shown that detonability of gas-phase JP fuel – HP blends increases significantly with the content of HP. In terms of the critical initiation energy, the JP fuel – air mixtures with 5% and 20% of HP were shown to be equivalent to stoichiometric ethylene–air and hydrogen–air mixtures, respectively.

(6) Detonation parameters (velocity D_0, temperature and pressure) of JP fuel – HP – air mixtures were shown to be almost independent of the molar fraction of HP, that is important for performance stability of advanced propulsion systems.

(7) It has been found that addition of HP vapor to the hydrocarbon–air mixture results in increase of the specific impulse I_{sp}. This effect becomes apparent at molar concentrations of HP exceeding 10%.

The results can be used for elaborating improved strategies of active and passive control of combustion and detonation in advanced propulsion engines.

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