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

Frolov S.M., Basevich V.Ya., and Kuznetsov N.M.

N.N. Semenov Institute of Chemical Physics, Russian Academy of Sciences
4, Kosigin Str., Moscow 119991, Russia

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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