C-7

Autoignition of emulsified fuel drops with small additives of energetic nanocomposites

F.S. Frolov, S.M. Frolov
Semenov Institute of Chemical Physics RAS, 119991, Moscow, Russia

Droplets of emulsified motor fuel containing liquid hydrocarbon as a continuous phase and metal-based nanocomposite particles as a dispersed phase [1, 2] are believed to exhibit microexplosion behavior, when placed into a hot gaseous flow like that taking place in transportation engines. In preliminary investigations [1], powders of nanocomposite particles Al – MoO_3 and Mg-MoO_3 were shown to exhibit explosion-type reaction at relatively small heating of 500-600 K. Therefore it was instructive to estimate the possibility of emulsion-fuel drop ‘microexplosion’ using a mathematical model of single-component (liquid) drop heating, evaporation, and combustion [3]. The controlled microexplosion of emulsified liquid fuel can be effectively used for mixture homogenization in transportation engines and therefore decreasing the pollutants emission into the atmosphere.

Droplet combustion was modeled using a simple overall chemistry [3]. Ignition procedure – auto-ignition due to elevated temperature of the ambient gas – simulated the ignition process in Diesel engines.

Figures 1 and 2 show the predicted histories of the temperature at the droplet surface (solid lines) and in the droplet center (dashed lines) at pressure 10 bar (Fig. 1) and 20 bar (Fig. 2) and air temperature of 900 K (characteristic of Diesel engine). At pressure 10 bar, the liquid reach the characteristic explosion temperature (570 K) of metal-based nanocomposite powder only at the end of droplet lifetime. At pressure 20 bar, the time taken for the *n*-tetradecane droplet to heat up to the characteristic explosion temperature of powder varies from 0.2 ms (near-surface liquid layers) to 0.9 ms (droplet center). At higher pressures, this time is getting shorter.

These results are directly relevant to the behavior of emulsion-fuel droplets in Diesel engine. Based on these findings, one can expect that the microexplosion phenomenon will be more prominent at higher pressures. Available time for droplet combustion in Diesel engines is estimated as

$$\tau_{av} = 0.167\alpha / n$$

where α is the injection-plus-combustion timing in the engine (in crank angle degrees) and n is the engine speed in rpm. The estimated values of τ_{av} for various α and n indicate that at all reasonable injection-plus-combustion timing and engine speeds, emulsion-fuel droplets (30 micron in diameter) should be subject to microexplosion in Diesel engine. It is implied that microexplosion occurs when the whole droplet is heated up above the characteristic explosion temperature of metal-based nanocomposite powder.

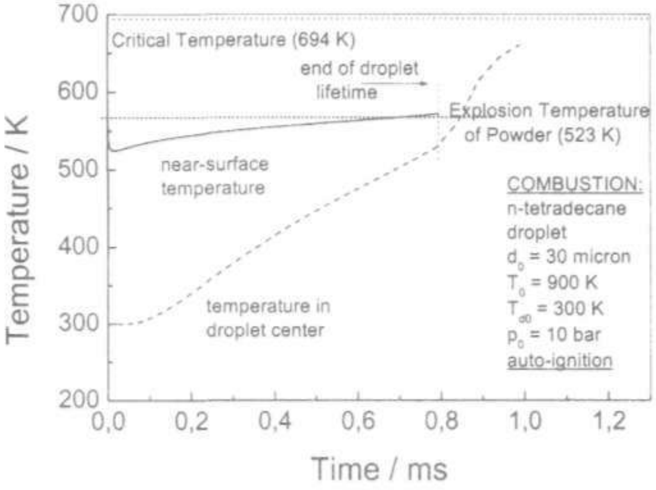

Fig. 1. Predicted histories of the gas temperature at the surface of the burning *n*-tetradecane droplet (solid curve) and liquid temperature in the droplet center (dashed curve) at pressure 10 bar (d_0 = 30 micron, T_0 = 900 K, T_{d0} = 300 K).

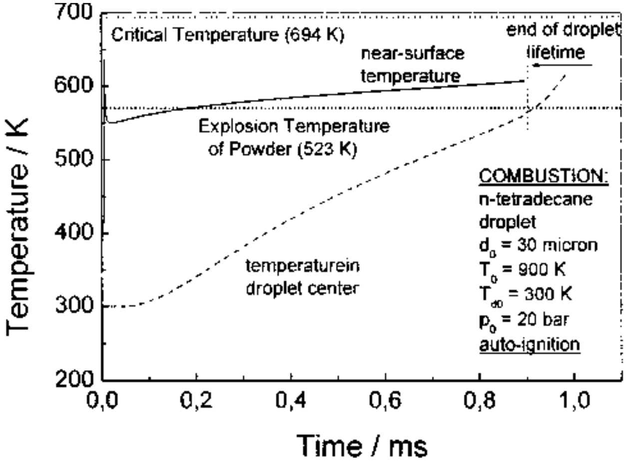

Fig. 2. Predicted histories of the gas temperature at the surface of the burning *n*-tetradecane droplet (solid curve) and liquid temperature in the droplet center (dashed curve) at pressure 20 bar (d_0 = 30 micron, T_0 = 900 K, T_{d0} = 300 K)

This work was supported by RFBR (grant #08-08-00068) and State contracts of Russian Federation #П502 and 019-600.2009.

---

1. Borisov A.A., Kolbanev I.V., Streletskii A.N., Troshin K.Ya., Frolov S.M., Frolov F. S. Autoignition of suspension fuels in air mixtures. In: Combustion and Explosion. Ed. by S.M. Frolov. Moscow, Torus Press, 2010, pp. 118-123.
2. Frolov F.S., Frolov S.M. Autoignition mechanism of suspension fuel drops. In: Combustion and Explosion. Ed. by S.M. Frolov. Moscow, Torus Press, 2010, pp. 124-128.
3. Frolov S.M., Basevich V.Ya., Frolov F.S., Borisov A.A., Smetanyuk V.A., Avdeev K.A., Hotz A.N. Correlation between drop vaporization and autoignition. Rus. J. Chemical Physics, 2009, Vol. 28, No.5, pp. 3-18.