

Effect of energetic powder additives on fuel drop autoignition

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ABSTRACT

Drops of liquid hydrocarbons thickened with ultra-dispersed metal-based nanocomposite particles exhibit microexplosion behavior, when placed into a hot gaseous flow like that in transportation engines. In our preliminary experimental investigations, powders of mechanically activated nanocomposite Al–MoO₃ and Mg–MoO₃ particles were shown to exhibit explosion-type reaction at relatively small heating of 500–600 K apparently without access of gaseous oxidizer. In view of it, we studied the possibility of thickened-fuel drop ‘microexplosion’ using a mathematical model of single-component drop heating, evaporation, and combustion. The controlled microexplosion of thickened-fuel drops can be effectively used for mixture homogenization in transportation engines and for decreasing the pollutants emission.

Drop combustion was modeled using overall chemistry. Ignition procedure simulated the ignition process in Diesel engines. Figures 1 and 2 show the predicted histories of the temperature at the drop surface (solid curves) and in the drop center (dashed curves) at pressure 10 bar (Fig. 1) and 20 bar (Fig. 2) and air temperature 900 K (characteristic of Diesel engine). At pressure 10 bar, the liquid reaches the characteristic explosion temperature (570 K) of metal-based nanocomposite powder only at the end of drop lifetime. At pressure 20 bar, the time taken for the *n*-tetradecane drop 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 relevant to the behavior of thickened-fuel drops in Diesel engine. As a matter of fact, recent experiments performed at Vladimir State University with four-cylinder Diesel engine indirectly confirm our estimates: the use of thickened Diesel oil with 1% to 4% (wt.) additive resulted in decreasing the ignition delay, maximum pressure, and the maximum rate of pressure rise, whereas the indicating efficiency increased by 10–12% thus implying more complete combustion.

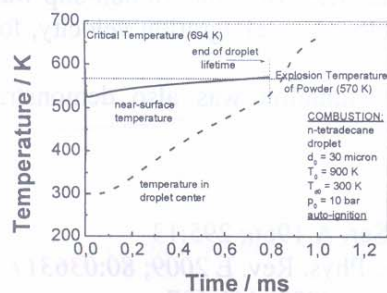


Fig. 1. Predicted histories of gas temperature at the surface of burning *n*-tetradecane drop (solid curve) and liquid temperature in the drop center (dashed curve) at pressure 10 bar ($d_0 = 30 \mu\text{m}$, $T_0 = 900 \text{ K}$)

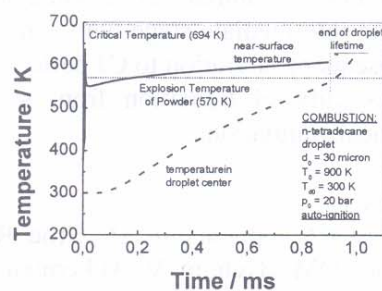


Fig. 2. Predicted histories of gas temperature at the surface of burning *n*-tetradecane drop (solid curve) and liquid temperature in the drop center (dashed curve) at pressure 20 bar ($d_0 = 30 \mu\text{m}$, $T_0 = 900 \text{ K}$)