Dynamics of secondary breakup of an emulsified fuel drop

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We consider a fuel drop of macroemulsion consisting of a spherical fuel layer (SFL), which bounds the water vapor bubble. Behavior of this system, which we called *fuel globule*, differs both from behavior of a liquid drop and of a gas bubble in an infinite liquid. In this regard the ordinary differential equation of a fuel globule radial motion of second order is derived and key estimations are obtained.

The numerical solution shows that SFL is affected by huge inertia forces, caused by acceleration of order $10^9 m/\sec^2$. At such accelerations $1kg$ of SFL mass is affected by inertia force of $10^9 N/kg$. The question regarding hydrodynamic instability of SFL of Rayleigh – Taylor type arises, and this allows us to formulate a hypothesis of the *possible SFL breakup by the instability mechanism*. The justification is carried out via the analysis of feasibility of necessary conditions for the instability realization. It is done on the basis of regularities of SFL motion, which are obtained numerically. Calculations show that in the DE combustion chamber the fuel globule makes damped oscillations with the period $T_{\mathrm{osc}} = (10^{-7} - 10^{-6})\sec$.

The analysis confirms that the external SFL surface is unstable and the necessary conditions are satisfied. The obtained relations give the opportunity to estimate the induction time t_{in} of instability, the sizes and quantity of droplets which are formed as a result of a fuel globule microexplosion. The t_{in} value is small, $t_{\mathrm{in}} \approx 10^{-8}\sec$, so that it gives the possibility of the $\approx e^{35}$-fold growth of the disturbance amplitude. Therefore it is obvious that the instability *has high probability of realization at external SFL surface* at the moment t_{m} of a fuel globule maximal expansion when the acceleration and related inertia forces are maximal. For water concentrations $\alpha_{20} > 30\%$ and at large ratio of vapor–to combustion chamber pressures there exists a possibility of the internal SFL surface instability.

The similarity of a fuel globule microexplosion and a drop breakup in a "claviform" mode in a airstream is used. The fuel globule surface is divided then onto the system of "claviform" cells, so that each of them is bursting similarly to a drop. At the stage of breakup the inertia forces are pulling out the liquid from SFL in the form of thin stems in outward radial direction, making up a "hedgehog" form, and are blowing out thin films at penetration of air through SFL in inward counter-direction (fig. 1). All the surface of a fuel globule is divided thus by the two-dimensional unstable disturbances into the system of "claviform cells", each of which consists of a stem and the surrounding air troughs. These cell elements form the droplets of different sizes at breakup. The total amount of droplets of secondary dispersion of EF is defined also by number of cells $N_{\mathrm{c}} = 4\pi b_{\mathrm{m}}^2/\lambda_{\mathrm{m}}^2$ (b_{m} is SFL radius at t_{m}, λ_{m} is disturbance wavelength). The stem generates $n_{\mathrm{sm}} = \dfrac{0.4\lambda_{\mathrm{m}}^2 h_{\mathrm{m}}}{\pi/6(0.3\lambda_{\mathrm{m}})^3} \approx 28 h_{\mathrm{m}}/\lambda_{\mathrm{m}}$ droplets, which have diameter $d_{\mathrm{sm}} \approx 0.3\lambda_{\mathrm{m}}$ (h_{m} is SFL thickness at t_{m}). There are also $n_{\mathrm{fm}} = \dfrac{0.6\lambda_{\mathrm{m}}^2 h_{\mathrm{m}}}{\pi/6(0.3h_{\mathrm{m}})^3} \approx 42(\lambda_{\mathrm{m}}/h_{\mathrm{m}})^2$ droplets of diameter $d_{\mathrm{fm}} \approx 0.3h_{\mathrm{m}}$ formed by the film.

Thus, the total number of the droplets formed at a fuel globule microexplosion equals to $N = N_{\mathrm{sm}} + N_{\mathrm{fm}}$, where $N_{\mathrm{sm}} = n_{\mathrm{sm}} N_{\mathrm{c}} = 28h_{\mathrm{m}}/\lambda_{\mathrm{m}} \cdot 4\pi b_{\mathrm{m}}^2/\lambda_{\mathrm{m}}^2 = 112\pi h_{\mathrm{m}} b_{\mathrm{m}}^2/\lambda_{\mathrm{m}}^3$, $N_{\mathrm{fm}} = n_{\mathrm{fm}} N_{\mathrm{c}} = 42\lambda_{\mathrm{m}}/h_{\mathrm{m}} \cdot 4\pi b_{\mathrm{m}}^2/\lambda_{\mathrm{m}}^2 = 168\pi b_{\mathrm{m}}^2/\lambda_{\mathrm{m}} h_{\mathrm{m}}$. These sizes are the key ones for calculation of further processes of preparation of homogeneous gas mixture in the diesel engine combustion chamber.

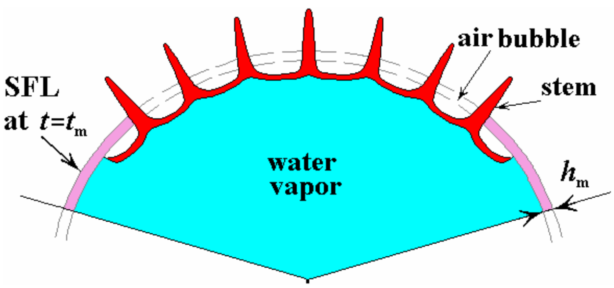

Figure 1. Bursting of a fuel globule.