Burning of two-phase fuel droplets in weightlessness

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In the present paper physical and mathematical models are developed, allowing to consider the effect of multiphase fuel (liquid + solid combustible materials) on the conditions of ignition and modes of propagation of combustion in poly-dispersed non-uniform mixtures. In this case, the combustion of different droplet fractions occurs in different modes: the volatile fraction evaporates and burns in the gas-phase mode, and the solid fuel fraction reacts with the oxidizer in the heterogeneous mode. The effect of the presence of a solid fraction in droplets reacting in a heterogeneous regime on the evaporation rate of the volatile fuel component is studied. The effect of tightness due to the presence of other droplets on the evaporation rate of each droplet is taken into account. The problem is acute for the fire safety in space studies. As it was shown in experiments conducted under strongly reduced gravity conditions, the burning of some structural materials is accompanied by evaporation of low temperature boiling components, which causes the vapor expansion and ejection of material droplets into the vicinity of the burning surface. Those droplets form clouds of droplets near the burning surface surrounded by combustible vapors, which could preserve this state for a long time in microgravity contrary to terrestrial conditions under which gravity makes droplets fall down thus preventing from formation of hazardous aerosol clouds. While in weightlessness such clouds of droplets can exist for long times characterized by combustible vapor concentration exceeding the burning limit. Thus, the clouds of rich mixture could stay in the heated atmosphere of reaction products for some time after flame extinguishing. An incidental air flow caused by switching on ventilation, or just moving of some crew members, could bring to increasing the oxidant concentration in the cloud and accidental volume ignition. The droplets of combustible materials thermally ejected from the surface and injected into the atmosphere have a complex composition, as a rule. In particular, one can distinguish in those droplets volatiles (substances forming a gaseous phase and burning in the contact with gaseous oxidant) and solid combustible particles (substances remaining solid and burning in a heterogeneous regime due to surface contact with an oxidant). The presence of two different types of substances within one agglomerate introduces serious peculiarities in combustion of such droplets. The existing models for evaporating droplet or solid particle combustion cannot be used directly for determining the burning rate.

The developed mathematical model showed that in the presence of condensed fuel in the droplet, the evaporation of the liquid is faster due to the additional energy release because of a heterogeneous reaction on the surface. When only the solid residue remains, the rate of mass consumption decreases abruptly, but then increases rapidly due to an increase in the temperature of the condensed residue due to energy release in heterogeneous reaction.

When the flame propagates in a poly-dispersed mixture, the thickness of the front reaches a dozens of centimeters. Then, as the flame approaches the walls of the chamber, the thickness of the front increases.

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