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SUPERCOMPUTER MODELING OF PULSE DETONATION ENGINES FED BY HYDROGEN

Abstract

Hydrogen being an ecological fuel is very attractive now for rocket engines designers. However, peculiarities of hydrogen combustion kinetics, the presence of zones of inverse dependence of reaction rate on pressure, etc. prevent from using hydrogen engines in all stages not being supported by other types of engines, which often brings back to zero the ecological gains from using hydrogen. Computer aided design of new effective and clean hydrogen engines needs mathematical tools for supercomputer modeling of hydrogen – oxygen components mixing and combustion in rocket engines. The paper presents the results of developing verification and validation of mathematical model making it possible to simulate unsteady processes of ignition and combustion in rocket engines. One of peculiarities of hydrogen-oxygen rocket engine is the following. On injecting liquid components fuel (hydrogen) having must lower critical temperature comes pre-evaporated and pre-heated in combustion chamber, while oxygen could be liquid then evaporating inside the chamber. Thus contrary to most types of engines hydrogen engine has an inverse mixture entering combustion chamber, in which fuel is gaseous and oxidant is liquid. Combustion in terrestrial conditions is strongly affected by thermogravitational instability, which provides additional very effective mixing of the components and formation of combustible mixture in the vicinity of each droplet. On the contrary, this mechanism does not work under low gravity conditions. Only diffusion contributes to mixing, which makes ignition and combustion conditions less favorable. It should be mentioned, that thermo-convective effect on droplet evaporation manifest as long as Mar=(eveporation time) / (convection time) number is larger then unity. This number for evaporating droplet could be evaluated as Mar=($(gr^3)^{0.5}$h)/(DCp(Te-Tw)). Under microgravity conditions Mar number tends to zero and thermo-convective mixing is not essential for all sizes of droplets. Thus ignition and combustion under microgravity needs special investigation. Onset of detonation being very dangerous for classical RAM engines could, however, serve the basis for creating new generation of engines - pulse detonating engines (PDE). For this issue the problems of detonation onset and deflagration to detonation transition should be simulated quite accurately, because these processes strongly depend on inlet conditions, mixture composition and geometrical characteristics of combustion chamber. The authors wish to acknowledge the support by Russian Foundation for Basic Research (Grants 12-08-91702 and 13-03-00003).