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SPACE PROPULSION SYMPOSIUM (C4)
Hypersonic and Combined Cycle Propulsion (5)

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EXPERIMENTAL AND NUMERICAL ANALYSIS ON FLAMEHOLDING MECHANISMS IN A SUPERSONIC COMBUSTOR EQUIPPED WITH A CAVITY FLAMEHOLDER

Abstract

Flameholding procedure and its plausible mechanisms in a supersonic combustor with gaseous fuel (H2, C2H4 or C2H2) combustion around cavity flameholders were investigated by experimental observation and large eddy simulation. The supersonic combustion process was observed using high-speed-framing camera on visible lights and ICCD (Intensified Charge-Coupled Device) on self-radiation of radicals. Comparisons from variable cavity configurations and variable injection position were made (seen from figs 1-4) and the pressure distribution along the combustor was given in fig 5-6. Two different stable flame stabilizing mode, cavity shear layer combustion and cavity shear layer plus jet beam combustion, were observed. Large eddy simulations with hybrid RANS/LES and partially premixed flamelet model are conducted to the supersonic combustion flowfields. The partially premixed flamelet model is a hybrid method using G equation level set method for premixed combustion and Z mixture fraction equation for non-premixed combustion. In this paper the G equation level set equation was used for calculating the flame front position and gave bound for non-premixed combustion region. The results show that the cavity shear layer plays a very important role in the flameholding process. Part of fuel is convected into the cavity shear layer and an inceptive flame is formed in the cavity shear layer. Counter-rotating vortices induced by the jet interact with the cavity shear layer and the flame in the cavity shear layer fluctuates with the shear layer oscillation. Flame is likely to spread along the counter-rotating vortices, go through the center of the jet and ignite the whole downstream fuel jet eventually. Combustion products, which are generated from the cavity shear layer and the jet, are convected into the cavity by the unsteady motion of the cavity shear layer and transported with the recirculation flow to the cavity front wall. These hot products and their intermittent combustion then heat up the cavity and the fuel that enters into the cavity shear layer is ignited due to flame-backward propagation. Thus the flameholding cycle is formed. Combined with the understanding of the function of recirculation zone with high temperature, it could be considered that recirculation-zone ignition mechanism and triple flame stabilizing mechanism are both plausible flameholding mechanisms of cavity flameholders in low total-enthalpy supersonic flows. These two mechanism types have a competition-relation on the ignition.