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Hypersonic Air-breathing and Combined Cycle Propulsion (9)

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HEAT TRANSFER ENHANCEMENT OF SUPERCRITICAL HYDROCARBON FUEL IN REGENERATIVE COOLING CHANNELS WITH MICRO-RIBS OF SCRAMJET

Abstract

Regenerative cooling process is very important for effective thermal protection of the propulsion systems, including the rocket, supersonic combustion ramjet (scramjet), and some combined cycle propulsion. The cooling process is accomplished by circulating the hydrocarbon fuel in micro channels surrounding the combustion chamber, prior to fuel injection. The operating pressure is generally higher than the fuel's critical pressure, thus leading to fluid flows and heat transfer at a supercritical pressure. For the sake of drastic property change of supercritical fuel and local high heat flux in cooling channel in scramjet, micro-rib has been used as heat transfer structures to weaken thermal stratification in channels and local heat transfer deterioration. A 3D numerical model has been built to investigate the flow and heat transfer characteristics of supercritical hydrocarbon fuel in smooth channel and enhanced channels with micro-ribs. Parametric analysis has been carried out to explore the effect of the dimensions of micro-ribs on the thermal behaviors of the cooling channel. The results have shown that the height and pitch of micro-rib arrays have significant influence on it. With the increase of the rib height, the effect of channel side wall on heat transfer is strengthened and shock effect as a locally remarkable heat transfer enhancement phenomenon might occur. For specific thermal conditions and cooling requirements, there exists an optimal micro-rib dimension defined as h/e and p/e to achieve the best comprehensive heat transfer by ensuring the full development of secondary flow to obtain the most effective perturbation of micro-ribs and avoiding the thickening of laminar sub-layer from fluid reattachment point behind the obstacles. In the present studies, the optimal micro-rib dimension is: e=0.3mmh=0.144mmp=3mmwhere h/e=0.48p/e=10