SPACE PROPULSION SYMPOSIUM (C4)
Interactive Presentations (IP)

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NUMERICAL AND EXPERIMENTAL STUDY OF SUPERSONIC FILM COOLING WITH CRACKING HYDROCARBON FUEL AS COOLANT

Abstract

This paper proposed the method to extend the cooling capacity of hydrocarbon fuel in a scramjet engine or a combined cycle engine through combining the regenerative cooling with supersonic film cooling, with the gaseous hydrocarbon fuel of the exit of regenerative cooling channel being used as the film coolant. Through basic analysis, the supersonic film cooling with hydrocarbon fuel as coolant was found to be a kind of flow with non-equilibrium cracking reaction, the cracking reaction will have significant effects on the heat transfer characteristics of the cooling film. To validate its feasibility of the supersonic film cooling using gaseous hydrocarbon fuel as coolant and explore its heat and mass transfer characteristics, numerical model and experimental table were established. The numerical and experimental study of supersonic film cooling with cracking hydrocarbon fuel as coolant were carried out. The numerical and experimental results indicate that supersonic film cooling using hydrocarbon fuel as coolant is very efficient, and larger blowing ratio and film thickness were beneficial for improving the film cooling efficiency. The non-equilibrium cracking reaction has due effects on the supersonic film cooling. On one hand, the cracking reaction absorbs heat and that is beneficial for improving the film cooling efficiency. On the other hand, the cracking reaction will significantly disturb the flow and enhance the mixing by changing its thermophysical properties and that is bad for improving the film cooling efficiency. The overall effects of cracking reaction on the film cooling efficiency depends on the balance between the good effects and bad effects. Increasing the blowing ratio and the film thickness will reduce the good effects and enhance the bad effects because the conversion of fuel depends on the fuel temperature and its residence time. While increasing the blowing ratio means reducing the residence time of the fuel and a larger film thickness means a lower film temperature, which slows down the cracking reaction of fuel. The results of this paper can be a guidance of designing the supersonic film cooling using cracking hydrocarbon fuel as coolant and it helps improve the cooling capacity of hydrocarbon fuel in a hydrocarbon fueled scramjet engine or combined cycle engine.