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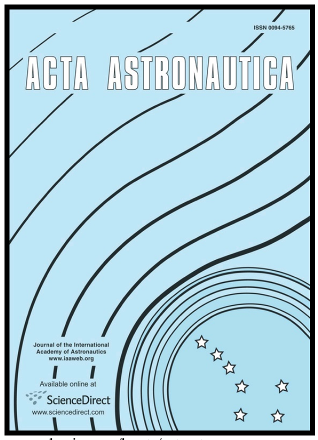

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Numerical Investigation of Scale Effect of Various Injection Diameters on Interaction in Cold Kerosene-fueled Supersonic Flow

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Abstract

The incident shock wave generally has a strong effect on the transversal injection field in cold kerosene-fueled supersonic flow, possibly due to its affecting the interaction between incoming flow and fuel through various operation conditions. This study is to address scale effect of various injection diameters on the interaction between incident shock wave and transversal cavity injection in a cold kerosene-fueled scramjet combustor. The injection diameters are separately specified as from 0.5 to 1.5mm in 0.5mm increments when other performance parameters, including the injection angle, velocity and pressure drop are all constant. A combined three dimensional Couple Level Set & Volume of Fluids (CLSVOF) approach with an improved K-H & R-T model is used to characterize penetration height, span expansion area, angle of shock wave and sauter mean diameter (SMD) distribution of the kerosene droplets with/without considering evaporation. Our results show that the injection orifice surely has a great scale effect on the transversal injection field in cold kerosene-fueled supersonic flows. Our findings show that the penetration depth, span angle and span expansion area of the transverse cavity jet are increased with the injection diameter, and that the kerosene droplets are more prone to breakup and atomization at the outlet of the combustor for the orifice diameter of 1.5mm. The calculation predictions are compared against the reported experimental measurements and literatures with good qualitative agreement. The simulation results obtained in this study can provide the evidences for better understanding the underlying mechanism of kerosene atomization in cold supersonic flow and scramjet design improvement.

Key words: Scale effect, Transversal cavity injection, Cold supersonic flow, Couple Level Set & Volume of Fluids (CLSVOF), K-H & R-T model

1. Introduction

Development of an optimum supersonic combustion ramjet (scramjet) engines are pivotal for the realization of hypersonic vehicles [1]. Understanding the effect of the injection system design on the interaction characteristics between incoming flow and fuel in cold supersonic flow is a key issue for development of scramjets. However, design of the optimum injection system with great performance capabilities is really a challenge [2]. This is predominantly due to the fact that the hypersonic vehicles are generally operated at high Mach number, e.g. 8, which indicates that the residence time of the supersonic free-stream within the combustion chamber of the scramjet is extremely short, typically on the order of milliseconds [1]. Too short residence time of the fuel incurs incomplete mixing and, hence, strongly affects the combustion efficiencies [2].

Currently, studies have already addressed the design of injector systems for improving the fuel-air mixing