Numerical Investigation of Supersonic Combustion of the HyShot II in the Shock Tunnel*

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ABSTRACT

There has been widespread interest in air-breathing supersonic combustion and its applications in scramjets. Due to the complexity of the engine and the high cost of experimental investigations, numerical investigations have been adopted by many researchers and, once validated by the measured results, they can be used to capture the salient features of the combustion phenomenon and flows within the scramjet. This paper aims at using the commercial software, FLUENT, to investigate the thermodynamic properties in the HyShot II combustor. To assess the effect of different turbulence models in the supersonic hydrogen-air combustion process, three turbulence models, namely, the Spalart-Allmaras (SA) model, the Realizable $k-\varepsilon$ model (RKE), and the Shear Stress Transport turbulence model ($SST-k\omega$) have been implemented. The evaluation of chemical reaction mechanisms is done by considering both the single-step and the multi-step reaction mechanisms. It is found that the SST-$k\omega$ model shows best results and significant difference in pressure and temperature is observed between the results obtained using the single-step and the 19-step reaction mechanisms.

Keywords: HyShot, Scramjet, Turbulence, Supersonic-combustion, Hydrogen

I. INTRODUCTION

Recent interests in scramjet engine have attracted efforts from numerous researchers to the topic of supersonic combustion. The University of Queensland devised a ballistic re-entry vehicle called HyShot to achieve supersonic combustion conditions for a flight mach number of approximately $M = 8$. A double wedge intake and two back-to-back combustors constituted the HyShot engine. It was supplied with hydrogen fuel and air mixture at an equivalence ratio of 0.3 [1]. The aerodynamic test of the HyShot configuration was carried out in the High Enthalpy Shock Tunnel Göettingen, HEG, of the German Aerospace Center. Because of the complexity of the air-breathing engine, computational fluid dynamics was used to support the experimental design and the analysis experimental data of supersonic combustion [2-5].

Recent development of computer hardware has improved the effectiveness of computational fluid dynamics (CFD) tools in supersonic combusting flows. Karl et al. [5] have successfully simulated the intake flow field and revealed that the flow in this region was highly two-dimensional and the assumption of uniform inflow conditions in spanwise direction at the combustor entrance plane were justified. This allows the use of the existing symmetries in the combustor flow field to reduce the size of the computational domain to one eighth of the original span. The domain is then bounded by two symmetry planes, one at the center of an injector and the other between two injectors. They assumed a Probability-Density-Function (PDF) model to study the influence of turbulent fluctuations on the species source terms in detailed chemistry schemes.

Boyce et al. [6] employed the Baldwin-Lomax turbulence model and the 12-species 25-reaction