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STUDY ON LOW-COST PREDICTION OF THE CAVITY FLAME HOLDER FLOW FIELD IN A SCRAMJET AND ITS APPLICATION TO DESIGN OPTIMIZATION

Abstract

Scramjets are expected to be used for future space travel and intercontinental high-speed transportation. However, the development of a scramjet requires large-scale test facilities and a large number of trial-and-error hardware fabrication and testing. Therefore, the application of CFD analysis technology is important to enable development at a smaller cost. However, CFD analysis of such supersonic combustion flow fields is currently technically difficult and the prediction accuracy is not sufficient. In addition, since the number of analytical grid points in a 3D analysis is in the order of a billion, even if a supercomputer is used, a calculation time of about one month per case is required, and its application to multi-objective optimization is difficult at the present time. Given this background, in order to apply multi-objective optimization, which is effective in accelerating future research and the development of actual hardware, it is essential to have an analysis method with a low computational load and moderate accuracy that can run many cases per day. The objective of this study is to develop a simulation method that can complete the calculation of the supersonic combustion flow field in a scramjet within a few hours at the workstation level, and to use it for multi-objective optimization. Since flame holding in a scramjet is a difficult and important technique, this study focuses on simulating the inside of a scramjet cavity flame holder. Therefore, in order to simulate the results of combustion experiments in previous studies at low cost, we performed many cases of 2-D and 3-D calculations applying various analytical grids and turbulent combustion models using CHARIOT, JAXA's in-house code that has been applied in many past cases. As a result, we were able to reproduce the mixing conditions in the flame holder as in combustion experiments and optimize the combination of models to achieve both cost and accuracy. Furthermore, Schlieren visualization experiments of non-reactive flow were conducted for many cases to verify the validity of the developed simulation method. These results show that the developed simulation method can be used for multi-objective optimization in the analysis of supersonic combustion flow fields such as scramjet. Finally, this simulation method was applied to optimize the design of flame holder geometry and fuel injection method in the previous study to confirm the improvement of mixing and flame holding performance.