Paper ID: 53559
oral

IAF SPACE PROPULSION SYMPOSIUM (C4)
Propulsion Technology (3) (10)

Author: Mr. Masaki Adachi
Mitsubishi Heavy Industries, Ltd., Japan, masaki_adachi@mhi.co.jp

Mr. Akira Ogawara
Mitsubishi Heavy Industries, Ltd., Japan, akira_ogawara@mhi.co.jp
Mr. Daiki Watanabe
Mitsubishi Heavy Industries Ltd. Japan, Japan, daiki1_watanabe@mhi.co.jp
Dr. HIDEKI MORIAI
Mitsubishi Heavy Industries, Ltd., Japan, hideki_moriai@aeroeng.mhi.co.jp
Prof. Ryoichi Kurose
Kyoto University, Japan, kurose@mech.kyoto-u.ac.jp
Mr. Takayuki Nishiie
Japan, nishiie@nufd.jp

DEVELOPMENT STATUS OF NUMERICAL SIMULATIONS FOR ROCKET ENGINE DESIGN ACTIVITIES - TOWARDS PRECISE PREDICTION OF COMBUSTION INSTABILITIES -

Abstract

Since higher reliability is necessary for enhancing competitiveness in the rocket engine world, the requirements for the precise predictions of local physical phenomena and unsteady characteristics such as oscillations are increasing in order to achieve higher reliable design. For this purpose, it is essential to effectively utilize the numerical simulation technology. Mitsubishi Heavy Industries, Ltd. (MHI) has been developing a new Japanese booster engine of H3 Launch Vehicle, i.e. LE-9, under the contract with Japan Aerospace Exploration Agency(JAXA) and challenging to develop and utilize the numerical simulation code for precisely predicting the turbulent combusting field in a rocket engine chamber for the design of the LE-9. In this paper, we introduce the summary and current status of the developing numerical simulation code, and show some new results on the relationship between chamber pressure and heat release rate oscillations, which is a key phenomenon to elucidate the combustion instability mechanism, in a rocket engine chamber (hydrogen/oxygen reaction at 9.8 MPa). In order to precisely capture the unsteady turbulent flow behavior and the detailed reaction chemistry, Large-eddy Simulation (LES) with a flamelet approach is employed. As the flamelet approach, an unsteady flamelet/progress variable (UFPV) approach considering 8 chemical species and 21 reactions and real gas effects is employed (Kishimoto et al., J. Heat Trans., 2017). The LES code has been developed based on an unstructured LES solver; FrontFlow/Red extended by Kyoto University, CRIEPI and NuFD (e.g. Tachibana et al., Combust. Flame, 2015). The LES results are validated by comparing with the experimental data done by JAXA at the high temperature and pressure combustion test facility in Kakuda Space Center. In the experiment, the chamber pressure is arbitrarily excited by adjusting a siren wheel. The results show that the characteristics of the combustion field such as high reaction rate location and flame configuration predicted by the present LES are consistent with those observed in the experiment. It is found that the present LES can also well capture the interaction between the pressure and heat release rate oscillations in the process of the evolution of combustion instabilities in the chamber. The phase delay, which is a parameter in the transfer function between the pressure and heat release rate oscillations, predicted by the LES agrees well with that evaluated in the experiment. Furthermore, the parameter study of the excitation frequency suggests that the propagation speed is hardly affected by the excitation frequency.