Numerical Study of Detonation Process in Rotating Detonation Engine and Its Propulsive Performance

(The Singapore Poland Science & Technology Co-operation, 2006-2010)

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This project was part of the Joint Singapore-Poland Science and Technology cooperation, in particular, a collaboration between the Institute of High Performance Computing (IHPC) of A*STAR, Singapore and the Warsaw University of Technology, Poland, in 2006-2010. IHPC aimed to develop numerical modelling and perform computational fluid dynamics simulations of detonation processes in a rotating detonation engine (RDE) model, and the Warsaw University of Technology was tasked to build its experimental facilities and perform the experiment work to study various aspects associated with the detonation in RDE. Here, we present the work carried out at the Institute of High Performance Computing during the successful collaboration under this co-operation agreement.

Numerical studies on detonation wave propagation in rotating detonation engine and its propulsive performance with one- and multi-step chemistries of a hydrogen-based mixture are presented. The computational codes were developed based on the 3D Euler equations coupled with source terms that incorporate high-temperature chemical reactions. The governing equations were discretized using Roe scheme-based finite volume method for spatial terms and 2nd order Runge-Kutta method for temporal terms. One-dimensional detonation simulations with one- and multi-step chemistries of a hydrogen-air mixture were performed to validate the computational codes and chemical mechanisms. In 2D simulations, detonation waves rotating in a rectangular chamber were investigated to understand its flow field characteristics, where the detailed flow field structure observed in the experiments was successfully captured. Three-dimensional simulations of two-waved rotating detonation engine with an annular chamber were performed to evaluate its propulsive performance in the form of thrust and specific impulse. It was shown that rotating detonation engine produced constant thrust after the flow field in the chamber was stabilized, which is a major difference from pulse detonation engine that generates repetitive and intermittent thrust.

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