Numerical study on three-dimensional rotating detonation wave in cylinder tube

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Abstract: A rotating detonation wave propagating in a cylinder tube is three-dimensionally simulated with one-step chemical reaction model. The governing equation is Euler equation on general coordinate. Overset grid approach is used to avoid the difficult in computing singular points on the tube center line. A rotating detonation wave (DW) is generated through direct ignition of injected combustible gas by one-dimensional ZND detonation wave (DW). After several millisecond s, the flow field converges to two rotating detonation waves propagating with center symmetry.

Keywords: rotating detonation wave, hollow combustion chamber, continuous, 3D simulation

1 Introduction

About CDEs' (continuous detonations engine) numerical simulation, all of the former works[1] are about co-axial cylinder tube. However, this model may cause engine cooling difficulties in real engine design. Contrast to a co-axial tube[2], a cylinder tube without inner wall may greatly reduce the difficulties in engine cooling. Here, we make a three-dimensional numerical simulation to investigate the physical phenomenon of rotating detonation propagating in cylinder tube.

2 Problem Statement

The one-step chemical kinetic model was used in this simulation. The governing equations are the three-dimensional Euler equations which are here expressed in general coordinates. Besides, we used the overlapping grid system to take precautions against the singularity on the axis of the chamber. On numerical format, MPWENO was used to catch the shock waves and detonation waves.

Fresh gas is continuously injected into the combustor through small slits or orifices at the outer annulus ($3cm \leq r < 6cm$) at the head wall. The inner area ($r<3cm$) at the head wall is solid wall without injection nozzle. Detonation products are ejected from the exit end to provide thrust. The whole tube is initially injected with quiescent, combustible gas mixture. It ignited by a ZND DW (detonation wave) (showed in Fig. 1). A premixed stoichiometric H_2/air mixture injection condition is set according to the local wall pressure following Laval tube theory.

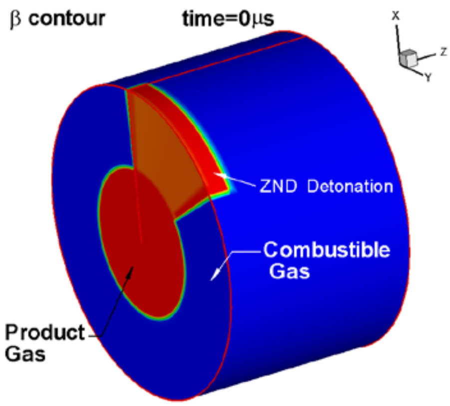

Figure 1 Initial condition

3 Conclusion and Future Work

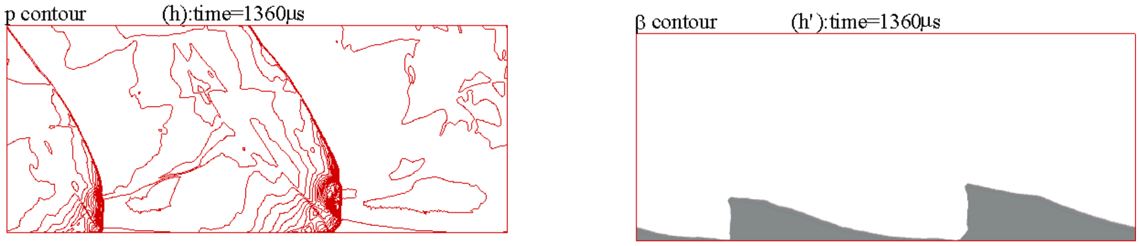

Figure 2 pressure contour and reaction progress parameter at 1360 μs

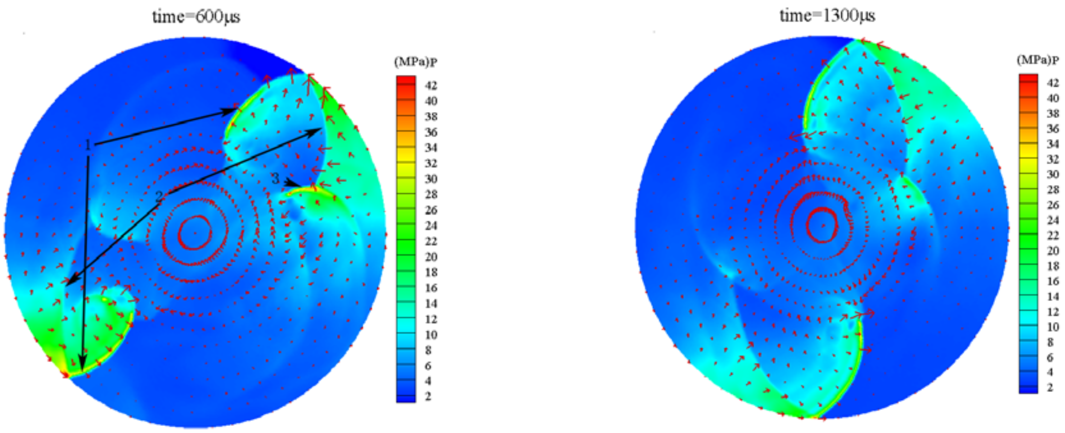

Figure 3 Axial cut (z=0.2cm) pressure contour

Till to 1360 μs , the entire flow field just has small pressure disturbance and the flow field automatically convergent to two quasi-steady detonation waves.

Rotating Detonation Waves can continuously propagate in hollow cylinder tube. The heat load which in co-axial tube is avoid in the hollow tube. CDEs represent an essentially innovative combustor design for a future propulsion system. They are easy to substitute as combustors for conventional aviation systems to achieve mainly higher performances. Moreover, the simple CDE design offers economic and low-risk benefits when combined with existing engines. Once proven to be effective, CDEs are expected to be immediately available as upgrades for jet engines or rocket motors.

References

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