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쐐기 및 원추 주위의 불안정한 충격파 유도연소 해석

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Analysis of Unstable Shock-Induced Combustion over Wedges and Conical Bodies

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Abstract

Mechanism of a periodic oscillation of shock-induced combustion over a two- dimensional wedges and axi-symmetric cones were investigated through a series of numerical simulations at off-attaching condition of oblique detonation waves (ODW). A same computational domain over 40 degree half-angle was considered for two-dimensional and axi-symmetric shock-induced combustion phenomena. For two-dimensional shock-induced combustion, a 2H2+O2+17N2 mixture was considered at Mach number was 5.85 with initial temperature 292 K and initial pressureof 12 KPa. The Rankine-Hugoniot relation has solution of attached waves at this condition. For axi-symmetric shock-induced combustion, a H2+2O2+2Ar mixture was considered at Mach number was 5.0 with initial temperature 288 K and initial pressure of 200 mmHg. The flow conditions were based on the conditions of similar experiments and numerical studies.[1,3]

Numerical simulation was carried out with a compressible fluid dynamics code with a detailed hydrogen-oxygen combustion mechanism.[4,5] A series of calculations were carried out by changing the fluid dynamic time scale. The length wedge is varied as a simplest way of changing the fluid dynamic time scale. Result reveals that there is a chemical kinetic limit of the detached overdriven detonation wave, in addition to the theoretical limit predicted by Rankine-Hugoniot theory with equilibrium chemistry. At the off-attaching condition of ODW the shock and reaction waves still attach at a wedge as a periodically oscillating oblique shock-induced combustion, if the Rankine-Hugoniot limit of detachment isbut the chemical kinetic limit is not.

Mechanism of the periodic oscillation is considered as interactions between shock and reaction waves coupled with chemical kinetic effects. There were various regimes of the periodicmotion depending on the fluid dynamic time scales. The difference between the two-dimensional and axi-symmetric simulations were distinct because the flow path is parallel and uniform behind the oblique shock waves, but is not behind the conical shock waves. The shock-induced combustion behind the conical shock waves showed much more violent and irregular characteristics.

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From the investigation of characteristic chemical time, condition of the periodic instability is identified as follows; at the detaching condition of Rankine-Hugoniot theory, (1) flow residence time is smaller than the chemical characteristic time, behind the detached shock wave with heat addition, (2) flow residence time should be greater than the chemical characteristic time, behind an oblique shock wave without heat addition.

References

1. Morris, C. I., Kamel, M. R. and Hanson, R. K., "Shock-Induced Combustion in High-Speed Wedge Flows," Twenty-Seventh Symposium (International) on Combustion, The Combustion Institute, 1998, pp.2157-2164.
2. Toong, T.-Y., Combustion Dynamics: The Dynamics of Chemically Reacting Fluids, McGraw-Hill, New York, 1983, p. 240.
3. Choi, J.-Y., Jeung, I.-S. and T.-S. Roh, "Periodical Oscillation of Combustion Induced by Oblique Shock Wave," AIAA-2002-3717, 38th AIAA/ASME/SAE/ASEE Joint Propulsion, 7-10 July, 2002, Indianapolis, IN.
4. Choi, J.-Y., Jeung, I.-S. and Yoon, Y., "Computational Fluid Dynamics Algorithms for Unsteady Shock-Induced Combustion, Part 1: Validation," AIAA Journal, Vol. 38, No. 7, July 2000, pp.1179-1187.
5. Choi, J.-Y., Jeung, I.-S. and Yoon, Y., "Computational Fluid Dynamics Algorithms for Unsteady Shock-Induced Combustion, Part 2: Comparison," AIAA Journal, Vol. 38, No. 7, July 2000, pp.1188-1195.

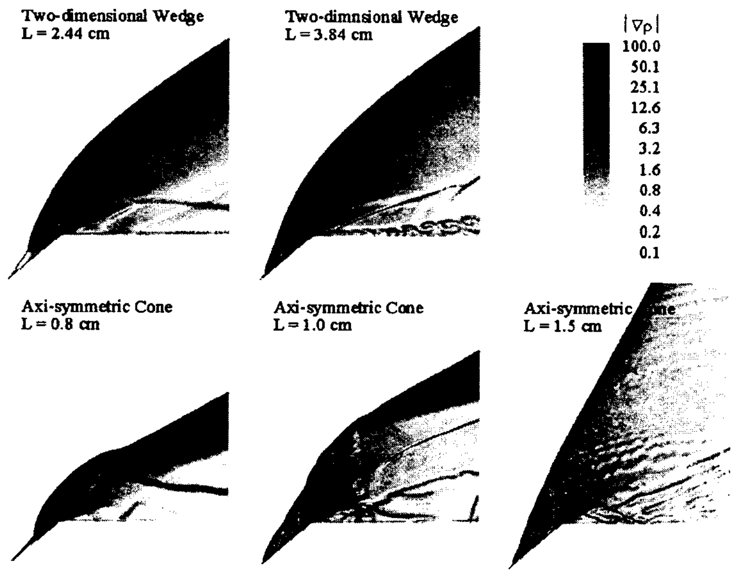

Fig. 1 Instantaneous density gradient plots for shockinduced combustion over two-dimensional wedges and axi-symmetric cones. (L is the length of the inclined portion of the wedge)