SUMMARY OF Ph.D. DISSERTATION

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Title

Unsteady Features on One-dimensional Detonations and its Application for Wedge-induced Oblique Detonations

Abstract

There are great expectation to an oblique detonation engine and a ram accelerator as propulsion systems for aerospace planes in the next generation. In the study and development of the above mentioned propulsions, the detonation has to be safety utilized and be reliably initiated. In order to control the detonation in the propulsions, it is necessary for us to investigate the initiation behind the shock wave. Detonations essentially have three-dimensional features. However, one-dimensional features appear in multi-dimensional experiments and simulations. The results of one-dimensional features have been utilized in elucidation of multi-dimensional nature.

This study aims at revealing the unsteadiness of one-dimensional unsteady detonation wave front and the explosion nature behind the shock wave. Based on the results of numerical study of one-dimensional unsteady detonation, I investigate an analogy between one-dimensional piston-supported unsteady detonations and two-dimensional wedge-induced steady oblique detonations, and the analogy is applied to a prediction of the wave structure of the wedge-induced steady oblique detonation.

Chapter 1 is the introduction of this study and describes the propulsion systems utilizing detonation waves. I explain the hypersonic small-disturbance theory that proves the analogy between the one-dimensional unsteady flow and the two-dimensional steady flow. This theory is the motivation of this thesis. Lastly, I refer the studies of the shock-induced combustion around projectile as an example of the application of the one-dimensional detonation features.

In Chapter 2, the detailed features of one-dimensional detonation are indicated. A one-step chemical reaction obeying an Arrhenius rate expression and 19 forward and backward chemical reactions for hydrogen-oxygen combustion mechanism are used. The unsteadiness of the detonation wave front and the features of the explosion behind the shock are investigated using each reaction model. When the detailed chemical reaction model is used, the induction region can be reproduced regardless of gas conditions. Furthermore, the features related to the second explosion limit appear in the flow field because the detailed chemical reaction model can reproduce the production and deactivation of OH radical.

In Chapter 3, I carry out the inviscid numerical simulations of one-dimensional piston-supported unsteady detonations and two-dimensional wedge-induced steady oblique detonations based on the discussion of the features in detonations for both reaction mechanisms. By means of the application of the analogy between two detonations, the prediction of the wave structure in the wedge-induced oblique detonation is investigated. Navier-Stokes simulations of the oblique detonations are carried out in an attempt to discuss the effect of viscosity for the analogy and the prediction. In the Navier-Stokes simulations, the boundary layer in the flow field creates a stronger shock at the leading edge and a higher temperature behind the shock. This higher temperature shortens the induction length. If we know the exact oblique shock strength, the induction length can be predicted by the results of the piston-supported detonation.

Chapter 4 is the summary of this thesis.