Analysis for analog system of detonation with two step chemical reaction model

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ABSTRACT The paper builds the analog system of detonation with loss and the chemical reaction of two step reaction model, wherein an induction zone is followed by a energy and heat release zone.Steady state of detonation wave structures are obtained by analytic method. The stability study of ZND detonation is researched by normal-mode method in this paper.

1 INTRODUCTION

The Euler equation is used to study the detonation performance. Euler equations contain mass conservation equation, energy conservation equation and momentum conservation equation. Excessive variables in the Euler equation make calculations and theoretical analysis more difficult. Analog system of detonation can simplify the Euler equations. The simplified model can capture many of the phenomena of the much more complicated reactive Euler and Navier-Stokes equations governing physical detonation and eliminate enough of technical complexities so as to be mathematically easy.

2 ESTABLISHMENT OF ANALOG SYSTEM

In this paper, On the basis of the Fickett model, consider the effect of the loss term, and establish a new analog system of detonation as follows:

$$\frac{\partial u}{\partial t} + \frac{\partial}{\partial x}\left(\frac{1}{2}u^2\right) = q\frac{\partial \lambda}{\partial t} - \kappa\left(\frac{u}{u_{CJ}}\right)^m \tag{1}$$

Where, analog quantities u can represent such as speed, pressure, temperature. The reaction term is used to simulate the reaction rate in the Euler equation, where the form of the simplified combustion model is chosen. In the reaction term, q is the exothermic coefficient of the reaction, that unit of chemical reaction to release energy, and λ is the reaction progress variable that records the completion of the reaction. In the loss term, κ is the loss parameter, which represents the curvature of the detonation wave front. The loss index m represents the sensitivity of the loss term to the local thermal state, and u_{CJ} is a constant based on the CJ state. The chemical reaction is a two-step induction-reaction model with independently controlled induction and reaction stages in the form:

$$\begin{aligned} \frac{\partial \lambda_i}{\partial t} &= -H(\lambda_i)\, e^{\alpha\left[(u/2u_{CJ})-1\right]} \\ \frac{\partial \lambda_r}{\partial t} &= \left[1 - H(\lambda_i)\right] H(1-\lambda_r)(1-\lambda_r)^{\upsilon}\left(u/u_{CJ}\right)^n \end{aligned} \tag{2}$$

In the chemical reaction, λ_i is the process variable of the induction zone, λ_r is the process variable of the reaction zone, ν is the reaction order, $H(\ )$ is the Heaviside function, α is the reaction rate induction parameter, and the reaction rate index n is the sensitivity of the reaction rate to the local thermal state.

3 CRITICALITY OF DETONATION

Steady state of detonation wave structures are obtained by analytic method. By changing the value of the sensitivity exponent of reaction rate n and the sensitivity coefficient of loss rate m, we get the diagrams of steady detonation velocity and the loss coefficient κ under the corresponding parameter(Fig.1) and detonation failure of linear boundary(Fig.2), and derive the critical characteristics of detonation failure conditions finally.

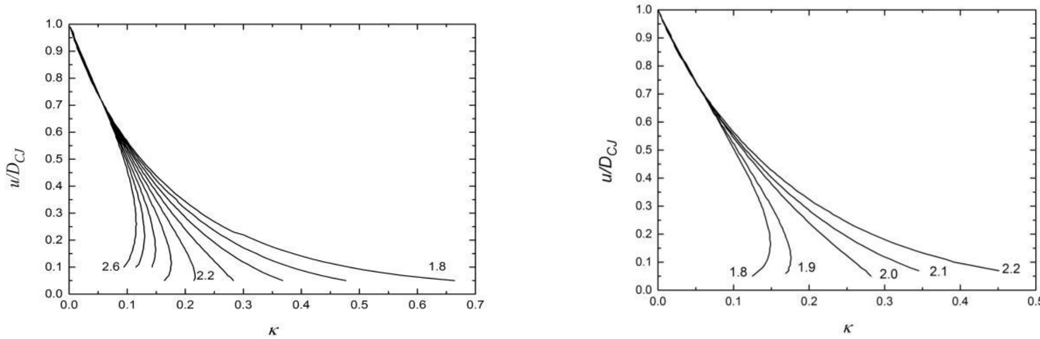

Fig.1 Detonation velocity and curvature curve with different *n*(left); with different *m*(right)

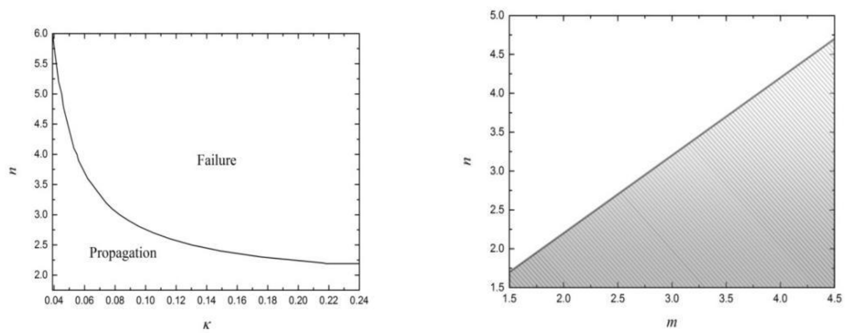

Fig. 2 Linear boundary of detonation propagation and failure(left); The diagram of *m*-*n* when the inflection point(right).

4 STABILITY ANALYSIS

The linear stability is observed by applying the unsteady small perturbations in the steady-state ZND solution to observe the perturbation growth or decay process. Assuming that the perturbation is very small, the basic equation can be linearized near the steady one-dimensional ZND solution. Normal-mode method is used to study the stability of the analog system. A radiation (closure) condition is derived and applied at the end of the reaction zone. An analysis is performed to investigate whether the ideal, steady-state detonation can keep stable to small perturbations.

5 REFERENCES

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