THE EFFECT OF SHOCK INDUCED TURBULENT BOUNDARY LAYER ON DEFLAGRATION TO DETONATION TRANSITION IN DUCTS

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1. Introduction

Deflagration to detonation transition (DDT) in most gaseous combustible mixtures is known to take place in sufficiently long ducts. Despite intensive studies of the DDT phenomenon, universal theory is still lacking. An *"explosion in explosion"* [1] is one of important subtle processes in general view of DDT. The entity of *"explosion in explosion"* is that a detonation wave is abruptly created somewhere between the flame and foregoing sequence of shock and compression waves. But experimental observations show that a localised explosion, if occurs, does not necessarily gives rise to detonation. The thermodynamic parameters of the shock-compressed gas in multiple shocks and compression waves under conditions pertaining to DDT have been analysed in [1]. It has been found that the pressure and temperature of critical particle (fluid particle located in the center of *"explosion in explosion"* [1]) appear to be outside the explosion limits. Moreover, the delay time integral for the critical particle has been found to be much less than unity. This implies that shock compression itself does not provide conditions favouring autoignition of the critical particle. The question arises: what is the reason for onset of localised exothermic centers?

There are a few explanations to the phenomenon dealing with the specific features of the turbulent boundary layer (TBL) arising behind a precursor shock wave. These are:

1) The effect of mean flow kinetic energy dissipation in TBL [2,3]. Under certain conditions, the profile of the mean static temperature in TBL exhibits maximum which can result in the enhancement of chemical energy release.
2) The effect of temperature fluctuations in a compressible TBL. Non-homogeneous turbulence in combination with vigorous turbulence dissipation in TBL can result in the origin of exothermic centers.
3) The effect of mixing between the fresh mixture and the combustion products entering TBL from the flame *"brush"* [1].

This paper deals with the comparative study of these effects in a 2D geometry of TBL.

2. Mean Flow Kinetic Energy Dissipation

The mean flow and mean temperature fields estimations for compressible TBL have been made based on previous work [3]. The mean static temperature increase inside a TBL is shown to have a drastic effect on the ignition delay time of a fluid particle entering a boundary layer only if nearly adiabatic wall conditions are adopted. It has been found that for most cases temperature increase in TBL is of the order of 10-30 K.

3. Temperature Fluctuations

For modelling the effect of temperature fluctuations on the development of exothermic chemical reaction in TBL the joint pdf method [4] has been used. Since we consider the process within the induction period, a significant simplification is used in the mathematical model, that is the decoupling of reaction-diffusion processes from the flow dynamics. This means that the reaction-diffusion processes are modelled on the ground of *"frozen"* flow pattern.

Mean flow properties in a shock-induced TBL have been specified by using semi-empirical correlations for velocity components, turbulent kinetic energy and its dissipation [5-10].

The Lagrangian Monte Carlo method was implemented for solving the reaction-diffusion problem in TBL for hydrogen-oxygen and methane-oxygen mixtures. One-step overall reaction as well as a systematically reduced detailed reaction mechanism of fuel oxidation have been implemented.

Numerical solution has demonstrated the possibility of formation of multiple exothermic centers in TBL, preferably in zones with high dissipation rate of turbulent kinetic energy.

4. The Effect of Mixing Between Cold and Hot Mixture Pockets

For modelling the effect of mixing between the fresh mixture and combustion products, the joint pdf approach similar to that used in Section 3 has been applied. The problem has been solved in shock fixed coordinates. Initially, the flame *"brush"* was modelled as a highly turbulent region occupied by combustion products. Preliminary 2D finite volume calculations using Eddy Dissipation model [11] were made for obtaining the longitudinal pressure gradient in the problem as well as other flow parameters. The counter flow diffusion of combustion products taking place in Monte Carlo calculations was shown to deform the lead flame front by creating a flame tong which propagates inside boundary layer towards the shock. Under certain shock intensities, auto-ignition regions arise in front of the flame tong.

5. Conclusion

The present study allows one to estimate the significance of different effects for the DDT phenomenon. The effects of temperature dissipation coupled with mixing between fresh mixture and combustion products appeared to be dominating in the development of *"explosion in explosion"*.

Further studies including coupling between reaction-diffusion process in turbulent boundary layer with flow dynamics are currently carried out.

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