DEFLAGRATION TO DETONATION TRANSITION IN METASTABLE MEDIA

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Propagation of waves in metastable systems is sustained by the energy release triggered by a wave front. Combustion waves in chemically reacting systems, and boiling waves in superheated fluids can be considered as typical examples of such self-sustained waves that can have two modes of propagation: subsonic and supersonic, - due to different mechanisms. The process of transition from one mode of propagation to another is the most intriguing issue. Investigations of deflagration to detonation transition in gases and pulverized fuel-air mixtures are carried out in pulse detonating devices. The control of detonation onset is of major importance in pulse detonating devices. The advantages of detonation over constant pressure combustion bring to the necessity of promoting the DDT and shortening the pre-detonation length. For the most of fuel-air mixtures being heterogeneous the problem of liquid droplet interaction with a surrounding gas flow with account of heat and mass transfer and atomization becomes of key interest. The paper contains the results of theoretical investigations on detonation onset peculiarities in homogeneous and polydispersed hydrocarbon–air mixtures. The problem of shock wave initiation of combustible dispersed mixtures is discussed .A mathematical model for liquid droplet interaction with the gas flow is developed with regard to non-equilibrium evaporation and atomization. Extensive numerical simulations of droplet thermal and mechanical relaxation in gas flows with account of evaporation and atomization are undertaken and summarized.

Fig.1. Onset of detonation in the flame zone

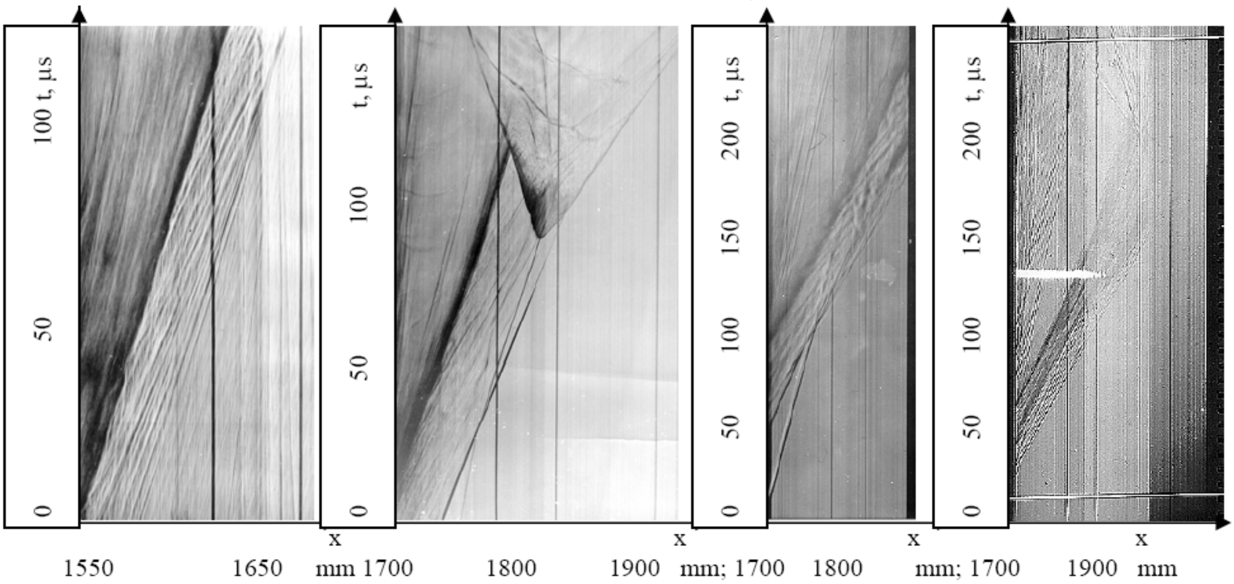

Fig.2. Compression waves ahead of an accelerating turbulent flame.

Fig.3. The onset of detonation ahead of turbulent flame on a contact discontinuity.

Fig.4a. Auto-ignition in a hot spot ahead of the flame giving birth to a new flame zone.

Fig.4b. Auto-ignition in a number of hot spots ahead of the flame

Experimental investigations of the sensitivity of DDT processes to mixture parameter variations have a natural limitation on the precision of the results, because various modes of detonation onset depend on the stochastic flow pattern created by accelerating turbulent flames, thus making the transition processes non-reproducible in its detailed sequence of events. Figs. 1 - 4 demonstrate the schlieren pictures of the detonation onset illustrating different scenarios of DDT in hydrocarbon – air gaseous mixtures. Besides, it is hardly possible to vary different parameters independently in physical experiments. That increases the importance of numerical modeling for investigating the detonation initiation sensitivity to governing parameter variations. Numerical investigations of the transition processes provide a unique possibility to vary each parameter independently and monotonically.

The paper presents the results of theoretical and experimental investigations of the detonation initiation in homogeneous gaseous and heterogeneous polydispersed mixtures of hydrocarbon fuels with air.

The mathematical model for liquid droplet interaction with the gas flow is developed with account of non-equilibrium evaporation and atomization. The developed mathematical model has made it possible to take into account the non-equilibrium effects in order to distinguish two different regimes of droplet evaporation in a heated gas flow: one stage heating and evaporation, and two stages of heating containing a cooling phase in between. Extensive numerical simulations of droplet thermal and mechanical relaxation in gas flows with account of evaporation and atomization have been undertaken and summarized. Mathematical models able to predict the onset of detonation in turbulized polydispersed mixtures are developed. The problems of fuel droplets atomization, evaporation and combustion being the key factors for ignition delays and shock waves attenuation evaluation in heterogeneous mixtures and the non-equilibrium effects in droplets atomization and phase transitions are taken into account. Two types of initiation: initiation by a shock wave (Fig. 5) and by a spark ignition (Fig. 6) are investigated.

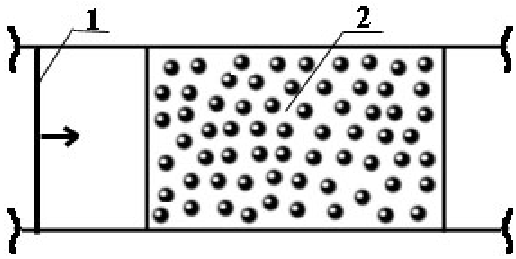

Fig. 5. Initiation by a shock wave (1) entering dispersed mixture (2)

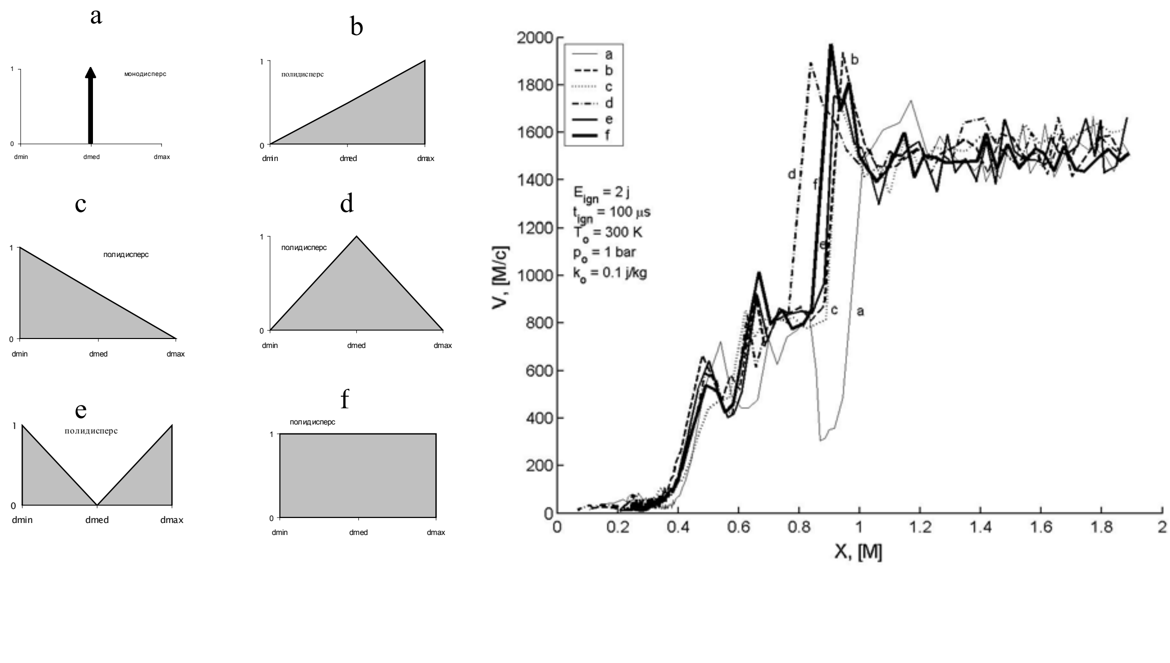

Fig. 6. The droplet size distribution effect on the detonation onset in polydispersed mixtures

The developed model has made it possible for the first time to investigate the effects of droplets distribution non-uniformity on the DDT in polydispersed mixtures.

The authors of the present paper are much in debt to President of Russian Federation grant (НШ-19.2003.1), Russian Foundation for Basic Research (grant 02-03-32232) for financial support.