Three-dimensional simulation of combustion, detonation and deflagration to detonation transition processes in cone and wedge induced focusing

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Self-sustaining waves can propagate in meta-stable media; energy needed to support such waves is released by the wave itself. As a rule, two regimes of propagation exist, subsonic and supersonic; the difference is based on the different mechanisms of medium activation. Processes of transition between those regimes are less studied up to now, in comparison with pure subsonic or supersonic modes. Knowing mechanisms of controlling detonation initiation is important in order to work out effective preventive measures, such as suppressing deflagration to detonation transition in case of combustible mixture ignition, and mitigation of a detonation wave in case it is already developed. On the other hand, the advantages of burning fuel in a detonation regime in comparison with slow burning at constant pressure attract increasing attention to pulse detonation burning chambers and to their possible application to new generation engines.

Codes for simulation of deflagration, detonation and transition processes in homogeneous turbulized mixtures accounting for hybrid structure of supercomputer were developed.

A unique validation and verification basis, incorporating the data of laboratory experiments and exact solutions was developed. Comparison of numerical results with experimental data present in the validation basis was performed. The validation basis could be used for validating different codes including commercial ones for description of unsteady-state processes in chemically reacting mixtures in the domains of complex geometry.

The paper presents results of numerical and experimental investigation of mixture ignition and detonation onset in shock wave reflected from inside a wedge. Contrary to existing opinion of shock wave focusing being the mechanism for detonation onset in reflection from a wedge or cone, it was demonstrated that along with the main scenario there exists a transient one, under which focusing causes ignition and successive flame acceleration bringing to detonation onset far behind the reflected shock wave. Several different flow scenarios manifest in reflection of shock waves all being dependent on incident shock wave intensity: reflecting of shock wave with lagging behind combustion zone, formation of detonation wave in reflection and focusing, and intermediate transient regimes. Comparison of numerical and experimental results made it possible to validate the developed 3-D transient mathematical model of chemically reacting gas mixture flows incorporating hydrogen – air mixtures.

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