Development of Richtmayer-Meshkov Instability at Interaction of Diffusion Mixing Layer of Two Gases with Passing and Reflected Shock Waves

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1 Introduction

The problem of mixing of gases with strongly differing molecular weights is an urgent topic for simulation of explosion phenomena in layer systems. Indeed with an action of shock waves on a contact surface between hydrocarbons and air conditions can be realized which are favorable for the explosive hazard mixture formation. It makes the investigation of the mixing of light and heavy gases under the shock wave influence to be important. Instability development in an area of the gas mixing with accelerated movements of the gases is an urgent task for energy commulation facilities and devices as well.

Traditionally a mixing layer is considered to be a density discontinuity surface, i.e. a contact discontinuity. Shock wave interaction with a disturbed contact discontinuity leads to the Richtmayer-Meshkov instability. Finally in vicinity of the initial contact discontinuity a region of turbulent mixing is formed which separate the compressed gas flows.

Numerous papers devoted to the numerical simulation of the Richtmayer-Meshkov instability based on the Euler equations did not take into account an influence of mutual penetration of the gases. Therefore it is believed to be interesting to investigate the problem on a base of two-velocity two-temperature approach for the gas mixture where the each mixture component has its own velocity and temperature. This approach allows to describe different stages of the instability development process taking into account the gas interpenetration. Previously a shock and compression wave interaction with a mixing layer has been studied [1, 2].

2 Results

In the paper the process of the Richtmayer-Meshkov instability development for the problem of the shock wave interaction with the disturbed mixing layer is simulated in a frame of two-velocity two-temperature mixture model. The process of subsequent multiple layer interaction with waves reflected from a wall is considered as well. The initial harmonically disturbed mixing layer has been generated on a base of solution proposed in [1]. The disturbance amplitude equals a_0, the wave length is λ, and the initial mixing layer thickness is δ_0. The following cases of the shock wave interaction with the mixing layer have been considered: with the shock wave moving from a light gas to a heavy one and from a heavy gas to a light gas. The mixture parameters inside the layer are described by the equations for the two-velocity two-temperature mixture dynamics [1, 2]. Outside the layer the Euler equations for the pure gas are applied. The numerical method for solution of the equations has been presented in [1, 2]. The shock wave moves from the top to the bottom. At the top boundary the gradients of all parameters have been set to zero, at the bottom boundary the rigid wall conditions have been applied. At the rest two boundaries the symmetry conditions have been imposed.

First for the test purpose a one-dimensional problem of shock wave interaction with an undisturbed mixing layer and following reflection of the wave from the wall has been solved. The results of the investigation are in complete agreement with results of the paper [3] on moments of the reflected shock wave and subsequent waves' arrival.

Then the shock wave interaction with the harmonically disturbed mixing layer has been investigated in 2D approach.

In Fig. 1 isolines of molar concentration of the heavy gas SF_6 for different time moments after the start of the contact surface interaction with the shock wave are presented. The shock wave travels from the air (light gas) into the SF_6 at Mach number 1.32, the distance from the centre of the mixing layer to the wall at the initial time moment is 10 cm, initial thickness of the mixing layer is 15 mm.

The shock wave interaction with the mixing layer leads to the mixing layer compression and after the exit of the shock wave from the layer the disturbance amplitude increases as it has been described earlier in [1]. Later the reflected shock wave interacts with the layer. It leads to the layer straightening and disturbance phase change (the reflected wave moves from the heavy gas to the light one) and to the sharper growth of the layer thickness. Further a heavy gas jet appears and a mushroom structure is formed.

In Fig. 2 a comparison with experimental data [4] on rate of the disturbance amplitude increase is shown. The shock wave travels from the air to the SF_6 at Mach 1.31, the symbols stay for the experiment [4]. The line 1 corresponds to the case when the distance from the centre of the mixing layer to the wall at the initial moment is 10 cm and a_0=0.1 mm, λ=6 cm, δ_0=15 mm. The line 2 corresponds to the case of the distance from the centre of the mixing layer to the wall of 55 cm and a_0=0.05 mm, λ=6 cm, δ_0=15 mm. The symbol *S* denotes the moment of the first contact of the reflected shock wave with the layer. It can be seen that after the reflected shock wave interaction with the mixing layer the disturbance amplitude increases dramatically.

The shock wave propagation from the heavy gas into the light gas has been investigated too. In this case the disturbance phase change occurs before the reflected shock wave coming. Later under the additional influences of the reflected compression waves the heavy gas jet is generated with the subsequent mushroom structure formation. In the case of the shock wave transition from the light to the heavy gas the more intensive increase of the disturbances is observed in comparison to the shock wave propagation from the heavy to the light gas.

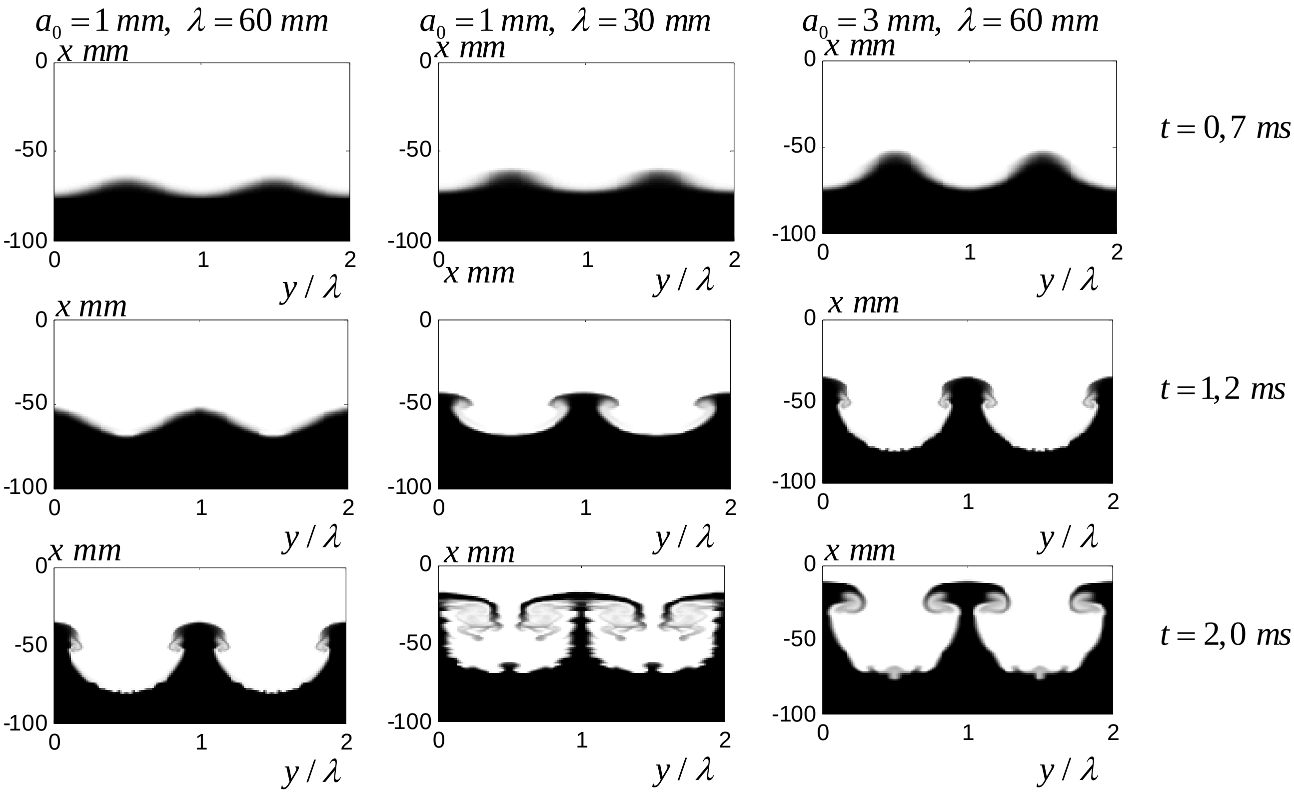

Figure 1. Molar concentration isolines for SF_6.

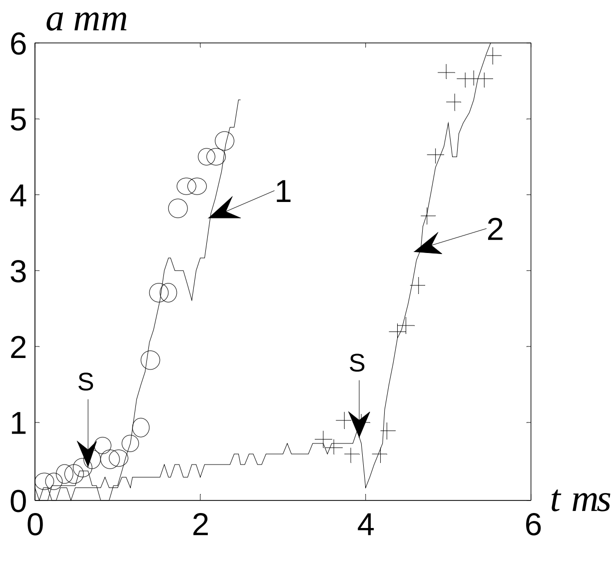

Figure 2. The disturbance amplitude dependence vs. time for the different distances between the mixing layer and the wall.

References

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