HYDRODYNAMICS SHOCK TUBES AND MECHANICS PROBLEMS

V. K. Kedrinskii

Lavrentyev Institute of Hhydrodynamics , Lavrentyev pr.15, Novosibirsk, 630090 Russia

A number of problems of high-velocity hydrodynamics require laboratory simulation of rather strong shock-wave loads with controlled parameters. For these purposes, a variety of hydrodynamic shock tubes (HST) was designed to apply different generation techniques which can be selected depending on specific research objectives. The four basic designs are a conical shock tube (FST), a hydrodynamic one-diaphragm tube (GST), an electromagnetic tube (E-MST), and a hydrodynamic pulse two-diaphragm tube (2dST). These schemes can be applied to study problems for many scientific fields: chemical reaction kinetics in solutions, mechanics of shock wave loading of multi-phase media, physical acoustics and explosive eruption of volcanoes. The paper will be devoted to some basic results obtained both under experimental and numerical studies within the mentioned problem.

As known, the method of shock waves is widely used for experimental studies of relaxation processes in gases at high temperatures and sometimes for physical-chemical studies of condensed media. The method of high-velocity collision (2dST)) [1] was used to determine the velocity and the shift of themodynamic equilibrium for reversible chemical transformations in solutions and has allowed one to study the relaxation process for the case of temperature and pressure conservation after the jump [2]. The working out of 2dST for generation of strong (up to 1000 MPa) shock waves has required to create the special semi-conductor gauges of pressure [3].

An electric-discharge hydrodynamic shock tube, wherein a shock wave was produced by an explosion of a wire near the bottom was used for experimental study of the process of shock waves interaction with single bubble, containing passive [4] or reactive gas mixture [5], its propagation in a two-phase bubble layer. It was shown that of the incident shock wave is split into two waves : the shock wave pulse (precursor) transformed by the layer and the wave reradiated by a bubble layer. The absorption of an incident wave energy and its reradiation by bubbles in a layer are inseparably linked and simultaneous processes, whose extreme manifestations do not coincide in time in view of the sluggishness of the collapse processes. It appears that there is the layer length L at which the layer behaves "collectively", it completely absorbs the shock wave energy (the pressure gauges record only a precursor) and reradiates it as attenuating oscillation with their own characteristic frequency.

Passive bubbly media can be considered as the active ones which are able to absorb and to reradiate acoustic pulses and thus to play a role of active media in a problem of "acoustic laser". The results of numerical analysis of wave generation by a spherical bubbly cluster excited by the stationary plane shock wave in HST will be discussed. This process can be considered as the hydrodynamical analogy of a "pump" in laser systems. It was found that the different velocities of wave propagation in a cluster and surrounded liquid result in the effect of shock wave focusing, with gradient front, inside cluster. The latter generates a powerful acoustic pulse. The dependences of its amplitude on the parameters of bubbly system and incident wave are discussed.

An analysis of pressure-field dynamics was performed for an axially symmetric problem of interaction of a shock wave with a “free” bubble system (toroidal clusater) giving rise to a steady oscillating shock wave. The results of a numerical study of the near-axis wave structure are presented for a focusing shock wave emitted by a bubble cluster. It is shown that the wave reflected from the axis has irregular structure. The Mach disk developing on the axis has a core of finite thickness with a nonuniform radial pressure distribution. The evolution of the Mach-disk core is analyzed, and the maximum pressure in the core is computed as a function of the gas volume fraction in the cluster. The effect of geometric parameters of the toroidal bubble cloud on the cumulative effect is examined.

The wave structure in active bubble media in shock tubes with sudden changes of profiles in the form of "discontinuities" in cross section and a one-phase liquid waveguide is analyzed numerically. In axisymmetric formulation, wave amplification due to reflection from a wall and focusing at the butt-end of a rigid rod aligned coaxially with the channel are studied. In this configuration, the amplification effect results from two - dimensional cumulation of the shock wave after it leaves the annular channel and reaches the butt-end of the rod. A Mach configuration is formed in the focus spot. The geometrical characteristics of the shock tube allow one to control (to some extent) the amplification coefficient and the coordinates of the focus spot. In particular, it is shown that the wave can be focused near the second discontinuity of cross section a rigid wall (in the region of passage through the interface to the waveguide) and intensified upon reflection. If the waveguide radius is equal to the height of the Mach stem, the reflected wave has a maximum amplitude.

The full system of equations for the problem of rarefaction-wave passage over the magma-melt column in the gravity field is derived with the use of the kinetic theory of phase transformations, and the problem is numerically solved. With allowance for diffusion zones and nucleation frequency as a function of supersaturation, the dependence of the number of cavitation nuclei on time formed in the course of phase transformations behind the rarefaction-wave front is found.

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