NUMERICAL SIMULATION OF STRONG EXPLOSION DYNAMICS USING MULTIPROCESSING SYSTEMS

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Introduction of scientific calculations of vector, matrix and multiprocessing computing systems into practice opens new opportunities to numerically simulate many scientific and technical problems [1]. One of such directions is the high-temperature hydrodynamics.

In the present work the problem on the strong explosion in view of radiant heat transfer is considered [2-3]. This problem is of one of the classical problems of radiation hydrodynamics.

In this work the real thermal and optical properties of air in the range of temperatures $\mathrm{T} = 0.026 \div 10^2$ eV and densities $\rho = 1.29 \cdot 10^{-9} \div 1.29 \cdot 10^{-2}$ g/cm^3 are used. The relations $\mathrm{P} = \mathrm{P}(\mathrm{T}, \rho)$ and $\mathrm{E} = \mathrm{E}(\mathrm{T}, \rho)$ are taken in table form from work [4]. Spectral characteristics of radiation are considered in multigroup approach [5]. The group absorption factor $k_\varepsilon = k_\varepsilon(\mathrm{T}, \rho)$ contains about 2000 spectral groups in the range of quantum energy from 0.03 eV up to 10^4 eV [6-7].

The equations of gas dynamics are solved by means of completely conservative finite-difference schemes of second-order accuracy [8-9]. To describe shock waves artificial viscosity is introduced.

Below we shall consider the solution of the problem for flat geometry (flat explosion) when the radiation transfer equation is precisely integrated over angle. As known, the expression for a radiant flux in a flat layer can be written as:

$$S_\varepsilon(x) = 2\int_0^L S_{\varepsilon p}(\xi) k_\varepsilon(\xi) E_2\left(\left|\int_\xi^x k_\varepsilon(\eta) d\eta\right|\right) Sign(x-\xi)\ d\xi. \tag{1}$$

Using the numerical integration the function of a source is approximated by the linear dependence inside cells that provides to achieve a limit of radiation heat conduction.

Initial characteristics of explosion are the following: energy $\mathrm{E}_0 = 18.6$ kJ/cm^2, the linear size of energy-release area is 0.96 cm, the temperature in it is $\mathrm{T}_0 = 10^6$ K, the initial pressure is $\mathrm{P}_0 = 5.7 \cdot 10^4$ atm, the density in all space is $\rho_0 = 1.29 \cdot 10^{-3}$ g/cm^3, the environmental pressure is $\mathrm{P_f} = 1$ atm. Fig. 1 and 2 show some calculation results. Here the profiles of temperature, density, velocity, pressure and radiant flux at an initial stage ($t \le 10^{-2}$ sec) are plotted. At the initial stage, at the given explosion parameters, a radiation (thermal) wave extends into the environment. The hydrodynamic picture of a gas flow is expressed poorly. In it the compression does not exceed one and a half time since the wave moves over the area heated by radiation, a mass velocity is approximately equal to 20 km/sec. By the moment $t = 2 \cdot 10^{-7}$ sec this area generates a strong shock wave. The formation of a shock wave is well seen on the density profiles. By this time, the two-wave configuration is formed. First, the strong shock wave moves, in it the gas compression is determined by the state equation and is higher than 10. Then the weak shock wave extends over this radiation-heated area, the difference of mass velocities is approximately equal to 2. At later time moments the shock wave separated from this area heated by radiation the pressure profile characteristic for adiabatic motions is formed behind its front. In the course of time shock wave decays and transforms to acoustic wave. Some part of energy in the transparent part of the spectrum leaves the explosion region in the form of radiation.

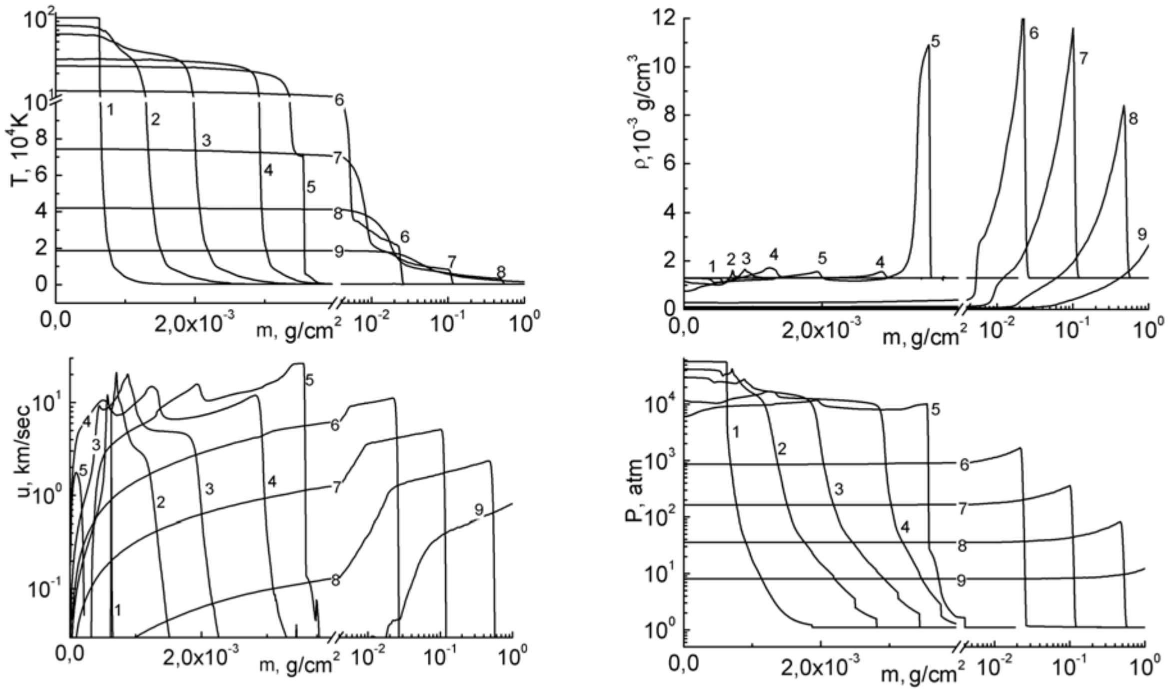

Fig. 1. Profiles of temperature, density, velocity and pressure: 1 – t = 10^{-10}, 2 – 10^{-8}, 3 – 3.2×10^{-8}, 4 – 10^{-7}, 5 – 2.5×10^{-7}, 6 – 10^{-5}, 7 – 10^{-4}, 8 – 10^{-3}, 9 – 10^{-2} sec

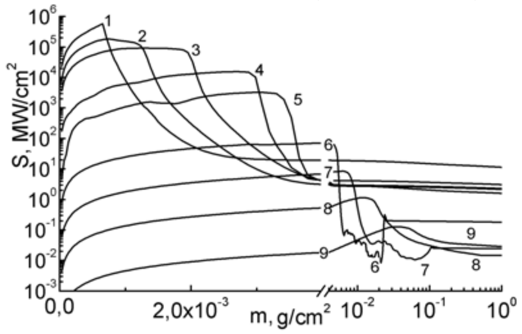

Fig. 2. Profile of radiation flux

This work realizes the multisequencing of radiant flux calculation. Message Passing Interface is used for multisequencing of calculation.

Efficiency of parallel computations is found by comparison of solution times for the considered problem on a variety of processors cluster "SKIF-500" [10]. Efficiency of a computing algorithm is shown in Table 1 and is calculated as $Eff = 100t_1/(Nt_N)$ where t_1 is the solution time on one processor, t_N - on N processors.

Table 1

N	1	3	5	9	13	15
Eff %	100	97	95	92	86	85

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