SIMULATION OF A LAYERED SPHERICAL SYSTEM UNDER SHOCK COMPRESSION WITH ACCOUNT FOR RADIATIVE HEAT TRANSFER IN DIFFERENT APPROXIMATIONS

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One of the directions in the study of implosion in lasers is the mathematical modeling of sharpening regimes – the problems whose solution is allowed to be infinite but within a finite span of time. These regimes were earlier considered in the study of extreme solutions in [1]. These are shock-free compression in hydrodynamics, thermal explosion, shock cumulation and others [2], [3]. The joint simulation of radiative hear transfer and hydrodynamics may greatly change the behavior of solutions, specifically, make infinite solutions finite but with a delta-like behavior of basic quantities. It is thus becomes interesting to study the processes that are close to the sharping regimes and simultaneously involve radiative heat transfer and hydrodynamics.

The problem on a convergent shock wave was first solved by G. Guderley in 1942 [4] and independently by L. D. Landau and K. P. Stanyukovich in 1944 [5]. The general description of a spherical shock wave can found in [6] and [7]. At the time when the wave reaches the center it focuses and reflects from the center. When heat transfer is considered, the temperature gradients near the focus of the convergent wave grow and then heat conduction and radiation become the prevailing mechanisms of energy dissipation. The problem on a convergent shock wave with radiative heat transfer was solved by E. I. Zababakhin and V. A. Simonenko in 1965 [8], who showed that heat conduction changed the pattern of motion: instead of a finite density and an infinite temperature there appeared an infinite density and a finite temperature. Due to heat conduction, before the shock wave there appears a zone where the gas not only heats but also starts to move and thicken. The front of this zone is called the thermal precursor.

Unbounded cumulation can also be obtained in other ways. As shown in [9], density and pressure may also grow in a system that consists of alternating light and heavy plane layers. It is much more difficult to describe the motion of a shock wave in such systems than in a homogeneous medium. That is why these systems are mainly modeled numerically. In the spherical layers the degree of cumulation is much higher than in the plane ones because the shock wave strengthens due to the combined action of two factors – sphericity and layering.

Ref. [10] proposes a test problem on compression of a simple spherical system of two substances with account for radiative transfer in different approximations. The density was shown to sharply increase in the center of the system and to reach a maximum after the third shock wave passed. Such regimes where the average material densities become several orders greater can apparently be grouped with the sharpening problems. Before the regime gets stationary, the basic hydrodynamic quantities (temperature, density, and boundary velocity) are oscillating functions. The oscillations caused by strong shock waves are very sharp and high precision methods are needed to reproduce them acceptably accurate. The virtue of the problem is that all approximations to radiative transfer in this statement give close results for the basic thermodynamic quantities and after the stationary regime is reached they have exact values identical in all approximations.

For the testing of multi-dimensional codes simulating radiative gas dynamics, Ref. [11] proposes problems on shock compression of a layered spherical system of several substances with simultaneous account for radiative heat transfer and gas dynamics. In these problems, material density becomes maximal after the second or third shock wave passes.

The paper discusses a solution to one of these problems in a kinetic model with minor changes in their statement and the use of six approximations: radiative heat transfer, diffusion, quasi-diffusion in parabolic and hyperbolic forms, P1, and P1/3. The goal is to find which of the approximations is least computer time demanding for determining the times when shock waves reach the center of the sphere and the maximal values of hydrodynamic quantities close to the kinetic model.

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