Radiation Hydrodynamics of Explosive Phenomena in Laboratory and Astrophysics

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In a flow accompanied by high-temperature gases or plasmas, it becomes impossible to disregard an influence of radiation energy transport. The phenomenon in which flowfield is affected by radiation is generally called a radiation hydrodynamic phenomenon which is studied for many years especially for astrophysical plasmas. However, such a phenomenon is not restricted to astrophysics, but we can find it in the terrestrial environment or in a laboratory typically as an explosion phenomena.

Radiation hydrodynamics phenomena often play an important role in various laboratory plasmas. We can find them in not only high temperature dense plasmas such as inertial fusion plasmas but also weakly ionized plasmas, for example, flowfield around a vehicle entering the planetary atmosphere and laser-produced plasmas related to the space environment development. However, there are usually analytical and computational difficulties to obtain the solutions, since we should deal with flowfield, radiation transport, and atomic/molecular radiative processes integrative.

Radiative processes are severely depends on the matter temperature because the excited states of atoms and molecules should be populated. Therefore, it tends to be accompanied by a shock wave on the ground in many cases. A flowfield around an atmospheric entry object is one of the problems. Moreover, just after a rapid development of laser technique in the 70s, explosion (implosion) dynamics of high-temperature plasmas produced by intense laser has been studied as radiation hydrodynamics.

Since the radiative transfer equation has six dimensions, the solution can not be obtained without any assumptions at the moment. Fortunately, however, we can make some assumptions according to the property of the flowfield interacting the radiation and reduce the dimensions of the equation. One example is the case of a flowfield of an optically thick media. In this case, we can assume isotropy of a radiation field and just handle the moment equations of the radiation transfer equation. Another is the case of an optically thin media, which can regarded as a flowfield with a steady radiation field. Then the so-called ray-trace method can be conducted for solving the radiative transfer equation.

For an integrated numerical simulation, we should choose proper models for the subject as mentioned above in order to avoid the difficulties originated from radiative properties. The author has addressed numerical simulations from a radiation hydrodynamic viewpoint on various laser-produced plasmas for fusion,[1] short-wavelength optical source,[2] and propulsion[3] or flight technique,[4] atmospheric hypersonic flow of entry objects,[5],[6] and astrophysical flow related to accretion disc around binary stars[7] and standing shock wave of supernova cores.[8]–[11] In this paper, the outline of numerical computation is shown and some examples about those researches are introduced.

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