EFFECT OF CAVITATION ON SPHERICAL BLAST WAVES

SANTOSH KUMAR

Physics Department, Agra College, India

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Abstract. For spherical blast waves propagating through a self-gravitating gas with an energy input $E_a = E_0 t^\beta$, where $E_a$ is the energy released up to time $t$, $E_0$ is a functional constant, and $\beta$ is a constant, kinetic, internal heat, and gravitational potential energies have been computed. Taking the parameter $A^2$, which characterises the gravitational field, equal to 2, variations of the percentages of these energies for $\beta = 0, \frac{1}{2}, \frac{2}{3},$ and 3 with shock strength have been presented. For $\beta = 3$, the effect of cavitation on the percentages of kinetic energy and internal heat energies has been explored.

1. Introduction

For a pre-explosion state governed by a self-gravitating equilibrium state equation, the propagation of a spherical blast wave with energy input $E_a = E_0 t^\beta$ through a self-gravitating gas has been investigated (cf. Sakurai, 1956; Kumar et al., 1978a, b; or Chaturani and Ram, 1978) in the recent past for four values of $\beta$, viz., $\beta = 0, \frac{1}{2}, \frac{2}{3},$ and 3. For $A^2 = 2$, the kinetic, internal heat, and gravitational potential energies have been computed in this paper. Their dependence on (i) parameter $\beta$ and (ii) shock strength has been discussed. For lower values of shock strength there are two values of $\beta$ at which the equipartition between internal heat and kinetic energies occurs, whereas for strong shocks the two values come closer. Sharing of the energy supplied with the advancement of the shock among the three forms is studied. It is also observed that the hottest region is always located near the piston. Finally, for $\beta = 3$, the effect of cavitation on the percentages of kinetic and internal heat energies has been explored.

2. Energy Considerations and Temperature Distribution

The non-dimensional form of the energy balance equation for the flow between the shock and inner expanding surface, is given (cf. Chaturani and Ram, 1974) as

$$w^\beta = \left[ \frac{\gamma DZ^3}{2y} \int_{x_p}^1 hf^2x^2 \, dx \right] +$$

$$+ \left[ \frac{DZ^3}{(\gamma - 1)y} \int_{x_p}^1 gx^2 \, dx - \frac{1}{(\gamma - 1)} \int_0^Z PZ^2 \, dZ \right] -$$

$$- \left[ 2\gamma A^2 MDZ^2 \int_{x_p}^1 hix \, dx - 2\gamma A^2 \int_0^Z MDZ \, dZ \right]. \tag{1}$$

where the symbols have their usual meanings. In this expression the term on the left-hand side is the measure of total energy delivered from the source up to time \( t \). The first, second, and third term on the right-hand side, respectively, measures the kinetic energy of the flow, the internal energy gained from the source, and the change in the gravitational potential energy of the medium due to redistribution of the mass in the perturbed state. If we assume the gas to be ideal, the temperature \( T \) at any point \( x \) in the shocked region for \( \gamma = 1.4 \), is given by

\[
\frac{T}{T'} = 1 - 0.8(xz)^2 + 0.48(xz)^2 \frac{U^2}{C^2} g, \tag{2}
\]

where \( T' \) is the temperature at the centre in the unperturbed state. The kinetic, internal heat, and gravitational potential energies are calculated as the percentages of the total energy by evaluating the integrals occurring on the right-hand side of (1) by Simpson’s rule. Now, for blast waves with their total energy increasing as a power of time, in order to explore how the energy increase is distributed among the various energies, we define \( E_{Ki} \) and \( E_{Hi} \)

\[
E_{Ki} = \frac{(\text{kinetic energy})_{Z_2} - (\text{kinetic energy})_{Z_1}}{(\text{total energy})_{Z_2} - (\text{total energy})_{Z_1}}, \tag{3}
\]

and

\[
E_{Hi} = \frac{(\text{heat energy})_{Z_2} - (\text{heat energy})_{Z_1}}{(\text{total energy})_{Z_2} - (\text{total energy})_{Z_1}},
\]

where \( Z_2 \) and \( Z_1 \) are the non-dimensional shock radii between which we calculate the increase in the total energy.

3. Results and Discussion

Figure 1a depicting the distribution of temperature in the blast wave region for different positions of the shock front indicates that the hottest region is always located near the piston. For smaller values of \( \beta \), the temperature increases very rapidly with distance from the shock front, however, for \( \beta = 3 \) it has a slowly increasing trend. Figure 1b displays the distribution of kinetic energy in the blast wave region for different positions of the shock front. The kinetic energy increases towards the shock front except for \( \beta = 3 \) where the trend is reversed. For \( \beta = 0 \), a little increase in kinetic energy in the central region with the advancement of the shock is notable. An increase in \( \beta \) reduces the temperature of the shock front (refer to Figure 2i(a)).

Figure 2ii showing the variations of the percentages of kinetic and internal blast wave energies with the position of shock front indicate that an equipartition of these energies occur at non-dimensional shock radii \( z = 0.093 \) and \( 0.585 \) for \( \beta = \frac{3}{4} \) and 3, respectively. An increase in gravitational potential energy with \( \beta \) is evident from Figure 3i(b). Sharing