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The Motion of Weak Plane Shock Waves in Highly Viscous Medium

Dr. Praveen Kumar

Deptt. of Physics, V.R.A.L.Govt Girls Degree College, Bareilly (U.P.)

Abstract-

The propagation of weak plane shock waves in highly viscous uniform medium has been investigated by CCW method. It is found that the shock velocity decreases as shock advances for low viscous region of a medium to the high viscous region. The pressure and particle velocity behind strong shock decreases with adiabatic index and Small decreasement in the pressure and particle velocity is found with the increase in viscosity coefficient. It is shown that applications of the CCW method and the neglect of overtaking disturbances are equivalent.

Key words- shock wave, CCW method and viscosity.

Inroduction-

Weak shock theory applies of very weak shocks and it is mainly concerned with the flow profile behind the shock front (the shock wave). In this theory an initial pressure pulse is allowed to propagate along the straight rays given by geometrical acoustics (keller 1954).The pulse of non-linearized by allowing the speed of propagation to increase with over pressure. Eventually the shock overturns and at that point shocks are fitted into the pressure profile using the equal area tube. For weak shocks, the propagation speed of the shock front is proportional to the pressure jump (over pressure at the discontinuity).

On the effect of viscosity on the shock waves for a hydrodynamical medium by Huseyin cavus (2013). Anand Raj and H.C.Yadav (2011) studied propagation of shock waves in a viscous medium. R. S. Myong (2014) Analytical solutions of shock structure thickness and asymmetry in Navier stockes/ fourier framework. Anand Raj and H.C.Yadav (2016) studied the effect of viscosity on the structure of shock waves in a non - ideal gas. G. Nath (2016) Propaation of spherical shock wave in mixture of non - ideal gas and small solid particles under influence of gravitational field with conductive and radiative heat fluxes. M. Singh and A. Patel (2018) Travelling wave solution of shock structure in a an unsteady flow of a viscous non ideal gas. R. Arora and A. Chauhan (2019) Similarity solution of strong shock waves for isothermal flow in an ideal gas. Chauhan et. al. (2020) converging shock waves in a Vander Wall's gas of variable density.

The aim of the present part is to study the propagation of weak spherical shock waves propagating in a uniform medium. When shock moves freely. The shock strength, shock velocity, pressure and particle velocity both decreases as spherical shock. The effect of overtaking disturbances is to inhance the values. The results obtained here are compared with those M. Singh and A. Patel (2018).

Basic Equations:

The general equations of exploding shock waves in presence of uniform viscous medium

$$\frac{\delta u}{\delta t} + u\frac{\delta u}{\delta r} + \frac{1}{\rho}\frac{\delta P}{\delta r} - \frac{4}{3}\mu\frac{\delta u}{\delta r} = 0$$

$$\frac{\delta \rho}{\delta t} + u\frac{\delta \rho}{\delta r} + \rho\frac{\delta \rho}{\delta t} + \frac{\alpha\rho u}{r} = 0$$

$$\frac{\delta P}{\delta t} + u\frac{\delta P}{\delta r} - a^2\left[\frac{\delta r}{\delta t} + u\frac{\delta \rho}{\delta r}\right] = 0$$

where, u(r,t), P(r,t) and ρ (r,t) denote particle velocity, pressure, density at a distance r from the origin at time t, γ is the adiabatic index of gas μ is the coefficient of viscosity and $\alpha = 2$ for spherical shock waves.

Boundary Conditions:

Let P_0 and ρ_0 denotes the unperturbed values of pressure and density in front-

$$P = a_0{}^2\rho_0\left[\frac{2M^2}{(\gamma+1)} - \frac{(\gamma-1)}{(\gamma+1)}\right]$$

$$\rho = \rho_0\left[\frac{(\gamma+1)M^2}{(\gamma-1)M^2+2}\right].$$

$$U = \frac{2a_0}{(\gamma+1)}\left[M - \frac{1}{M}\right]$$

$$a = a_0\sqrt{\frac{\left[2\gamma M^2-(\gamma-1)\right]\left[(\gamma-1)M^2+2\right]}{(\gamma+1)}}$$

where, is Mach number, U is the shock velocity, a and a_0 are the sound velocity in disturbed and undisturbed medium respectively.

Weak Shock Waves:

For weak shock waves i.e. (U<<a0) the boundary conditions, M = 1+ ε reduce to-

$$P = \frac{\gamma P_0}{(\gamma+1)}\left[\frac{(\gamma+1)}{\gamma} + 4\varepsilon\right]$$

$$\rho = \rho_0\left[1 + \frac{4\varepsilon}{(\gamma+1)}\right]$$

$$U = a_0[1+\varepsilon]$$

$$u = \frac{4 a_0 \varepsilon}{(\gamma+1)}$$

Characteristic Equation For Freely Propagation of Shock Wave:

The characteristic equation for exploding shock is given as-

$$dP + \rho a\, du + \frac{\alpha \rho a^2 u}{r}\frac{dr}{(u+a)} - \frac{4}{3}\frac{\mu \rho a\, du}{(u+a)} = 0$$

Solving, this equation-

$$\varepsilon = k r^{-\frac{\alpha}{\left[2-\frac{4\mu}{3 a_0}\right]}}$$

The expression for shock velocity may be written as-

$$U = a_0\left[1 + k r^{-\frac{\alpha}{\left[2-\frac{4\mu}{3 a_0}\right]}}\right] \quad [1]$$

The expression for shock strength may be written as-

$$M = \frac{U}{a_0} = \left[1 + k r^{-\frac{\alpha}{\left[2-\frac{4\mu}{3 a_0}\right]}}\right] \quad [2]$$

Results and Discussion:

Weak Plane Shock Waves:

Expression (1) and (2) represents the shock strength and shock velocity for the freely propagation of weak shock, in uniform medium. Shock strength is a function of propagation distance r, adiabatic index γ, shock symmetry parameter μ and viscosity coefficient μ.

Table:Variation of variable with adiabatic index for weak plane shock wave

$(r = 10, \mu = 0.000172, \alpha = 0 \; and \rho = 1.29)$

γ	U	M	P	U
1.33	2.0623	2.195	3.144	2.151
1.40	2.1678	2.195	3.295	2.197
1.66	2.2609	2.195	3.526	2.286
1.69	2.3706	2.195	3.603	2.369
1.75	2.4597	2.195	3.738	2.425

Conclusions:

It is concluded that shock strength, shock velocity, pressure and particle velocity decrease with propagation distance and viscosity coefficient. These parameter increases with adiabatic index. But similar results are found for strong shock propagating in non- uniform medium.

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