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Explosive Induced Cylindircal Shock Wave

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ABSTRACT:

This paper deals with the explosive induced cylindrical shock wave. Flow induced by the generation and propagation of a cylindrical imploding shock is simulated by numerical method. Shock is generated by detonating circular explosive shells. The problem is formulated by Euler's Equation in non- conservative form. The solution is carried out by operator splitting technique. The special distribution of physical parameters are shown in figures.

I. INTRODUCTION

The imploding shock waves has been an attractive topic in fluid dynamics, applied physics and engineering.. The problem was first solved by Guderly [1]. The similarity solution was presented and self amplifying character of wave was suggested. Experimental demonstration of such shock wave was given by Perry and Kontrowiz [2]. Researcher began to take growing interest in this field in the mid 1960's. Dennen and Wilson [3] produced shock waves in air by electrically exploding thin metallic film on the inner surface of glass cylinders. Trajectories of the shock waves were compared in the similarity solution. Important work was done in this field by Lee [4], Glass [5], Seito and Glass [6], and Matsuo et al. [7]. In fluid dynamics, implosion problems have been frequently used as test problem for numerical methods. Such as first finite difference method and random choice method. The problem, which is the practical importance, was first treated by Bach and Lee [8] and there after Matsuo [9]. The initial propagation of shocks generated by an instantaneous energy deposition at the cylindrical surfaces is analyzed using perturbation technique. The global solution, that is a solution that can describe the whole history of fluid motion, from the initial stage to focusing stage was first presented by Matsuo [10]. The method of integral relation was adopted there. The behavior of the solution was compared in detail with the similarity solution. It was shown that the sock trajectory quickly approaches the similarity solution but the special distribution of flow properties approaches it very slowly, in fact it never reaches the self similar implosion limits. Saito and Glass adopted the random choice method to analyze the explosive driven hemispherical implosion. The imploding shock is assumed to propagate through the combustion product the motion of which is prescribed by similarity solution. The estimated temperature was compared with spectroscopic ally measured temperature. Van Dyke and Guttmann [11] solved the spherical and cylindrical problem using series expansion in powers of time. Using various numerical methods Matsuo [12] simulated strong imploding shocks travelling through atmospheric air. From the application point of view very imploding shock and detonation waves furnish a promising means to produce an extreme condition o f ultra high temperature, pressure and density. In fact, even the application to thermonuclear fusion was considered. However, the most promising application is excepted in synthesizing material, e.g. diamonds from graphite.

In the present work , the flow induced by the generation and propagation of a cylindrical imploding shock in numerically simulated. The shock is generated by detonating circular explosive shells. The problem is closely associated with the explosive chamber developed by Matsuo for producing an extreme condition of ultra high pressure and temperature (135000 K). Operator splitting method is used to simulate the problem.

II. FORMULATION OF PROBLEM

We consider a circular explosive shell of thickness 'd' and radius 'R_o', air being field inside the inner shell. The shell explosion are initiated and initiation energy being negligibly small compared with chemical energy of explosive. After the shell explosion, a cylindrical shock wave propagate towards the center and finally converges there, Reflection then, succeed and complicated interaction emerged. We do not take into account the multiple interaction of shock waves. It is assumed that the explosive thickness 'd' is sufficiently small compared to the radius R_o. It is further assumed that detonation front with Chapman-Jouguet propagation velocity suddenly appears at the instant of initiation, and propagate through the air. Therefore the detonation front from a given boundary with known flow properties. The conservation laws are written as –

$$\frac{\partial u}{\partial t} + \frac{\partial F}{\partial \gamma} + w = 0 \qquad (2.1)$$

Where,

$$U = \begin{bmatrix} \rho \\ \rho u \\ E \end{bmatrix},$$

$$F = \begin{bmatrix} \rho u \\ \rho u^2 + p \\ u(E+p) \end{bmatrix}$$

Where as 't' and 'γ' ' are independent variables, that represent time and space coordinate respectively and other quantities, ρ ,u, P and E are density, particle velocity, pressure and total energy per unit volume.

Equation (2.1) applies to air and the combustion gas since they both are assumed to be in viscid and non conducting.

Assuming polytrophic gas, E is represented by,

$$E = \frac{1}{2}\rho u^2 + \frac{p}{\gamma - 1} \qquad (2.2)$$

Where γis ratio of specific heats.

The boundary condition on the front are,

$$\rho = \rho_{co},\ u = u_{co},\ p = p_{co} \qquad (2.3)$$

where, ρ_{co}, u_s, and p_{ack} are respectively density, particle velocity and pressure at Champman-Jouguet detonation front.

These are constant values and known when the explosive is specified. Another boundary condition is imposed on the outer surface of explosive, it is written as,

$$u = o \text{ at } r = R_o$$

we define the non-dimensional quantities as follows,

$$\bar{\gamma} = \frac{\bar{\gamma}}{R_0},\quad t = \frac{C_0 t}{\sqrt{\bar{\gamma}_0}\,R_0},\quad \bar{p} = \frac{\bar{p}}{\bar{p}_0},\quad \bar{\rho} = \frac{\bar{\rho}}{\bar{\rho}_0} \qquad (2.4)$$

$$u = \frac{u\sqrt{\gamma_0}}{C_0},\ T = \frac{T}{T_0},\ \varepsilon = \frac{R_0 - R_S}{R_0}$$

where T is temperature, γ_o, ρ_o, p_o, C_o and To are respectively the ratio of specific heats, density, pressure, velocity of sound and temperature in undisturbed fluid and R_s being the coordinate of the shock front.

III. NUMERICAL CALCULATIONS AND RESULT :

Let Δr and Δt be increments in the variables r and t, where Δr = Ro/N, N being number of mesh, that are contained inside the circle r = Ro.

The operator splitting technique applied to the problem is as follow -

$$\frac{U^{*}_{J}-U^{n}_{J}}{\Delta t} \qquad F_r(U^{n}_{J}) \qquad (3.1)$$

and

$$\frac{U^{*}_{i}-U^{*}_{j}}{\Delta t}=-W(U^{*}_{i}) \qquad (3.2)$$

where subscript r denotes the partial differentiation with respect to 'r' and

$$U^{n}_{i}=U(\,j\Delta r, n\Delta t) \qquad (3.3)$$

Equation (3.1) suggests that the positional value U* is a solution of the plane flow problem. The increment of Δt was determined by Courent-Friedrchs-Lewy condition, which is written as,

$$\Delta t \le \frac{\Delta r}{|u|+C} \qquad (3.4)$$

where C is the sound velocity.

The condition of symmetry was used for the boundary condition, at the rigid wall r = R_o that is,

$\rho_{N-½} = \rho_{N+½}$, $U_{N-½} = U_{N+½}$, $p_{N-½} = p_{N+½}$ (3.5)

where N indicate the mesh point on the wall.

For the present problem the number of mesh N was taken 1000. The explosive Pentaerythritol tetranitrate (PETN) was assumed for calculation. The characteristic values are,

ρ_{∞} = 1.34 x 10^3 Kg/M^3

u_s = 1.40 x 10^3 m/sec.

Pcj = 7.68 x 10^9 Pa

Ucj = 5.55 x 10^3 m/sec

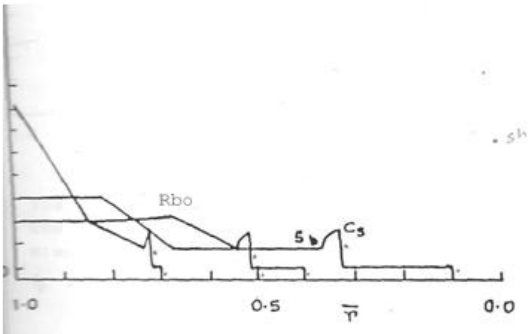
γ = 2.98

∈ = 5.65 Ms/Kg.

where, Ucj is the Champam – Jouget wave velocity and is the specific chemical energy of PETN. It is to be noted here that the value γ is larger than 5/3, the maximum value that perfect gases can take. It implies that the combustion gas of PETN is not a real perfect gas. The ratio of specific heats of air, (γ_o) is assumed to be 1.4.

As the shock approaches the center more closely, the distribution of flow properties would become steeper and steeper in a very small region Just behind the shock front. At a later stage of implosion, the shock wave is.. accelerated by self amplifying effect as a result of decreasing frontal area. Special distribution of flow properties are shown in fig.

The flow induced by the generation and propagation of cylindrical imploding shock is numerically analyzed. The shock are supposed to be generated by detonating explosive sell. The distribution of flow variables are shown in fig.



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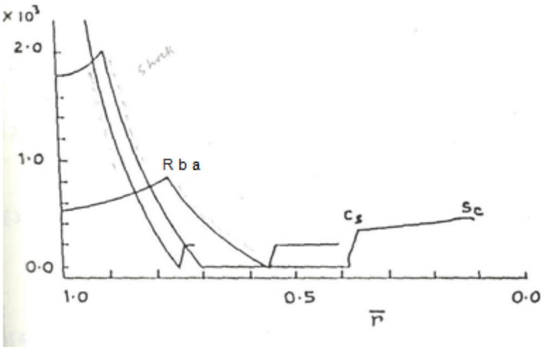

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