STUDY OF ALUMINISED EXPLOSIVES BY UNDER WATER EXPLOSION TECHNIQUE

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ABSTRACT

Pressure and velocity of detonation of various aluminised explosives are found by the technique of under water explosion using streak camera. Results are compared with those obtained theoretically by Singh elsewhere. It is found that theoretical and experimental values of pressure agree fairly well.

INTRODUCTION

Determination of explosive parameters is the first requirement, when an explosive is developed. Some of these explosive parameters can be determined theoretically, if the products of detonation are known(Kmlet and Jacob (1968), Mader (1979), Singh (1983)). But the velocity of detonation can only be determined experimentally. Therefore, it is required to establish a simple but accurate experimental technique for the measurement of pressure and velocity of detonation of an explosive . Most of the methods developed (Cook 1961) to measure detonation pressure are based on the continuity conditions of shock pressure and particle velocity across the interface between the explosive and themedium to be shock loaded. In the present paper we have used water as the medium and the technique thus used is known as 'acquarium technique'.

For determining detonation pressure of various high explosives, the knowledge of shock parameters in water is necessary. Various authors viz. Cook (1961), Walsh and Rice (1957) have attempted to find the equation of state of Water, Singh (1982) have shown that different forms of euqations of state can be related.

In the first part of the present paper, we have determined the Hugoniot equation ofstate of water by measuring the shock velocity and the free surface velocity in water using streak photography technique. In the second part, velocity and pressure of detonation is studied for various aluminised and non-aluminised explosives.

BASIC THEORY

For measuring detonation pressure, knowledge of equation of state of water, is the first requirement. There are two types of equations of state reported in the literature. First is Tait's equation (Cole 1948) and second is Hugoniot equation (Walsh and Rice 1957, Cook 1961, Singh et.al.1980). Singh (1982) had shown that these two equations can be related under certain conditions. We have determined Hugonoit equation of state of water, experimentally, by measuring the shock velocity and the particle velocity at the surface of water column. Hugoniot equation of state is obtained by fitting a second degree curve the data thus obtained (Table III) and is given as

$$U \quad a \quad bu_2 \quad c\,u_2^2 \qquad \text{.......(1)}$$

Where a, b, and c are water constants. It is to be noted that it is not possible to measure particle velocity u_2 directly. Particle velocity u_2 is related with the free surface velocity u_{fs} by the relation,

$$u_2 \quad 1/2 \quad u_{fs} \qquad \text{.......(2)}$$

which is easy to measure.

Knowing equation of state of water, explosive pressure can be determined by measuring shock velocity U_t at the explosive water boundary. Transmitted pressure p_t in water is given by

$$pt = \rho_0 \quad U_t \quad u_t \qquad \text{.......(3)}$$

Where ρ_0 , U_t , u_t are density, shock velocity and particle velocity of water at the explosive-water boundary. Particle velocity u_t is obtained from relation (1).
Knowing p_t and U_t, explosive pressure can be calculated from the shock impedence equation (Pack 1957, Buchanan and James 1957) given by

$$p_D = \frac{p_t(\rho_t U_t + \rho_D U_D)}{2\rho_t U_t} \qquad \text{........(4)}$$

where the symbol p, ρ , U stand for shock pressure, density and the shock velocity and the subscripts D and t denote values of the parameters for the explosive and the water respectively. The detonation pressure P_D can be calculated provided the shock impedence (ρ U) for the two media, and the transmitted pressure are known. The fact that water is transparent and thus permits convenient and continuous observation for shock velocity measurement by high speed photography, suggests that detonation pressure in an incident medium may be measured by transmitting them into water.

Such a method, where the water medium is basically used as a detonation pressure measuring gauge, by observing the transmission of shock wave into it, is known as ''Acquarium technique'' (Cook MA 1961).

THEORETICAL STUDY OF DETONATION PARAMETERS

Theoretical determination of explosive parameters was studied by Kamlet and Jacob (1968) for CHON explosives. They gave relations for detonation velocity and pressure in terms of detonation products. Experimentally determined explosive parameters are compared with those obtained theoretically by Kamlet and Jacob 's relations are given in Table I.

Values of U_D and p_D for aluminised explosives are also measured experimentally by streak photography technique and are shown in the table II. From table I, it can be seen that theoretical and experimental values of U_D and p_D for CHON explosives is quite agreeable.

Theoretical study of aluminised explosives is done by Singh (1983). He has assumed in this study that aluminsed explosives release energy in two phases. In first phase, Aluninium reacts with the oxygen present to form AlO and Al_2O as the oxides. It was assumed that if the formula for aluminised explosive is given as $C_xH_yO_zN_wAl_t$ then explosives products after detonation will be given as

$$C_xH_yO_zN_wAlt \longrightarrow \frac{Y}{2} H_2O + \frac{t}{2} AlO + \frac{t}{4} Al_2O + \frac{1}{2}(Z - Y/2 - \frac{3t}{4})CO_2 + \frac{W}{2} N_2 + (X - \frac{Z}{2} + \frac{Y}{4} + \frac{3t}{8}) \text{ Camp} \quad \ldots 5$$

TABLE No. 1

No.	Details of charge	Density in gm/cc	Experimental		Theoretical		
			VOD in mm/µ sec	Pressure in K. bars	VOD in mm/µ sec	Pressure in K. bars	Energy in Cals/gm
	RDX/TNT 90/10	1.7056	8.149	286.98	8.2442	288.48	1544.966
	RDX/TNT 80/20	1.70199	8.04	280.52	8.1594	285.396	1416.5219
	RDX/TNT 70/30	1.698	7.96	267.866	8.049	277.3158	1418.2562
	RDX/TNT 60/40	1.68	7.8	255.63	7.8556	256.14	1393.74
	TNT	1.605	6.8	178.296	6.852	193.8977	1275.42
	Tetryl	1.514	7.438	226.79	7.83	243.62	1528.5634

TABLE No. II

S.No.	Details of charge	Density in gm/cc	Experimental			Theoretical Energy in Cals/gm.	Percentage deviation of velocity from explosive
			VOD in mm/μ sec.	Pressure in K. bars.	Energy in Cals./gm		
1.	Aluminised Explosive RDX/TNT/Al./Wax. 20/50/25/5	1.70	6.8943	185.53	553.9608	607.98	9%
2.	Aluminised Explosive RDX/TNT/Al. 0/50/50	1.9334	6.1239	124.87	202.6212	130.2577	35.7%
3.	Aluminised Explosive RDX/TNT/Al. 5/50/45	1.901	6.375	135.92	232.0906	161.9778	30.2%
4.	Aluminised Explosive RDX/TNT/Al. 10/50/40	1.87	6.5814	150.18	282.6355	227.1562	19.6%
5.	Aluminised Explosive RDX/TNT/Al 15/50/35	1.84	6.792	163.92	337.1627	296.3531	2%
6.	Aluminised Explosive RDX/TNT/Al 20/50/30	1.8058	7.081	190.64	458.5380	471.3598	2%
7.	Aluminised Explosive RDX/TNT/Al 25/50/25	1.779	7.173	204.96	557.9625	609.4829	9%
8.	Aluminised Explosive RDX/TNT/Al. 30/50/20	1.789	7.5095	253.13	851.0540	766.9147	10%
9.	Aluminised Explosive RDX/TNT/Al. 35/50/15	1.7723	7.62	257.685	870.9931	911.5735	10%
10	Aluminised Explosive RDX/TNT/Al. 40/50/10	1.751	7.76	261.37	876.3148	1064.0841	21%
11.	Aluminised Explosive RDX/TNT/Al. 45/50/5	1.734	7.88	264.929	883.9392	1187.917	34%

Energy of explosion, calculated thus is mainly responsible for the shock formation. In table II we have compared energy of explosion of different aluminised explosives obtained from relation (5) with that obtained experimentally. Value of γ is given by the relation

$$\gamma = \frac{\rho_D U_D}{p_D} - 1$$

Knowing γ, energy is given by

$$Q = \frac{U_D^2}{2(\gamma^2 - 1) J}$$

Where J is the Joule's mechanical equivalent of heat. It is seen that experimentally calculated energy agrees with the energy evolved in the first phase reaction only.

In the second phase AlO and Al_2O present will react with CO_2 to form Al_2O_3. This is highly exothermic reaction and will evolve large quantity of heat. This energy is responsible for the sustainance of shock and also for increasing the impulse of shock (Singh 1983).

EXPERIMENTAL SET UP

The complete experimental set up for determining the shock parameter data for water is given in the Figure 1. The water was contained in a wooden tank of size 30 cm cube, the two opposite sides of which were made of glass for photographing the event. A cylindrical high explosive cast charge 5 cm in diameter and 20 cm in length was immersed in water from the base of the tank and was detonated to generate the shock wave in water. Observation of propagation of shock wave in water and motion of free surface of water were made with Model 770 Nano second Ultra Speed Streak Camera, designed and developed by Beckman and Whitley USA and installed in TBRL. In this camera the rotating mirror assembly consists of mioor 2.5 Cmx 5 cm, Beryllium mirror, empowered by an air driven turbine. This mirror is capable of a top speed of 3000 RPS where the camera writing rate slightly more than 10mm/ µs. is obtained. The camera records the event through a slit with the width of the order of 0.1 mm, thereby giving the timeresolution of the order of 10 nanoseconds. The camera records only driving 1/12 th of the whole resolution of the rotating mirrorand the record is obtained on a 203mm length of a 70 mm film.

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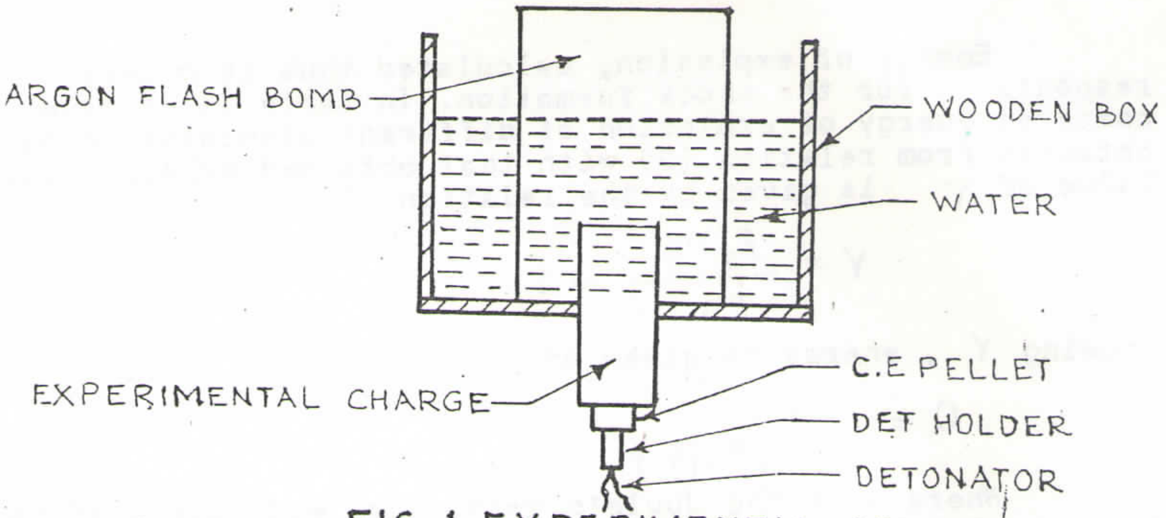

FIG.1 EXPERIMENTAL SET-UP

The motion of the shock wave under water and the motion of the free surface were observedunder a very strong back illumination from an argon flash bomb. This light bomb comparised of a card board container made leakproof and filled with argon gas and having plastic explosive on one end. The front rectangular face 30cmx15cm was covered with a transluscent perspect sheet which served as a diffusing screen.The length of the gas container and the quantity of the explosive in it controles the life time of such a source.

The height of the light bomb was so adjusted that about half of it extends beyond the water surface in the wooden box as viewed through the camera. The recording by the streak camera was done through a narrow slit passing through the cylindrical experimental charge.

The triggering of the argon flash bomb and the charge were properly synchronised and a streak camera trace as shown in figure 2 was obtained.

Different sets of values of shock velocity and particle velocity were obtained by varying water column above the charge surface immersed in water. Using various sets of values of shock velocity and the particle velocity, the shock parameters of water were found out.

After having calibrated water as pressure measuring gauge the detonation pressures of various high explosives were found repeating the experiment, using different explosives in different trials.

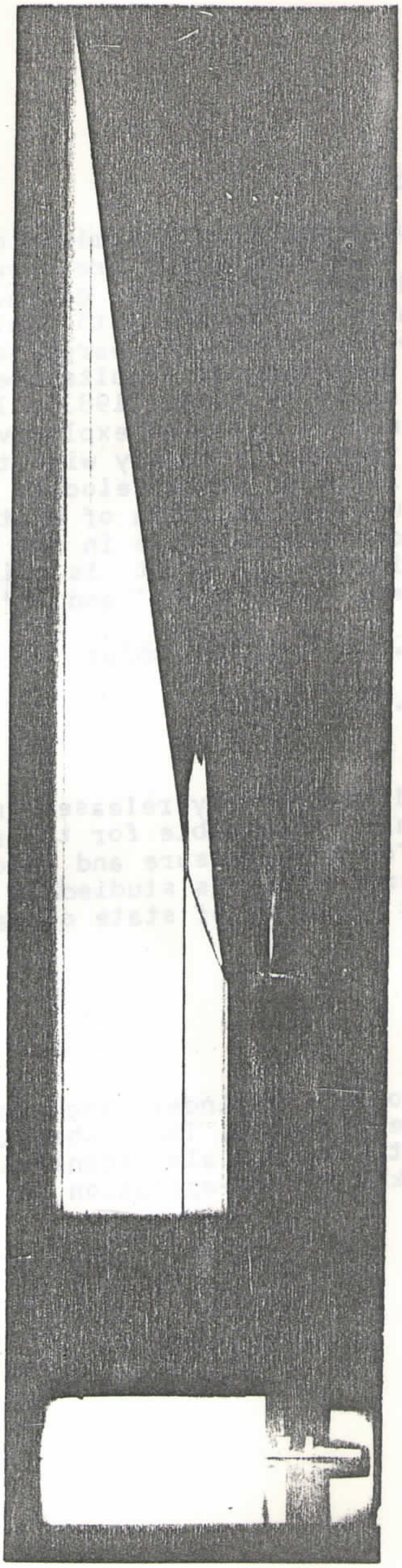

FIG.2: A TYPICAL STREAK RECORD

RESULTS AND CONCLUSIONS

In table 1, experimentally determined detonation parameters of various CHON explosives are shown. Also values obtained by Kamlet and Jacob (1968) are given. It is seen that experimental values tally reasonably with that obtained by K-J formulas. In table II, detonation parameters for aluminised explosives are given. Experimental results are compared with that obtained theoretically by Singh (1983). It is found that the energy of explosion of aluminised explosives which is released in first reaction tally fairly with that obtained experimentally. Table III give shock velocity and particle velocity at the free surface. Equation of state of water is found by fitting a second degree curve in the data given in table III. We have neglected 'c' as it is quite small and only a staight line is fitted. Value of 'a' and 'b' is obtained as,

$$a = 1.556 \pm 0.057 \ \text{mm}/\mu\text{s}$$

$$b = 1.91 \pm 0.087$$

It is calculated that energy released in the first phase of reaction is only responsible for the formation of shock wave. Technique for the pressure and velocity of detonation of various explosives is studied in the present paper and also Hogoniot equation of state of water is determined.

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TABLE No. III

Sr.No.	Shock Velocity in mm/µ sec.	Corresponding Particle Velocity in mm/µ sec.
1.	4.01	1.225
2.	2.79	0.610
3.	2.74	0.675
4.	2.21	0.380
5.	3.06	0.840
6.	2.865	0.730
7.	2.050	0.300
8,	2.478	0.3635
9.	2.277	0.3171
10.	2.420	0.42595
11.	2.119	0.2917
12.	2.415	0.462
13.	3.950	1.250
14	3.750	1.152
15.	2.119	0.349

a = 1.556 mm/µ sec. ± 0.057 mm/µ sec.

b = 1.91 ± 0.087

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