Explosion test of explosives by aluminium block

by J. Sato*

Synopsis

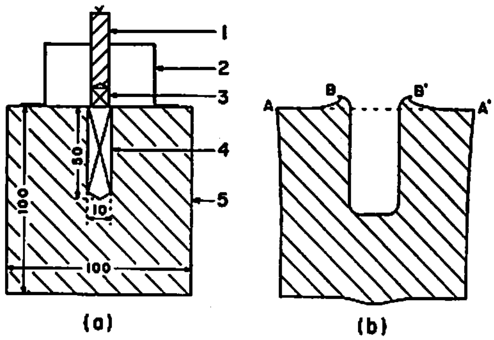
By measuring an enlarged volume of a central hole in an aluminium block blasted by an explosive charge in the hole, the available or specific energy of the explosive was examined. The empirical formulas were obtained for the organic explosive compounds. The specific energies of commercial explosives, evaluated from the formula, are in good agreement with those published by the explosive makers. The specific energies of explosives in the cases of the explosion under liquid were evaluated. An effect of nonexplosive component of a plastic-bonded explosive on the specific energy was ascertained. The present test is easily carried out at a low cost, and is suitable for our laboratory.

1. Introduction

The Trauzl lead block test has been widely applied to estimate a static effect of gas due to an explosion of explosive. The lead block, however, is too heavy and expensive to be used frequently in our laboratory. In this work, by using the aluminium block in an experimental manner different from that of the Trauzl test, an attempt has been made to estimate a relation between an enlargement and an available or a specific energy of explosive.

2. Experimental

The aluminium bars**(100 mm in diameter) were obtained from the same lot, because it is most important to use bars of the same quality to obtain successful results. With a lathe, about two hundred blocks (Fig. 1) were prepared. The Brinell hardness tests for these blocks showed values ranging from



1. detonator; 2. cardboard; 3. booster (tetryl : 1 g); 4. explosive; 5. aluminium block

Fig. 1 Schematic cross sections of aluminium block before (a) and after shot (b) Unit : mm.

Recieved , 1974.

* Department of Chemistry, National Defense Academy, Yokosuka.

** Chemical analysis (%). Al : 99.63, Fe : 0.26, Si : 0.10, Ti : 0.01, Cu : trace, Mn : trace, Mg : trace, Zn : trace. Tensile strength : 10.7 Kg/mm^2, Elongation : 45%.

24.0 to 24.9*. Such a variatiom in hardness has no significant effect on the results obtained in the present test. To prevent a misfire due to the small diameter of explosive, a tetryl pellet (1 gr.) was used as a booster with a No.6 electric detonator.

A cylindrically expanded hole with a rip was obtained (BB′ in Fig. 1-b). Before and after the shot, the volume of the hole was measured by filling water with a pipette**. The volume surrounded with the rip above the level (AA′ in Fig.1-b) which was found with a spherometer was subtracted from the volume of the water. As the average value of the expanded volume due to the booster alone was found to be 0.2 cm³, the net enlargement (V) is obtained from the following equation:

$$V=V_2-V_1-0.2$$

Table 1 Some of data of enlargement for organic explosive compounds

Explosive	W (g)	ρ (g/cm³)	V (cm³)	$\bar{V}$ (cm³)	$Wf\times10^{-2}$ (Kg-m)	Remarks
PETN	2.4	0.6	18.7	18.9	3.34	∘ f=139.3(Kg-m/g)
	2.4	0.6	19.0		〃	∘ F=535.8 (Kg-m/g)
	3.2	0.8	27.3	28.0	4.46	∘ No. of run (n) : 13
	3.2	0.8	28.7		〃	∘ Range of weight (R) : 2.4~4.7g
	3.6	0.9	33.4	33.6	5.02	
	3.6	0.9	33.7		〃	
	3.8	1.0	38.5	38.5	5.29	
	4.0	1.0	39.2	40.6	5.57	
	4.0	1.0	40.9		〃	
	4.0	1.0	41.0		〃	
	4.0	1.0	41.4		〃	
	4.6	1.14	47.9	47.9	6.41	
	4.7	1.17	49.7	49.7	6.55	
RDX	4.0	1.0	41.4	42.4	5.88	∘ f=147.0
	4.0	1.0	41.8		〃	∘ F=500.2
	4.0	1.0	43.0		〃	∘ n : 16
	4.0	1.0	43.2		〃	∘ R : 3.2~5.2 g
Tetryl	4.0	1.0	32.5	32.8	4.94	∘ f=123.4
	4.0	1.0	33.0		〃	∘ F=378.7
						∘ n : 12
						∘ R : 2.4~4.8 g
PA	4.0	1.0	27.8	28.5	4.30	∘ f=107.5
	4.0	1.0	28.0		〃	∘ F=318.6
	4.0	1.0	29.0		〃	∘ n : 12
	4.0	1.0	29.3		〃	∘ R : 2.4~4.8 g
TNT	4.0	1.0	26.3	27.4	3.82	∘ f=95.6
	4.0	1.0	27.9		〃	∘ F=283.4
	4.0	1.0	28.1		〃	∘ n : 16
						∘ R : 2.4~4.9 g

ρ : Density of charge $\bar{V}$: Average of V.

* Test load : 125 Kgs., Test ball : 5 mm in diameter. ** Graduation of 1/10 cm³.

where V_1 and V_2 are the volumes before and after the shot respectively.

3. Results and Discussion.

3.1. Relation between enlargement and available or specific energy for organic explosive compound.

Hexogen (RDX), penthrite (PETN), tetryl, picric acid (PA) and trinitrotoluene (TNT) were used. A changing in enlargement with varying the weight of charge (W) was measured.

Some of the enlargements measured are given in Table 1. In the present test, as well as in the Trauzl one, nonlinear relation exsists between the V and W values. On the Trauzl test, Neubner[1] has proposed a quantity defined as the kraftzahl, $KZ=(300/w)\times 10$, where w is a weight of charge to produce the enlargement of 300 cm³. In general, an actual effectiveness of explosion is not directly proportional to a computed value of available energy (F). Yamaga[2] has found the following linear relation between the KZ and F values: $KZ=0.73\times F+135$. The F values quoted from ref. 2 are given in the last column of Table 1, together with the values of specific energy (f). Following the example by Yamaga, the author attempted to plot $35/w'$ against F to find a linear relation, as is shown in Fig.2. A weight of charge (w') to produce the enlargement of 35 cm³ was determined graphically from the plots of V vs. W for each explosive. By the method of least squares, the line is obtained as follows:

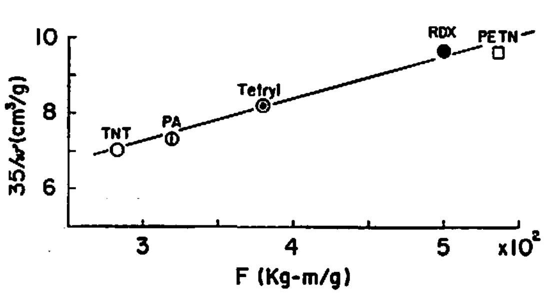


Fig. 2 Plots of $35/w'$ vs. F for organic explosive compounds

$$35/w'=1.12\times 10^{-2}\times F+3.85 \qquad (1)$$

the standard deviation$=0.25$

The result essentially corresponds to Yamaga's one and the $35/w'$ value to the KZ one by Neubner.

On the other hand, Gordon et al.[3] have reported that the expanded volume in the Trauzl test can be closely related to the specific energy of explosive. The straight line fitted to the plots of V vs. $W\times f$ in Fig. 3 is represented as follows:

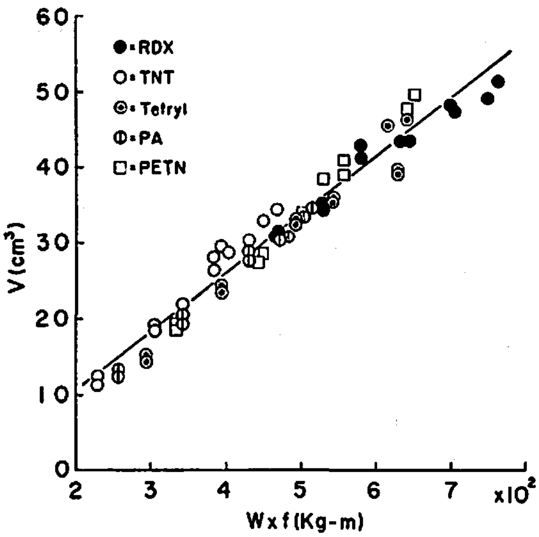


Fig. 3 Plots of V vs. $W\times f$ for organic explosive compounds.

$$V=7.76\times (W\times f\times 10^{-2})-4.98 \qquad (2)$$

the standard deviation$=2.22$

Thus, the V value can be considered as an indication of the specific energy.

3.2. Evaluation of specific energy of commercial explosive.

Substituting the W and V values for the commercial explosive into the equation (2), the experimental value of specific energy (f_e) can be evaluated. The results obtained are shown in Table 2 in comparison with the f_m values published by the explosive makers. The agreement between the f_e and f_m values

Table 2 Data for commercial explosives

Explosive	W (g)	ρ (g/cm³)	$\bar{V}$ (cm³)	n	D (cm³)	f_e (Kg-m/g)	f_m (Kg-m/g)
Shingiri-Dynamite	6.2	1.56	40.3	3	0.5	94.1	95.6
Enoki-Dynamite	6.25	1.56	44.1	3	0.7	101.2	89.6
Kuro-Carlit	4.0	1.00	29.2	3	0.4	110.1	108.6
Kaba-Carlit	4.0	1.00	20.3	3	0.7	81.4	80.6

D : Difference between maximum and minimum values of V.

is excellent. Even a specific energy of explosive with a complicated component can be evaluated by setting up an empirical formula for organic explosive compounds.

3.3. Effect of nonexplosive component on specific energy of plastic-bonded explosive.

The plastic-bonded explosives of PETN/EP 815[4] and PETN/EP 871[4] were employed as examples. The f_p value in Table 3 was calculated from the weight of PETN component alone. Since in every case the f_e value is larger than the f_p one, nonexplosive component is considered to be contributed to increase in specific energy. The rate of increase for PETN/EP 815 is considerably larger than that for PETN/EP 871. Therefore, the EP 815 component is more effective on the specific energy.

Table 3 Data for PETN/EP compositions

EP	PETN/EP (wt. %)	W (g)	$\bar{V}$ (cm³)	n	D (cm³)	f_e (Kg-m/g)	f_p (Kg-m/g)	$\frac{f_e-f_p}{f_p}\times 100$ (%)
EP 815	75/25	4.9	43.6	2	0.3	127.8	104.7	22
	70/30	5.0	43.8	2	0.6	125.8	97.6	29
	60/40	5.4	34.8	2	0.4	95.0	83.5	14
EP 871	75/25	5.55	42.6	2	1.3	110.5	104.3	6
	70/30	5.2	36.8	2	1.7	103.5	97.5	6
	60/40	5.2	29.3	2	1.6	85.0	83.7	2

3.4. Evaluation of specific energy of explosive from enlargement due to explosion under liquid

The block was placed in a steel cylinder (30 cm in inner diameter, 40 cm in height) filled with the liquid. To avoid wetting of the charge in the hole, the opening was

Table 4 Data obtained by explosion under liquid

Liquid.	Explosive	W (g)	$\bar{V}$ (cm³)	n	D (cm³)	f_e (Kg-m/g)	f (Kg-m/g)	$\frac{f_e-f}{f}\times 100$ (%)
Water (ρ=1.00)	TNT	3.86	21.8	2	0.1	89.4	95.6	− 6
	PETN	3.90	32.2	2	0.4	122.9	139.3	−12
	Kuro-Carlit	3.90	24.7	2	0.5	98.1	116.2	−16
$CaCl_2$-Solution (ρ=1.37)	TNT	3.91	21.8	2	0.7	88.3	95.6	− 8
	PETN	3.91	30.3	2	0.6	116.3	139.3	−17
	Kuro-Carlit	3.85	22.8	2	0.3	93.0	116.2	−20

sealed with a cellophane tape. Every f_t value in Table 4 is smaller than the f value quoted ref. 2. The fact is due to a large resistance of liquid against a high-speed deformation on the expanding of aluminium block. The rate of decrease for PETN or Kuro-carlit with the large f value is remarkable in comparison with that of TNT with the small f value.

3.5. Comparison of the present test with the Trauzl one

Comparisons between the two tests are summerized in Table 5. The ratios of the values of V and KZ for the organic explosive to those of TNT are shown in Table 6. Although the two tests differ from each other in experimental condition, there is a fair agreement between their results. Therefore, the present test is useful to examine a static effect of gas due to an explosion of charge, as well as the Trauzl one.

Table 5 Comparison of experimental condition

Condition	Present test	Trauzl test
Block		
Material	Aluminium	Lead
Size	100 mm dia., 100 mm long	200 mm dia., 200 mm long
Weight	1 Kg	70.5 Kg
Central hole	10 mm dia., 50 mm depth	25 mm dia., 125 mm depth
Explosive		
Charging	Whole of the hole (Semi-open type)	Bottom of the hole(Sand-closed type)
Weight	4 g	10 g
Detonator	Out of the hole	In the hole
Booster	Tetryl pellet (1 g)	No

Table 6 Relative values of V and KZ

Explosive	Enlargement		Kraftzahl	
	Present	Trauzl	Present	Trauzl
TNT	1.00	1.00	1.00	1.00
PA	1.04	1.01	1.02	1.01
Tetryl	1.20	1.24	1.16	1.18
PETN	1.48	1.59	1.36	1.44
RDX	1.55	1.49	1.37	1.36

Acknowledgememt

The author wishes to express hearty thanks to Prof. Y. Nomura for his valuable guidance throughout this work and for his kind inspection of the manuscript.

References

1) R. Neubner; Z. ges. Schiess-Sprengstoffw., 23, 53 (1928)
2) N. Yamaga; J., Ind. Expl. Soc., Japan, 1, 36 (1939), in Japanese.
3) W. E. Gordon, F. E. Reed, and B. A. Lepper; I. & E. C., 47, 1794 (1955).
4) H. Lee, and K. Neville "Handbook of Epoxy Resins" McGraw Hill, (1967) Chap. 4, p. 66.