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# Note: Estimating the charge size in explosive forming of sheet metal

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Note: Estimating the charge size in explosive forming of sheet metal

In the explosive forming of sheet metal some relatively easy method of estimating the size of the charge is needed. This short note describes a method in which the size of the charge is found by equating the work done in forming the component to that part of the explosive energy available for doing work on the component.

Rigorous solutions for the work done in forming a component, even for simple shapes, are usually complicated. However, if we recognise that in the processes of interest the sheet metal is formed either by biaxial tension or uniaxial tension then the work done can be estimated from this equation:

$$W.D. \quad = \quad t\,\delta A\,Y \qquad (1)$$

where $\delta A$ is the imposed change in surface area, $Y$ is the uniaxial yield stress and $t$ is the initial thickness of the sheet. If work-hardening is to be included then

$$W.D. \quad = \quad t\,\delta A\left\{Y + \frac{1}{2}\frac{\delta A}{A}\,H\right\} \qquad (2)$$

where $H$ is the slope of the plastic stress-strain curve.

Consider the forming of a circular diaphragm of diameter 'a' to a spherical cap of radius 'r' and central height 'h'. Then

$$\text{spherical surface area} = \pi\left\{\frac{a^2}{4} + h^2\right\}$$

$$\text{original area} = \frac{\pi a^2}{4}$$

$$\text{and } \delta A = \pi h^2$$

and from equation (1)

$$W.D. \quad = \quad t\pi h^2 Y \qquad (3)$$

Let us now assume that the total explosive energy can be represented by a sphere (with the charge at the centre) and that the proportion of the explosive energy available for deforming the blank is given by the surface area of the spherical sector acting on the blank divided by the surface area of the corresponding sphere. For a circular diaphragm we have

$$\text{explosive energy available} = \frac{W\eta\theta^2}{4} \qquad (4)$$

where $2\theta$ is the solid angle subtended by the blank at the charge, $W$ is the chemical energy released on detonation and $\eta$ is the efficiency of energy transfer. Now equating equations (3) and (4) we obtain

$$t\pi h^2 Y = \frac{W\eta\theta^2}{4}$$

or (5)

$$h^2 \alpha \frac{W\theta^2}{tY}$$

Figures (1) and (2) give experimental results for a wide range of conditions. (In figure 1 the stand-offs varied from 17 to 134 cms, the sheet thicknesses from .066 to .254 in., the yield stresses from 10.7 to 12.9 tons/in$^2$ and the charge size from 54 to 428 grms. In figure 2 the variables were material, stand-off and diaphragm diameter.) In spite of the scatter it can be seen that equation (5) fits the experimental results quite well.

In expanding a cylindrical tube to a spherical form where the material is allowed to draw in axially from the free ends, the change in surface area is given by

$$\delta A = \frac{4}{3}\pi l h$$

where l is the length of tube and h is the maximum radial deflection. Substituting in equation (1) gives

$$WD = \frac{4}{3}\pi l h t Y \qquad (6)$$

If $2\theta$ is the angle subtended by the tube at the centrally positioned charge then the proportion of energy reaching the blank is

$$\text{explosive energy available} = W\eta\sin\theta \qquad (7)$$

equating equations (6) and (7) gives

$$W\eta\ \sin\theta = \frac{4}{3}\pi l h t Y$$

or

$$W\eta \frac{l}{(l^2 + D^2)^{\frac{1}{2}}} = \frac{4}{3}\pi l h t Y$$

(where D is the original tube diameter)

and $$h\ \alpha\ \frac{WtY}{(l^2 + D^2)} \qquad (8)$$

Figure 3 gives experimental values (material and thickness constant) and again the theory can be seen to give good agreement with experiment.

The efficiency $\eta$ was found to be approximately 25% for the diaphragms and 40% for the tubes.

Although lacking rigour the method presented here could be useful in calculating the charge size for forming complicated shapes from sheet metal where calculation of the change in surface area will be simple compared with a rigorous plasticity solution.

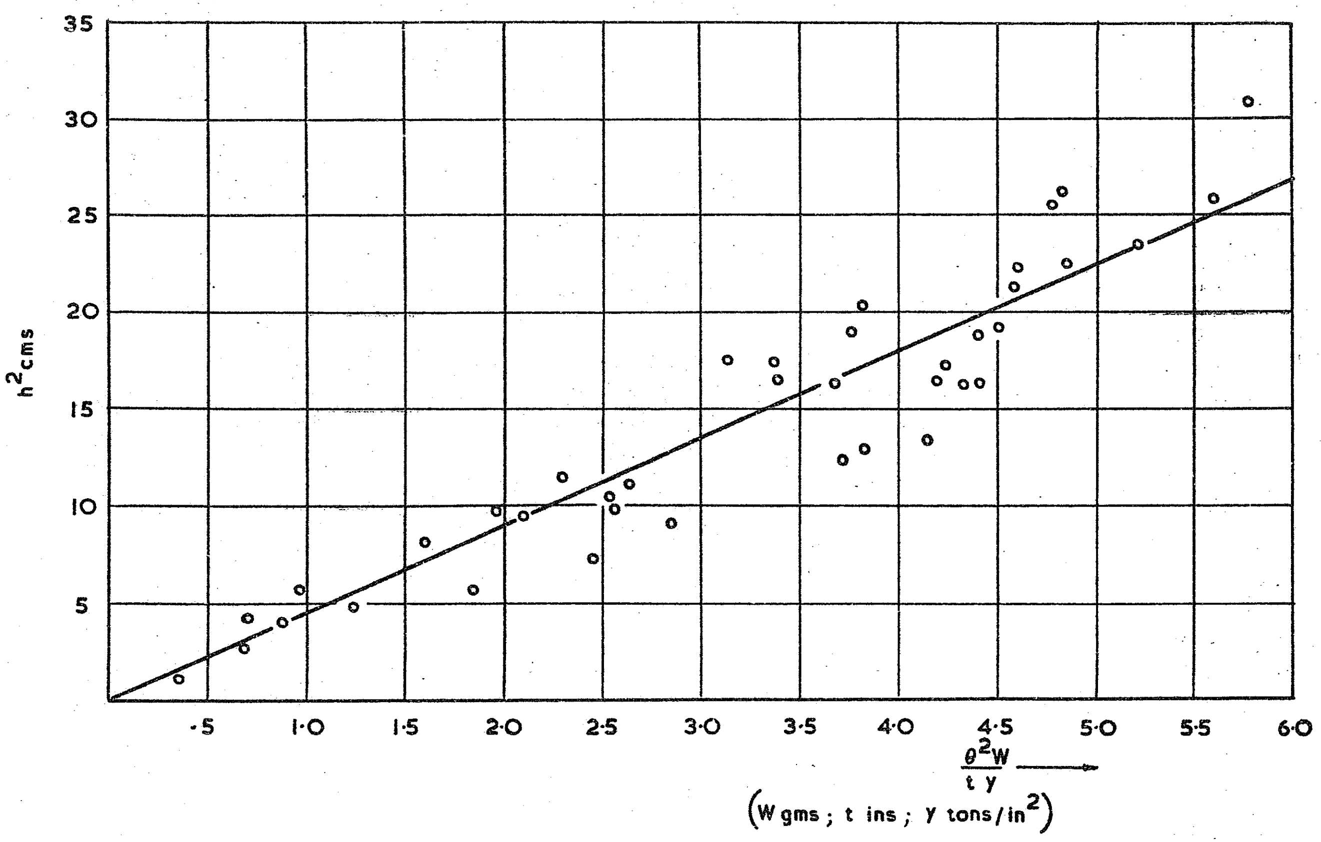


FIG. 1. EXPLOSIVE FORMING OF ANNEALED MILD STEEL DIAPHRAGMS 13·96 cm DIAMETER – EVACUATED TOOL UNDER WATER

EXPERIMENTAL RESULTS OF h,t,w,y AND STAND-OFF BY PERMISSION OF R.A.R.D.E (DATA UNPUBLISHED)

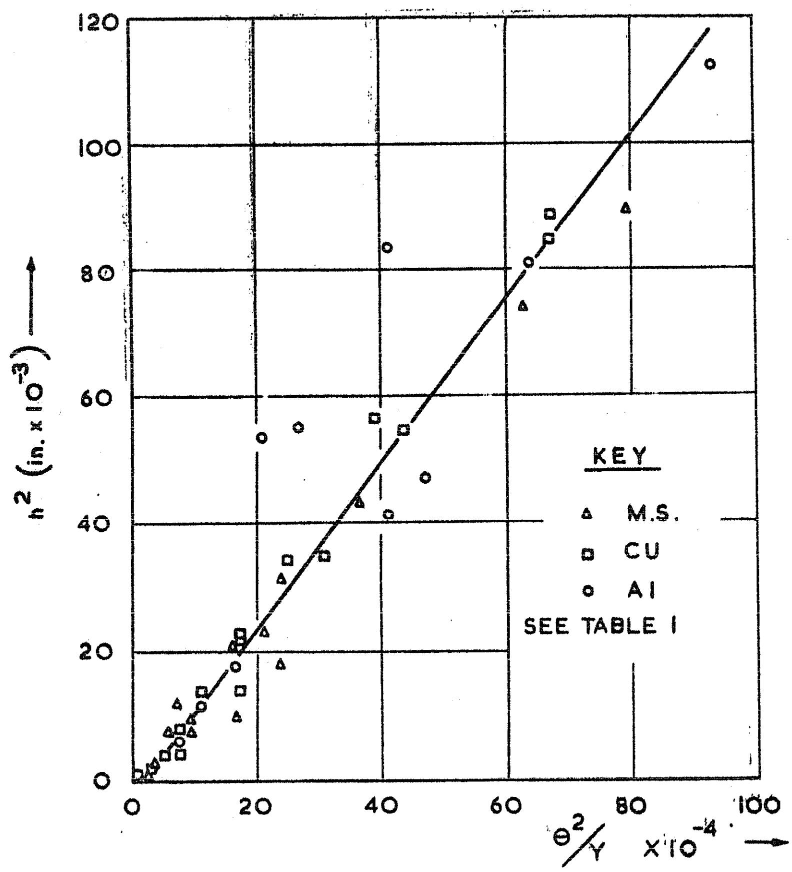


FIG. 2. EXPLOSIVE FORMING OF CIRCULAR SHEET METAL DIAPHRAGMS.

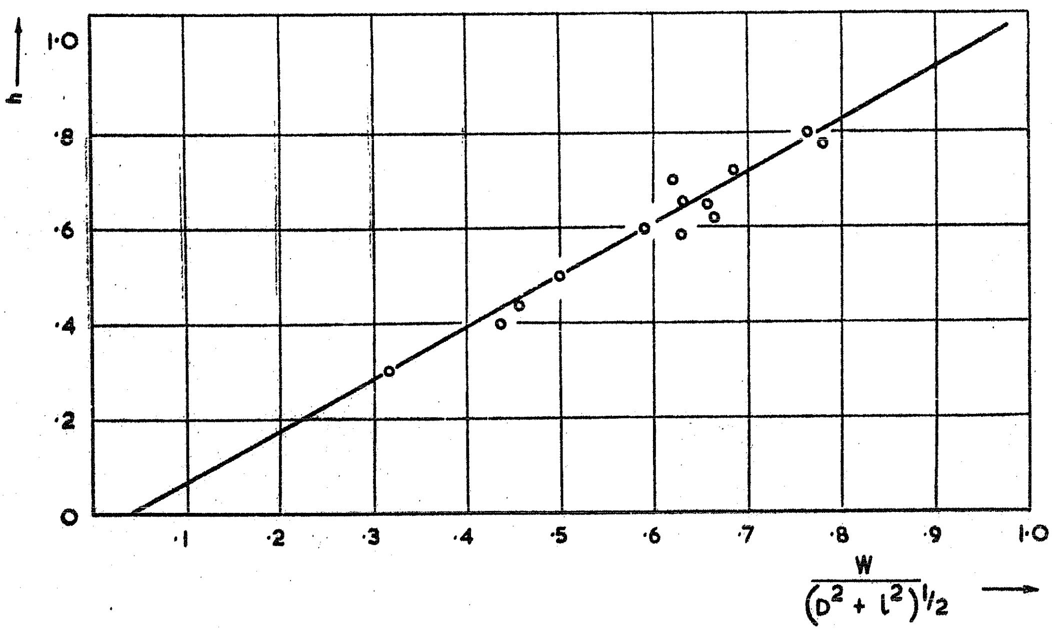


FIG. 3. EXPLOSIVE FORMING OF STAINLESS STEEL TUBES — 26 S.W.G. DTD 571.