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SHORT COMMUNICATION

New Pressing Technique for Preparation of Small-Calibre Shaped Charge

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ABSTRACT

Explosive filling in small-calibre shaped charges is carried out by pressing technique. At present, pressing is carried out by single action method which suffers from a drawback of density gradient in the charge from the face of the tool. A new method—double action pressing—has been established which eliminates this problem. Filling quality of charge of 30 mm calibre prepared by this method especially with respect to the density gradient is presented and discussed.

INTRODUCTION

Shaped charges are extensively used for defeating hard targets like armoured vehicles. The greater penetration of a shaped charge is primarily due to the formation of high velocity jet by the collapse of the liner material under the influence of high detonation pressures generated by the explosive column. High performance shaped charges require a perfect rotational symmetry and material homogeneity. To obtain a desired shape of a detonation wave, the density distribution of the explosive in the charge must meet certain specifications and must be symmetrical. The pressing of shaped charges is a well-known procedure in ammunition technology. However, to obtain high quality charges, the parameters of the pressing process, especially the pressure as a function of time and place have to be tuned to the properties of compacted particulate solids[1]. The pressing technique, however, suffers from a drawback of pressure gradient resulting in density gradient (in the charge) from the face of the tool. This pressure distribution or the density gradient becomes more pronounced in case of complex geometries like taper charges as compared to that of the cylindrical ones.

A method was established for the preparation of small-calibre, high performance, shaped charges by a new pressing technique. The method established in this Laboratory for the preparation of a charge of calibre 30 mm is described in the next section.

2. EXPERIMENTAL DETAILS AND PROCEDURE

The RDX/wax (95/5) composition procured from an Indian ordnance factory was used for the preparation of the charges. The liners made from electrolytic grade copper of purity > 99.98 per cent were procured from trade. Liners of calibre 30 mm, thickness 1 mm and cone angle 60° were chosen for the preparation of charges. A resin coating was applied on the outer surface of the liner before introduction into the mould for better anchoring of explosive with the liner.

Charges of 60 mm length were prepared by two methods: single and double action. In the single action pressing technique, the liner fixed on the base plate was introduced into the mould. Weighed quantity of the explosive composition was poured into it and a dead load of 15 tons was applied for a dwell time of 15 s. The base plate was then removed and the charge was extracted. In the double action pressing technique, a spacer of thickness 5 mm was introduced between the base plate and the mould body. First stage of press operation was carried out as described earlier except that the forward motion of the ram was arrested by a

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limiter. Pressure was released and the spacer plate was then removed and pressed again. During this mode, the ram along with mould body moved in the downward direction, resulting in pressing of explosive from bottom. The charge was then extracted from the mould.

The density distribution in cylindrical charge along the X-axis was determined at six different positions by Archimedes' principle.

3. RESULTS AND DISCUSSION

Conventionally, in pressing operations during the preparation of the charges, explosive powder is poured into the mould and pressed at a desired pressure. If the length of the charge is large compared to the diameter, the pressing is done in increments. This method can be used for the preparation of solid cylindrical charges. However, it cannot be used for the preparation of shaped charges as the ram movement during the first increment is likely to damage the apex of the cone. Shaped charges in the present study were, therefore, prepared by filling the mould in a single increment.

It is known that when a high pressure is applied at one end during the pressing operation, the friction between the explosive and walls causes a gradient of pressure[2]. As a result, the density decreases gradually from the face of the ram. Pressure experienced (P_a) at a distance from the point of application of pressure is related to the pressure applied (P_b) by the equation:

$$P_a = P_b \exp\left\{\frac{(2\,F_w\,k)\,(X-L)}{R}\right\}$$

Where,
- P_b = Pressure applied (kbar)
- P_a = Pressure experienced (kbar)
- L = Length of charge (cm)
- X = Distance from the opposite side of the tool
- R = Radius of the charge
- F_w = Coefficient of friction (0.113)
- k = Internal material friction (0.55)

The internal material friction present in the particulate solids can be related to the heap angle (ϕ) by the formula[1]

$$K = K \tan(0.75\,\phi)$$

Now having obtained the pressure experienced at different distances of the charge and knowing the bulk density, the maximum achievable density of the explosive powder and the compressibility factor, one can calculate the consolidation density using the relation[1].

$$\rho = \rho_f \times (\rho_0 - \rho_f)e^{\beta P}$$

Where,
- ρ = Density of the charge (g/cc)
- ρ_0 = Bulk density (g/cc)
- ρ_f = Max achievable density (g/cc)
- β = Compressibility factor
- P = Pressure

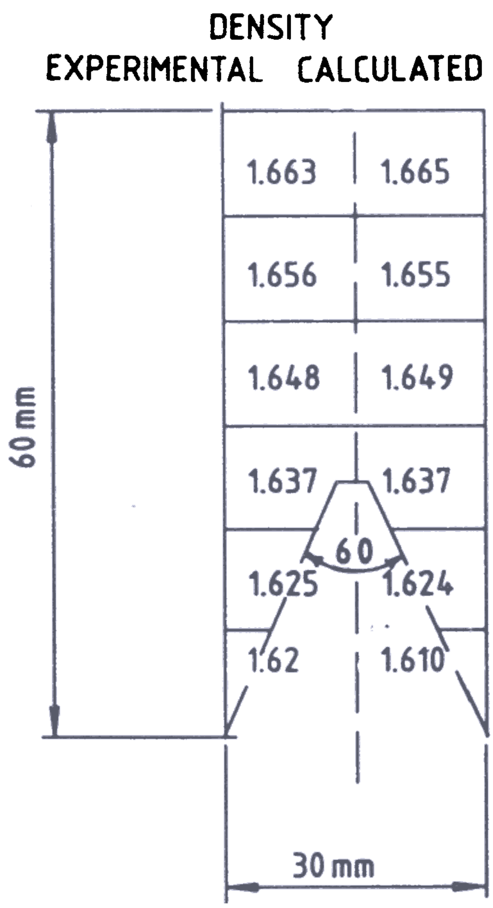

Figure 1. Comparison of calculated and experimental density variation in cylindrical charge.

Density values, thus calculated at six different positions in a shaped charge pressed by single action method have been compared with the experimentally determined density values in Fig. 1. It was observed that the density variation between the top and bottom ends of the charge is as high as 3 per cent.

A close scrutiny of the charge towards the end of the copper liner showed that the explosive is not consolidated into a homogeneous mass as shown in Fig. 2. This is ascribed to the lower pressure experienced by it inspite of longer dwell times. The mass constituting the jet increases from about 20 per cent at the apex of the cone to about 60 per cent at the base[3]. Adequate explosive filling near the base is thus essential to enable the liner to collapse and participate in the penetration. Also, the capability of the shaped charge gets affected as a result of lower jet velocities ($\nless$ 3000 m/s) which is a consequence of poor consolidation at the base of the liner[4].

The overall performance of the shaped charge prepared by the single action press method is thus expected to be lower than desired. This was improved by adopting the double action press method for the preparation of the charge.

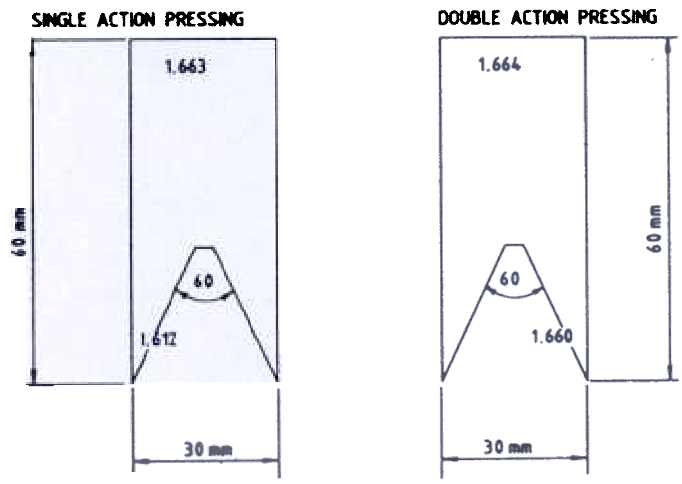

Figure 2. Variation in density between top and bottom in single and double action pressing methods.

In the double action pressing method, the explosive composition in the mould is compressed in two modes. In the first mode, the pressure acts from the top by the downward movement of the ram. After the spacer is removed, application of pressure moves the base plate in the upward direction. Both ends of explosive feel equal pressure values. The mass in the middle is compressed from both directions and attain a density comparable to that at either end. Figure 3 compares the density distribution in a cylindrical shaped charge

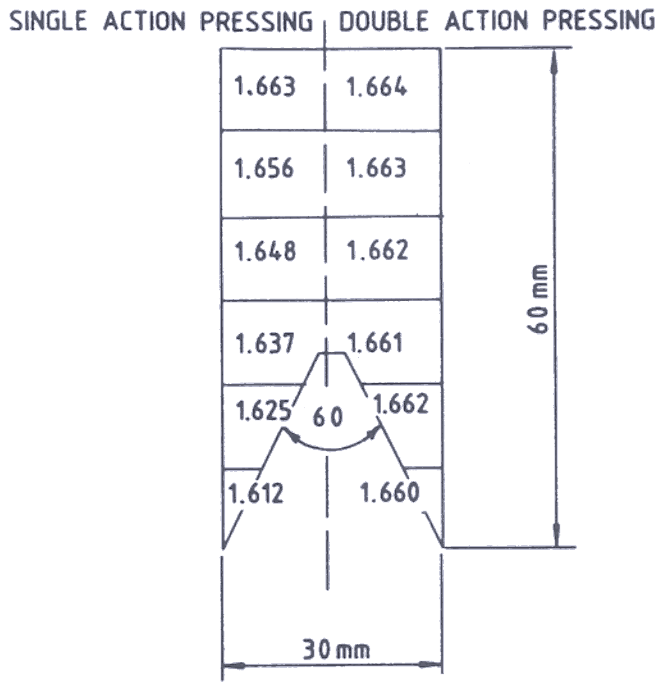

Figure 3. Comparison of density variation by the two pressing techniques.

prepared adopting the two different pressing techniques. The density variation observed from one end of the charge to the other is very low in the double action pressing method. Further, due to the action of pressure at the base of the cone, the explosive composition is distributed uniformly around the liner at the base and thus giving rise to higher *c/m* ratio. Higher *c/m* ratio is known to improve the performance of shaped charges[3]. It is also observed that, within the same volume, as high as 2 per cent extra composition could be accommodated using this method, thus giving rise to better *c/m* ratio around the liner.

The ultimate test of an ammunition is its performance against a target. Of the two types of charges, the charges prepared by double action pressing give greater penetration. Thus, cylindrical charges prepared by the single action pressing technique, evaluated on mild steel at 2D stand-off, show a penetration of 128-130 mm which is increased to 136-140 mm for the charges prepared by the double action pressing method. The explosive composition accommodated in each of the double action pressed charges is larger than that prepared by the single action pressing method. The increase in the quantity of explosive, uniform distribution of density and better consolidation of the explosive near the base accomplished during the double action pressing technique are among the important factors that have contributed to the improved performance with reference to penetration.

4. CONCLUSION

Results of density history of the charges prepared by the single and double action pressing methods indicate that the double action pressing technique produces better density and homogeniety. The density gradient which is to the tune of about 3 per cent in cylindrical charge gets eliminated by resorting to double action pressing technique, which ultimately improves the performance of the shaped charge.

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