# Characteristics of Solid Metal Using Underground Explosion Pressing

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## ABSTRACT

This paper presents the results of an experimental study aim for enhancing the understanding of some characteristics of solid metal using pressing method within a confined underground area. For that purpose, pressing will be done using different weight of explosive (Emulex). Significance of this research is knowledge about characteristics of solid metal at such heavy duty press and it will open up a new prospect to use explosive as an economical way. The objectives of the research is to investigate the characteristics of solid metal by underground explosive test. The effect of the explosive charge on the pressure distribution along the compacted specimen of solid metal which is placed in the mold of Underground Explosion Pressing apparatus. The plunger is place on the solid metal and the explosive material (Emulex in conical shaped charge) was placed directly on the upper base of plunger before buried all the apparatus underground. Once exploded, force generated from explosive cause the plunger to press the solid metal. The amount of explosive used are 500g and 750g. The microstructure of solid metal is analysed using Scanning Electron Microscope (SEM) while the hardness of specimens is tested using Rockwell Digital Hardness and the decrement thickness of specimen also been observed. As a conclusion from this research, the method for Underground Explosion Pressing is suitable for pressing the solid metal.

## 1. INTRODUCTION

Heavy duty press machine commonly used to compress heavy components for aircraft, spacecraft, and power-generation facilities. China company has built a 160,000 Tons heavy duty press machine which helps China to build its space program. Other modern countries that have heavy duty press exceeding 50,000 tons are Russia, Germany, Japan, and Korea. This research aim is to create a new method for pressing that just used commercial explosive (Emulex). Explosive compaction is one of the methods in powder metallurgy [1, 2]. Explosive compaction is also one of the techniques to fabricate the sandwich structure. This technique is an original material synthesis technology, which is used the energy created from explosive and operate on the metal in the form of a shock wave to fabricate solid bulk material. The energy that produces from the explosive can replace the force from the heavy duty press machine. A plate of metal is layered on a mold. A plunger is place on the metal. Once exploded, the plunger will press the solid metal. Ideally, the more energy produced from the explosive, the stronger the material will be [3].

## 2. EXPERIMENTAL PROCEDURE

### 2.1. Material Selection

Type of explosive that are used in this research is commercial explosive (Emulex). Emulex is explosive material that is a sensitive emulsion explosive with a greyish-yellow paste like texture wrapped in plastic film or rigid paper tube cartridges. It has an excellent fragmentation when the proper grade is matched to the rock conditions, excellent water resistance and has superior resistance to dynamic pre-compression. Its density can vary from 1.17g/cm$^3$ until 1.19 g/cm$^3$. The detonation velocity of the Emulex range from 4500m/s to 5700m/s. The characteristics of Emulex are, it has excellent handling, safety and stable. Explosive blast generates a heavy duty pressing compaction. For that reason, it must take into relevant aspects of the parameter apparatus to ensure that it can withstand the blast load from the explosion. The specimen use for this explosion pressing are solid metal. There are two specimens use based on different weight of Emulex.

### 2.2. Preparing Shaped Charge

Type of explosive that are used for this experiment is commercial explosive (Emulex) with weight 500g and 750g. The first step to prepare the shaped charge explosive by weight the Emulex using analytical balance. Then, Emulex explosive has been placed and compacted in the pipe tube with same diameter 21.9mm but different height which are 98mm for 500g of and 148mm for 750g. Figure 1 shows the preparation of Emulex shaped charge. The type of shaped charge used is conical shape charge, since conical shape provide greater penetration ability.

Figure 1: Preparation of Emulex Shaped Charge.

### 2.3. Preparation for Underground Explosion

The solid metal was pressed using Underground Explosion Pressing. This explosive pressing method is used explosive material (Emulex), detonator, plunger and mold. Before the blast test, a hole with depth 1.5m was dig using a backhoe loader. Then, the lower base, mold and solid metal specimen was placed underground in a vertical position. The plunger was placed on the solid metal and fit the mold. After that, the explosive material (Emulex in conical shaped charge) was placed directly on the upper base of plunger. Then, the detonator is insert into the explosive material and connected with electric detonator. The hole with all explosive apparatus is buried and compacted with the soil until the apparatus is fully covered. Lastly, three sandbags with weight 50kg each was put on the soil to reduce energy loss. Figure 2 shows the schematic diagram of Underground Explosion Pressing Method. The high speed camera is set at 60m away to capture the moment of blast test.

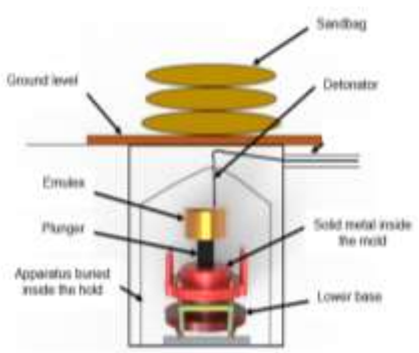


Figure 2: Schematic Diagram of Underground Explosion Pressing

## 3. NUMERICAL CALCULATION

Density can be measured using equation 1, where is the density in g/cm$^3$, is the mass of the specimen, and is the volume of the specimen, cm$^3$.

$$\boldsymbol{\rho} = m/V \quad (1)$$

### 3.1. Force Produced by Emulex

From Walters, 2007 [4];

$$\text{Penetration depth,} \quad \mathrm{P} = \frac{(\mathrm{V_o} - \mathrm{V_{min}})\mathrm{t}}{\gamma_\mathrm{E}} \quad (2)$$

Where to find initial velocity, $V_o$ based on Henry, 1967 [7];

$$\mathrm{V_o} = \sqrt{2\mathrm{e}}\left[\frac{m}{c} + \frac{1}{2}\right]^{-\frac{1}{2}} \quad (3)$$

$m$ = Mass of Casing
$c$ = Mass of Explosive

Where to find target material strength, $\gamma_\mathrm{E}$ based on Simon and Di Persio,1969 [7];

$$\gamma_\mathrm{E} = \sqrt{\frac{\mathrm{P_r}}{\mathrm{P_j}}} \quad (4)$$

Where to find minimum velocity, $V_{min}$ based on Poole, 2005 [5];

$$\mathrm{V_{min}} = \frac{\mathrm{H_D} - \mathrm{P_{SD}}}{\mathrm{k_j} \times \mathrm{p_j}} \quad (5)$$

$\rho_\mathrm{j}$ = Density of Emulex
$\mathrm{H_D}$ = Height depth of penetration
$\mathrm{P_{SD}}$ = Force produced by Emulex
$\mathrm{k_j} = \frac{1}{2}$

Therefore, Penetration depth, P can be derive from equation 3, equation 4 and equation 5;

$$\mathrm{P} = \frac{\left(\sqrt{2\mathrm{e}}\left[\frac{m}{c} + \frac{1}{2}\right]^{-\frac{1}{2}} - \frac{\mathrm{H_D} - \sigma_\mathrm{SD}}{\frac{1}{2}\mathrm{p_j}}\right)t}{\sqrt{\frac{\mathrm{P_r}}{\mathrm{P_j}}}} \quad (6)$$

### 3.2. Stress Propagation in Plunger

From Walters, 2007;

$$\text{Wave velocity,}\ \mathrm{C_p} = \sqrt{\frac{\frac{\mathrm{d}\sigma}{\mathrm{d}_\varepsilon}}{\rho}} \quad (7)$$

Where,

$$\mathrm{d}_\sigma = \frac{\mathrm{F}}{\mathrm{A}} \quad (8)$$

Where,

$$d_\varepsilon = \frac{\Delta l_f}{l_f} - \frac{\Delta l_o}{lo} \quad (9)$$

Therefore, $\mathrm{C_p}$ can be derive from Eq. 8 and Eq. 9;

$$C_p = \sqrt{\frac{\frac{F}{A}}{\frac{\frac{\Delta l_f}{l_f} - \frac{\Delta l_o}{l_o}}{\rho}}} = \frac{E}{\rho} \quad (10)$$

**ρ** = Density of plunger
**E** = Young's modulus
**F** = Force produced by Emulex (kN)

### 3.3. Force Produced Impacted on Solid Metal

From Poole and Yavuz [5] [6];

$$P = \frac{(\gamma_{pw-1})\, m (\sqrt{2e} \sqrt{\frac{1}{\rho}\left(\frac{V_1}{V_0}\right)^{\gamma_{pw}}}}{2\left[(V_1 - V_0)(\frac{V_1}{V_0})\right]} \quad (11)$$

## 4. RESULTS AND DISCUSSIONS

### 4.1. Thickness of Specimen

The thickness of solid metal was observed and compared from the original size. This explosive pressing method cause the changes and decrement for the specimen thickness as in Table 1. Thus, when more explosive is use, the desire thickness can be achieve.

Table 1: Result of both specimens before and after explosion

| Specimen | Explosive used | Before explosion | After explosion |
|---|---|---|---|
| A | 500grams |  Thickness: 10$mm$ Diameter : 25$mm$ |  Thickness: 5.7$mm$ Diameter: 33.5$mm$ |
| B | 750grams |  Thickness: 10$mm$ Diameter : 25$mm$ |  Thickness: 3.9$mm$ Diameter: 41.6$mm$ |

### 4.2. Hardness of Specimen

The hardness result for specimen is generated by using Rockwell Digital Hardness. The specimen shows the highest hardness on mass of Emulex 750g, since the specimen get more impaction of pressing during the explosion. Hardness result of the specimen with explosion of 750g Emulex is generated 43.7HRA while for the specimen with explosion of 500g Emulex is generated 33.8HRA. So, it can be concluded when more explosive is used, the hardness of specimen will be increase and a desire hardness can be achieve.

Table 2: Result of hardness test

| Specimen | Explosive used | Hardness Result |
|---|---|---|
| A | 500grams | 33.8 HRA |
| B | 750grams | 43.7 HRA |

### 4.3. SEM Microstructure

The morphologies of the specimen were observed using Scanning Electron Microscope (SEM). Figure 3 shows the microstructure of the both specimen surface after explosion pressed. The particles are linked together and exhibit pores. It can be seen that as the amount of Emulex increases, the porosity decreases because higher pressing forces can produce the effective binding of particle in the solid metal. The surface of the metal is dusty with the presence of impurities because of the rusting effect and scratches effect after polishing process by using sandpaper. The white area represents the indention point of the pressing when performing the blast test.

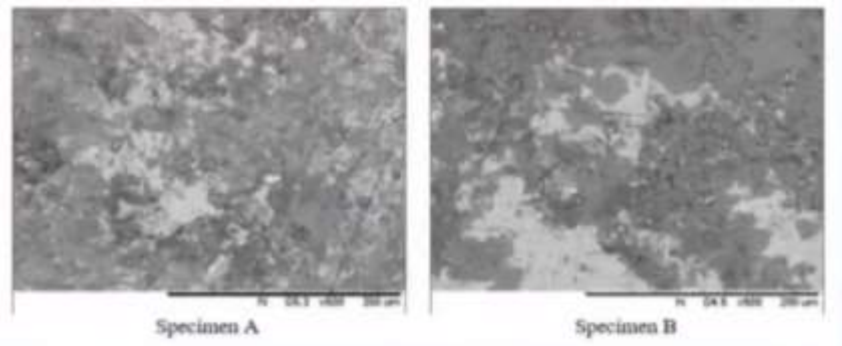


Figure 3: SEM microstructure of specimen after explosion

### 4.4. Pressing Force

The pressing force is determine from numerical calculation is as Table 3. It proven when more explosive is used, the higher pressing force can be achieve.

Table 3: Result of force pressing

| Specimen | Explosive used | Pressing force |
|---|---|---|
| A | 500grams | 25,150 Tons |
| B | 750grams | 37,700 Tons |

## 5. CONCLUSION AND RECOMMENDATIONS

As a conclusion from this research, the method for Underground Explosion Pressing is suitable for pressing the metal powder. The research is successful to achieve the objective and suitable for pressing the solid metal using explosive. The effects are depend on the type and amount of explosive used. Recommendation could be apply to the future research is investigate the amount of explosive need to achieve 160,000 Tons of pressing force or comparing the field blast test result with simulation result using ANSYS AUTODYN Software.

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