Characteristic of Solid Metal using Underground Explosion Pressing

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Abstract. This paper presents the results of an experimental study aim at enhancing the understanding of some characteristics of an interior explosion within a confined underground area on specimen used, as well as the effect of the explosive charge size on the pressure distribution along the compacted specimen which is placed in the apparatus. The study involved blast test which provides a measured pressure based on the amount of explosive used. The type of explosive used for this experiment is Emulex with detonation velocity range from 4500 m/s to 5400 m/s. The microstructure of specimen A and B is analyzed using Scanning Electron Microscope (SEM). Then, the hardness of both specimens is tested using Rockwell Digital Hardness and the result for specimen A is 33.8 HRA, while for specimen B is 43.7 HRA. Besides that, the bending strength of specimen A and B had been tested using Calcium Carbide Explosive Shape charge and the force that applied to the specimen B during the bending strength is 243,160.68 kN, while for specimen A, there is no effect of bending strength test.

1. Introduction

Heavy duty press machine commonly used to compress heavy components for aircraft, spacecraft, and power-generation facilities. China company has built a 160,000tons heavy duty press machine which absolutely leads to high cost. Other modern countries that have heavy duty press exceeding 50,000 tons are Germany, Korea, Russia and Japan This research aim is to create a new method for pressing that used commercial explosive (Emulex). The energy that produces from the explosive can replace the force from the heavy duty press machine. Ideally, the more energy produced from the explosive, the stronger the material will be.

This research used Underground explosion method to press the solid metal (mild steel). Underground explosion method is selected since confined space can give more blast energy. An underground explosion of compact materials has been studied by the previous researcher[1,2]. Several things that have been investigated including the dynamic behaviors of concrete at high pressures and craters of soil that formed. But, the underground explosion comes with the problem of shock loading and high cost. Underground explosion method has been used in the study on dynamic behavior of concrete at high strain and pressure.

Confined explosions have an extreme effect which can lead to serious damage compare to the open air explosion. The geometrical factors of the space where the explosion occurs such as the opening size of the explosion chamber and the height of the explosive, affect the results of the explosion. The opening size of the apparatus is determined by the explosive used.
confined space, geometrical dimensions, and the explosive location influence the effect of the confined explosion [3,4]. The analysis of internal explosion in confined space has been studied by the previous researcher that focus on the pressures at the inner space boundary and the response analysis of the boundary structural elements. This analysis can assess the induced damage and predict the elements’ response in confined space. There is one problem in confined space that is the shock wave interaction with the boundaries of the confined space. The force from an explosive charge detonated within a confined space consists of two stages. The first stage consists of the initial high pressure, a short period of reflected wave and several following reflected shocks while the second stage consists of a slowly decaying pressure. Previous research has presented the importance of the role of confined space with various geometries in an explosion [5,6,7]. The explosion of shaped charges inside the confined space creates conditions for combustion of aluminum particles. After the explosion of charges in the confined chamber filled with air and argon, different forms of the spectra were obtained. The explosion effect is strongly depending on the confinement volume and the charge type. Other researcher studied the suppression consequence of water mist for explosion fire in a confined space through experiment and the results shows that the accelerating flame overpressure can be reduced by water mist droplets.

Besides that, a shaped charge explosive method also takes into account as a method to generate more pressure impact during the blast test. Shaped charge is explosive with high penetration ability and is used mainly for military purpose. In military applications, shaped charges used against various types of armor, particularly as anti-tank devices. Shaped charges come in a wide variety of geometry and the geometric most common charge is conical shaped and hemispherical shape, but the best use is a conical shape, as it will provide greater penetration ability[8,9].

2. Experimental Procedure

2.1. Material selection
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. Moreover, an important role is the thickness, size, and amount of the materials to be used also acts as the appropriate of a parameter to accommodate heavy duty pressing. The material use for this explosion compaction are mild steel for the cylinder and the upper and lower part is P20. Steel are containing a small percentage of carbon, strong and tough.

In the underground explosion, the apparatus used to consist of several parts which are the lower base, bolt and nut, mold, piston and upper base. The design of this apparatus was created by the previous designer. Figure 1 shows the main assembly of the apparatus for underground explosion while Figure 2 display the explode diagram of an assembly for the underground explosion apparatus.
2.2. Preparing shape 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 shape charge is by weight the Emulex using kitchen scale. Then, Emulex explosive has been placed and compacted in the pipe tube with same diameter 21.9 mm but different height which is 65 mm for 500g and 150 mm for 750g. Figure 3 and 4 shows the preparation of Emulex shape charge. The type of shape charge used is conical shape charge, since conical shape provide greater penetration ability.

2.3. Method of Underground Explosion

Preparation of underground explosion is start with the specimen that is used to press using underground explosion. There are two specimens (A and B) with both height 10 mm and diameter 25 mm. The material for the specimens is mild steel. Figure 5 shows the setup of the underground explosion. During the blast test, a hole with depth 0.5 m is dig using excavator. Then, placed the underground explosion apparatus in the hole and make sure the apparatus is set up in vertical position, and at the same time, the specimen is put in the mold. After that, the shell cover is placed to prevent the apparatus get away from the original position. The conical shape charge is located on the top of underground explosion apparatus and at same the time, the detonator wire is connecting to shape charge. Next, soil is land fill until it fully covers the
apparatus. Lastly, three sand bang with weight 50 kg each is place on the soil to give more impact to the explosion. Then, high speed camera is set to capture the moment of blast test.

![Figure 5. Schematic diagram of Underground Explosion pressing](image)

2.4. Test method

Universal Testing Machine is used to eject the specimen that is overly attached to the mold. After that, the specimen had been cleaned and polish using sand paper. The diameters and thickness of the specimen were measured using Vernier calipers. The hardness of the specimen was tested using Rockwell Digital Hardness machine. Then, the microstructure of the specimen surface was analyzed using Scanning Electron Microscope (SEM). The last method to test the specimen is bending strength. Bending strength is done by using Calcium Carbide Explosive Shape Charge. Figure 6 shows the Calcium Carbide Explosive Shape Charge. The first step to carry out this experiment is the preparation of shaped charge explosive which is made of carbide fill up inside plastic with a cone shape and cover with modelling clay as shown in Figure 6(a). The amount of calcium carbide used to fully fill the shape charge mold is 16g for specimen A and B. Figure 6(b) shows specimen is placed in simply supported condition so that the metal plate get space to bend between the gap after experienced energy from the explosion. Figure 6(c) shows the shaped charge explosive, is placed on top of the specimen to get the result of the explosion.

Bending strength for both specimens can be calculated using Eq. (1):

$$\Delta_{\text{max}} = \frac{-PL^3}{48EI}$$  (1)

Where $\Delta_{\text{max}}$ is deflection, $P$ is the load, $N, L$ is the length of the specimen, $m, E$ is the Young Modulus of mild steel ($210 \times 10^9 Pa$), $I$ is the moment of Inertia of specimen, $m^4$

Moment of Inertia of the specimen can be calculated using Eq. (2):

$$I = \frac{1}{4}mr^4$$  (2)

Where $I$ is the moment of Inertia of specimen, $m^4$, $r$ is the radius of the specimen, $m$. 
3. Results and Discussions

3.1. Hardness of specimen

The hardness result for specimen A is 33.8 HRA, while the hardness for specimen B is 43.7 HRA. Specimen B shows the highest hardness since specimen B get more impaction during the explosion. Table 1 shows the result of both specimens before and after explosion. Specimen A with weight of explosive used, 500g shows the thickness is decrement from 10mm to 5.7mm, while the diameter is increase from 25.5mm to 33.5mm. For specimen B, with weight of explosive 750g, shows the thickness of specimen is decrease from 10mm to 3.9mm, while the diameter is increase from 25mm to 41.6mm. So, as a conclusion, when more explosive is used, the thickness of specimen will be decrease and the diameter of the specimen will be rise.

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

3.2. SEM microstructure

Figure 7 shows the SEM microstructure of mild steel, specimen A, and B after the explosion. From Figure 7(a) and Figure 7(b) there are slightly difference in the microstructure of the steel surface after pressed using 500g and 750g of Emulex. From Figure 7(a), the porosity is more on the surface of the
specimen compared to Figure 7(b). The surface of the metal is dusty with the presence of impurities such as the rusting effect and scratches effect after polishing process. The white area represents the indentation point of the pressing when performing the blast test. The white area on specimen B in Figure 7(b) is larger than the white area on specimen A in Figure 7(a) because the impact force is larger on specimen B in Figure 6(b).

![Figure 7](image7a.png) ![Figure 7](image7b.png)

**Figure 7.** (a)SEM microstructure of specimen A after explosion (b) SEM microstructure of specimen B after explosion

### 3.3. Bending strength

Figure 8(a) is the specimen A after bending strength test, it shows no changed after the bending strength test. Then, Figure 8(b) is the specimen B after bending strength test, as shown, the specimen is bent after the test. From the calculation using Eq. (1) and Eq. (2), the force that applied to the specimen B during the bending strength is 243,160.68\(kN\). So as a conclusion, the specimen A is not bend after the test method because, the diameter and thickness of the specimen A is higher than specimen B.

![Figure 8](image8a.png) ![Figure 8](image8b.png)

**Figure 8.** (a)Specimen A after bending strength (b)Specimen B after bending strength
4. Conclusion
As a conclusion, from this research, the method for Underground Explosion Pressing is suitable for pressing the solid metal (mild steel), since the result for specimen A is decrement from 10mm to 5.7mm, while specimen B is decrease from 10mm to 3.9mm. The hardness result for specimen A is indicated clearly to be 33.8 HRA, while the hardness for specimen B is 43.7 HRA. Then, the SEM microstructure for specimen A shows the porosity is more than specimen B. Last but not least, the bending strength result shows that, the specimen A, has no change since the specimen is not bend after the test, while the specimen B is bend after the test. The force that applied to the specimen B during the bending strength is 243,160.68 kN.

5. References
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Acknowledgments
This research is fully funded by FRGS grant name Characteristic of Powder Surpassing 160,000 tons Press using Explosive Pressing (FRGS 9003-00542). Besides, the blast test of this research was done with the help of Lt Col Associate Professor Ariffin Bin Ismail and blast research team from Universiti Pertahanan Nasional Malaysia.