

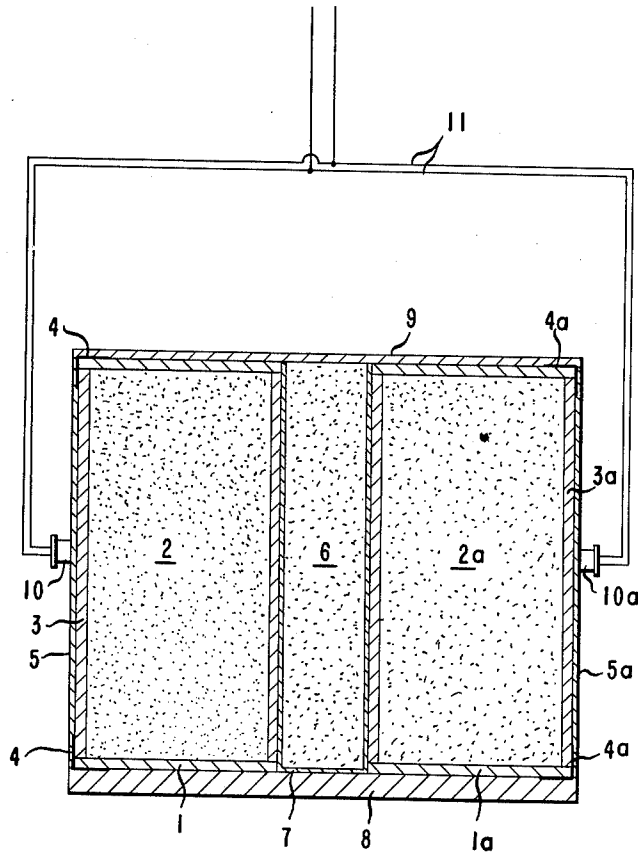
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J. P. SWED

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COMPACTION PROCESS

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INVENTOR
JAMES P. SWED

BY

Julius H. Steinberg

ATTORNEY

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COMPACTION PROCESS

James P. Swed, Gibbstown, N.J., assignor to E.I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

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The present invention relates to a process for compacting powders into the form of a slab. More particularly, this invention relates to a novel dual compaction technique whereby two large, individual metal slabs of unusually high density and strength are produced simultaneously by means of explosively-generated pressures.

Powder metallurgy techniques are widely employed in fabricating metals. In essence, the technique involves compression of the loose powder into a consolidated mass which in most cases is then further processed. For example, this further processing usually includes sintering to make the mass coherent. Whatever the further processing entails, however, the quality of the compact is largely dependent upon the uniformity and degree of compression obtained in the first step, and the strength of the compact is directly dependent upon the density of the compact. At present most compacts of powdered metals are produced by introducing loose powder into a die and compressing it by means of a mechanical press or a piston operated by hydraulic pressure. More recently, an explosive powder compacting technique has been developed for preparing cylindrical compacts which represents an improvement over mechanical methods in that larger pieces may be compacted, compacts of greater density and strength are obtained and the sintering step may be eliminated. See Belgian Patent No. 573,164 dated November 20, 1958. A need exists in the art whereby non-cylindrical compacts, e.g., bars and slabs, may also be prepared by means of advantageous explosive pressures.

The present invention represents a technique for producing virtually crack-free slabs from powders. The technique of the present invention involves packing the powder to be compacted into two metal boxes of identical size, aligning the filled boxes with one of the largest surfaces of each box facing but separated from each other, interposing a shock absorbing material between the boxes, covering the opposite large surface of each box with a uniform layer of a high-velocity detonating explosive, and initiating both layers of explosive simultaneously. Because two compacts are formed simultaneously, the new technique is a time- and money-saving improvement over prior art methods. Also, compacts formed by this technique are not deformed as a result of uneven pressure because any shock waves from the explosion which have traveled past the compact are trapped within the shock absorbing material and are not reflected back into the compact.

In order to describe the invention more fully, reference now is made to the accompanying drawing which illustrates one embodiment of the invention.

Referring specifically to the FIGURE, 1 and 1A represent identical rigid parallelepipedal containers, e.g., of steel; 2 and 2A represent the powders to be compacted. Metal plates 3 and 3A are fastened by tapes 4 and 4A to the containers. A layer of high-velocity detonating explosive 5 and 5A is fastened to the outer opposing sur-

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face of each container. 6 represents shock-absorbing material, e.g., iron powder, in a container 7. 10 and 10A represent electric blasting caps connected to a source of electricity by wires 11. A base 8 may optionally be used to attenuate the shock waves, and putty or other similar material 9 may be placed on top of the apparatus as protection against marring from the initiator.

In the sequence of operations of the present invention, the passage of current through wires 11 fires the electric blasting caps 10 and 10A which initiate the explosive layers 5 and 5A. The resulting detonation wave proceeds across the metal plates 3 and 3A, the blasting force compacting the powders 2 and 2A in the containers 1 and 1A. The shock absorber 6 attenuates the magnitude of any tension waves reflected back into the powder, thus minimizing the possibility of cracking and spalling of the compacts. In order to illustrate the invention further, reference is now made to the following examples.

Example 1

Two open containers made of $\frac{1}{16}$ " thick steel, each 10 inches square and 1 inch deep, are packed with titanium powder. Steel backings are taped to the loaded containers and the external surfaces of the backings are covered with a 6 g./sq. in. sheet of an explosive composition containing 50% red lead, 35% PETN, $7\frac{1}{2}$ % of butyl rubber, and $7\frac{1}{2}$ % terpene resin. This explosive composition is described in detail in copending application Serial No. 65,012, filed October 26, 1960, in the name of C. J. Breza and assigned to the assignee of the present application.

The 10" square faces of the containers are placed in alignment 2 inches apart, with the explosive-covered faces on the outside. The 2-inch space is filled with iron powder, and the space sealed by tape. A commercial detonator is fastened to the midpoint of one edge of each explosive layer. The entire assembly is placed in a sealed polyethylene bag and immersed in water. The initiators are actuated by the passage of electric current through the lead wires and initiate the explosive layers. The containers are recovered, and the compacts removed therefrom.

The compacts produced are very strong, have the appearance of solid metal plates, and have a density greater than 95% of theoretical.

Example 2

Two containers identical to those in Example 1 are vibrator-packed with titanium powder. Steel backings are taped to the loaded containers and the external surface of the backings are covered with the same explosive as in Example 1.

The containers are arranged as in Example 1, and the space is filled with iron powder. The apparatus is placed on a foamed polystyrene plate $1\frac{1}{2}$ inches thick, the top of the apparatus is covered with putty, and the entire assembly immersed in water. The explosive is detonated as in Example 1. The containers are recovered and the compacts removed therefrom.

The compacts thus produced are well consolidated, have a density greater than 95% of theoretical, and are free of cracks and spalls.

Example 3

When the procedure of Example 2 is followed, except that the indicated materials are substituted for the titanium powder, the materials named are used as cushioning

materials, and the explosive used is as designated, the compacts obtained are well consolidated and free of cracks and spalls.

Run No.	Powder	Cushioning Material	Explosive
A-----	Cu-----	sand-----	70% PETN, 15% butyl rubber, 15% resin terpene.
B-----	Fe-----	Cu powder--	Do.
C-----	graphite--	do-----	85% PETN, 7½% butyl rubber, 7½% resin terpene.
D-----	Ni-----	Ni powder--	Do.
E-----	Al-----	Al powder--	95% RDX, 5% plasticizer.

The method exemplified above is applicable to any compressible powder, such as aluminum, iron, copper, beryllium, magnesium and other metals as well as metal oxides, such as red-lead, iron, iron oxides, and non-metallic materials such as graphite and carborundum. The invention will find extensive use especially in compacting refractory metals, e.g., titanium, tungsten, niobium, as can be seen in the examples. The method is also particularly useful in compacting powders containing hard and/or abrasive particles which would quickly ruin any die. In essence then, the present method is suitable for any powder that can be mechanically compacted, and for many that previously were not susceptible of compaction. Because the explosive layer can be made as large as desired, no limitation exists with respect to area of the compacts which can be produced by means of the present invention. The depth of the compacts, being proportional to the loading of the explosive layer, can be controlled easily, and very thick sheets or slabs can be made.

The layer of a shock-absorbing material is required to avoid the formation of spall and crack defects in the compacted slabs. By absorbing the energy remaining in the shock wave after passage through the layer of powder whose compaction is desired, the shock-absorbing material minimizes any reflection of the compression wave. In order to be effective as a shock absorber, the material should be irreversibly compressible to at least ½ of the original volume before achieving full density. So that it will provide adequate backing for the compacted powder, the material should be at least ¼ full density, i.e., capable of reduction beyond ¼ of its original volume. Further, to minimize rarefaction waves being formed at the interface of the box containing the powder being compacted and the shock absorbing material, this material should have a sonic impedance not more than plus or minus about 50% of that of the powder being compacted. Such materials will provide for adequate transmission of the shock wave. As used herein, the term "sonic impedance" is defined as the density in grams per cubic centimeter times the velocity of sound in the medium in centimeters per second. Any metal powder or irreversibly compressible non-metal is suitable as a shock absorbing material.

The width of the space containing the shock absorbing material between the powder-containing boxes is not generally critical and will generally be based on such factors as the size of the compact to be formed, the amount of explosive used, etc. The width will usually be from about ½ to 2 times the thickness of one of the powder layers.

For many fabrications, the compacts formed by this method can be used directly. If supplementary processing is desired, the higher density and strength and greater uniformity of the compact obtained by the proposed method compared to compacts produced by conventional mechanical means increases the amount of material per unit of volume as well as providing a more uniform and regular melting zone, the latter feature permitting the elimination of the remelting operation previously required in order to obtain a uniform billet.

The very high densities that can be obtained by explosive compaction techniques are ascribable to the behavior

of particulate matter exposed to an explosive shock wave. When an explosively produced shock front moves through a powder, the shock is characterized by a very high particle velocity. This high velocity results in large magnifications of pressure when two particles collide. Deformation and yielding of the particle then result in the high density compacts that are characteristically obtained. As the distance between the explosive and the powder increases, the explosive loading must increase correspondingly in order to counterbalance the attenuation of the shock as the wave passes through the intervening medium. In any event, the quantity of explosive used must be at least sufficient to compress the powder to near theoretical density.

The explosive selected to compact the powder in accordance with the method of the present invention must detonate at a relatively high velocity in order to provide the magnitude of pressure required. By the term "high-velocity detonating explosive," we mean a composition having, when unconfined, a velocity of detonation of at least 1200 meters per second. The particular explosive selected in any instance is not critical to the present invention, and will depend primarily on the degree of compaction desired and the size of the compact to be prepared. As is readily apparent, the quantity of explosive used must be sufficient to guarantee propagation of the detonation throughout the explosive layer. In the case of a thin compact, the quantity of explosive per unit area required is so small that the less sensitive compositions, such as HMX, RDX, TNT and the like, would not propagate the detonation. On the other hand, the more sensitive explosives, such as PETN and nitroglycerin-based compositions, will propagate detonation in thin layers as well as thick layers. Consequently, when compacts having a substantial depth are desired, a much wider range of explosive compositions can be used satisfactorily.

The initiating means is not critical to the present invention. Point, line or plane initiation may be used.

In order to reduce noise and air blast from the detonation of the high explosive, we prefer to effect the operation under water. The water also serves to provide additional confinement to the assembly which permits the use of a smaller quantity of explosive to obtain a compact of a specified size and density. However, the water is not required to transmit the pressure of the explosive detonation, therefore no confinement of the water is necessary. Obviously, when the assembly is submerged, the explosive composition must be water resistant.

The container holding the powder to be compacted may be of any composition, provided that it is water-resistant in those cases wherein submergence prior to initiation is desired. Containers composed of plastic, metal, and the like are contemplated. If desired, the containers may be composed of the same material as the compacts, thereby eliminating the necessity of removing the compacts. As is obvious, the shape of the containers depends on the shape of the desired compact although it will be recognized by those skilled in the art that unsymmetrical and complicated geometrical configurations may introduce complications.

Flat compacts of various configurations, e.g., round, rectangular, etc., may be readily produced in accordance with the present invention. Additionally, the present invention is applicable to producing compacts having undulated, tilted, or irregular surfaces by employing a suitably shaped container or by introducing bars of other elements into the powder and removing them after compaction of the powder. Also, if desired, mandrels may be incorporated in the powder to fabricate compacts having controlled voids. In such a case, wear on the mandrels and cracking of the die due to the geometry of the configuration is avoided by covering the mandrel with adequate powder to insure that the compaction will not reduce the powder layer below the position of the mandrel. Similarly, wires or other reinforcing elements may be

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placed in the powder prior to compaction. Also, two different materials or two different thicknesses of material can be compacted at the same time using the proposed process as long as the explosive load is balanced, e.g., essentially the same on both sides.

The invention has been described in detail in the foregoing. Many modifications and variations not specifically discussed that lie in the scope of the invention will be readily apparent to those skilled in the art. Accordingly, I intend to be limited only by the following claims.

I claim:

1. A method for compacting powder into 2 separate slabs simultaneously which comprises loading powder into 2 containers each having at least one pair of essentially parallel sides, positioning a layer of explosive on one of said parallel sides of each of the said containers, said layers of explosive having a surface configuration substantially coextensive with the surface configuration of the said side, positioning said containers in parallel alignment a distance apart with the explosive layers on the parallel sides most distant from each other, filling the space between the containers with a shock absorbing material irreversibly compressible to a size between about $\frac{1}{2}$ to $\frac{1}{10}$ of its original volume and having a sonic impedance of not more than about plus or minus 50% of

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that of said powder, and thereafter initiating said explosive layer.

2. A method as claimed in claim 1, wherein said assembly is waterproof and immersed in water prior to initiation of said explosive layer.

3. A method as claimed in claim 1, wherein the powder to be compacted is metallic.

4. An assembly for use in compacting powdered materials which comprises two containers each having at least one pair of parallel sides, a uniform layer of explosive adjacent one of said parallel sides of each of said containers, and detonating means in initiating relationship with each of said explosive layers, said containers being disposed in parallel alignment a short distance apart with the explosive layers on the parallel sides of the respective containers which are most remote from each other, the space between the containers being completely filled with a shock absorbing material irreversibly compressible to a size between about $\frac{1}{2}$ to $\frac{1}{10}$ of its original volume.

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