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T. A. ANDERSEN ET AL
COMPACTION PROCESS

3,158,474

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2 Sheets-Sheet 1

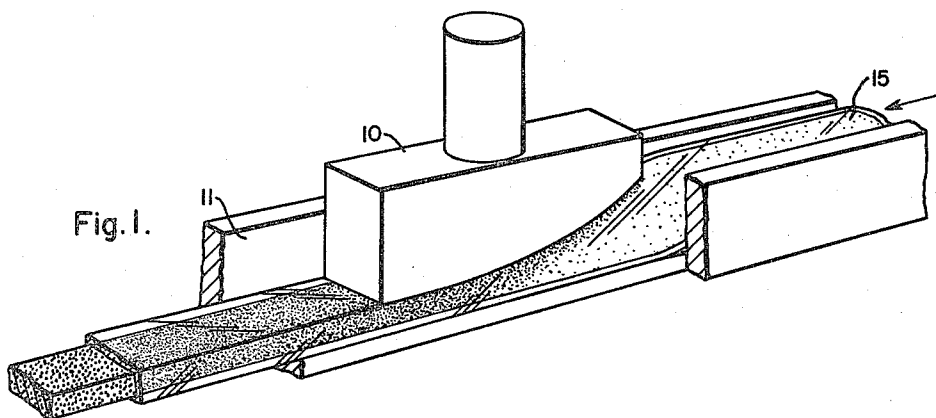
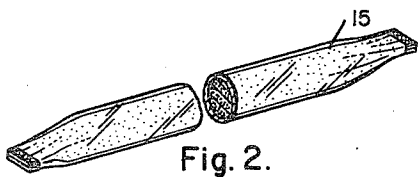
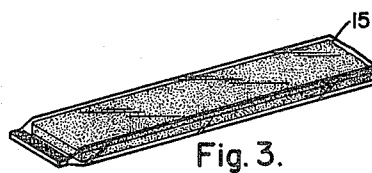
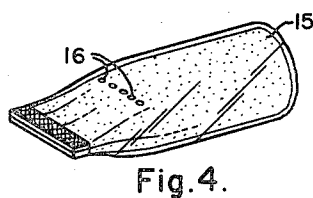
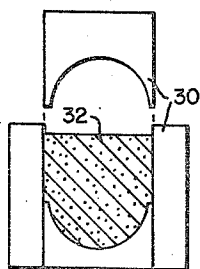


Fig. 5A.

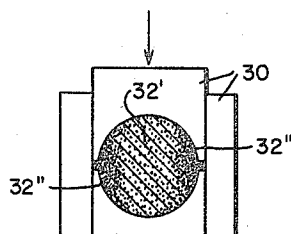


Fig. 5B.

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2 Sheets-Sheet 2

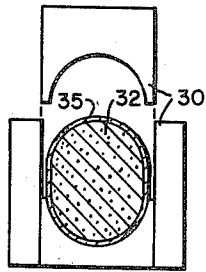


Fig. 6A.

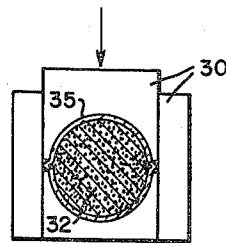


Fig. 6B.

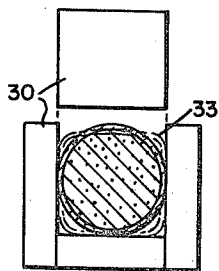


Fig. 7A.

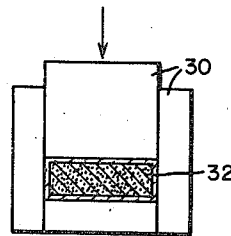


Fig. 7B.

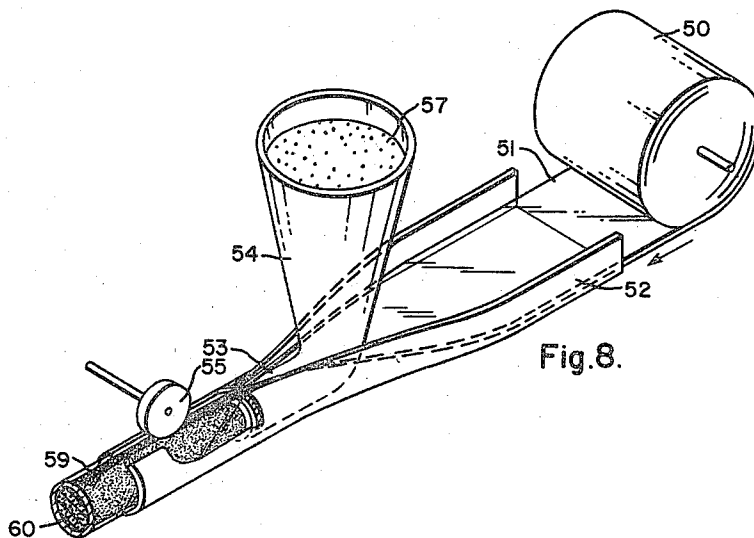


Fig. 8.

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COMPACTION PROCESS

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6 Claims. (Cl. 75—214)

This invention is directed to a method for compacting powders contained in thin envelopes of flexible, resilient material.

In copending application Serial No. 776,990, filed November 28, 1958, now abandoned, and entitled "Process and Apparatus for Producing Powdered Metal Members," by Frank Emley and C. Deibel, assigned to the assignee of the present invention, there is disclosed a method and apparatus for producing, by a cyclic continuous compaction process, compacts of powdered metal. The subject matter of the invention disclosed herein is particularly applicable to the process described in the Emley et al. application.

Finely divided powders present certain handling problems and dangers which tend to inhibit and make more costly full commercial utilization of such powders. For example, chromium and titanium powders are subject to oxidation in contact with air, and the oxides formed may not be desirable in the finished compact. There are instances where extremely fine powders must be used, and such fine powders are often pyrophoric. Thus, cerium, zirconium and even iron powders are pyrophoric in the ultra fine powder state and such powders must be shielded from contact with air to prevent dangerous fires. Beryllium powder on the other hand, is poisonous, while uranium powder is radioactive. Clearly, a means for isolating and conveniently handling metal powders during working operations upon them is sorely needed.

Metal powders generally are awkward to handle, particularly in processes which are continuous in nature, because the flow characteristics of the metal powders may vary and with this variance the powder compacts made will lack uniformity.

Accordingly, it is a primary object of this invention to provide a method for forming metal powder compacts in which the metal powder is confined within a thin flexible, and resilient envelope and then the envelope with the contained powder are subjected to a cyclic continuous compaction process.

Other objects of the invention will in part be obvious, and will, in part, appear hereinafter.

For a better understanding of the nature and objects of this invention, reference may be made to the following detailed description and drawings, in which:

FIGURE 1 is a perspective view partly in section of a continuous compaction press with an envelope filled with metal powder in the die cavity thereof;

FIG. 2 is a perspective view of the powder-filled envelope of this invention;

FIG. 3 is a perspective view of a compact formed in the process of this invention shown with the thin adherent envelope;

FIG. 4 is a view of the end of a powder-filled envelope similar to that of FIG. 2 but with a modified structure;

FIGS. 5A and 5B are cross sectional views of a die cavity filled by the customary gravity flow techniques;

FIGS. 6A and 6B are views of a die cavity circular in cross-section filled with metal powder in accordance with this invention;

FIGS. 7A and 7B are views of a die cavity having a rectangular cross-section filled in accordance with this invention; and

FIG. 8 is a perspective view of an apparatus for making powder-filled envelopes of indefinite length.

This process relates to the compaction of metal powder, especially in the cyclic continuous compaction process, with the metal powder confined for compaction in a thin, flexible and resilient envelope.

Broadly, this process for the compaction of metal powder in a die comprises the steps of (1) completely filling with a quantity of metal powder a relatively thin, flexible, and resilient envelope, (2) placing the powder-filled envelope in said die, (3) compacting the metal powder and envelope in the die, (4) removing the compacted metal element with the adherent envelope from the die, and (5) removing the envelope from the compact.

More particularly, the process of this invention relates to the compaction of the metal powder in a die having a cavity of predetermined configuration, and includes the steps of (1) confining a quantity of metal powder within a relatively thin, flexible, and resilient envelope having a shape closely approximating said predetermined configuration with said powder completely filling said envelope, (2) sealing said envelope, (3) placing the powder-filled envelope in said die, (4) compressing the envelope and metal powder in the die, (5) removing the compacted metal member with the adherent envelope from the die, and (6) stripping the envelope from the compact.

The envelopes employed in this invention may be formed from rubber or resinous plastic material such as polyethylene, polyvinylchloride, or polyvinylchloride acetate film.

While many plastic film materials may be used, the film should have the following properties if the best results are to be obtained: (1) the material should be thin so that it can take the shape of the die more readily, (2) it should be strong both in tension and compression, (3) it should be easy to seal, preferably by heat welding, (4) it should be relatively inert so that undesired reactions with the metal powder do not occur, (5) it should be elastic so that the metal powder is firmly contained, (6) it should have relatively uniform wall thickness so that variations of pressure and hence of density do not occur.

FIGURE 1 illustrates the process of this invention used with a cyclic continuous compaction press. A presser head 10 is vertically reciprocable in the trough 11, and the powder-filled envelope 15 is fed in a horizontal direction through the trough as indicated by the arrow. The envelope 15 is intermittently fed through the trough so that the presser head compresses the envelope and metal powder in a series of overlapping compaction strokes, each compaction stroke occurring while the envelope and powder are at rest. While the powder movement in the apparatus as shown in FIG. 1 is horizontal, it is clear that with the powder contained in an envelope, the process may be carried out just as easily in an inclined position or even with vertical movement of the powder-filled envelope. Also, while single-action compaction is disclosed, double-action compaction, with two presser heads compacting the powder from opposite sides (top and bottom, for example), is feasible.

The powder-filled envelope 15 is shown in FIG. 2 before compaction. After compaction, the envelope and compacted metal powder appear as is indicated in FIG. 3. In this latter condition the envelope can easily be removed from the compact, one method being simply to mechanically strip the envelope from the compact. In another method of removal, the bar shown in FIG. 3 can be sintered without first stripping the envelope, and in that case the envelope quickly volatilizes in the heat of the sintering furnace. A relatively short powder-filled envelope is illustrated in FIG. 2, but it is contemplated that the envelope may be of great length, fifteen or twenty feet, or even more, if compacted bars of great length are desired.

Some difficulty has been experienced with the entrap-

ment of air within the envelope during the compaction strokes in processes in which the metal powder may be permitted to come into contact with the air. Pockets of entrapped air tend to stretch the envelope as the pressing head compacts the metal powder. The envelope may rupture and lie in folds on the powder and the impression of these folds will result in an undesirable irregular compact surface. Evacuation of the envelope prior to compaction will, of course, eliminate this difficulty. Another method for preventing the entrapment of air is illustrated in FIG. 4 where a powder-filled envelope 15 is shown with a series of tiny holes 16 at the end of the envelope. The holes 16 provide an escape path for air which otherwise would be entrapped within the envelope. Such holes may be provided along the length of the envelope as well, and if the holes are small, little powder will be lost therethrough.

FIGS. 5 and 6 show the application of the method of this invention to a particularly vexing problem in the compaction of metal powders. In FIG. 5A, there is shown a die 30 of the type used for producing bars of circular cross-section. The die 30 has been filled with metal powder 32 by the ordinary gravity flow techniques. In FIG. 5B, the die 30 with the compacted metal powder is shown after the compaction stroke, and it is clear that because of the powder distribution inherent in the gravity flow method, that the density of the compact is greater in the areas 32'' than in the central diametral area 32'. This non-uniform density will affect the properties of the sintered bar made from the compact, since shrinkage in the bar during sintering will not be uniform. Also, the quality of the product ultimately rolled, forged, or extruded from the sintered bar will also, to some degree, be affected by the non-uniformity of the density of the original compact.

In FIG. 6A, the powder-filled envelope 35 of this invention is positioned in the die 30. The envelope 35 closely approximates in cross-sectional shape or contour that of the compact desired. Thus, the excess powder which is distributed close to the walls of the die when a gravity fill with loose powder is employed, is not present when the powder is confined in the flexible and resilient envelope 35. Examining FIG. 6B then, it will be noted that substantially uniform density is obtained across both vertical and horizontal diameters of the compacts formed.

The powder-filled envelopes have handling characteristics somewhat similar to rope or packing, and therefore may be forced to assume the general shape of a die by a pre-pressing operation, provided the die has a relatively simple cross-sectional contour. Thus, in the dotted line showing at 33 in FIG. 7A, a powder-filled envelope having a generally circular contour has been forced to conform to a die having a cavity which is rectangular in cross-section. In this manner, the powder-filled envelopes may be made to roughly conform to dies having cavities of T-shape and channel-shape contour by pre-pressing, if that is desired. However, pre-pressing is not mandatory, as is indicated in the following example in which a pre-pressing operation was not used.

Example

Iron powder was poured into a 36 inch length of .0015 inch thick by 1.5 inch diameter plastic tubing. The tubing was made from polyvinyl chloride plastic film sold under the name "Visten." The envelope was evacuated and then heat sealed. The evacuation avoided the entrapment of air which could become troublesome as the powder-filled envelope is compressed. The powder-filled envelope was positioned within a two inch wide channel die of rectangular cross-section and continuously compacted with a 50 ton load, as shown schematically in cross section in the solid line showing of FIG. 7. A "green" bar measuring two inches by 0.5 inch by 30 inches was produced in this fashion. The plastic en-

velope sustained the rigors of this operation without failure and closely adhered to the press bar surface. The plastic envelope was then stripped off the bar and discarded without damage to the surface of the bar. The bar produced was smooth surfaced and in condition for sintering.

For forming powder-filled envelopes of indefinite length, a flat plastic sheet may simultaneously be formed into tube shape, heat sealed, and filled with metal powder. One method of accomplishing this is shown in FIG. 8 in which a roll 50 of flat plastic sheet is rotated to move the sheet 51 in the direction indicated by the arrow through a guide channel 52. The sheet 51 is continuously formed into tube shape between the guide channel 52 and the delivery end 53 of a hopper 54, and heat-sealed into shape by the heated rotating sealing disc 55 (heating means not shown) as it is filled with powder 57 from the hopper. The sealing disc forms a weld 59 in the tube-formed sheet 50. The powder may be forced from the hopper into the envelope under pressure, if that proves desirable. The powder-filled envelope 60 may be fed directly into a cyclic continuous compaction press, of the type discussed above, to form compacted metal powder bars of any required length.

Compaction of metal powders in accordance with this invention offers many advantages, several of which are set forth below:

(1) *Protection of powders.*—By charging powder into the plastic envelope which is closed at one end, and evacuating the envelope before final sealing, the powders are protected from the atmosphere before, during, and after compaction. Thus, the powders are protected against oxidation which is of particular value in the handling of pyrophoric powders, and the shelf life of many powders is increased since contamination with oxide is prevented.

(2) *Protection of personnel.*—Materials which are toxic or dangerous to humans in some other way, such as beryllium or radioactive powders, are prevented from coming in contact with humans by the plastic envelope.

(3) *Protection of pressing head and die.*—Some fine metal powders tend to accumulate between the pressing head and the die walls when the die is filled with loose powder. As the pressing head reciprocates, a galling action occurs which can cause severe damage to both pressing head and die. With the powder contained in accordance with this invention there is no loose powder to cause damage by galling.

(4) *The contoured powder fill.*—The production of bars of circular cross sections having a uniform density is facilitated by the method of this invention. By the use of the plastic envelope, the metal powder enters the pressing region in a fill corresponding more closely to the desired final shape than is possible with the normal gravity fill of powders.

(5) *Lubrication.*—Certain plastic film materials used in the practice of this invention will provide a lubricating action with the walls of the die and thus act to prevent sticking and to permit the finished compact to be readily removed from the die.

It will be understood that the specific method described in this specification may be modified to some extent without departing from the essential spirit and scope of the invention. In general, the above specification is exemplary rather than limiting.

We claim as our invention:

1. In a process for the compaction of metal powder in which a presser head compacts the powder in a die having a cavity of predetermined configuration, the steps of, (1) confining a quantity of flowable metal powder within a relatively thin, flexible, and resilient envelope of organic material having a shape closely approximating said predetermined configuration, with said powder completely filling said envelope, (2) sealing said envelope, (3) intermittently moving the powder-filled envelope

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through said die in contact with the walls thereof, (4) compacting the envelope and metal powder when at rest in the die to produce a powder compact element by employing the presser head to force the powder-filled envelope into forming contact with the walls of said cavity, (5) removing the compacted metal element with the adherent envelope from the die, and (6) removing the envelope from the compact.

2. In a process for the compaction of metal powders in which a pressure head compacts the powders in a die having a cavity, the steps of, (1) confining a quantity of metal powder within a relatively thin, flexible and resilient envelope provided with a plurality of small holes therein to permit the escape of air, with said powder completely filling said envelope, (2) moving the powder-filled envelope through said die cavity in contact with the walls thereof, (3) incrementally compacting the envelope and metal powder in the die with said presser head to form a compacted metal element by forcing the powder-filled envelope into forming contact with the walls of said die cavity, the air within the envelope being forced through said holes during compaction, (4) removing the compacted metal element with the adherent envelope from the die, and (5) sintering the green compact in a furnace whereby the envelope is volatilized during an early stage.

3. In a process for the cyclic continuous compaction of metal powder in a die having a cavity employing a presser head which reciprocates into the die cavity to compact the metal powder therein, the steps of, (1) sealing a quantity of loose flowable metal powder within a relatively thin, flexible, and resilient envelope formed from organic material with said powder completely filling said envelope, (2) intermittently moving the powder-filled envelope through said die cavity, (3) incrementally compacting the metal powder and envelope in the die cavity so that the metal powder and envelope conform to the shape of the die cavity and the metal powder is consolidated to form a compacted metal element, (4) removing the compacted metal element with the adherent envelope from the die cavity, and (5) stripping the envelope from the compact.

4. In a process for the cyclic continuous compaction of metal powder in a die having a cavity of predetermined configuration, which process employs a presser head capable of reciprocation into said die cavity to compact the powder therein, the steps of, (1) confining a quantity of flowable metal powder within a relatively thin, flexible, and resilient envelope of organic material with said powder completely filling said envelope, (2) evacuating the envelope, (3) intermittently moving the powder-filled envelope through said die cavity, (4) compacting the envelope and metal powder when at rest incrementally in the die with the presser head whereby the metal powder and envelope conform to said predetermined configura-

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tion and the metal powder is compressed to form a compacted metal element, (5) removing the compacted metal element with the adherent envelope from the die, and (6) removing the envelope from the compact.

5. In a process for the cyclic continuous compaction of metal powder in a die having a cavity, a portion of said cavity being essentially semi-circular in cross-section, the process employing a presser head having a pressing surface which is concave and provides an essentially semi-circular cross-section mating with the similar portion of said die cavity to form an essentially circular die cavity cross-section, the steps of, (1) confining a quantity of loose, flowable metal powder within a relatively thin, flexible, and resilient organic envelope having a substantially circular cross-sectional contour, with said powder completely filling said envelope, (2) sealing said envelope, (3) evacuating said envelope, (4) intermittently moving said powder-filled envelope through said die, (5) incrementally compacting the envelope and metal powder when at rest in the die by reciprocating said presser head into said die cavity whereby the metal powder is consolidated to form a compacted metal element having an essentially circular cross-section, (6) removing the compacted metal element with the adherent envelope from the die, and (7) removing the envelope from the compact.

6. In a process for the cyclic continuous compaction of metal powder to form compacted metal members, the compaction being accomplished by the coaction between a die having a cavity of predetermined configuration and a presser head capable of reciprocation into said die cavity, the steps comprising, confining a predetermined quantity of flowable metal powder in a relatively thin, flexible and resilient envelope formed from an organic film material, intermittently feeding the powder-filled envelope horizontally through said die cavity, reciprocating said presser head into said die cavity when said envelope is at rest to compact the powder beneath said presser head and, thereby in a series of overlapping strokes, incrementally compact the metal powder in said envelope to form an integral compacted metal member which conforms to the shape of said die cavity, removing the compacted metal member with the adherent envelope from the die cavity, removing the envelope from the compacted metal member.

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