Feb. 3, 1948. H. H. LESTER 2,435,227

METHOD AND APPARATUS FOR PRODUCING ARTICLES FROM POWDERED MATERIALS

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Fig. 1.

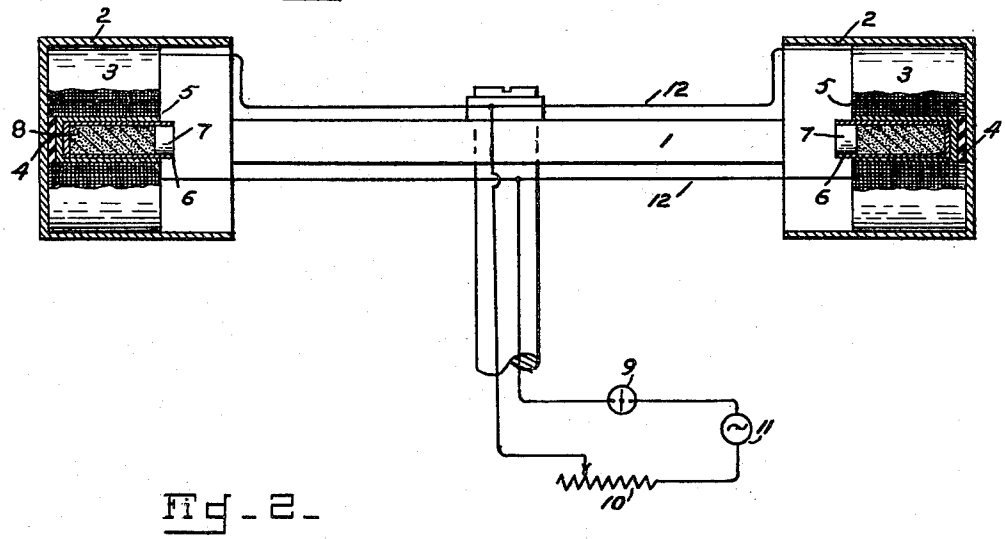
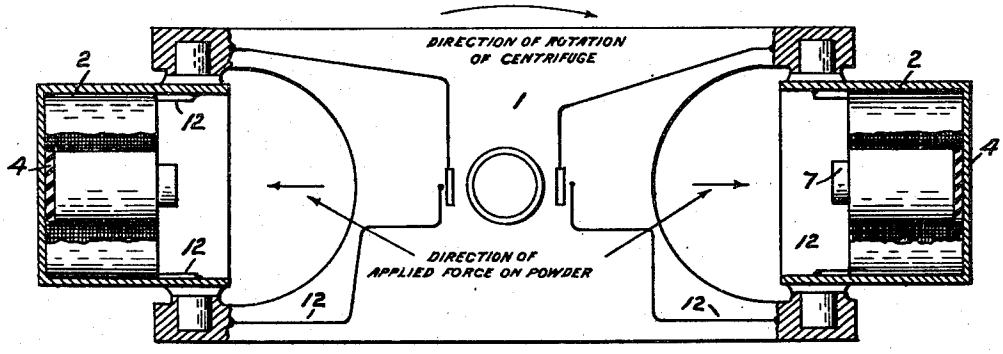


Fig. 2.



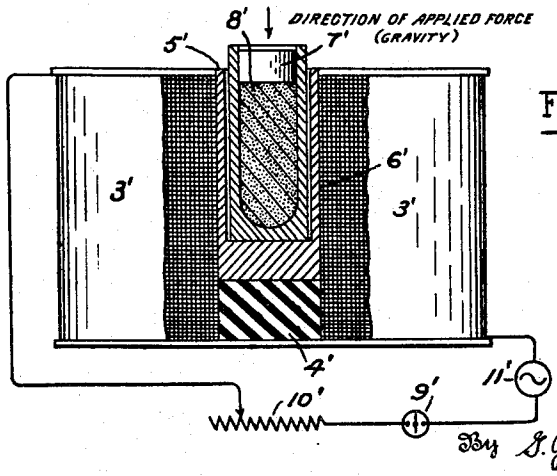


Fig. 3.

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METHOD AND APPARATUS FOR PRODUCING ARTICLES FROM POWDERED MATERIALS

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The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

The present invention relates to powder metallurgy in which various articles are formed from powdered metals, their alloys or compounds, and particularly to the powder metallurgy of articles wherein a dense and compact structure is the desideratum.

In the formation of articles from powdered metals, the usual process comprises compacting the mass of powder to a desired shape and size, usually by the application of pressure to the powder which is contained in a rigid mold; the removal from the mold of the compacted mass, which after compacting has sufficient rigidity to retain its shape; and the further consolidation of the material by heat, which causes the individual particles to "sinter" or weld together. The final consolidation is usually accompanied by a diminution in volume of the compacted powder mass.

It is seen that an essential preliminary stage of manufacture is the initial compacting of the loose powder in the mold. This operation reduces the volume of the loose powder by varying amounts, depending upon the nature of the powder. In some cases this initial compression reduces the volume of the loose powder to one-third of its initial volume.

The initial compacting has heretofore been carried out principally by the application of pressure to the powder contained in the mold that is at room temperature, in which case the operation is known as "cold pressing" or with the mold and powder at an elevated temperature which may be the sintering temperature, in which case the operation is known as "hot pressing." Compacting of the loose powder has been accomplished by the suspension of the powder in a plastic binding material, and the extrusion of the plastic mass through a die by high pressure. The early tungsten lamp filaments were made in this way.

While some articles of powder metallurgy manufacture can be successfully compacted by pressure applied to loose powder, as described above, others cannot—for instance, long, slender articles, such as drill rods or similar objects where the length, along which the compressive force must be applied, is substantially greater than the transverse dimension. In such cases the movement of the particles in compacting under the applied pressure develop frictional resistance between each other and between the powder particles and the walls of the mold. In addition, arches or "bridges" are formed which interfere with compacting and leave small voids and layers of high density so that with some articles, there results in regions remote from the surface, where the compressive force is applied, non-uniformities in density that are reflected in the final sintering operations, and that tend to make the finished articles unsuitable for use. Also, where the individual powder grains are very hard, as for instance, particles of tungsten, titanium, and boron carbides, they are not crushed or plastically deformed by any compressive forces that can be applied practically to the powder in the mold, so that there necessarily remain interstitial voids between the individual grains, even though compacted with the highest pressures practicable to apply. This limitation in the application of pressure for the compacting of metal powders has been well recognized, and is shown by the A. S. M. Metals Handbook, 1939, (published by the American Society for Metals) on page 105. Various methods have been employed to overcome the defect, such as the incorporation in the powder of lubricants such as paraffin; by the introduction of small increments of powder and pressing serially; and by pressing transversely in the case of slender articles, but such steps are no more than makeshifts in securing the desired results. For instance, where lubricants, such as paraffin, are employed, the lubricants are decomposed in the sintering operation, giving rise to gaseous products or residues which may remain in the finished article as small gas pockets or as impurities.

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In addition to the above objections, the "cold pressing" method of compacting is necessarily an expensive operation, involving elaborate presses, and necessarily slows production, and adds materially to the costs of manufacturing.

It has been found that these objections may be substantially overcome by following the present invention.

The powdered materials, whether the same be of a pure metal, alloy, compound, or mixtures thereof, with or without a binder material, are placed in a mold cavity of the desired shape of the finished article. The mold may be of a heat-resistant material, such as graphite or aluminum oxide, or in some cases a metal. A plug of smaller size than the mold opening, and made of some material such as graphite or metal, and having sufficient mass when the mold is vibrated to produce a tamping action, is placed in the mold opening. The mold and its contents are then vibrated

either mechanically or electrically by means of a solenoid coil, which acts directly on the mold and contents, or by means of a steel core inserted in the solenoid, and which acts on the mold through the intermediary of a rubber or similar buffer. The object of the vibration is to bring about a condition of maximum powder density and an optimum uniformity of distribution in the particles of the powder.

By the term "vibration" I have in mind the short, irregular linear motions imparted to powder particles through impulses produced either directly or indirectly by electrical or mechanical means and from collisions between particles. It is recognized that, in addition to the vibratory motions, as thus defined, the individual particles are subjected to directive forces, either from gravity, centrifugal action, or the action of the plug as described below which tend to cause a general shift in the direction of the directive forces.

In the practice of this invention it is recognized that the vibratory motions of the individual particles may be derived from various frequencies and amplitudes of a vibration of the solenoid or of the mechanical vibrator. A sixty-cycle current passed through an ordinary solenoid in which a steel core was inserted with provision for regulating the amperage of the current has been found to produce suitable results. In use, the magnitude of the oscillations of the solenoid have been varied by varying the amperage thru the coil to produce the optimum packing as measured by the sinking of the plug into the mold.

If it is assumed that all particles are rounded in contour and of substantially the same size and shape, a condition of maximum density of the loose powder would occur when every particle has come into as close contact as is possible, without sintering, with its neighbors, and where there are no bridges or regions of non-uniform density and where each particle, acting under the influence of gravity has approached as closely as possible to the center of gravity of the earth, consistent with its location in the mass of particles and with the supporting forces of the particles beneath it. Such ideal packing could not be completely realized by any practical method of compacting, but a substantial approach to it could be made if the particles were vibrated and allowed to approach equilibrium positions while in a state of properly controlled vibratory motion.

This substantially ideal packing would still leave interstitial voids between the particles which are in contact. These voids would be larger for larger particles, and smaller for smaller sized particles. If we now assume a mixture of particle sizes, and if the amounts of the different particle sizes were in a correct proportion, there would result, under the influence of a properly controlled vibration, a condition in which the largest voids between the largest particles were filled by smaller-sized particles and the voids among the smaller-sized particles are filled by still smaller-sized particles, and so on, until the smallest-sized particles have been used in filling the successively smaller-sized voids.

Such a condition is ideal and could not be easily realized in practice. However, in any powder mixture containing varieties of particle size, the vibratory motion applied to this mixture, as herein described, and utilizing the mechanical assistance of a plug, and with the assistance of an additional directive force, such as gravity or centrifugal force, will produce a substantial approach to the optimum density conditions, and to an optimum description of particle size, which includes an optimum density distribution.

In addition to the vibration produced either mechanically or electrically, it has been found highly advantageous to subject the particles to centrifugal force in a centrifuge, so that each particle in the mass is subjected to a force which contributes to the compacting of the mass. This centrifugal force is superior to an applied pressure in that each particle is acted upon individually by the centrifugal force, and for this reason the tendency to form bridges in the material is lessened. This centrifugal force may be considered as a directive force influencing the linear motions of the particles, which are in states of vibration; the vibratory motion acting to permit the freer movement of the particles in the direction of the centrifugal force.

In addition to the vibration and the directive force which might be centrifugal or gravitational, the action of a plug, inserted as described above, is found to be desirable for the satisfactory compacting of the material.

The plug is smaller than the opening in the end of the mold, yet it fits snugly enough to prevent substantial loss of powder. It is vibrated along with the mold and powder and usually has a different frequency of vibration—that is to say, if the mold were vibrated by placing it above and in contact with the steel core of the solenoid, gravity, instead of centrifugal force, would be the directive force in this case. The plug would be moved upward and against the force of gravity by an impulse received from the vibrating solenoid. The time of the single up and down excursion would be determined by the acceleration imparted to the body by gravity, and would be governed by the laws of falling bodies, except in so far as the motion of the plug was influenced by friction with the side of the mold, and influenced by the impinging powder particles from the surface of the vibrating powder mass. Since the motion of the plug is governed largely by gravitational forces, it is highly improbable that the up and down motion thus imparted to the plug would occur with the same frequency that characterizes the motion of the solenoid, which is governed by the frequency of the alternating current. It is seen that the plug may be regarded as a mechanical vibrator or a mechanical hammer which makes impacts on the top surface of the powder mass. It is believed that this mechanical action of the plug is essential for the compacting of the upper layers of the powder. It is believed that the compacting of the extreme upper layer of the powder mass cannot be accomplished by vibration alone. While the illustration of this action of the plug has been based upon the vibration of the powder while under the influence of gravity, the action of the plug would not be different in any essential feature, if the directive force were that obtained in centrifuging.

When compacting different metal powders it may be found desirable to control the motion of the plug in the mold in order to vary the compacting of the upper strata of the metal powder in the mold. The motion of the plug relative to the mold and/or powder, and consequently the density of the upper strata of metal powder in the finished article may be controlled by varying the mass of the plug or by damping its period of vibration.

In addition to the above described action of the plug, it is pointed out that desired shapes may be

imparted to the surface of the compacted powder by suitably shaping or engraving the end of the plug that comes in contact with the powder.

Summing up, the action of the plug in the mold appears to have the following functions:

1. To secure better compacting, particularly of the layer of powder immediately adjacent to the plug.

2. To secure suitably shaped bases.

3. To prevent the loss of powder.

When the powder is impacted by the application of pressure, as in the "cold pressing" method, the plunger, which is more or less completely impervious to gases, fits the mold with sufficient snugness so that the escape of gases from the powder during compacting is substantially impeded. Thus a certain amount of gas is entrapped in the compacted mass, which fact contributes toward a lowered density of the compacted mass. When compacting is accomplished through the practice of this invention, gases are not entrapped to so great an extent in the compacted mass, due to the fact that the vibrating particles offer little resistance to the passage of the gas through the volume of the powder mass, and the loosely fitting plug offers a minimum of resistance to their escape from the mold.

By the practice of this invention it is possible, as described above, to secure favorable preliminary packing and uniformity of packing of the compacted powder mass. In certain types of articles manufactured by the powder metallurgy process, it is sometimes desired that the finished product retain a certain degree of porosity. In the past, porosity in the finished product has been secured by the incorporation, in the compacted mass of materials which are decomposed during the sintering operation, thereby leaving small voids, the extent of such voids being controllable by the amount of decomposable materials incorporated in the powder mass. In the practice of the present invention, controlled porosity may be obtained, and the porosity achieved is of a smaller order of magnitude than that produced by the older methods. For example, if small particles, all substantially of the same size and roughly spherical in shape, of such materials as pure iron or pure nickel or other weldable metals were compacted in the practice of this invention, there being little or no binder material and the compacted mass heated in the usual manner for sintering, the particles would weld together or "sinter" at points of contact, leaving interstitial voids at points where the particles were not in contact. There would then be a state of final porosity in the finished product, there being cavities or interstitial voids between the adjacent grains.

If a similar operation were carried out with different sized metal particles from those used in the last illustration, different sized voids would occur in the finished product, so that by selecting the initial particle size, the size of individual voids, and the corresponding extents of porosity produced can be substantially controlled.

It is pointed out that in the cold pressing method, porosity can not be controlled in the manner explained, where the powders of ductile metals, such as iron or nickel are employed, except where the compacting pressures are below those which would produce plastic deformation of the individual grains.

It is pointed out also, that in certain cases as for instance in the case of sintered carbides, where binder materials are employed, and the

binder material becomes liquid during the sintering operation, controlled porosity, of the type described, could not be achieved, because the liquid binder material would be drawn by capillary action into the interstices between the grains, and thus tend to prevent porosity, except that in cases where the binder material is present in such small quantities that there would not be enough liquid material to fill up the voids, porosity could be obtained. Hence, it is seen that a condition for controlled porosity is the presence of insufficient binder material to fill up interstitial voids or no binder material.

An apparatus for carrying out the present invention is shown in the drawing and wherein:

Fig. 1 is a view principally in elevation of a centrifuge apparatus with the mold holders in position assumed when the apparatus is in operation.

Fig. 2 is a partial top plan view partly in horizontal section of the structures shown in Figure 1.

Figure 3 is a view principally in elevation of an apparatus for vibrating the mold and contents, with the central part of the solenoid shown in section.

The centrifuge comprises a head 1 and depending therefrom is a shaft by which the head is supported and rotated. The drive for the shaft may be of any particular kind and the speed controlled by suitable means as is well known to those skilled in the art. The head 1 supports the pivoted trunnion cups 2 which may be formed of any material desired. If desirable the cup may be formed of a non conductor, as such avoids heating of the material of the cup by induction and also permits of a simple construction for the conduction of electrical energy to the solenoid. The solenoid 3 is supported in the cup and is slidable therein for the ready removal of the same and the insertion of another solenoid. Concentric with the solenoid 3 is a cup of magnetic material 5 and in which is inserted the mold 6. The cup 5 is supported on a buffer 4 made of rubber, cork, wood or other resilient material. The mold cavity of the mold 6 may be made of any shape desired and will be the shape though not of the exact dimensions of finished product to be produced. The powdered material 8 to be compacted is inserted in the mold and a plug 7 which is loosely slidable in the mold is placed on top of powdered material. The electric current from an alternating current source 11 is controlled by switch 9 and supplied thru a variable resistance 10 and the leads 12 to the solenoid 3.

In operation the powdered material is inserted in the mold and a plug placed on top of the powdered material. The powder is compacted by the joint action of vibration, centrifugal force and the plug. With the apparatus shown in Figures 1 and 2 the compacting of the powder may take place with or without the use of centrifugal force in view of the fact that the trunnion cups are pivoted in the centrifuge head. If the centrifuge head is not rotated, the solenoid and the mold are held in a vertical position by gravity and with gravity acting as the directive force on the powdered material. If the centrifuge head is rotated the mold is held by centrifugal force in a horizontal or substantially horizontal position so that centrifugal force is the directive force applied to the powdered material.

The apparatus shown in Figure 3 is substantially a duplicate of the solenoid and mold structure used in the centrifuge. The solenoid 3' surrounds the cup 5' of magnetic material and the

buffer 4'. The mold 6' is of a shape to form a bullet of the powdered material 8'. The powdered material may be tungsten carbide. The electrical energy to vibrate the mold and the plug 7' is supplied by an alternating current source 11' and controlled as to the current flowing in the circuit by means of the variable resistance 10' and switch 9'.

The present invention has been described in conjunction with the preferred embodiments but it is to be observed that modifications and variations may be resorted to as one skilled in the art can readily understand.

I claim:

1. The method of producing an article from powdered materials which comprises placing the powdered material in a mold, vibrating said material and simultaneously with said vibrating action rotating said material about an axis normal to the direction in which the material is being vibrated to compact the material in the mold and thereafter sintering the compacted material to form an article of a coherent solid mass having a shape corresponding to that of the mold.

2. The method of producing an article from powdered materials which comprises placing the powdered material in a mold, applying pressure to said material by centrifugal force while subjecting said material to a vibrating motion in the direction of said force whereby the material is compacted in the mold, and thereafter sintering the compacted material to form an article of a coherent solid mass having a shape corresponding to that of the mold.

3. The method of producing an article from powdered materials which comprises placing the powdered material in a mold, subjecting the material to a vibratory force and simultaneously to a centrifugal force acting in a direction parallel to the direction of the vibratory force to compact the material in the mold and thereafter subjecting the compacted material to a sintering heat whereby an article of a coherent solid mass having a shape corresponding to that of the mold is formed.

4. The method of producing an article from powdered materials which comprises placing the powdered material in a mold, vibrating said material and simultaneously with said vibrating motion rotating said material about an axis normal to the direction in which the material is vibrating whereby the volume of the material is reduced.

5. The method of producing an article from powdered materials which comprises placing the powdered materials in a mold, subjecting the materials to a tamping force and vibratory motion and simultaneously with the same rotating the powdered materials in a direction normal to the direction of said motion to compact the materials and thereafter sintering the same to form an article of a coherent solid mass and having a shape corresponding to that of the mold.

6. An apparatus for producing an article from powdered materials comprising an arm mounted for rotation, a supporting means pivoted to said arm, a resilient member on said supporting means, a mold supported by said resilient member and adapted to receive powdered material, a weighted closure member slidably mounted within said mold for closing the same and for exerting a force upon the powdered material when the said arm is rotated and means to vibrate said mold and said weighted closure member whereby said powdered material will be compacted.

7. The method of producing an article from powdered materials which comprises placing the powdered material in a mold, applying pressure to said material both by centrifugal force and simultaneously by a vibrating weight moving in a direction parallel to said force whereby the material is compacted in the mold, and thereafter sintering the compacted material to form an article of a coherent solid mass.

8. An apparatus for producing an article from powdered materials comprising an arm mounted for horizontal rotation, a supporting means pivoted to an end of said arm, a resilient member carried by said supporting means, a mold supported by said resilient member and adapted to receive powdered material, a weight slidably mounted in said mold for movement towards and away from said resilient member for reducing the volume of the powdered material and means to vibrate said mold and said weight whereby said powdered material will be compacted.

9. The method of producing a porous article by powder metallurgy which comprises placing in a mold a mass of powdered material of controlled powder size throughout, applying pressure to said mass by centrifugal force while subjecting said mass to vibratory motion in the direction of said force whereby the mass is compacted in the mold, and thereafter sintering the compacted mass to form a porous coherent solid body having a shape corresponding to that of the mold.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,502,925	Stone	Aug. 29, 1924
1,932,520	Horsch	Oct. 31, 1933
1,954,904	Walter	Apr. 7, 1934
2,189,290	Moorhead	Feb. 6, 1940
2,193,413	Wright	Mar. 12, 1940
2,198,612	Hardy	Apr. 30, 1940
2,208,230	Rubissow	July 16, 1940
2,246,165	Dawihl et al.	June 17, 1941
2,304,723	Wolff et al.	Dec. 8, 1942

OTHER REFERENCES

Principles of Powder Metallurgy by W. D. Jones, published by Edward Arnold and Co., London, 1937, pages 47 and 48.