United States Patent [19]

Zapf

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[54] **PROCESS OF WORKING A SINTERED POWDER METAL COMPACT**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 849,354, Aug. 12, 1969, abandoned.

[30] **Foreign Application Priority Data**

Aug. 20, 1968 Germany 1758849

[52] **U.S. Cl.** **29/420.5,** 29/420, 29/DIG. 47, 75/200

[51] **Int. Cl.** **B22f 3/24**

[58] **Field of Search** .... 29/420, 420.5, DIG. 31, 29/DIG. 47; 264/111; 75/200

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[57] **ABSTRACT**

A process of manufacturing articles by means of powder metallurgy, including the conventional steps of forming a blank out of metal powder compressing the blank and sintering it. Pursuant to the disclosure, an additional step is provided, wherein the sintered blank is subjected in a die to one or more further press operations in which the material of the blank is allowed to flow freely in the direction transverse to the direction in which pressure is applied. In this manner the density of the product is increased. Preferably the article is sintered again or annealed after the further press operation or operations to provide it with the required strength characteristics. The additional step is advantageously carried out at room temperature.

5 Claims, 5 Drawing Figures

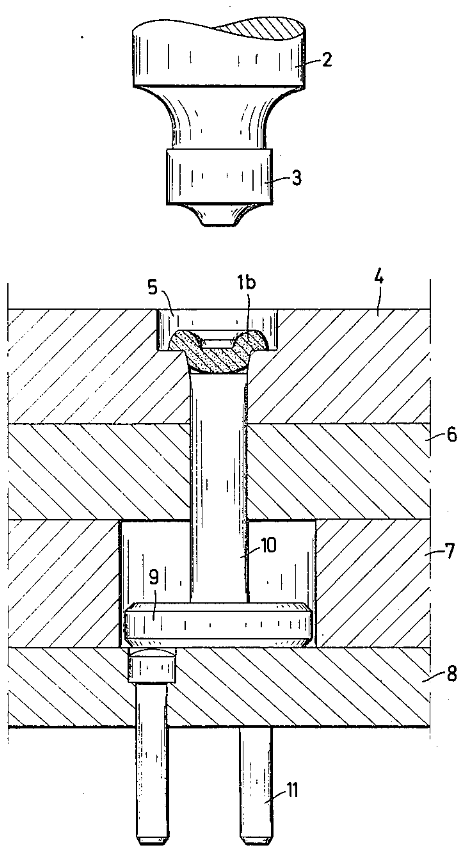


FIG. 1

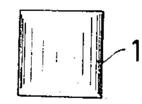


FIG. 2

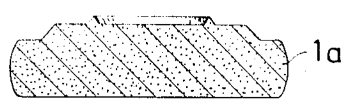


FIG. 3

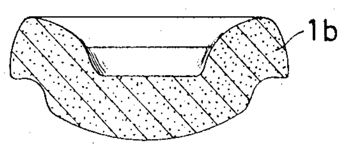
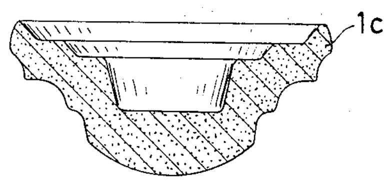


FIG. 4



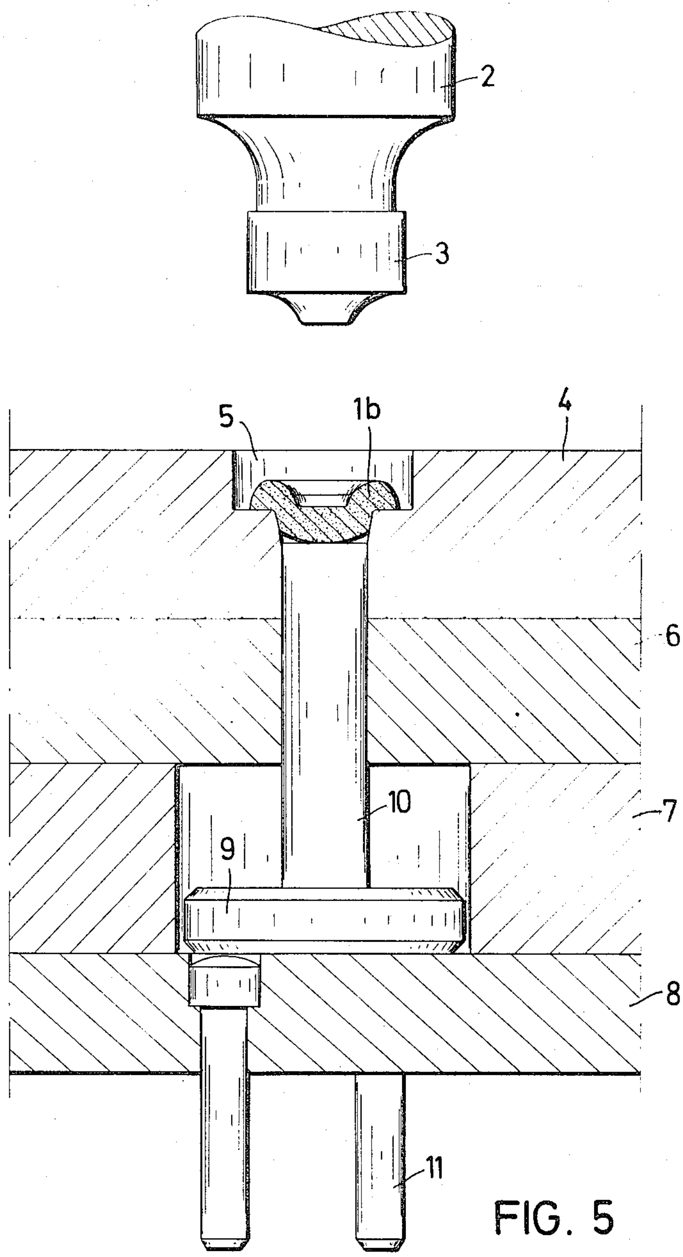


FIG. 5

PROCESS OF WORKING A SINTERED POWDER METAL COMPACT

CROSS-REFERENCE TO PRIOR APPLICATION

This is a continuation-in-part of copending application Ser. No. 849,354, filed Aug. 12, 1969, and now abandoned.

FIELD OF INVENTION

The invention relates to the manufacture of articles by powder metallurgy, wherein a blank is formed from metal powder, whereafter the blank is compressed and sintered.

BACKGROUND INFORMATION

Articles can be made using metal powders as a raw material by what is called the powder metallurgical process. This process is used in particular where other manufacturing processes such as casting, forging or machine cutting cannot be used, or only at high cost and under technical difficulties. The principle involved in the powder metallurgical process of manufacture is that a metal powder, or a mixture of powders consisting of metals and non-metals, is formed into the shape of the product by compression in a die. The blank formed in this way is then sintered at a high temperature.

A precise quantity of the metal powder, measured either by volume or by weight, is introduced into the die and compressed by a punch. Alternatively, in order to obtain a more homogeneous densification, two punches can be used acting in opposite directions. The densified intermediate product obtained in this way is a compressed blank whose shape and dimensions are determined by the shapes of the press tools used, and by the amount of pressure applied. The compressed blank is then sintered at a high temperature so as to bond the particles together by a process of diffusion. To prevent oxidation of the material, the sintering is usually conducted under a protective gas, or in a reducing atmosphere.

In order to improve the dimensional accuracy of the finished product it is known to subject the product, after sintering, to a second press operation called calibrating or sizing. The sizing is done by subjecting the product to a second press operation in a completely closed die, to the effect that at the end of the sizing operation the product is a precise positive replica of the fully closed die, which can be regarded as the corresponding negative shape, or female mould.

It is known that the mechanical strength of a sintered product is a function of its density. Both the tensile strength and the hardness increase linearly with density. On the other hand, the dynamic properties of the product for example the elongation at rupture, the notch impact strength and the elasticity increase nonlinearly with the density. What this means in practice is that sintered products which are going to be subjected to high working stresses, for example in the processing industries, must have a high density.

However, it has been found that economically obtainable pressures can give no more than approximately 85 percent at most of the theoretical maximum density, that is to say of the density which one would obtain in a completely compacted product. The compaction is limited mainly by the fact that the material work hardens during the press operation, preventing complete compaction.

It is possible, by particularly difficult and costly process, to give a product made of a soft metal a density as high as 93 to 96 percent of the theoretical value. This is obtained by subjecting the compressed blank to an annealing or pre-sintering operation and then pressing it again. This method is called double pressing, but is still not capable of compacting the material completely.

It is nowadays becoming increasingly important to produce sintered products of high density, because sintered products are being used increasingly as stressed parts in various applications, particularly in civil engineering.

SUMMARY OF INVENTION

The object of the present invention is to provide a simple process for producing products by powder metallurgy which have densities considerably higher than those hitherto obtainable.

To this end, according to this invention, an article is manufactured by powder metallurgy by a process in which, after a blank has been compressed and sintered, it is then subjected to one or more further press operations in a die in which the material of the blank is allowed to flow freely in the direction transverse to the direction in which pressure is applied. This further press operation is advantageously performed at room temperature.

Articles made in this way have a very high density and great mechanical strength. The new process is based on the surprising discovery that sintered products, even though consisting of porous material, are nevertheless capable of undergoing considerable plastic deformation, involving a free flow of the material. This can be shown, for example, quite simply by squashing a sample between two flat plates. Using comparatively little pressure, densities are obtained as high as 99.0 to 99.6 percent of the theoretical maximum value.

The process, in accordance with the invention for producing sintered articles is quite simple. In the first stage of the process a measured quantity of a metal powder is compressed in a press to produce a compressed blank having a density between 50 and 85 percent of the theoretical density. In this first compression the press tools can be of customary construction. In the second stage of the process, the pressed blank is sintered in the usual way, preferably under a protective gas. In the third stage of the process the compressed and sintered blank is subjected to a second press operation using press tools arranged in such a way that the material can flow freely in the direction transverse to the direction in which pressure is applied, without being impeded by the press tools. This, of course, requires that there is sufficient space between the wall of the die and the blank. Thus, the lateral dimension, to wit, the dimension of the die which is transverse to the pressure direction, must be larger than the lateral dimension of the blank to be compressed so that the walls of the die do not form any resistance to the free flow of the material during the press operation. By this method, the density of the product is increased to between 85 and 99.9 percent of the theoretical maximum density. The re-densification of the product, or superdensification, can, if desired, be repeated several times. The product is at the same time given a different shape by the re-densification press operation.

Products which have been re-densified in this way can often be used without further processing, provided that only tensile strengths are involved, that is to say, not elongation at rupture. However, the product is preferably subjected to a fourth stage of the process, in which it is either sintered or annealed, This gives the optimum tensile strength and elongation at rupture. Finally, the product can be calibrated, hot or cold, stamped or embossed, or forged.

It has been found that sintered products made by the process of the present invention are so tough that they can be used as initial blanks for cold forging, extrusion pressing or flow pressing to give final products of complex shape by deformation without cutting. Furthermore, due to their comparatively high densities, these sintered products can be used as initial blanks for precision forging. This amounts in practice to hardly more than a final calibration of the product at high temperature, and requires only comparatively moderate pressures. Sintered products made in accordance with the present invention have also been found suitable for use as initial blanks for cold embossing.

An example of a process in accordance with the invention will now be described with reference to the accompanying drawings in which:

FIG. 1 is a side elevational view of a cylindrical, compressed sintered blank;

FIG. 2 shows the blank of FIG. 1 after it has been shaped into an article by being subjected to an additional press operation in accordance with the invention;

FIG. 3 shows the article of FIG. 2 which, after a heat treatment, has again been subjected to a press operation pursuant to the invention;

FIG. 4 shows the finished article which has been obtained by subjecting the article of FIG. 3 to a further inventive press operation; and

FIG. 5 is a vertical section through a press arrangement suitable for carrying out the inventive procedure.

The cylindrical blank 1 of FIG. 1 has a diameter of 15.1 mm and a height of 14.8 mm, as well as a hardness HB 5/2.5 of 63 kp/mm². The blank was formed in customary manner from electrolytic iron powder which was cold-pressed and subsequently sintered for about 1 hour at 1250°C in a cracked-gas atmosphere. The sintered blank thus obtained was then shaped in accordance with the invention by subjecting it to an additional press operation. This was effected in the press arrangement of FIG. 5 having a die 4 which is sufficiently large so as to allow the material of the blank of FIG. 1 to flow freely within the die in the direction transverse to the direction in which pressure is applied. The additional press operation in the press of FIG. 5 was carried out at oom temperature and at a pressure of 2 Mp/cm². During this additonal pressing, the material of the blank flowed within the die in outward direction, to wit toward the die wall, transverse to the direction of pressure, namely transverse to the direction of movement of the punch tool. In this manner, the article shape 1*a* shown in FIG. 2 was obtained. This shape 1*a*, which thus corresponds substantially to a round disc, had a diameter of 24 mm and a hiehgt of 6.4 mm. This means that the diameter, as compared to the diameter of the original blank 1 of FIG. 1 increased by almost 9 mm. While the density of the blank 1 of FIG. 1 was 7.3–7.4 g/cm³, the density of the article 1*a* of FIG. 2 rose to 7.8 g/cm³. The Brinell hardness value was 140 kp/mm².

Subsequent to the formation of the article of FIG. 2, the disc 1*a* thus obtained was heated for 1 hour at 1250°C in a gas atmosphere in order to restore the formability of the cracked article which is largely lost by the cold-shaping in the press. The heat-treated article of FIG. 2 was then cooled to room temperature and had a density of 7.75 g/cm³ and a Brinell hardness of 71 kp/mm². The article was then again inserted into the press of FIG. 5 and shaped while permitting the material of the article to flow freely in the direction transverse to the press direction. In this manner and without changing the density, the Brinell hardness value increased to 146 kp/mm² while the article assumed the dish-like shape 1*b* of FIG. 3. During this second press operation as described above, the diameter of the article did not change. However, this fact notwithstanding and due to the deformation of the article into a dish-like shape, the material of the article did flow freely in the direction transverse to the press direction, to wit, a radial return flow in the direction towards the press axis took place.

The article 1*b* obtained according to FIG. 3 was finally subjected to a terminal cold-shaping in which the material of the article flowed freely in lateral direction, whereby the article of the final shape 1*c*, shown in FIG. 4, was obtained. The largest diameter of this article 1*c* was 27.8 mm while its height was 13 mm. It follows that the diameter increase from the original blank of FIG. 1 to the final article 1*c* of FIG. 4 was more than 12 mm. The density of the article changed during the final cold shaping by an insignificant degree only and thus has a value of 7.8 g/cm³. By contrast, the Brinell hardness increased significantly and indicated a final value of 165 kp/mm².

The data of the above experiment are compared in the following Table with the results of additional tests which were carried out with a powder RZ 150 prepared according to the so-called RZ-process developed by G. Naeser, H. Steffe and W. Scholz.

Powder	Starting condition		After first inventive press operation		Heat treatment		After second inventive press operation		After third inventive press operation	
	Density (g./cm.³)	Hardness HB 5/2.5 (kp./mm.²)	Density (g./cm.³)	Hardness HB 5/2.5 (kp./mm.²)	Density (g./cm.³)	Hardness HB 5/2.5 (kp./mm.²)	Density (g./cm.³)	Hardness HB 5/2.5 (kp./mm.²)	Density (g./cm.³)	Hardness HB 5/2.5 (kp./mm.²)
Electrolytic iron	7.33	63	7.80	140	7.75	71	7.75	146	7.78	165
RZ 150	7.31	64–66	7.79	140–177	7.76	77–79	7.72	150	7.80	167

The data of the Table indicate that the inventive procedure results in a significant increase in the density. Such density increase cannot be obtained according to the prior art procedure, for example according to the customary double-press technique. This could be demonstrated by a comparison test wherein an electrolytic iron powder corresponding to the powder of the above test could be compacted to a density of 7.4 g/cm^3 only. Further, the data of the Table indicate that the increase in the density causes also a significant increase in the hardness and thus also in the strength of the article. The increase in the strength values is demonstrated by the fact that the starting blank of FIG. 1 has a tensile strength of 25 kp/mm^2 while the final article of FIG. 4 has a tensile strength of 54 kp/mm^2.

The pressing is preferable performed by press tools, as shown in FIG. **5**, consisting of an upper punch **2**, with an exchangeable punch tool **3**, working in a die **4**. The redensified product **1**a of FIG. **2** is introduced into the die **4** through an opening **5**. The die **4** rests on a pressure plate **6**, which rests on a spacer ring **7** reposing on a base plate **8**. The spacer ring **7** contains a foot plate **9** of an ejector piston **10** which works in bores passing through the pressure plate **6** and the die **4**. An ejector pin **11** works in a bore in the base plate **8** and acts on the foot **9** of the ejector piston **10**, so that when the pin **11** is lifted, the piston **10** pushes the deformed product **1***b* out of the die **4** through the upper opening **5**. The additional press operations may be performed in the same press arrangement by choosing suitable punch tools and die. The die, of course, has always to be sufficiently large so as to permit the free flow in transverse direction.

What I claim is:

1. In a process for manufacturing an article by powder metallurgy comprising the steps of forming a blank from metal powder, compressing said blank and sintering said blank, the improvement comprising the additional step of subjecting said compressed and sintered blank to a least one additional press operation in a die in which the material of said blank is allowed to flow freely in the direction transverse to the direction in which pressure is applied and carrying out the at least one additional press operation at room temperature.

2. A process as claimed in claim **1**, wherein said blank is deformed during said additional press operation to form said article to its final shape.

3. A process as claimed in claim **1**, comprising the further step of sintering or annealing said blank after said further press operation.

4. A process as claimed in claim **1**, wherein a plurality of said additional press operations are performed.

5. A process as claimed in claim **1**, wherein the additional press operation is carried out so as to increase the diameter of the blank.

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