PATENT SPECIFICATION

(11) 1333 523

NO DRAWINGS

(21) Application No. 11118/72 (22) Filed 9 March 1972

(44) Complete Specification published 10 Oct. 1973

(51) International Classification B22F 3/14

(52) Index at acceptance

C7D 8D A1

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1333523

(54) METHOD OF MAKING BERYLLIUM SHAPES FROM POWDER METAL

(71) We, KAWECKI BERYLCO INDUSTRIES, INC., a corporation organized and existing under the laws of the State of Pennsylvania, United States of America, located at Reading, Pennsylvania, P.O. Box 1462, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

Most widely commercially acceptable method of making beryllium shapes consists of converting cast beryllium billets into powder, placing the powder in a die and sintering under pressure and elevated temperatures in vacuum to achieve near theoretical density. The shapes produced by this method are then machined to final dimensions.

This method is aimed at achieving a fine grain beryllium structure since the present state of the art shows coarse grain beryllium is extremely brittle and cannot be used for structural applications. This method of converting coarse grain billets into fine powder, then sintering under pressure at elevated temperatures results in a fine grain uniform beryllium product. "It is well known however that the prolonged sintering step can result in grain coarsening which deteriorates the mechanical properties of the beryllium". It can further be seen that machining of shapes out of a solid pressed beryllium block is lengthy, costly and difficult. Inasmuch as beryllium metal is expensive, it is apparent that a more economical method of making beryllium shapes is very desirable. This has led to another method of preparing beryllium shapes.

Another means consists of first compacting the powder by mechanical or hydrostatic means into shapes and then sintering without pressure at elevated temperatures in vacuum or inert environment. This however does not result in a fully dense material, nor does the material have optimum mechanical properties.

The present invention consists of first cold pressing beryllium shapes at room temperature using either the isostatic pressure technique or conventional mechanical compacting methods, and subsequently pressing mechanically to final dimensions while simultaneously heating the shape. This enables advantage to be taken of the economics of using the isostatic pressure technique and at the same time overcomes the difficulties of the prior art. The first pressing of the beryllium powders brings the powder to about 60 to 95% of theoretical density. The second pressing brings the shape to 99% or greater theoretical density while at the same time achieving material that has improved yield strength, ultimate strength and good elongation as compared to conventional pressing methods. This method also allows easy non-destructive inspection and testing prior to the re-pressing step. It also allows in-process repairs and reclamation of defective parts.

The utilization of lower pressing pressure to achieve equivalent density levels at the equal temperature levels presents economies in the die assemblies and equipment size. It also allows pressing at lower temperatures, producing as previously stated, better mechanical properties because of reduced grain growth. This method lends itself to production of more intricately shaped configurations. This is primarily because during the repressing step, material movement unlike that in conventional powder pressing is greatly minimized and consequently parts can be made closer to final desired shape with less die friction and internal friction.

An additional advantage includes the ability to produce parts with greater length/diameter ratio which greatly limits conventional powder metallurgy methods.

It is found that this pressing method, because of a minimal grain growth, results in good elongation (or ductility) with good ultimate strength and yield strength. It is also more economical to achieve a beryllium shape of theoretical density.

It is therefore an object of the present invention to produce a beryllium shape of theoretical density having increased yield strength, ultimate strength and elongation, while at the same time improving economy of the over-all process due to reduced material input and subsequent machining to the final configuration.

A further object of the instant invention is to set forth a method of producing a beryllium or beryllium alloy shape of increased strength and theoretical density by means of cold pressing beryllium powder to 60 to 95% of its theoretical density and subsequently mechanically pressing while heating under vacuum or inert environment, to produce a beryllium shape of theoretical density and desired shape.

The method of the instant invention for making beryllium shapes consists of first cold pressing a beryllium shape from metal powder at room temperature using either the isostatic pressing technique or conventional mechanical compacting methods. Isostatic pressing is a method of applying pressure simultaneously and equally in all directions. The process involves placing of powder beryllium in a flexible container of rubber, polyvinyl chloride, synthetic resins or other suitable material which serves as a mold and is tightly sealed against any possible leaks. The container or mold is then placed inside a pressure vessel, said vessel being sealed off and then hydrostatic pressure is applied to all surfaces of the pressed part. The pressure is then released and the pressed part extracted from the pressure vessel cavity. The result is the production of a product having uniform strength and density of 60 to 95% of theoretical obtainable density. This part can be handled readily, machined to closer final size and inspected prior to further processing. A satisfactory cold pressed beryllium part results if pressed isostatically at a pressure of 30,000 psi minimum. The pressures can go as high as 90,000 psi, however, a preferred range is found to be from 40,000 to 65,000 psi. Below 30,000 psi, binder material has to be used to allow material handling.

Following the cold pressing step a recoining operation by means of application of both pressure and temperature is used to further densify the part. Because the part is relatively dense to start with at this point, lower temperatures and pressures are needed to achieve full density. This as previously stated, results in a material having finer grain size than a product which is pressed into a block directly from powder by present commercial methods and results in improved mechanical properties of material.

The greater the temperature used during the second pressure the less pressure is needed to achieve full density and vice versa. It has been found that pressures of from 100 to 10,000 pounds per square inch and temperatures between 1400°F to 2150°F are operational; however, an optimum or preferred temperature range is between 1500°F and 1900°F. The following table indicates the pressures used and temperatures in the present invention as related to pressures and temperatures used in other conventional methods.

TABLE I

Pressing Temperature	2000°F	1950°F	1900°F	1800°F	1700°F	1600°F
Pressure Required by Conventional Process to Achieve 99% density (effective pressure on the metal)	800 psi	900	1000	1240	No Data	No Data
Pressure Required by Present Invention Process to Achieve 99% density (effective pressure on the metal)	200	240	300	420	800	1800
Pressure ratio: Convention method / Present invention method	4:1	3.75:1	3.33:1	2.95:1	—	—

Using the temperatures and pressures as indicated in Table I, the following mechanical properties were determined in beryllium parts produced by the method of the instant invention.

TABLE II
Typical Mechanical Properties of Beryllium by Various Methods

Method	Density	Ultimate Strength	Yield Strength	Elongation
Conventional Hot Press	99%	44,000 psi	33,000 psi	1.5%
Cold Press & Sinter	94%	32,000	29,000	0.5%
Cold Press & Hot Press (present invention)	99%	50,000	44,000	2.0%

Many variable shapes can be produced by the above method such as slabs or cylinders, hollow cones and hollow cylinders.

As set forth above, the present invention discloses a new method for producing beryllium shapes of increased yield strength, ultimate strength and elongation having theoretical density and fine grain size. This method is much more economical and produces a beryllium shape of final dimensions doing away with the necessity of lengthy machining of beryllium parts and producing at the same time beryllium shapes of better mechanical properties due to the lower temperatures used thus preventing grain growth.

WHAT WE CLAIM IS:—

1. A method of making beryllium shapes of at least 99% of theoretical density, comprising first pressing beryllium powders at room temperature and pressures of from 30,000 pounds per square inch to 90,000 pounds per square inch, second hot pressing at pressures of from 100 to 10,000 pounds per square inch and at a temperature from 1400°F to 2150°F.

2. The method according to claim 1 characterized in that the first pressing at room temperature is an isostatic pressing.

3. The method according to either claim 1 characterized in that the first pressing is a mechanical compacting pressing.

4. The method according to claim 1, 2 and 3 characterized in that the first pressing produces a shape which is 60 to 95% of theoretical density.

5. The method according to claims 1, 2, 3 and 4 characterized in that the first pressing is done at a pressure of from 40,000 to 65,000 psi.

6. The method according to claims 1, 2, 3, 4 and 5 characterized in that said second pressing step is done at a temperature of between 1550°F and 1900°F.

7. A beryllium metal shape of at least 99% theoretical density produced by the method of claim 1.

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Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1973.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.