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[54] METHOD OF MAKING BERYLLIUM SHAPES FROM POWDER METAL

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[58] **Field of Search**.....75/214, 226, 200, 150, 223; 29/182

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[57] **ABSTRACT**

A method of making beryllium or beryllium alloy shapes from powder metal by first pressing the beryllium or beryllium alloy shape either by isostatic pressing or conventional mechanical compacting methods at room temperature to 60 percent to 95 percent of theoretical density at a pressure of between 30,000 and 90,000 psi or above and subsequently pressing and heating to final size and density at temperatures between 1,400° F and 2,150° F (preferably 1,550° F to 1,900° F) and pressures of from 100 to 10,000 psi effective pressure on the compacted powder, preferably at 100 to 2,500 psi. The second pressing of the shape is done with mechanical pressure simultaneously with the application of heat under vacuum or inert environment.

7 Claims, No Drawings

METHOD OF MAKING BERYLLIUM SHAPES FROM POWDER METAL

BACKGROUND OF THE INVENTION

The 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.

SUMMARY OF THE INVENTION

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 takes advantage 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 percent of theoretical density. The second pressing brings the shape to 99 percent 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 in 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 percent 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.

DESCRIPTION OF THE PREFERRED EMBODIMENT

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 percent 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 with no upper limit. The pressures can go as high as 90,000 psi or above, however, a preferred range is bound 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 temperatures between 1,400° F to 2,150° F are operational; however,

an optimum or preferred range is between 1,500° F and 1,900° 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: Conventional 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 patent application)	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.

As this invention may be embodied in several forms without departing from the spirit or essential characteristics thereof, the present embodiment is therefore illustrative and not restrictive and since the scope of the invention is defined by the appended claims, all changes that fall within the metes and bounds of the claims or that form their functional as well as conjointly cooperative equivalents are therefore intended to be embraced by those claims.

We claim:

1. A method of making beryllium shapes of at least 99 percent 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 1,400° F to 2,150° F.

2. The method of claim 1 wherein the first pressing at room temperature is an isostatic pressing.

3. The method of claim 1 wherein the first pressing is a mechanical compacting press.

4. The method of claim 1 wherein the first pressing produces a shape which is 60 to 95 percent of theoretical density.

5. The method of claim 1 wherein the first pressing is done at a pressure of from 40,000 to 65,000 psi.

6. The method of claim 1 wherein the subsequent pressing step is done at a temperature of between 1,550° F and 1,900° F.

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

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