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(54) Forming aluminium and titanium alloys by powder metallurgy

(57) A process for forming a high-strength metal alloy material having a predetermined chemical composition, comprises

mixing a particulate enriched metal alloy which contains at least one alloy constituent in an amount at least 10% greater than desired in the final alloy material and which has a particle size of less than 40 mesh, with a particulate metal filler having a particle size of less than 40 mesh, the two particulate metals being mixed in such proportions such that the resultant mixture contains alloy constituents in the proportions desired in the final alloy material,

passing the powder mixture through a powder-rolling mill to compact the same to form a solidified mass having a density of at least 80% of theoretical, and

sintering the solidified mass at a temperature sufficient to cause interparticle bonding and diffusion of the alloy constituents to form a homogeneous mass of metal alloy material having the desired chemical composition. The alloys and filler metal may be of Al or Ti.

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SPECIFICATION

Preparation of high-strength metal alloy materials

This invention is concerned with the formation of a high-strength metal alloy material by powder metal metallurgy techniques, and with the metal alloy materials so produced.

Powder metallurgy is used to day to form structures which have physical and chemical properties at leat equivalent to those of articles cast from an alloy of the same composition. However, conventional powder metallurgy techniques are not useable with many alloy compositions. For example, it often arises that when conventional powder metallurgy techniques are used in an attempt to produce a high-strength aluminium alloy from particles of a prealloyed material, a structure is obtained which does not have the desired physical properties.

We have now developed a process whereby powder metallurgy techniques can be applied to a wider range of alloys and, in particular, to aluminium-based alloys.

According to the present invention, there is provided a process for forming a high-strength metal alloy material having a predetermined chemical composition, which comprises

mixing a particulate enriched metal alloy which contains at least one alloy constituent in an amount at least 10% greater than desired in the final alloy material and which has a particle size of less than 40 mesh, with a particulate metal filler having a particle size of less than 40 mesh, the two particulate metals being mixed in such proportions such that the resultant mixture contains alloy constituents in the proportions desired in the final alloy material,

passing the powder mixture through a powder-rolling mill to compact the same to form a solidified mass having a density of at leasy 80% of theoretical and

sintering the solidified mass at a temperature sufficient to cause interparticle bonding and diffusion of the alloy constituents to form a homogeneous mass of metal alloy material having the desired chemical composition.

The metal filler can be either a ductile pure metal or alloy which is capable of acting as a binder for the enriched metal alloy. Suitable metal fillers include, for example, aluminium, aluminium alloys, titanium, and titanium alloys.

The enriched metal alloy can be any alloy which will enhance the physical properties of the metal filler. If a metal in the enriched metal alloy does not readily diffuse into the metal filler, at least part of the final desired amount of the metal concerned can be added to or alloyed with the filler material. Preferred enriched metal alloys comprise aluminium, zinc, magnesium and copper and, optionally, cobalt.

In the practice of the invention various alloy compositions have been studied. One such is a high-strength aluminium alloy having a nominal composition, by weight, of 6.5% zinc, 2.5% magnesium, 1.5% copper, 0.4% cobalt, balance aluminium. The enriched alloys used to make this alloy that have been stuided have had the following composition limits: 7.15—9.75% zinc, 2.75%—3.75% magnesium, 1.65—2.25% copper, 0.4% cobalt and have represented enrichment factors of 10, 20, 40 and 50% with respect to the composition of the desired alloy. These enriched alloys have been blended with a filler alloy consisting of 99.6% aluminium — 0.4% cobalt in the respective weight ratios of enriched alloy-to-filler alloy of 10:1, 5:1, 5:2, and 2:1. To date, the 50% enriched alloy has worked the best, but 50% is not a limit to the enrichment factor which can be higher. In general, the enrichment factor may be from 10 to 90%.

Many variables affect the physical properties of the final product. However, the maximum tensile properties developed so far have been for an aluminium base strip having the above-stated nominal composition and made with −100 mesh powders using a 50% enriched alloy, the strip, following sintering, having been reduced 79% and subjected to a heat treatment which included solutionizing at 900°F (482°C) followed by a water quench, and then ageing for 24 hours at 250°F (121°C). This strip had an ultimate tensile strength of 93,000 psi (6510 kg/cm^2), a 0.2% offset-yield strength of 83,000 psi (5810 kg/cm^2), and total elongation of 13.5%.

In addition to the above-described aluminium alloys, titanium base high-strength metal alloys can be readily produced by means of the present invention. Typically, such alloys are formed by mixing the desired ratio of −40 mesh pure titanium particles with −40 mesh particles of an enriched alloy consisting, by weight, of 25% titanium, 45% aluminium, and 30% vanadium, and then subjecting the resulting mixture to powder rolling and sintering as already described.

In order that the invention may be more fully understood, the following examples are given by way of illustration.

EXAMPLE 1

The desired final alloy was of the following composition, by weight: 6.5% zinc, 2.5% magnesium, 1.5% copper, 0.4% cobalt, balance aluminium.

An enriched alloy composition was produced which was 50% richer in all alloy constituents than desired in the final alloy. The enriched alloy was atomized in a conventional manner to form particles having an average particle size of −40 mesh. The enriched alloy particles were blended with pure aluminium filler particles having an average particle size of −40 mesh in a weight ratio of 2 parts of enriched alloy to 1 part of pure aluminium filler. This blend was then powder-rolled by conventional means without the use of any surface layers to obtain a density of more than 80% of theoretical. The pure soft aluminium acted as a filler material and encapsulated the hard, non-deformable enriched alloy particles. After sintering, the microstructures of the product showed almost total redistribution of the alloy constituents by a diffusion mechanism. This sintered strip, was 75% reduction and heat treatment, gave tensile properties of: 83.0 ksi ultimate tensile strength, 71.0 ksi 0.2% yield strength, and 13.5% elongation.

EXAMPLE 2

While the final alloy material obtained by the procedure of Example 1 had satisfactory physical properties, the uniformity of diffusion of cobalt throughout the final structure was not entirely satisfactory. To improve this feature, an enriched alloy was prepared as described in Example 1 except that the proportion of cobalt was equal to the amount desired in the final product; all other alloy constituents were 50% more than the amount desired in the final product as before. This enriched alloy was atomized to particles having an average particle size of −40 mesh and 2 parts thereof were blended with 1 part of −40 mesh, 99.6% aluminium — 0.4% cobalt filler alloy. The blended mixture was placed in the hopper of a powder-rolling mill and fed between the nip of the rolls to yield a relatively dense (greater than 95% of theoretical density) product. The consolidated strip was then sintered at 900—1100°F (482—593°C) for two hours in an inert atmosphere to enhance interparticle bonding and promote homogenization by diffusion of the alloying elements contained in the enriched alloy.

The resultant strip material had excellent physical properties and the cobalt metal was uniformly diffused throughout the product. The properties of this strip material could be further optimized by cold reduction followed by heat treatment.

CLAIMS

1. A process for forming a high-strength metal alloy material having a predetermined chemical composition, which comprises

mixing a particulate enriched metal alloy which contains at least one alloy constituent in an amount at least 10% greater than desired in the final alloy material and which has a particle size of less than 40 mesh, with a particulate metal filler having a particle size of less than 40 mesh, the two particulate metals being mixed in such proportions such that the resultant mixture contains alloy constituents in the proportions desired in the final alloy material,

passing the powder mixture through a powder-rolling mill to compact the same to form a solidified mass having a density of at least 80% of theoretical, and

sintering the solidified mass at a temperature sufficient to cause interparticle bonding and diffusion of the alloy constituents to form a homogeneous mass of metal alloy material having the desired chemical composition.

2. A process according to claim 1, in which the metal filler is aluminium, and aluminium alloy, titanium or a titanium alloy.

3. A process according to claim 1 or 2, in which the enriched metal alloy comprises aluminium, zinc, magnesium and copper.

4. A process according to claim 3, in which the enriched metal alloy comprises, by weight, 7.15 to 9.75% zinc, 2.75 to 3.75% magnesium, and 1.65 to 2.25% copper.

5. A process according to claim 3 or 4, in which the enriched metal alloy also includes cobalt.

6. A process according to claim 5, in which the enriched metal alloy includes, by weight, approximately 0.4% cobalt.

7. A process according to any of claims 1 to 6, in which the enriched metal alloy contains up to 90% more of said alloy constituent than desired in the final alloy material.

8. A process for forming a high-strength metal alloy material, substantially as herein described in either of the Examples.

9. A high-strength metal alloy material having a predetermined chemical composition, when produced by the process claimed in any of the preceding claims.

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