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# SELF-LUBRICATING BEARING COMPOSITIONS

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## ABSTRACT OF THE DISCLOSURE

Method of making a bearing or brake-lining body containing a solid lubricant (e.g., graphite) in an amount of 4 to 25% by weight, with a base-metal component consisting of copper or nickel or mixtures thereof and, possibly, lead (up to 20% by weight), tin, zinc, cobalt, manganese and/or silver, wherein 0.5 to 2% by weight of phosphorus is incorporated in the composition in the form of phosphorus-containing alloys or compounds (e.g., phosphorus copper having 15% by weight phosphorus); the powdered mass is shaped by pressing and subjected to heat treatment in an oxidizing atmosphere or an anti-oxidation blanket at a temperature between 700° and 850° C. Thereafter, a further hot or cold pressing takes place.

## SPECIFICATION

Our present invention relates to a method of producing ductile-metal bodies containing a solid lubricant by powder-metallurgy techniques, with copper and/or nickel as the base metal which constitutes the major part of the mass.

It has already been proposed to produce, by powder-metallurgical techniques, self-lubricating alloys which may be used, for example, as low-friction bearing materials or low-wear brake-lining materials, a solid lubricant (e.g., graphite) being added in powdered form to a mixture of metal powders. The resultant mixture may then be rendered coherent by a treatment involving pressure or heat. The materials thus produced possess, however, only a very slight ductility and have a very low impact resistance.

It is an object of the invention to provide an improved sintered-powder composition or cermet (ceramic-metal composition) suitable for use in bearings and brakes or the like, which has enhanced ductility, reduced brittleness, and increased impact resistance.

Another object of the invention is to provide an improved method of making bearing or brake bodies with these properties.

The invention resides, in large measure, in our discovery that phosphorus in the form of a phosphorus alloy or compound may be added to the powder mixture in a quantity such that the proportion of phosphorus contained in the end product amounts to at least 0.5% by weight to surprisingly yield a body of self-lubricating quality which has greater impact strength (in spite of earlier beliefs that the presence of phosphorus increases brittleness in castings) and improved ductility.

The addition of phosphorus to cermets is already known in the art. Thus, attention has already been drawn to the fact that the addition of small quantities of a phosphide when cermets are produced from powdered metals is of advantage, for example, in order to remove impurities (Kieffer-Hotop, Pulvermetallurgie und Sinterwerkstoffe, 1948, pp. 125 and 178). The phosphorus here involved is the phosphorus which naturally accompanies the various metals, i.e., occurs naturally therewith. It has also been suggested that phosphorus, inter alia, should be added to the powder mixture as a deoxidation medium.

In both cases, the phosphorus is not only used for a different purpose, but also the amount used is considerably smaller than in the method of the invention. In view of the well known reactivity of phosphorus and its resulting, observed tendency to react explosively with other materials even when deoxidation is carried out with relatively small quantities of phosphorus, larger quantities have not hitherto been used.

In contradistinction to conventional practice, the method of the invention expressly involves the use of relatively large quantities of phosphorus (and the surprising results obtainable thereby) so that the amount of phosphorus contained in the end product is substantially higher than that found in conventional self-lubricating materials. The amount of phosphorus added to the base metal, according to the invention in the form of phosphorus alloys or compounds, is still somewhat greater than the amount remaining in the end product, in order to allow for volatilization and burn-up which occur during heat treatment, and for the deoxidation reaction. The method of the invention enables a material to be obtained which is substantially less brittle and more ductile than other, conventional self-lubricating materials, while possessing a higher degree of elasticity and impact resistance. Its surface properties and strength also show substantial improvement over those of conventional materials.

A favorable composition of phosphorus and particles of base metal may be achieved by submitting the material, or the compressed-powder mixture, to a heat treatment at a temperature between 700 and 850° C. and preferably between 750 and 780° C. until the mass is rendered coherent.

In one particular embodiment of the invention, the phosphorus is added in the form of a phosphorus-copper compound or alloy, such as phosphor copper, preferably with a phosphorus content of between 5 and 20% by weight. The method of the invention enables materials to be produced with a high degree of ductility and impact resistance if the phosphorus compound or alloy is added in a quantity such that the amount of phosphorus contained in the end product is up to 2% by weight.

The method of the invention may be effected in either an oxidizing or an oxygen-free atmosphere. In the former case, the percentage of burn-off loss will be higher and the reaction more spontaneous. In both cases the preliminary pressure, by means of which the mass is shaped to a desired configuration, has to be increased to about 5 mp./cm.$^2$. Heat treatment is effected at a temperature of about 750 to 780° C. When using the method of the invention, it has been found to be of particular advantage, when the heat treatment is carried out in an oxidizing atmosphere, to add to the base-metal powder (i.e., copper or nickel or mixtures thereof) about 6% by weight of the powdered phosphorus copper with a 15% (by weight) phosphorus content and, subsequently, to hot-press the material.

Particularly good results are obtained if the method of the invention is practiced in an oxygen-free atmosphere, such as in a protective or anti-oxidation atmosphere, specifically a hydrogen-containing blanket. This has numerous important advantages. The phosphorus is permitted thereby to diffuse among and within the metal particles more completely so that the final structure is better defined and more uniform. It is possible to produce thin-walled sintered products and to achieve higher production tolerances during the subsequent cold-pressing process.

In another embodiment of the new method, when the heat treatment is carried out in an oxygen-free atmosphere, about 10% by weight of the powdered phosphorus copper with 15% phosphorus content is added to the primary metal powder. The greater degree of diffusion of the phosphorus among the metal particles, achieved when the method of the invention is used in conjunction with an oxygen-free atmosphere, yields a reduced fatigue notch factor (by conventional tests) and good ductility in the metal product obtained. In this particular embodiment, the invention provides for the preliminary and subsequent pressing of the material to be effected in the same die, thus considerably increasing the saving achieved by the new process. Advantageously, when the material is treated in an oxygen-free atmosphere, the heat treatment is followed by a cold-shaping and/or coining process. In a development of the invention it is also advisable, when treating the material in an oxygen-free atmosphere, to effect a final annealing step at a temperature of up to 750° C. in a hydrogen atmosphere.

The invention enables relatively large quantities of solid lubricant to be added to the mixture for the material to be produced, without thereby impairing its ductility and impact resistance. The invention thus provides for a finely powdered solid lubricant to be added to the powder mixture in a quantity of between 4 and 12% or in granulated form in a quantity of between 8 and 25% by weight.

The invention also relates to materials thus produced by powder metallurgy; according to the invention, the material has the following composition: copper and/or nickel primary metal, a phosphorus content of about 0.5 to 2% by weight, and a solid lubricant, such as graphite, in a proportion of between 4 and 25% by weight. This material possesses a high degree of ductility and impact resistance while retaining excellent properties of self-lubrication. A particularly important feature of this material of the invention resides in that the phosphorus combines with the primary metal on the surface of the primary-metal particles. The contact between the primary-metal particles is thus permanently established by the combination of the phosphorus with the primary metal.

The material may also contain metals such as lead, tin, zinc, nickel, cobalt, manganese and/or silver, in order to improve the physical properties of the material. Advantageously, where lead is included in the material, the lead content may be up to 20% by weight.

In order that the invention may be more clearly understood, reference will now be made to the following specific examples.

## Example I

A powder mass was formed by combining 6% by weight of phosphorus copper (containing 15% by weight phosphorus) with copper particles (balance) of the type conveniently used in sintered-copper bearing materials and about 8% by weight of finely powdered graphite. The intimately mixed mass is cold-pressed at 5 mp./cm.$^2$ with a holding time of about 10 seconds. Thereafter, heat treatment was carried out for a period of 5 minutes in the normal furnace atmosphere of a muffle furnace fired by gas and containing oxygen. The heat-treatment temperature was 780° C. and a treatment period of 5 minutes was employed; it was found that the heat treatment could successfully be carried out at temperatures above 750° C. and most conveniently between 750° and 850° C., although the range of 750° to 780° C. was most desirable. Thereafter, the somewhat coherent body was hot-pressed at a pressure of 1.5 to 3 mp./cm.$^2$, depending upon the ratio of cross-ectional area to diameter and considering losses due to die friction; the hot-pressing step was carried out over a period of about 10 seconds. The body was removed from the die and found to have a markedly greater ductility and impact resistance than a body produced with copper particles of the identical size and under the identical conditions but lacking an admixture of phosphorus copper.

The impact strength and ductility was further increased by admixing up to 20% lead with the particles prior to the cold-pressing step, the ductility improving until the maximum lead content was reached.

It was found that between 4 and 12% by weight of the finely coated graphite did not affect the physical properties but could be used with excellent solid-lubrication results. Furthermore, tests showed that 8 to 25% by weight of graphite could be combined with the mass prior to cold-pressing when the graphite was in granular form.

A separate die was required for the cold-pressing step in order to achieve the desired density since the filling height was considerable. We have discovered that it is possible to reduce the filling height by a precompression of the powder, apart from any definite die conforming to the final or an intermediate shape, and thereafter granulating the precompressed mass. For example, an intermediate product could be produced by cold-pressing the composition described above in conventional cold-pressing dies and heating the precompressed mass in the furnace. The product may then be granulated and treated as indicated earlier.

Whenever hot-pressing is used, according to the present invention, we preheat the hot-pressing die to a temperature of 300° C. to 400° C. so that the blanks contained in the heating cups of the die are treated in the desired temperature range until hot-pressing pressure is achieved. After the pressure has been maintained for the specified holding time, the pressure is reduced and the pressed body removed and cooled in ambient atmosphere. If temperatures above 150° C. are employed for the hot-pressing step, a subsequent annealing or normalizing step may be carried out with good results.

When nickel is substituted for the copper of Example I in mixtures containing from 10% copper and 90% nickel to 10% nickel and 90% copper without or with up to 20% lead or other adjuvant metals (in the base-metal component), similar results are obtained.

## Example II

Three mixtures were prepared containing, respectively, copper, nickel and 50%/50% copper-nickel as the base-metal component and 10% by weight of powdered phosphorus copper (15% phosphorus content) and varying amounts of graphite between 4 and 25% by weight as indicated earlier, the graphite content within this range not affecting substantially the ductility and impact resistance. Each of the samples was subjected to cold-pressing at a pressure of 5 mp./cm.$^2$ for a period of 10 seconds and then to oxygen-free sintering as described below. The cold-pressed blanks were packed in hermetically sealed containers to which powdered graphite and charcoal had been placed to preclude decarburization. The heat treatment was carried out at a temperature of 750° C. in nonoxidizing atmosphere for at least 20 minutes. Thereafter, the containers were opened and heat-treated blanks were removed and cooled. The cold-pressing was carried out at 3 mp./cm.$^2$ over a period of 10 seconds.

In this system, the heat treatment was effected between two cold-pressing steps at ambient temperature and a graphite range of 4 to 12% by weight was found to be most desirable. Again, up to 20% by weight of lead could be added to each of these samples with improved ductility as indicated earlier.

## Example III

With compositions prepared as described in Examples I and II, thin-walled test blanks were prepared. In this case, a preliminary pressing and granulation was not carried out. The cold-pressing was effected at a pressure of 5 mp./cm.$^2$ for the period indicated earlier and the heat treatment was effected at temperatures between 750° C. and 850° C. in a furnace atmosphere of hydrogen. Thereafter, cold-pressing was carried out at pressures up to 8 mp./cm.$^2$ and followed by an annealing at temperatures up to 750° C. in a hydrogen atmosphere.

In all of these samples, the bodies had greater impact resistance and ductility than corresponding specimens made without the phosphorus copper. When agglomerated powder is used, the agglomeration pressure should be lower than the cold-pressing pressure. In this case, after each of two heat treatments, the bodies are cooled in a protective atmosphere to a temperature below 200° C. and usually to room temperature before the second cold-pressing. In this system, the same set of dies may be used for both pressing stages while graphite, in the range of 4 to 12% by weight, is effectively employed in the compositions.

We claim:

**1.** A bearing composition consisting of a uniformly coherent mass of particles of a base metal selected from the group consisting of copper, nickel, and mixtures thereof, 0.5–2% by weight of phosphorus, and 4–25% by weight of graphite.

**2.** The bearing composition of claim **1** wherein the phosphorus is present as phosphor copper containing between 5 and 20% by weight of phosphorus.

**3.** The bearing composition of claim **2** wherein said phosphor copper contains 15% by weight of phosphorus and is present in an amount of 6–10% by weight of the bearing composition.

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