Patented Feb. 6, 1945 2,368,943

UNITED STATES PATENT OFFICE

2,368,943

POWDER METALLURGY OF BRASS

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No Drawing. Application February 11, 1941, Serial No. 378,445

13 Claims. (Cl. 75—22)

This invention is concerned with the powder metallurgy of brass and contemplates the manufacture of improved brass objects by powder metallurgical methods. The invention provides improvements in such methods and contemplates the production of improved brass objects of accurate configuration having physical properties superior to those heretofore obtainable in brass objects formed by compression and heat-treatment of metal powders.

It has been proposed heretofore to form brass objects by powder metallurgical methods. Thus, it has been proposed to form metal compacts by compressing pre-alloyed powders of brass or intimate mixtures of the powders of the constituent elements, i. e., copper and zinc, and to heat the compact to weld together the particles thereof. However, the physical properties of the resulting brass objects have been inferior to the properties of brass objects made by casting, forging and the like. The use of brass objects formed by powder metallurgical methods has, therefore, been much restricted. Moreover, the metal compacts have manifested a tendency to swell or puff during heat-treatment (especially when the compacts were unconfined) so that the resulting brass objects frequently have been distorted or porous. In many instances, the final object has been distorted almost beyond recognition. Thus, compacts of pre-alloyed brass powders or of mixtures of copper and zinc powders in the form of rectangular slugs have been distorted into pillow shapes during heat-treatment. Moreover, even when serious distortion did not occur, the brass objects formed heretofore by powder metallurgical methods have compared unfavorably with cast or forged brass with respect to tensile strength, impact strength, and, especially, ductility.

As a result of my investigations, I have discovered that the difficulties described above may be overcome in large measure by including in the powder compacts from which the brass objects are made a small proportion of phosphorus, i. e., 0.1% to about 1% on the weight of the powder. Thus, I have found that:

(1) The tendency of "brass" compacts (i. e., compacts made by compressing unalloyed or pre-alloyed powders of copper and zinc), to puff during heat-treatment increases as the zinc content of the compact is raised;

(2) This tendency to puff can be combated successfully (even when the compact is unconfined during heat-treatment) by including in a brass compact (consisting predominantly of copper and zinc and containing from 90% to 55% copper, with the balance predominantly zinc), a small proportion of phosphorus, say, 0.1–1% by weight, which small proportion prevents distortion during heat-treatment and permits the production of small brass particles of accurate configuration;

(3) The incorporation in such compacts of phosphorus in the aforementioned proportions not only prevents puffing of the compacts during heat-treatment but also improves the physical properties of the resulting brass objects and especially the ductility and "twistability" thereof;

(4) The presence of lead in "brass" compacts containing no phosphorus tends to reduce ductility and results in the production of objects with black surfaces and heterogeneous structure due to sweating and segregation of the lead, but the inclusion of small proportions of phosphorus in the compact permits the lead to be included therein in substantial proportions, i. e., up to about 6%, without bringing about sweating and segregation and with resultant increases not only in the ductility of the brass object, but also in its machinability. Generally speaking, the higher the copper content of the compact the greater is the proportion of lead that can be included therein advantageously;

(5) When the compact is unconfined during heat-treatment, the surface of the resulting brass object becomes rougher as the phosphorus content is raised. But, as the copper content of the compact is raised the greater is the proportion of phosphorus that can be included without causing

the surface of the resulting object to be roughened excessively during heat-treatment;

(6) As the phosphorus content of the compact is raised, the temperature of heat-treatment of the compact to give optimum physical properties in the resulting brass object decreases;

(7) In general, the presence of aluminum in the compacts is undesirable whether or not such compacts contain phosphorus;

(8) The effect of small proportions of manganese (say, up to about 1%) in the compacts is beneficial under certain circumstances, but harmful in others and depends upon the nature of the brass powder employed to form the compact. If the compact is formed of "diffused" brass powders (i. e., brass powder formed by heating a mixture of copper and zinc powders to bring about the formation of brass powder by diffusion) manganese brings about a slight increase in ductility if no phosphorus is present, but decreases ductility substantially while improving surface characteristics of the heat-treated object if phosphorus is present. If the compact is made of atomized brass (i. e., powder produced by atomizing and chilling molten brass), the presence of small proportions of manganese in the compact decreases tensile strength of the heat-treated object without improving the surface characteristics thereof or curing puffing when no phosphorus is present. If phosphorus is present in such compacts, the manganese brings about a marked decrease in strength and does not improve the surface of the resulting heat-treated object;

(9) Atomized brass powders give best results with compacts containing a large proportion of copper, say, 90%. For compacts containing a smaller proportion of copper, say, 70% or less, it is preferable to employ diffused brass powders.

To summarize, my invention contemplates the production of brass objects by compression of metal powders containing copper and zinc (the copper content of the powder ranging from about 90% to about 55%, and the balance being predominantly zinc) to form a compact, and the heat-treatment of the compact to bring about a welding together of the powder particles therein, phosphorus in proportions ranging from about 0.1% to about 1% on the weight of the powder being included in the metal powders, in order to prevent puffing of the compact during heat-treatment and to improve the physical properties (particularly ductility) of the resulting brass object. Puffing of "brass" compacts tends to be most pronounced when they are subjected to heat-treatment in a relatively unconfined state, i. e., outside of the mold. Hence, the above-described process offers its greatest advantages when the compact is heat-treated in a relatively unconfined state.

In order to improve the machinability of the resulting brass object, the above-described process may be modified by including in the compact substantial proportions of lead, but not exceeding 6% by weight. When the phosphorus is present, such incorporation of lead may be effected without sweating and segregation and with an increase in ductility as well as in the machinability of the resulting brass object.

If the copper and zinc employed in making the compact are in the form of "diffused" brass powder, i. e., powder formed by heating an intimate mixture of copper powder and zinc powder to bring about alloying of the copper and zinc while the powder form is maintained, up to 1% manganese may be included in the compact with improvement in the surface characteristics of the heat-treated object but with sacrifice of a considerable degree of ductility.

The presence of aluminum (even in proportions as low as 1% or less) should be avoided, for aluminum tends to cause the compact to become fused and distorted at very low temperatures.

These and other features of my invention will be more thoroughly understood in the light of the following detailed description of presently preferred practices thereof, taken in conjunction with the comparative test data which illustrate the advantages obtainable in the practice of my invention as compared with heretofore customary practices.

The compacts may be prepared from a mixture of the elements included therein, or from pre-alloyed powders. Thus, the copper and zinc may be employed as an intimate mixture of the respective powders, or as powdered brass. I prefer to employ the copper and zinc in a pre-alloyed form. Brass powder may be prepared for use in the invention by atomizing molten brass or by subjecting a mixture of copper and zinc powders to a preliminary heat-treatment to bring about diffusion and alloying of the copper and zinc with each other while maintaining these metals in the powdered condition. As indicated hereinbefore, atomized powder is superior to diffused powder in certain instances and vice versa.

The phosphorus may be added in elemental form as powdered red phosphorus, or as phosphor-copper or other combination of phosphorus and metal. In any case, the phosphorus should be in finely-divided form and should be intimately incorporated in the powder mixture prior to the formation of the compact.

In the tests reported hereinafter, the phosphorus was sometimes added as finely-divided phosphor-copper containing 7.55% by weight phosphorus, and in other instances the phosphorus was included with the copper and zinc in a pre-alloyed brass powder produced either by atomization or diffusion. Both systems of adding the phosphorus are satisfactory and neither offers outstanding advantages over the other, so far as the character of the final product is concerned.

In all of the tests reported hereinafter, the compacts were made by compression in a ring-shaped mold under a force of 50 tons per square inch. The brass powders employed were all fine enough to pass through a 200 mesh screen. Phosphor-copper employed was of —325 mesh and the lead powder use was likewise all through —325 mesh.

The powders, preparatory to compression in the mold, were mixed in a non-oxidizing atmosphere for three hours. Thorough mixing is required and a rotary mixer turning at about 100 R. P. M. (i. e., relatively rapidly), produces the necessary degree of homogeneity of the powder in the three hour period.

The compacts were sintered for two hours in an atmosphere of hydrogen and were thereafter cooled in such atmosphere prior to exposure to the air. The temperature of heat-treatment varied from 800° C. to 900° C. Specific treatment temperatures for the various compacts and data as to the character of the resulting brass objects are given in the following table.

Ductility was determined by twisting the brass objects until fracture occurred and measuring the degree of twist.

TABLE I

Composition, treatment and properties of brass objects made in accordance with the invention

No.	Kind of brass powder used	Constituents, parts by weight				Temp., °C	Nature of surface of sintered object	Ductility [1]
		Cu	Zn	P	Pb			
								Degrees
1	Atomized	90	10	¼		890	Excellent	300
2	do	90	10	½		875	Good	350
3	do	90	10	1		860	Good, slight roughness	380
4	do	90	10	1	6	820	do	360
5	Diffused	90	10	1		830	do	360
6	do	90	10	1	6	870	do	225
7	Atomized	70	30	¼		890	Good	250
8	do	70	30	½		875	Good, slight roughness	200
9	do	70	30	1		820	Fair, medium rough	300
10	Diffused	70	30	1		860	Fair, slight roughness	400
11	Atomized	70	30	1	1	820	Rough	270
12	Diffused	70	30	1	1	820	do	200
13	do	70	30	1		860	do	270
14	do	70	30	1	[2] 1	870	Good	180

[1] As measured by angular degrees twist before fracture.
[2] Parts by weight manganese.

A series of comparative tests were run in order to demonstrate the effect of no phosphorus and various percentages of phosphorus (with and without lead) in 90–10 brasses and 70–30 brasses. The results of these tests are given in Table II as follows:

TABLE II

No.	Kind of brass powder used	Constituents, parts by weight				Temp. of heat treatment, °C.	Nature of surface of sintered object	Degrees twist before fracture
		Cu	Zn	P	Pb			
A	Atomized	90	10			900	Excellent	270
1	do	90	10	¼		890	do	300
2	do	90	10	½		875	Good	350
3	do	90	10	1		860	Good, slight roughness	380
4	do	90	10	1	6	820	do	360
B	do	70	30			900	Smooth, but compact puffed	100
7	do	70	30	¼		890	Good	250
8	do	70	30	½		875	Good, slight roughness	200
9	do	70	30	1		820	Good, medium rough	300
11	do	70	30	1	1	820	Rough	270
C	Diffused	70	30			900	Smooth, but compact puffed	160
10	do	70	30	1		860	Fair, slight roughness	400
12	do	70	30	1	1	820	Rough	200

It will be observed that in the case of the 90–10 brasses it is unnecessary to include phosphorus in order to prevent puffing of the compacts during heat-treatment. However, inclusion of various proportions of phosphorus up to 1% in such compacts brings about a marked improvement in the ductility of the brasses giving a serious roughness to the surface. Moreover, if phosphorus in proportions of 1% is incorporated in the compact, it is possible to incorporate as much as 6% by weight of lead, thus improving the machinability of the product while at the same time maintaining high ductility.

As shown from the data in Table I, atomized brass is to be preferred when manufacturing brasses in the 90–10 range, since higher ductility, generally speaking, is obtained with this material.

When manufacturing 70–30 brasses in accordance with my invention, the optimum proportion of phosphorus to include is somewhat less than 1%, since such a proportion of phosphorus tends to bring about considerable roughening of the surface. However, in cases where an absolutely smooth surface is not desired, it is practicable even with the 70–30 brasses to use as much as 1% phosphorus, for this permits a substantial increase in the ductility of the resulting object. In the case of the 70–30 brasses, it is desirable to use diffused powder rather than atomized powder, because a higher ductility is thus attained.

With the 70–30 brasses (if lead is included with a view toward improving machinability), it is desirable to use less than 6%. Good results are obtained employing approximately 1% lead and 1% phosphorus.

As shown by the data of Table II, the optimum temperature of heat-treatment depends upon the ratio of copper to zinc present and also upon the proportion of phosphorus. Thus, the higher the zinc content and the higher the phosphorus content, the lower should be the treatment temperature. With 90–10 brasses containing about ¼% phosphorus, optimum results are obtained at a treatment temperature of about 890° C. The treatment temperature for such brasses drops to about 870° C. when the phosphorus content is raised to ½% and to 860° C. when the phosphorus content is raised to 1%. With 70–30 brasses, optimum results are obtained at about 890° C. when ¼% phosphorus is present, at about 850° C. when the phosphorus content is raised to ½% and about 840° C. when the phosphorus content is raised to 1%. Generally speaking, the treatment temperature for the various brasses will range from about 900° C. to about 800° C. Temperatures in excess of 900° C. should be avoided.

As indicated hereinbefore, aluminum is an undesirable ingredient in the compacts made and treated in accordance with my invention. Thus, a 70–30 brass containing no phosphorus but with 1% aluminum had good surface characteristics

but was fused during heat-treatment at 900° C. and badly distorted. Under similar circumstances, except that the 70–30 brass containing 1% aluminum also contained 1% phosphorus, the resulting brass object had a powdery surface and was brittle and weak after heat-treatment at 860° C.

My preferred practice in the case of 90–10 brasses, when both high ductility and good surface is required, is to use 90–10 "atomized" brass powder mixed with ½% phosphorus as finely-divided phosphor-copper. This mixture is compressed under high pressure, say, 50 to 75 tons per square inch, and is thereafter sintered in hydrogen for two hours at about 875° C. If a slight roughness of surface can be tolerated, the phosphorus content may be raised to 1% in which case the optimum heat-treatment temperature is about 830–860° C.

In producing brasses of the 70–30 type, I prefer to employ "diffused" brass powders containing about ¼% to ½% phosphorus. The heat-treatment conditions are the same as those for the 90–10 brasses, except that the treatment temperatures should be about 10° less. If a relatively rough surface can be tolerated in the final object, the phosphorus content can be raised to ½–1% and such increase in phosphorus content brings about a substantial increase in ductility.

Any non-oxidizing atmosphere can be employed in heat-treatment but a hydrogen atmosphere appears to be most suitable in that it permits a higher ductility to be obtained.

The invention may be applied to the manufacture of a variety of brass forms, but offers particular advantages in the manufacture of brass objects that must be accurately shaped and of high ductility and machinability, for example, cartridge cases, rivets, slide fastener parts, etc.

The high ductility of brass objects produced in accordance with my invention is illustrated by the fact that they can be repeatedly cold rolled without intermediate annealing until a reduction in thickness of 87–97% is attained, without developing edge cracks or other defects. Thus, brass objects made in accordance with my invention containing about 70 parts of copper, 30 parts of brass, and ¼ to ½ part of phosphorus are extremely ductile as indicated by the following results of cold rolling tests, in which the samples were rolled as many as eighteen times without intermediate annealing and without the development of cracks even at the edges of the samples:

TABLE III

Sample No.	Initial thickness	Passes	Final thickness	Per cent red. thickness
	In.		*In.*	
X	.104	14	.009	91
Y	.104	15	.006	94
Z	.104	18	.003	97

I claim:

1. In the production of brass objects by compression of metal powders containing copper and zinc, the copper content of the powder ranging from about 90% to 55%, to form a compact and the heat-treatment of the compact to bring about a welding together of the powder particles therein, the improvement which comprises including in the metal powders employed to form the compact phosphorus in proportions ranging from about 0.1% to 1% of the weight of the powder.

2. In the production of brass objects by powder metallurgical methods, the improvement which comprises forming a compact by compressing a loose mass of metal powders having dispersed therein about 0.1% to 1% phosphorus and about 90% to 55% copper, the balance being substantially all zinc, and heat-treating the compact to bring about diffusion welding of the powder particles of the compact.

3. In the production of brass objects by powder metallurgical methods, the improvement which comprises forming a compact by compressing a loose mass of metal powder having dispersed therein about 0.1% to 1% phosphorus and about 90% to 55% copper, the balance being substantially all zinc, and heat-treating the compact in a relatively unconfined state to bring about diffusion welding of the powder particles of the compact.

4. In the production of brass objects by powder metallurgical methods, the improvement which comprises forming a compact by compressing a loose mass of metal powder having dispersed therein about 0.1% to 1% phosphorus, about 90% to 55% copper, and lead in substantial proportions but not exceeding 6%, the balance being substantially all zinc, and heat-treating the compact to bring about diffusion welding of the powder particles thereof.

5. In the production of brass objects by powder metallurgical methods, the improvement which comprises forming brass powder by heating an intimate mixture of copper powder and zinc powder to bring about diffusion of the copper and zinc with resultant formation of brass powder, forming a compact by compressing the resultant brass powder together with phosphorus in proportions ranging from about 0.1% to 1% and manganese in substantial proportions but not exceeding about 1%, the copper content of the compact being about 90% to 55%, and heat-treating the compact to bring about diffusion welding of the powder particles thereof.

6. In the production of brass objects by powder metallurgical methods, the improvement which comprises forming a compact by compressing a loose mass of metal powders containing about 0.1% to 1% phosphorus, about 90% to 55% copper, the balance being substantially all zinc, and heat-treating the compact in a non-oxidizing atmosphere at a temperature ranging from about 800° C. to 900° C. to bring about diffusion welding of the powder particles.

7. In the production of brass objects by powder metallurgical methods, the improvement which comprises compressing into a compact a loose mass of brass powder containing of the order of 90% copper and 10% zinc, the said brass powder having been formed by atomizing molten brass, and the loose mass containing about 0.1% to 1% phosphorus, and heat-treating the compact to bring about diffusion welding of the powder particles thereof.

8. In the production of brass objects by powder metallurgical methods, the improvement which comprises compressing into a compact a loose mass consisting predominantly of brass powder made by heat-treatment of a mixture of copper and zinc powder to bring about diffusion in the formation of the brass powder, the copper and zinc contents of the resulting diffused powder being of the order of 70% and 30%, respectively, said loose mass of powder containing about 0.1% to 1% phosphorus, and heat-treating the com-

pact to bring about diffusion welding of the powder particles thereof.

9. In the production of brass objects by powder metallurgical methods, the improvement which comprises forming a compact by compressing a loose mass of metal powder containing about 0.1% to 1% phosphorus initially combined with copper and about 90% to about 55% copper, the balance being substantially all zinc, and heat-treating the compact to bring about diffusion welding of the powder particles thereof.

10. A ductile brass article of accurate configuration comprising a compressed and sintered mass of metal powders containing from 90% to 55% copper and 0.1% to 1.0% phosphorus, the balance being substantially all zinc.

11. A ductile brass article of accurate configuration comprising a compressed mass of metal powder particles sintered together and containing from 90% to 55% copper, 0.1% to 1.0% phosphorus and lead in substantial proportions but not to exceed 6%, the balance being substantially all zinc.

12. A ductile brass article of accurate configuration comprising a compressed mass of metal powder particles sintered together and composed of a mixture of about 90 parts of copper, 10 parts of zinc, and 0.1 to 1.0 part of phosphorus.

13. A ductile brass article of accurate configuration comprising a sintered mixture of metal powder particles containing about 70 parts copper, about 30 parts zinc, and 0.1 to 1.0 part phosphorus.

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CERTIFICATE OF CORRECTION.

Patent No. 2,368,943. February 6, 1945.

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, first column, line 55, before the word "giving" insert --without--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 22nd day of May, A. D. 1945.

Leslie Frazer

(Seal) Acting Commissioner of Patents.