

1

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POWDER METALLURGY

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1 Claim. (Cl. 75-201)

This invention relates to metal powder compositions and products pressed and sintered from them.

In the production of iron articles by powder metallurgical techniques it is common practice to add to the iron powder various other powders to develop special properties, such as strength, porosity, corrosion resistance or the like in the pressed and sintered articles. It has been proposed to apply such methods to powdered iron substantially free from carbon mixed with from 0.25 to 1.0 percent of phosphorus. A disadvantage vexatious to fabricators of such mixtures is that the compacts undergo radial shrinkage during sintering. Such decrease in dimension is particularly objectionable in that the obtention of parts of the desired dimensions is difficult and waste may be high due to the necessity to reject undersized parts.

It is among the objects of this invention to provide iron powder compositions containing phosphorus and carbon in substantial amount which upon being formed into various articles by pressing and sintering undergo reduced and unobjectionable shrinkage as compared with similar compositions substantially free from carbon, and which may actually exhibit a desirable amount of radial growth.

It is another object of the invention to provide iron powders according to the foregoing object which may be pressed and sintered without modification of existing practices in those operations.

It is a further object to provide a process of suppressing radial shrinkage of articles pressed and sintered from powder mixtures containing iron and phosphorus.

This invention is predicated upon my discovery that the characteristic shrinkage of pressed and sintered articles of substantially carbon-free iron and 0.25 to 1.0 percent of phosphorus can be controlled in a simple manner by introducing a definite but limited amount of carbon, preferably by adding carbon, most suitably as graphite, to the original powder mixture. The resulting articles, contrary to the usual result of evidencing objectionable shrinkage, are characterized by reduced and unobjectionable shrinkage, by substantial dimensional stability, or by an increase in the radial dimension, according to adjustment of the original powder mixture.

Thus a major advantage of iron powder products made in accordance with this invention is that the shrinkage, or decrease in radial dimension, that occurs with mixtures of carbon-free iron powders containing phosphorus is minimized with an actual increase in dimension being obtainable, if desired, or a substantially stable dimension is obtained. Attendant also upon the use of this invention is the obtention of these desirable results without the necessity of using appreciable amounts of other expensive additive materials.

Iron powder mixtures in accordance with the present invention comprise about 0.25 to 1.75 percent by weight of added carbon, preferably as graphite, about 0.25 to 1.0 percent by weight of phosphorus, and the balance substantially all substantially pure iron. Other elements

2

may, of course, be present so long as they do not deleteriously affect the advantageous results described. These materials are usually present in impurity quantities and include, for example, manganese, silicon, sulfur, nickel, copper, vanadium, aluminum, and the like. Where silicon is present, its amount should be limited to a maximum of 0.4 percent, preferably 0.3 percent, by weight of the total mixture. These mixtures are then pressed and sintered according to conventional practice.

Phosphorus is generally present in the powder in amounts of about 0.25 to 1.0 percent by weight. The phosphorus to most advantage is introduced as ferro-phosphorus, for example as ferro-phosphorus containing about 15 to 35 percent by weight of phosphorus, and preferably ferro-phosphorus analyzing at about 24 to 26 percent phosphorus.

Products produced in accordance with the present invention are not characterized by the excessive brittleness that has been ascribed to the inclusion of carbon in these Fe-P powder compositions. Also, ductility and sintered strength and similar properties are consistently satisfactory in the articles of this invention. Certain combinations of properties are characteristic of each specific composition with the described ranges and the development of other special properties can be obtained through judicious use of additional components. By way of illustration, copper powder in amounts of about 3 to 10 percent by weight of the total composition can be included. Copper is known to limit shrinkage and even produce radial growth in pressed and sintered articles made from substantially carbon-free iron powder with small amounts of phosphorus. Its use in the compositions according to the present invention is beneficial where reduced shrinkage or greater growth is desired than is obtained in similar compositions containing the specified amounts of carbon but no copper. Copper also produces an increase in the modulus of rupture, ultimate tensile strength and hardness as compared with similar compositions containing no copper. Where the additional cost of the copper powder is not of pressing significance, its use may be indicated to obtain the further improvement in properties just described.

In practicing the invention, a typical powder mixture that I have used with satisfaction is an iron powder mixture containing about 2.50 percent by weight of a 250 mesh ferro-phosphorus having a phosphorus content of 24 to 26 percent by weight. The mixture has the following chemical and physical characteristics:

Table I

Chemical data¹—

Hydrogen loss, percent	0.72
Total carbon, percent	0.25
Acid insolubles, percent	0.25
Ferrophosphorus, 24-26% and 250 mesh, percent	2.50

Physical data¹—

Apparent density (Hall)	2.62
Flow (Hall)	28.60
Screen, percent—	
On 60	0.40
On 80	14.80
On 100	4.30
On 150	28.50
On 200	17.00
On 325	21.70
Th 325	13.30

¹ All percentages are by weight based on the total composition.

To samples of this mixture quantities of graphite were intimately admixed. The mixtures were then placed in steel dies, pressed at 30 t.s.i. and sintered in hydrogen for 30 minutes at 2020° F. One percent by weight of zinc stearate was added to all of the powder mixtures as a lubricant. Typical data on these compacts appear below. Modulus of rupture and radial growth or shrinkage were determined by use of the standard transverse bar 1.25" long x 0.500" wide by approximately 0.25" thick; radial measurements were based upon the green bar. For comparative purposes similar bars were also made from compositions obtained by adding copper to a sample of the starting mixture, while both copper and graphite were added to other samples. A bar of the iron powder alone also was made and tested. The data are:

Table II

Composition	Modulus Of Rupture, p.s.i.	Change In Radial Dimension, Percent ²	Ultimate Tensile Strength, p.s.i.	Elongation In One Inch, Percent	Hardness, RB
1. Mixture A ¹	80,000	-.95	36,000	2.00	48.0
2. Mixture A +.50% graphite.....	68,000	-.20	32,000	1.75	45.0
3. Mixture A +.75% graphite.....	74,000	+.16	33,000	1.50	46.0
4. Mixture A +1.0% graphite.....	75,000	+.30	37,500	1.50	48.0
5. Mixture A +1.5% graphite.....	66,500	+.36	32,600	1.50	52.0
6. Mixture A +3.0% copper.....	86,000	-.05	42,300	1.25	50.0
7. Mixture A +3.0% copper +.50% graphite.....	84,000	+.25	43,000	1.00	51.0
8. Mixture A +3.0% copper +.75% graphite.....	92,000	+.40	44,400	1.25	55.0
9. Mixture A +3.0% copper +1.0% graphite.....	94,000	+.50	45,300	1.25	58.0
10. Iron Powder alone.....	40,125	-.16	16,500	4.00	18.7 RE

¹ Mixture A in all cases is iron powder +2.50% FeP.

² Minus indicates shrinkage; plus indicates growth.

It will be observed upon comparing compositions 1 and 2 that the inclusion of carbon materially reduces the radial shrinkage of pressed and sintered iron-phosphorus powder mixtures. Indeed, in the upper ranges of carbon, significant growth was obtained (compare compositions 3, 4 and 5 with 2). In compositions 6 through 9, copper was included. By comparing compositions 7 with 2, 8 with 3, and 9 with 4, the effect of the conjoint use of copper and carbon can be observed. It can also be observed that compositions containing copper have the better properties as regards modulus of rupture, ultimate strength and hardness. Surprisingly, the use of carbon usually increases the value of these properties when copper is present rather than producing the expected decrease. This can be observed by comparing compositions 7, 8 and 9 with 6.

A further measure of control of shrinkage attends the choice of carbon added to the iron and phosphorus powder mixtures, for certain graphites have a more pronounced effect than others. This was demonstrated by preparing standard bars from powder mixes while varying the quantity and type of graphite. Two commercially available graphites were used. The data obtained are:

Table III

Composition	Modulus Of Rupture, p.s.i.	Change In Radial Dimension, Percent ²	Ultimate Tensile Strength, p.s.i.	Elongation In One Inch, Percent	Hardness, RB
11. Mixture A ¹ +.50% graphite I.....	67,000	-.25	31,000	1.00	44.9
12. Mixture A +.50% graphite II.....	67,500	-.24	28,600	1.00	41.8
13. Mixture A +.75% graphite I.....	68,600	+.18	32,700	1.00	42.1
14. Mixture A +.75% graphite II.....	68,300	-.18	30,600	.50	40.2
15. Mixture A +1.0% graphite I.....	73,600	+.35	37,500	1.00	42.4
16. Mixture A +1.0% graphite II.....	65,000	-.01	29,050	.50	44.9

¹ Mixture A in all cases is iron powder +2.50% FeP.

² Minus indicates shrinkage; plus indicates growth.

Upon comparing any of compositions 11 through 16 with composition 1, the reduced shrinkage attending the addition of carbon to iron-phosphorus powder mixtures will be apparent. The measure of this reduction varies with the type and amount of graphite added. Thus, 0.75 percent of graphite A resulted in growth while that amount of graphite B in a similar compact resulted in shrinkage, as may be seen by comparing compositions 13 and 14, or by comparing compositions 15 and 16. By using a mixture of different graphites, the growth or shrinkage of the resultant compact may be intermediate that obtained upon using an equal amount of either graphite alone.

According to the provisions of the patent statutes, I have explained the principle of my invention and have described what I now consider to represent its best em-

bodiment. However, I desire to have it understood that, within the scope of the appended claim, the invention may be practiced otherwise than as specifically described.

I claim:

That method of suppressing the radial shrinkage of articles manufactured by pressing and sintering, in an atmosphere consisting essentially of hydrogen, a mixture of powders consisting essentially of iron powder and about 0.25 to 1.0 percent by weight of phosphorus which comprises adding to said mixture sufficient elemental carbon to result in a carbon content of the pressed and sintered article of about 0.25 to 1.75 percent based on the total composition.

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