United States Patent Office 3,689,257 Patented Sept. 5, 1972

3,689,257

METHOD OF PRODUCING SINTERED FERROUS MATERIALS

Teishiro Oda and Takashi Daikoku, Nakasaki-shi, Japan, assignors to Mitsubishi Jukogyo Kabushiki Kaisha, Tokyo, Japan

No Drawing. Filed Apr. 23, 1969, Ser. No. 818,796
Int. Cl. B22f 1/00
U.S. Cl. 75—214 4 Claims

ABSTRACT OF THE DISCLOSURE

The uses of sintered ferrous materials for important structural machine parts are considerably limited because of substantially inferior mechanical properties in usual forgings and castings of the same composition in spite of the fact that sintering materials can be produced at relatively low cost and they eliminate machining due to the close tolerances obtainable.

In order to overcome the above-mentioned faults and to attain sintered ferrous materials with high density, high strength and excellent ductility, there is provided a method of liquid phase sintering of ferrous materials in which Fe-Si alloy powders with more than 7 weight percent of Si, and the remainder Fe are added to iron powders at the rate of 0.3–10 weight percent of Si.

BACKGROUND OF THE INVENTION

The present invention relates to a method of producing sintered ferrous materials.

Owing to the advantages that sintered materials can be produced at a relatively low cost and scarcely need to be machined because of the good dimensional accuracy of their products, sintered materials have been used as structural machine parts. But sintered materials inevitably become porous through their production method, and so they are inferior in mechanical properties to castings and forgings of the same composition. Particularly, in sintered ferrous materials where the variation of dimensions between before and after sintering is very small, such a tendency is so remarkable that the sintered ferrous materials in the present state are hardly applicable for important structural parts or for heavily loaded usages.

Efforts have been made to produce sintered materials having densities close to the theoretical value. The object of such effort was to remarkably enlarge the application of such sintered materials. A method has been developed for reducing the porosity of such sintered materials as much as possible and for rasing the density and consequently the strength of such materials. This prior attempt involves increasing the compacting pressure. For instance, in the case of reduced iron powder, the density of green compacts amounts to about 78% of the real density of iron at compacting pressure of 4 ton/cm.^{2}, and to 90% at 8 ton/cm.^{2}. Like this, the green compacts and consequently more dense sintered materials are attained by increasing the compacting pressure. On the other hand, this method leads to a short die life due to an increasing die wear and requires a large capacity press, so that the adoption of this method is difficult for practical reasons. Therefore, compacting pressure is limited to 4–6 ton/cm.^{2} at most, and then, the density of green compacts obtained in such a way is in general only on the order of 6.0–6.6 gr./cm.^{3}. Accordingly, when such green compacts are sintered, it is considerably more difficult to obtain dense sintered materials, because the progress of sintering is very low and the materials scarcely shrink owing to the solid phase sintering.

Moreover, as a manufacturing method for sintered ferrous materials of a high density, such a method as (1) multi-pressing and multi-sintering, (2) liquid phase sintering and (3) infiltration has been usually employed. However, these methods have the following faults:

(1) The multi-compacting and multi-sintering method is such that the compaction and sintering are repeated more than several times so that the cost of such a sintered material becomes inevitably expensive.

(2) The liquid phase sintering is a useful method as a means of attaining dense sintered products. For sintering of iron powders it has been intended to accelerate the sintering rate by the addition of boron or phosphorous to the iron powder in the form of powdered ferro-boron or ferro phosphorous, each of which yields the liquid phase at the sintering temperature employed. In this case, the greater the quantity of the additive, the better the densification attained, and so dense sintered products are attained. On the contrary, the addition of above 0.8% P and above 0.2% B causes hard and brittle eutectoid constituent to remain at the grain boundaries and as a result, to reduce considerably the ductility of the sintered materials, consequently, this method is not suitable for practical uses. Besides, a liquid phase sintering by the addition of Cu has been carried out, but this method is not practical because the intrinsic properties of Cu itself make a sintered iron brittle.

(3) Infiltration is the method of filling molten Cu into the pores of sintered iron by the use of capillary phenomenon thereby making the sintered materials dense. However, this method exceedingly limits the ductility of sintered products as in the case of liquid phase sintering by the addition of Cu.

SUMMARY OF THE INVENTION

The principal object of the present invention is to obviate the above-mentioned faults of the usual sintering methods and to produce sintered irons having high density, high strength and excellent ductility.

In accordance with the invention there is proposed a method of producing sintered ferrous materials comprising a sintering operation with the addition of Fe-Si alloy powders comprising more than seven weight percent Si the balance of said powder being Fe, to iron powders with an addition ratio to said powders of 0.3–10 weight percent of Si.

That is, the method of the present invention consists in adding to iron powders the Fe–Si alloy which is composed of more than 7 percent by weight of Si with the balance thereof being Fe, in place of boron or phosphorous since these letters can not be added thereto in such quantities to make a satisfactory improvement in the sintering characteristics of the iron powder. The solid solubility of Si into Fe is so large that quantities of Si up to 10% can be added. Consequently, the rate of sintering can be sufficiently improved, while the matrix can also be strengthened by Si so that it becomes easy to get sintered ferrous materials of high density, high strength and excellent ductility.

The effects of Fe-Si alloy in the present invention will be explained as follows: The alloys of below 7 weight percent Si, are not practical because their liquid phase may not be formed below 1400° C. On the other hand, Fe-Si alloys containing above 7 weight percent Si may yield a liquid phase below 1400° C. so that the liquid phase sintering can be carried out practically without question. In the above-mentioned composition range of Fe-Si alloys, alloys containing above 17.5 weight percent Si are especially favourable, since they form a liquid phase at 1200–1220° C. or higher. As will be shown in the following executed examples, the addition of these alloys are capable of accelerating markedly the progress of sintering at just above the temperature of liquid phase

formation, that is, even at 1225° C. Therefore, it is the feature of the present invention to be capable of sintering at temperatures near 1130–1220° C., which are generally adopted as the sintering temperatures of iron. In this case, as the quantities of Fe-Si alloy powders added, the addition of 0.3–10 weight percent Si to iron powders is desirable. The reason why this composition range is determined is as follows; the addition of less than 0.3 weight percent Si hardly improves the strength of sintered materials and the addition of more than 10 weight percent Si abruptly reduces their mechanical properties.

In short, according to the present invention, sintered ferrous materials having high strength and excellent ductility can easily be produced with usual forming pressure, so that the method of the present invention is exceedingly useful.

TABLE 1

	Fe-Si alloy (Si percent)	Sintering time (hr.)	0.2% proof stress (kg./mm.²)	Tensile strength (kg./mm.²)	Elongation (percent)	Reduction of area (percent)
The method of the present invention	0.3	1	11.9	23.1	12.0	11.0
		3	12.2	23.8	16.8	12.7
		5	11.9	24.5	17.6	12.9
	1	1	12.3	24.4	15.2	10.6
		3	12.8	26.2	15.2	11.4
		5	13.5	27.5	17.6	13.8
	2	1	22.9	40.8	16.8	16.4
		3	21.6	40.5	19.2	21.3
		5	22.3	42.8	26.0	33.4
	3	1	29.2	46.8	25.2	31.1
		3	28.5	47.6	26.8	33.7
		5	27.1	48.3	30.8	44.0
	4	1	36.5	53.7	23.6	28.7
		3	37.1	55.5	23.0	32.1
		5	35.2	54.3	20.0	21.3
	6	5	45.2	60.0	14.0	15.9
	8	5	46.8	63.3	12.4	11.1
	10	5	21.3	29.8	8.8	7.3
The usual method	----------	1	8.6	17.9	19.2	14.6
	----------	5	10.6	19.4	15.0	14.8

NOTE.—Sintering temperature=1,275° C.; compacting pressure=5 ton/cm.².

TABLE 2

	Fe-Si alloy (Si percent)	Sintering time (hr.)	0.2% proof stress (kg./mm.²)	Tensile strength (kg./mm.²)	Elongation (percent)	Reduction of area (percent)
The method of the present invention	3	1	27.0	43.2	18.8	19.
		3	28.7	46.8	26.0	29.
		5	27.8	47.2	26.8	32.
	4	1	35.8	50.6	18.8	23.
		3	37.8	54.1	23.2	33.
		5	38.2	55.9	26.0	30.
	6	5	46.2	60.0	16.2	16.
	8	5	54.6	63.8	8.6	8.
The usual method	----------	1	8.4	17.5	15.2	11.
	----------	5	9.6	18.0	18.4	13.

NOTE.—Sintering temperature=1,225° C.; compacting pressure=5 ton/cm.².

DESCRIPTION OF A PREFERRED EMBODIMENT

The examples executed according to the present invention will be explained as follows: In Table 1, the mechanical properties of the sintered irons sintered at 1275° C. are compared between the method of the present invention with different additions of Fe-Si alloys and the usual method. In Table 2, the mechanical properties of the sintered irons sintered at 1225° C. are compared between the method of the present invention and the usual method. From these executed examples it will clearly be seen that the method of the present invention permits the attainment of sintered irons with strength and excellent ductility.

Moreover, it goes without saying that the method of the present invention gives full play to the effect in the case of adding such alloying elements to iron as C, Mn, Cr, Ni, Cu, Co, W, Mo, Cb, Ti and the like for the purpose of strengthening of the matrix.

What is claimed is:

1. Process for production of high strength and density ferrous materials which comprises admixing ferrosilicon alloy powder with iron powder in an amount sufficient to yield a mixture of iron powder and ferrosilicon alloy powder having an amount of silicon therein from about 0.3 to about 10 percent by weight, said ferrosilicon alloy powder consisting essentially of silicon in an amount from just more than seven percent by weight of said alloy to an amount adapted to maintain said alloy in liquid phase at temperatures from about 1225° C. to about 1275° C., the remainder of said alloy being iron; whereby a ferrous material is produced having a tensile strength of from about 23 kg./mm.² to about 64 kg./mm.², and a 0.2% proof stress of from about 12 to about 55 kg./mm.².

2. The process of claim 1, in which the sintering is carried out for a period of from about one to about ten hours.

3. Process according to claim 1, in which the compacting is carried out at about 5 ton/cm.².

4. Process according to claim 3, in which the sintering is carried out for a period of from about one to about five hours.

(References on following page)

5

References Cited

UNITED STATES PATENTS

2,226,520 11/1939 Lenel ..... 75—200

OTHER REFERENCES

Constitution of Binary Alloys, Mat Hansen, 2nd edition, McGraw-Hill, 1958, TA490, H27aE, pp. 711–717.

6

R. L. Sands et al.: Powder Metallergy, p. 210, George Newnes Limited (1966), TN695S2.

CARL D. QUARFORTH, Primary Examiner

R. E. SCHAFER, Assistant Examiner

U.S. Cl. X.R.

75—200, 227