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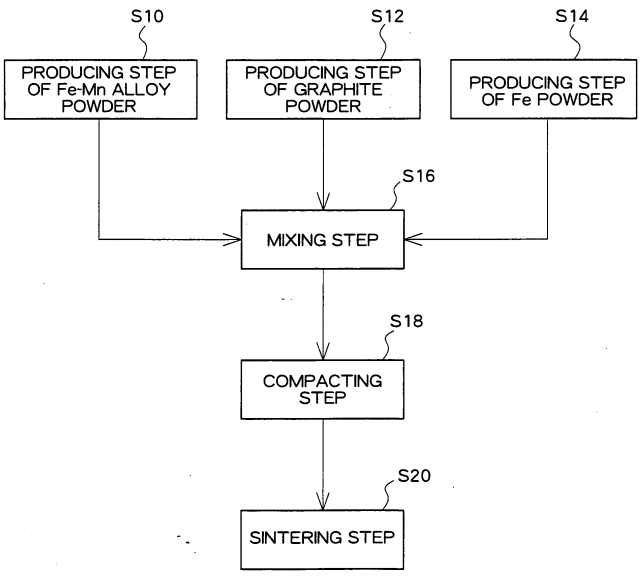
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(54) IRON-BASED SINTERED ALLOY

(57) There is here disclosed an Fe-based sintered alloy produced through a mixing step of mixing an Fe-Mn alloy powder, graphite powder and Fe powder by a mixer (S16), a compacting step of compacting the mixed powder at a predetermined pressure (S18), and a sintering step of sintering the resultant compact in a sintering oven at a predetermined temperature for a predetermined time (S20), the Fe-Mn alloy powder being **characterized by** containing 2-30 mass% of Mn. In particular, the mixing step (S16) is carried out by mixing 5-50 mass% of the Fe-Mn alloy powder, 0.2-2 mass% of the graphite powder, and the remainder of the Fe powder in the mixer. Consequently, mechanical strength of the Fe-based sintered alloy can be further improved.

Fig. 1



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Description

Technical Field

[0001] The present invention relates to an Fe-based sintered alloy, and more particularly, it relates to an Fe-based sintered alloy produced through a mixing step of mixing an Fe-Mn alloy powder, graphite powder and Fe powder, a compacting step of compacting the mixed powder, and a sintering step of sintering the resultant compact.

Background Art

[0002] A powder metallurgical technique has advantages that size control and compacting of a complex shape are easier and a cost is lower compared with parts producing techniques of casting, forging and the like. Therefore, the powder metallurgical technique is widely used. Particularly in sintered structure parts for automobiles, many Fe-based sintered alloys are used.

[0003] Among the Fe-based sintered alloys, Fe-Cu-based sintered alloys each produced by mixing an Fe powder, Cu power and graphite, followed by compacting and sintering, have heretofore been used. Here, the Cu powder is melted at a sintering temperature or less of the Fe powder to promote the sintering with the Fe powder, whereby mechanical strength of the sintered alloy is effectively improved. A sintering temperature of the Fe-Cu-based sintered alloys is usually in a range of 1100°C to 1200°C. The Fe-Cu-based sintered alloys are applied to, for example, clutch hubs, connecting rods and the like for automobiles.

[0004] Furthermore, in the Fe-based sintered alloy, the improvement of the mechanical strength has been made by adding any of various metallic powders and alloy powders. For example, in an Fe-Mn-Si-based sintered alloy produced by mixing an Fe-Mn-Si alloy powder including Mn and Si in place of the Cu powder with the Fe powder and graphite powder, compacting and then sintering the resultant mixture, the mechanical strength has been further improved. The above Fe-Mn-Si-based sintered alloy is principally sintered at 1200°C or more to promote the sintering of the Fe-Mn-Si alloy powder and the Fe powder, because a liquid phase line of the Fe-Mn-Si alloy powder is at substantially 1200°C (e.g., see Non-patent Literature 1).

[0005] Non-patent Literature 1: Zongyin Zhang and another, Fe-Mn-Si master alloy steel by powder metallurgy processing, Sweden, Journal of Alloys and Compounds, 2004, Vol. 363, p. 194-202.

Disclosure of the Invention

[0006] To lighten the weight of sintered structure parts for automobiles at a low cost, it is necessary to further improve mechanical strength of the parts at a sintering temperature equal to that of an Fe-Cu-based sintered alloy in the above conventional technique. Furthermore, in a case where an Fe-Mn-Si alloy powder is used in place of a Cu powder and sintered at the same sintering temperature as that of the Fe-Cu-based sintered alloy, during the sintering of the Fe-Mn-Si alloy powder and an Fe powder, the dispersion of an element such as Mn between the powders might be disturbed by an oxide film of Si in the alloy powder formed on the surface of the alloy powder. In consequence, the sintering cannot be promoted any more in some cases. Morever, owing to the addition of Si, an intermetallic compound of Fe and Si is formed in the Fe-Mn-Si alloy powder, and hence the alloy power becomes hard. In consequence, the density of a compact decreases, whereby the density of the sintered alloy also decreases, and hence sufficient mechanical strength cannot be obtained in some cases.

[0007] Accordingly, an object of the present invention is to provide an Fe-based sintered alloy having improved mechanical strength produced through a mixing step of mixing an Fe-Mn alloy powder, graphite powder and Fe powder, a compacting step of compacting the mixed powder, and a sintering step of sintering the resultant compact.

[0008] The Fe-based sintered alloy according to the present invention is an Fe-based sintered alloy produced through a mixing step of mixing an Fe-Mn alloy powder, graphite powder and Fe powder, a compacting step of compacting the mixed powder, and a sintering step of sintering the resultant compact, and the Fe-Mn alloy powder is characterized by containing Mn in an amount of 2-30 mass%.

[0009] In the production of the Fe-based sintered alloy according to the present invention, the mixing step is preferably accomplished by mixing 5-50 mass% of Fe-Mn alloy powder, 0.2-2 mass% of the graphite powder and the remainder of the Fe powder.

[0010] As understood from the above, in the production of the Fe-based sintered alloy according to the present invention, the Fe-Mn alloy powder is used in place of the Cu powder, and hence the mechanical strength can be improved at the same sintering temperature as that of the Fe-Cu-based sintered alloy of a conventional technique.

Brief Description of the Drawings

[0011]

Fig. 1 is a diagram showing production steps of an Fe-based sintered alloy, in an embodiment according to the present invention;

Fig. 2 is a diagram showing composition ratios of Mn and the like of Fe-Mn alloy powders produced in Examples A to D, Fe-Mn alloy powders in Comparative Examples E and F, an Fe-Mn alloy powder in Example G, and Fe-Mn-Si alloy powders in Comparative Examples H to J, in embodiments according to the present invention;

Fig. 3 is a diagram showing material powder mixing ratios and the like of Fe-based sintered alloys in Examples 1 to 4, Fe-based sintered alloys in Comparative Examples 5 to 7, an Fe-based sintered alloy in Example 8, and Fe-based sintered alloys in Comparative Examples 9 to 16, in embodiments of the present invention;

Fig. 4 is a diagram showing a shape of a compact which is compacted in a compacting step, in the embodiment according to the present invention;

Fig. 5 is a microgram showing a metallic texture of the Fe-based sintered alloy in Example 2, in the embodiment according to the present invention;

Fig. 6 is a diagram showing tensile strengths and the like' in cases where a plurality of conditions such as compacting conditions and sintering conditions are set in Fe-based sintered alloys in Examples 17 to 25, in the embodiments according to the present invention;

Fig. 7 is a diagram showing contents of Mn and the like contained in Fe-based sintered alloys in Examples 26 to 31, in the embodiments according to the present invention.

Best Mode for Carrying out the Invention

[0012] Embodiments of the present invention will be described in detail with reference to the drawings. Fig. 1 is a diagram showing production steps of an Fe-based sintered alloy. The Fe-based sintered alloy is produced by a step (S10) of producing an Fe-Mn alloy powder containing Mn in an amount of 2-30 mass%, a step (S12) of producing a graphite powder, a step (S14) of producing an Fe powder, a mixing step (S16) of mixing these powders, a compacting step (S18) of compacting the mixed powder, and a sintering step (S20) of sintering the resultant compact.

[0013] First, the step (S10) of producing the Fe-Mn alloy powder will be described.

[0014] The Fe-Mn alloy powder is produced by a gas atomization process so as to obtain the powder having less oxide contents. Needless to say, the production of the Fe-Mn alloy powder may be made by use of a mechanical production process such as pulverization, a production process by electrolysis, a chemical production process by reduction of an oxide or thermal decomposition, or a water atomization process for producing the powder from a molten metal by jet.

[0015] Here, Mn contained in the Fe-Mn alloy powder plays a role of promoting the sintering between the Fe-Mn alloy powder and the Fe powder by the diffusion of Mn during the sintering. The reason why the content of Mn in the Fe-Mn alloy powder is 2 mass% or more is that if the content of Mn is less than 2 mass%, the diffusion promotion of Mn is poor. The reason why the content of Mn is 30 mass% or less is that if the content of Mn is more than 30 mass%, compactibility of the powder in the compacting step (S18) deteriorates and mechanical strength of a sintered alloy cannot be improved. Therefore, the Fe-Mn alloy powder containing Mn in an amount of 2-30 mass% is used.

[0016] As the Fe-Mn alloy powder, there is used a powder passed through a sieve having a predetermined mesh to regulate particle diameters. If the Fe-Mn alloy powder has large particle diameters, a filling ratio of the powder is low during the compacting of the Fe-Mn alloy powder by the compacting step (S18), which has an influence on the mechanical strength of the sintered alloy. The Fe-Mn alloy powder having particle diameters of, for example, 5-50 μm is used. Needless to say, the particle diameters of the Fe-Mn alloy powder may be 5-200 μm or 5-100 μm, and these particle diameters are not particularly limited.

[0017] Next, the production step (S12, S14) of producing the graphite powder and Fe powder will be described. The graphite powder is produced by a mechanical production process such as pulverization and then it is used. Needless to say, the graphite powder may be produced by a chemical production process such as thermal decomposition and then it may be used. Furthermore, the Fe powder is produced by a water atomization process and then it is used. Needless to say, it may be produced by a mechanical production process such as pulverization, a gas atomization process, or a reduction process.

[0018] The mixing step (S16) of mixing the Fe-Mn alloy powder, the graphite powder and the Fe powder will be described. A mixed powder is obtained by mixing 5-50 mass% of the Fe-Mn alloy powder, 0.2-2 mass% of the graphite powder and the remainder of the Fe powder, and the resultant mixed powder is then used.

[0019] The Fe-Mn alloy powder is added to promote the diffusion of elements between the powders during the sintering. The reason why an amount of the Fe-Mn alloy powder is 5 mass% or more is that if a mixing ratio of the Fe-Mn alloy powder is less than 5 mass%, the promotion of the Mn diffusion is poor, with the result that the mechanical strength of the sintered alloy is not sufficiently improved. The reason why a mixing ratio of the Fe-Mn alloy powder is 50 mass% or less is that if the mixing ratio of the Fe-Mn alloy powder is more than 50 mass%, the compactibility of the powder in the compacting step (S18) deteriorates and the mechanical strength of the sintered alloy cannot be improved. In consequence, the Fe-Mn alloy powder is used in a mixing ratio of 5-50 mass%.

[0020] The graphite powder is added to reinforce the Fe-based sintered alloy. The reason why a mixing ratio of the graphite powder is 0.2 mass% or more is that if it is less than 0.2 mass%, a ferrite increases and hence hardness of the sintered alloy deteriorates, which leads to the deterioration of the mechanical strength. The reason why a mixing ratio of the graphite powder is 2 mass% or less is that if it is more than 2 mass%, a cementite increases and hence toughness of the sintered alloy deteriorates. Therefore, the graphite powder is used in a mixing ratio of 0.2-2 mass%.

[0021] In the mixing step (S16), the Fe-Mn alloy powder, graphite powder and Fe powder are sufficiently dried, and these powers are then put into a mixer, followed by mixing. It is to be noted that a lubricant may be added thereto for the purpose of decreasing friction between a mold and the mixed powder in the subsequent compacting step (S18). As the lubricant, a stearate such as zinc stearate is used. Needless to say, the stearate is not limited, and another type of lubricant may be used. As the mixer for mixing these powders, a V-type mixer may be used, but this is not particularly limited.

[0022] Next, the compacting step (S18) of compacting the mixed powder of the Fe-Mn alloy powder, graphite powder and Fe powder will be described. To impart a predetermined shape to the mixed powder, for example, a mold is packed with the mixed powder. The mold packed with the mixed powder is pressed in a monaxial direction to compact it. Needless to say, the press direction is limited to the monaxial direction, and the mixed powder may be pressed in an isostatic direction. As a pressure to compact the mixed powder, 800 Mpa is used. Needless to say, the pressure may be in a range of 500 MPa to 1500 MPa, but these pressures are not particularly limited.

[0023] As a compacting device, a pressing machine or the like is used in a case where the mixed powder is pressed in the monaxial direction. It is to be noted that in a case where the mixed powder is pressed in the isostatic direction, there is used a CIP (cold isostatic pressing) device, an HIP (hot isostatic pressing) device, or the like. Needless to say, any compacting machine may be used as long as it can apply the above pressure, and hence the aforesaid devices are not limited. The mixed powder is compacted at room temperature, but this temperature is not limited, and the mixed powder may be compacted while being heated.

[0024] Next, the sintering step (S20) of sintering the resultant compact will be described. The compact obtained by compacting the mixed powder is released from the mold, and then sintered in a sintering furnace. For an atmosphere in the sintering furnace, an inert gas, for example, an argon gas or a helium gas is used. Needless to say, the sintering atmosphere is not particularly limited, and a decomposed gas of ammonia, hydrogen, or a nitrogen gas may be used. A vacuum atmosphere may also be used.

[0025] As a sintering temperature, for example, 1150°C is used. Needless to say, the sintering temperature may be in a range of 1100°C to 1250°C. These sintering temperatures are not particularly limited. As a sintering time, for example, a time of 30 minutes is used. Needless to say, the sintering time may be in a range of 10 minutes to 120 minutes, and these times are not particularly limited. As the sintering furnace used in the sintering step (S20), a general sintering furnace for use in powder metallurgy can be used. The sintering furnace is not particularly limited, so long as it can adjust the above sintering atmosphere, sintering temperature and sintering time.

[0026] As will be understood from the above, according to the Fe-based sintered alloy, Mn in the Fe-Mn alloy powder diffuses in the Fe powder to promote the sintering, so that the mechanical strength of the Fe-based sintered alloy can be further improved. Accordingly, sintered structure parts for automobiles can be lightened at a low cost.

Example 1

[0027] Fig. 2 is a diagram showing composition ratios of Mn and the like of Fe-Mn alloy powders produced in Examples A to D, Fe-Mn alloy powders in Comparative Examples E and F, an Fe-Mn alloy powder in Example G, and Fe-Mn-Si alloy powders in Comparative Examples H to J. The alloy powders in Examples A to D, the Fe-Mn alloy powder in Example G, and the alloy powders in Comparative Examples E and F were produced by a gas atomization process using an inert gas. Furthermore, the alloy powder in Comparative Example H was produced by a gas atomization process using an inert gas, the alloy powder in Comparative Example I was produced by a pulverization process, and the alloy powder in Comparative Example J was produced by a water atomization.

[0028] In the alloy powders in Examples A to D, contents of Mn were 2.5 mass%, 6 mass%, 18 mass% and 28 mass%, respectively. The alloy powders in Examples A to D were Fe-Mn alloy powders containing 2-30 mass% of Mn. In the alloy powders in Comparative Examples E and F, contents of Mn were 1.5 mass% and 40 mass%, respectively. The alloy powders produced in Examples A to D and the alloy powders in Comparative Examples E and F were classified through a sieve of 330 mesh, and particle diameters of the Fe-Mn alloy powders were adjusted to 50 μm or less.

[0029] In the alloy powder in Example G, a content of Mn was 6 mass%. The particle diameter of the alloy powder in Example G was 100 μm or more, which was larger than that of the other alloy powders.

[0030] The alloy powders in Comparative Examples H to J were produced for comparison with the Fe-Mn alloy powders. In each of the alloy powders in Comparative Examples H to J, a content of Mn was 6 mass%, which was the same as that of Mn in the alloy powder in Example B. Furthermore, each of the alloy powders in Comparative Examples H to J contained 2 mass% of Si. For the alloy powders in Comparative Examples H to J, the production processes thereof were different from each other as described above, and hence contents of oxygen contained in the alloy powders were different. The content of oxygen in the alloy powder in Comparative Example H was 0.06 mass%, and compared with an oxygen content of 0.2 mass% in the alloy powders in Comparative Examples I to J, the alloy powder in Comparative Example H produced by the gas atomization process had the smallest oxygen content. The alloy powders in Compar-

ative Examples H to J were classified through a sieve of 330 mesh, and a particle diameter of each alloy powder was adjusted to 50 μm or less.

[0031] Fig. 3 is a diagram showing material powder mixing ratios and the like of Fe-based sintered alloys in Examples 1 to 4, Fe-based sintered alloys in Comparative Examples 5 to 7, an Fe-based sintered alloy in Example 8, and Fe-based sintered alloys in Comparative Examples 9 to 16.

[0032] In the Fe-based sintered alloys in Examples 1 to 4, a mixing ratio of the alloy powder in Example A was 45 mass%, a mixing ratio of the alloy powder in Example B was 30 mass%, a mixing ratio of the alloy powder in Example C was 10 mass%, and a mixing ratio of the alloy powder in Example D was 6 mass%, respectively. Mixing ratios of the Fe-Mn alloy powders in the Fe-based sintered alloys in Examples 1 to 4 were all in a range of 5 mass% to 50 mass%.

[0033] In the Fe-based sintered alloys in Comparative Examples 5 and 6, mixing ratios of the alloy powder in Comparative Example E were 60 mass% and 99 mass%, respectively. In the Fe-based sintered alloy in Comparative Example 7, a mixing ratio of the alloy powder in Comparative Example F was 2 mass%. In the Fe-based sintered alloy in Example 8, a mixing ratio of the alloy powder in Comparative Example G was 3 mass%.

[0034] Furthermore, in every case of the Fe-based sintered alloys in Examples 1 to 4, the Fe-based sintered alloys in Comparative Examples 5 to 7, and the Fe-based sintered alloy in Example 8, a mixing ratio of the graphite powder was 1 mass%, which was in a range of 0.2 mass% to 2 mass%.

[0035] In each of the Fe-based sintered alloys in Comparative Examples 9 to 11, a mixing ratio of the alloy powders in Comparative Examples H to J was 30 mass%, and a mixing ratio of the graphite powder was 1 mass%.

[0036] In each of the Fe-based sintered alloys in Comparative Examples 12 to 13, a mixing ratio of the alloy powder in Example B was 30 mass%. Furthermore, in the Fe-based sintered alloy in Comparative Example 12, a mixing ratio of the graphite powder was 0.1 mass%, and in the Fe-based sintered alloy in Comparative Example 13, a mixing ratio of the graphite powder was 2.5 mass%.

[0037] In the Fe-based sintered alloy in Comparative Example 14, a mixing ratio of the alloy powder in Example A was 55 mass%, and in the Fe-based sintered alloy in Comparative Example 15, a mixing ratio of the alloy powder in Example D was 3 mass%. In every case of the Fe-based sintered alloys in Comparative Examples 14 and 15, a mixing ratio of the graphite powder was 1 mass%. It is to be noted that the Fe-based sintered alloy in Comparative Example 16 was a conventional Fe-based sintered alloy which was mixed with a Cu powder stipulated in JIS S MF4050.

[0038] For the production of the Fe-based sintered alloy shown in Fig. 3, material powders of each Fe-based sintered alloy were mixed in a mixing ratio shown in Fig. 3 in the above mixing step (S16). Prior to the mixing, 0.8 mass% of zinc stearate was added as a lubricant to the material powders, and the mixing was carried out by use of a V-type mixer.

[0039] The mixed powder obtained by the mixing in the mixing step (S16) was compacted in the above compacting step (S18). The compacting was carried out by putting the mixed powder into the mold, and then pressing it at 800 MPa in a monaxial direction by a pressing machine. Fig. 4 is a diagram showing a shape of a compact which was compacted in the compacting step (S18).

[0040] The compact obtained in the compacting step (S18) was sintered in the above sintering step (S20). The sintering was carried out at a sintering temperature of 1150°C for a sintering time of 30 minutes in a nitrogen gas atmosphere by use of a sintering furnace. For the Fe-based sintered alloys shown in Fig. 3, tensile tests were carried out at room temperature in accordance with JIS Z 2241. A shape of each test piece for the tensile test was the same as shown in Fig. 4. Furthermore, a tensile test speed was 0.5 mm/minute in terms of a cross head speed of a tensile tester.

[0041] According to the results of the tensile tests, as shown in Fig. 3, the Fe-based sintered alloys obtained in Examples 1 to 4 had tensile strengths of 620-650 MPa. It is shown that all the Fe-based sintered alloys were more improved in tensile strength than the conventional Fe-based sintered alloy in Comparative Example 16. Furthermore, the Fe-based sintered alloys in Examples 1 to 4 had higher tensile strengths than the other Fe-based sintered alloys shown in Fig. 3, and particularly in the Fe-based sintered alloys in Examples 1 to 4, higher tensile strengths were obtained than the Fe-based sintered alloys using Fe-Mn-Si alloy powders in Comparative Examples 9 to 11.

[0042] For the Fe-based sintered alloys shown in Fig. 3, density measuring tests were carried out in accordance with JIS Z 2501. The shape of a test piece for each density measuring test was the same as shown in Fig. 4. According to the results of the density measuring tests, as shown in Fig. 3, the Fe-based sintered alloys obtained in Examples 1 to 4 had densities of 7.15-7.25 g/cm^3. As will be understood from the above, in the Fe-based sintered alloys in Examples 1 to 4, higher densities were obtained than the other Fe-based sintered alloys shown in Fig. 3.

[0043] To examine a diffusion state of Mn from the Fe-Mn alloy powder into the Fe powder, a concentration of Mn at a site formed from the Fe powder was analyzed using electron probe micro-analysis (EPMA). As an example, Fig. 5 is a microgram showing a metallic texture of the Fe-based sintered alloy in Example 2. As an analyzer, an X-ray microanalysis device (type: MACHS200, made by Shimadzu Seisakusho Ltd.) was used. In the Fe-based sintered alloys in Examples 1 to 4, the concentrations of Mn at the site formed from the Fe powder were in a range of 1 mass% to 2 mass%. In the Fe-based sintered alloys in Examples 1 to 4, the concentrations of

Mn at the site formed from the Fe powder were higher than the other Fe-based sintered alloys shown in Fig. 3, and it is shown that Mn was diffused in large quantities from the Fe-Mn alloy powder into the Fe powder during the sintering.

[0044] Fig. 6 is a diagram showing tensile strengths and the like in a case where a plurality of conditions such as compacting conditions and sintering conditions are set in Fe-based sintered alloys in Examples 17 to 25. The Fe-based sintered alloys in Examples 17 to 25 were produced by mixing 30 mass% of the alloy powder in Example B, 1 mass% of the graphite powder and the remainder of the Fe powder in mixing ratios, and setting a plurality of conditions of a compacting pressure in the above compacting step (S18) as well as a sintering temperature and a sintering time in the above sintering step (S20).

[0045] The Fe-based sintered alloys in Examples 17 to 19 were produced setting compacting pressures to 300 MPa, 500 MPa and 1500 MPa while a sintering temperature of 1150°C and a sintering time of 30 minutes were fixed. The Fe-based sintered alloys in Examples 20 to 22 were produced setting sintering temperatures to 1050°C, 1100°C and 1250°C while a compacting pressure of 800 MPa and a sintering time of 30 minutes were fixed. The Fe-based sintered alloys in Examples 23 to 25 were produced setting sintering times to 5 minutes, 10 minutes and 120 minutes while a compacting pressure of 800 MPa and a sintering temperature of 1150°C were fixed.

[0046] For the Fe-based sintered alloys in Examples 17 to 25, tensile tests and density measuring tests were carried out in the above test manners. As shown in Fig. 6, the Fe-based sintered alloys having tensile strengths of 600 MPa or more were obtained by compacting under compacting pressures of 500-1500 MPa, and then sintering at sintering temperatures of 1100°C-1250°C for sintering times of 10-120 minutes. Furthermore, the Fe-based sintered alloys having tensile strengths of 600 MPa or more had densities of 7.2-7.4 g/cm^3.

[0047] Fig. 7 is a diagram showing contents of Mn and the like contained in Fe-based sintered alloys in Examples 26 to 31. The Fe-based sintered alloys in Examples 26 and 29 were Fe-based sintered alloys including the alloy powder in Example A in mixing ratios of 30 mass% and 15 mass%, respectively. The Fe-based sintered alloys in Examples 27 and 30 were Fe-based sintered alloys including the alloy powder in Example C in mixing ratios of 25 mass% and 35 mass%, respectively. The Fe-based sintered alloys in Examples 28 and 31 were Fe-based sintered alloys including the alloy powder in Example D in mixing ratios of 15 mass% and 25 mass%, respectively. Furthermore, each of the Fe-based sintered alloys in Examples 26 to 31 included the graphite powder in a mixing ratio of 1 mass%.

[0048] Each of the Fe-based sintered alloys in Examples 26 to 31 was produced by mixing material powders in a material powder mixing ratio shown in Fig. 7 in the above mixing step (S16), pressing and compacting the mixed powder at 800 MPa in the above mixing step (S18), and then sintering the resultant compact at a sintering temperature of 1150°C for a sintering time of 30 minutes in the above mixing step (S20).

[0049] For the Fe-based sintered alloys in Examples 17 and 25, tensile tests, density measuring tests and concentration analyses of Mn at a site formed from the Fe powder were carried out in the above manners. A content of Mn in each Fe-based sintered alloy was measured and calculated using a high-frequency plasma atomic emission spectrometer (ICP).

[0050] As shown in Fig. 7, in the Fe-based sintered alloys in Examples 26 to 28, contents of Mn were 0.8 mass%, 4.5 mass% and 4.2 mass%, respectively. In the Fe-based sintered alloys in Examples 29 to 31, contents of Mn were 0.4 mass%, 6.3 mass% and 7.0 mass%, respectively. In every case of the Fe-based sintered alloys in Examples 26 to 28, tensile strengths were 600 MPa or more. Therefore, the content of Mn in the Fe-based sintered alloy which can obtain a tensile strength of 600 MPa or more was 0.5-5 mass%.

Claims

1. An Fe-based sintered alloy produced through
a mixing step of mixing an Fe-Mn alloy powder, graphite powder and Fe powder,
a compacting step of compacting the mixed powder, and
a sintering step of sintering the resultant compact,
the Fe-Mn alloy powder being **characterized by** containing 2-30 mass% of Mn.

2. The Fe-based sintered alloy according to claim 1, wherein the mixing step is **characterized by** mixing 5-50 mass% of the Fe-Mn alloy powder, 0.2-2 mass% of the graphite powder, and the remainder of the Fe powder.

Fig. 1

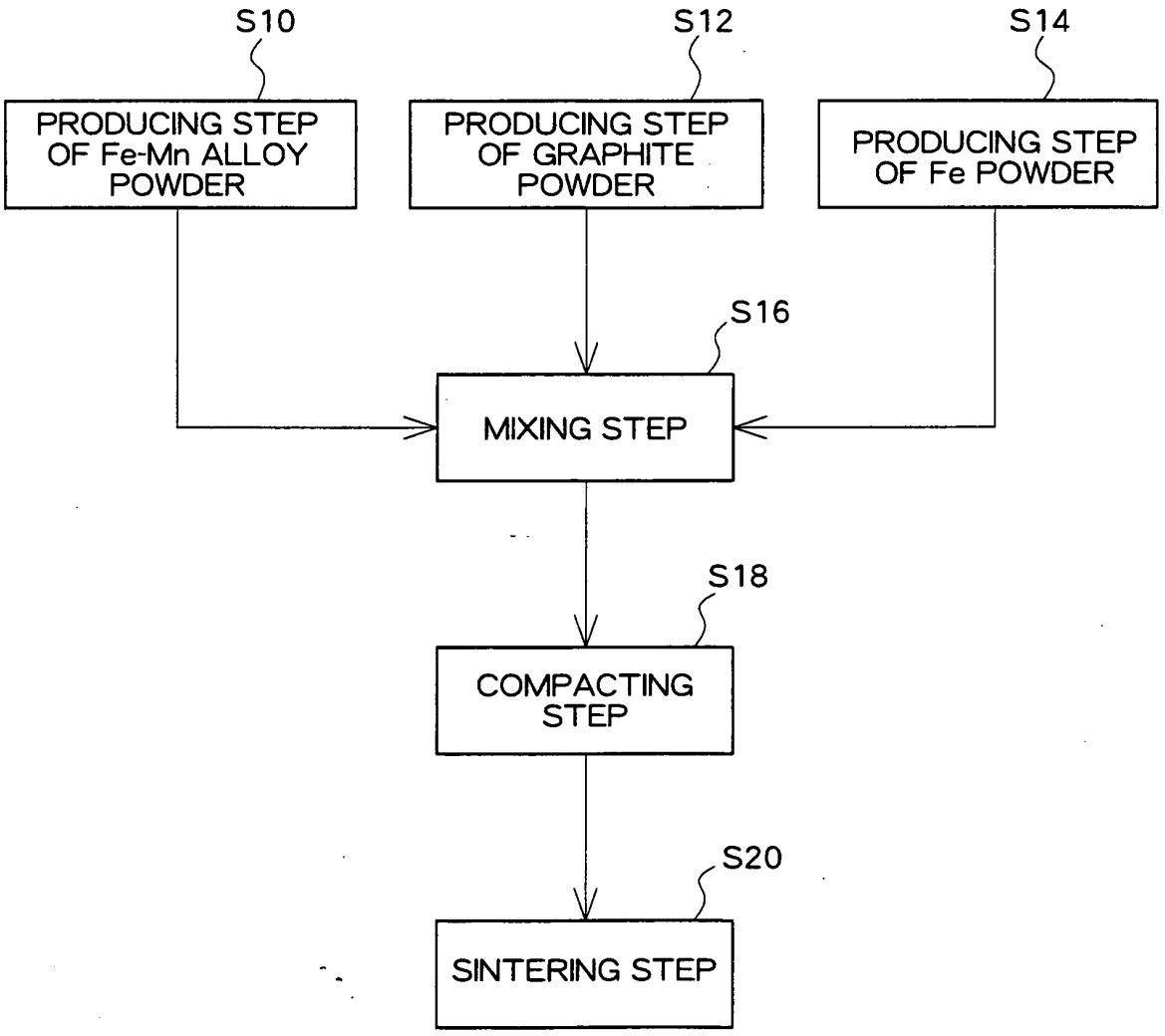

S10
S12
S14
PRODUCING STEP OF Fe-Mn ALLOY POWDER
PRODUCING STEP OF GRAPHITE POWDER
PRODUCING STEP OF Fe POWDER
S16
MIXING STEP
S18
COMPACTING STEP
S20
SINTERING STEP

Fig. 2

	CHEMICAL COMPONENTS %						
SIMBOL	Mn	Si	O	Fe	PARTICLE DIAMETER	PRODUCTION PROCESS	REMARKS
A	2.5	–	0.02	BAL	50 μm OR LESS	GAS ATOMIZATION	ALLOY POWDER EXAMPLE A
B	6	–	0.03	BAL	50 μm OR LESS	GAS ATOMIZATION	ALLOY POWDER EXAMPLE B
C	18	–	0.05	BAL	50 μm OR LESS	GAS ATOMIZATION	ALLOY POWDER EXAMPLE C
D	28	–	0.07	BAL	50 μm OR LESS	GAS ATOMIZATION	ALLOY POWDER EXAMPLE D
E	1.5	–	0.02	BAL	50 μm OR LESS	GAS ATOMIZATION	ALLOY POWDER IN COMPARATIVE EXAMPLE E
F	40	–	0.08	BAL	50 μm OR LESS	GAS ATOMIZATION	ALLOY POWDER IN COMPARATIVE EXAMPLE F
G	6	–	0.03	BAL	100 μm OR MORE	GAS ATOMIZATION	ALLOY POWDER EXAMPLE G
H	6	2	0.06	BAL	50 μm OR LESS	GAS ATOMIZATION	ALLOY POWDER IN COMPARATIVE EXAMPLE H
I	6	2	0.2	BAL	50 μm OR LESS	PULVERIZATION	ALLOY POWDER IN COMPARATIVE EXAMPLE I
J	6	2	0.2	BAL	50 μm OR LESS	WATER ATOMIZATION	ALLOY POWDER IN COMPARATIVE EXAMPLE J

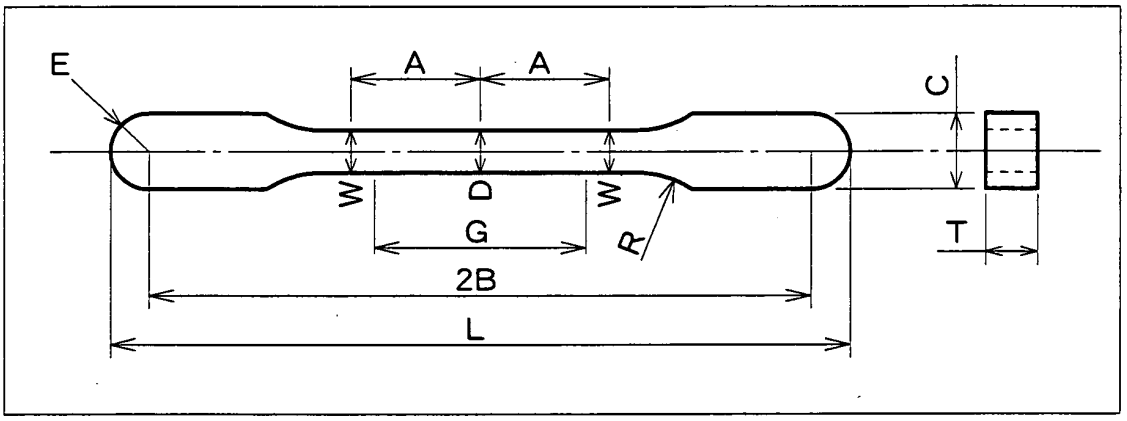
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Fig. 3

No.	ALLOY POWDER	MATERIAL POWDERS MIXING RATIO % ALLOY POWDER	GRAPHITE	COPPER POWDER	IRON POWDER	TENSILE STRENGTH (MPa)	DENSITY (g/cm 3)	CONCENTRATION % OF Mn AT SITE FORMED FROM IRON POWDER	REMARKS
1	A	45	1	–	54	620	7.23	1	SINTERED ALLOY IN EXAMPLE 1
2	B	30	1	–	69	650	7.25	2	SINTERED ALLOY IN EXAMPLE 2
3	C	10	1	–	89	630	7.2	2	SINTERED ALLOY IN EXAMPLE 3
4	D	6	1	–	93	620	7.15	1	SINTERED ALLOY IN EXAMPLE 4
5	E	60	1	–	39	480	7.1	0	SINTERED ALLOY IN COMPARATIVE EXAMPLE 5
6	E	99	1	–	–	420	6.95	–	SINTERD ALLOY IN COMPARATIVE EXAMPLE 6
7	F	2	1	–	97	500	7.05	0	SINTERED ALLOY IN CONTRACTIVE EXAMPLE 7
8	G	30	1	–	69	470	7.05	1	SINTERED ALLOY IN EXAMPLE 8
9	H	30	1	–	69	500	7.1	1	SNTERED ALLOY IN COMPARATIVE EXAMPLE 9
10	I	30	1	–	69	470	6.95	0.5	SINTERED ALLOY IN COMPARATIVE EXAMPLE 10
11	J	30	1	–	69	430	7.0	0	SINTERED ALLOY IN COMPARATIVE EXAMPLE 11
12	B	30	0.1	–	69.9	400	7.25	–	SINTERED ALLOY IN COMPARATIVE EXAMPLE 12
13	B	30	2.5	–	67.5	550	7.15	–	SINTERED ALLOY IN COMPARATIVE EXAMPLE 13
14	A	55	1	–	44	500	7.15	0	SINTERED ALLOY IN COMPARATIVE EXAMPLE 14
15	D	3	1	–	96	490	7.05	0	SINTERED ALLOY COMPARATIVE EXAMPLE 15
16	–	–	1	2	97	480	7.1	–	SINTERED ALLOY COMPARATIVE EXAMPLE 16

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Fig. 4



SIZE OF MOLD IS SHOWN.

GAGE LENGTH G=25

WIDTH AT CENTER D=5.70±0.02

WIDTH AT PARALLEL PORTION END W=5.96±0.02

THICKNESS T=4.00~5.00

RADIUS OF SHOULDER PORTION R=25

HALF OF PARALLEL PORTION LENGTH A=16

HALF OF GRIP PORTION LENGTH B=43.90±0.10

TOTAL LENGTH L=96.50±0.10

RADIUS OF END PORTION E=4.35

AREA TO BE PRESSED ABOUT 7.0 cm^2

WIDTH OF GRIP PORTION C=8.70±0.05

Fig. 5

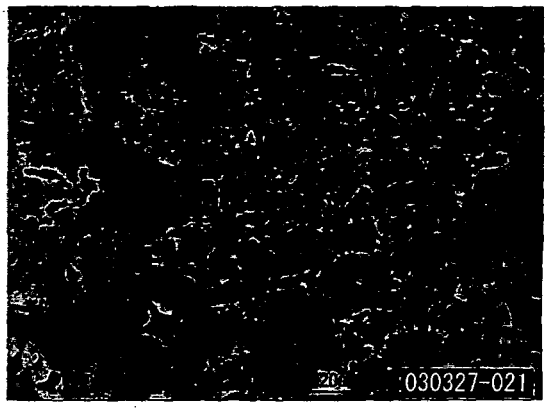


Fig. 6

No.	ALLOY POWDER	MATERIAL POWDERS MIXING RATIO % ALLOY POWDER	GRAPHITE	COPPER POWDER	IRON POWDER	TENSILE STRENGTH (MPa)	DENSITY (g/cm^3)	COMPACTING PRESSURE MPa	SINTERING TEMPRETURE ℃	SINTERING TIME (MINITES)	REMARKS
17	B	30	1	–	69	420	6.8	300	1150	30	SINTERED ALLOY IN EXAMPLE 17
18	B	30	1	–	69	600	7.2	500	1150	30	SINTERD ALLOY IN EXAMPLE 18
19	B	30	1	–	69	780	7.4	1500	1150	30	SINTERED ALLOY IN EXAMPLE 19
20	B	30	1	–	69	450	6.9	800	1050	30	SINTERED ALLOY IN EXAMPLE 20
21	B	30	1	–	69	600	7.2	800	1100	30	SINTERED ALLOY IN EXAMPLE 21
22	B	30	1	–	69	750	7.35	800	1250	30	SINTERED ALLOY IN EXAMPLE 22
23	B	30	1	–	69	480	7.05	800	1150	5	SINTERED ALLOY IN EXAMPLE 23
24	B	30	1	–	69	610	7.2	800	1150	10	SINTERED ALLOY IN EXAMPLE 24
25	B	30	1	–	69	700	7.3	800	1150	120	SINTERED ALLOY IN EXAMPLE 25

ALLOY POWDER B : Fe–6%Mn–0.03%O, PARTICLE DIAMETER 50 μm OR LESS, PRODUCED BY GAS ATOMIZATION

Fig. 7

SINTERED POWDER		MATERIAL POWDERS MIXING RATIO %							
No.	ALLOY POWDER	ALLOY POWDER	GRAHITE	IRON POWDER	TENSILE STRENGTH (MPa)	DENSITY (g/cm^3)	CONCENTRATION % OF Mn AT SITE FORMED FROM IRON POWDER	Mn AMOUNT wt% IN SINTERED ALLOY (CALCULATED VALUE)	REMARKS
26	A	30	1	69	600	7.2	1	0.8	SINTERED ALLOY EXAMPLE 26
27	C	25	1	74	610	7.15	4	4.5	SINTERED ALLOY EXAMPLE 27
28	D	15	1	84	610	7.15	4	4.2	SINTERED ALLOY EXAMPLE 28
29	A	15	1	84	490	7.0	0	0.4	SINTERED ALLOY EXAMPLE 29
30	C	35	1	64	440	6.9	2	6.3	SINTERED ALLOY EXAMPLE 30
31	D	25	1	74	430	6.9	2	7.0	SINTERED ALLOY EXAMPLE 31

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2006/305907

A. CLASSIFICATION OF SUBJECT MATTER
C22C38/00(2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22C38/00(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2006
Kokai Jitsuyo Shinan Koho 1971-2006 Toroku Jitsuyo Shinan Koho 1994-2006

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2000-509440 A (Stackpole Ltd.), 25 July, 2000 (25.07.00), Claims & WO 1997/042351 A1 & EP 000917593 A & AT 000207976 T & AU 002378297 A & CA 002252745 A & DE 069707891 T & ES 002163756 T & US 005881354 A1	1,2

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
30 May, 2006 (30.05.06)	06 June, 2006 (06.06.06)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **ZONGYIN ZHANG.** Fe-Mn-Si master alloy steel by powder metallurgy processing. *Sweden, Journal of Alloys and Compounds,* 2004, vol. 363, 194-202 **[0005]**