

(19)



(11)

EP 4 035 798 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:

03.08.2022 Bulletin 2022/31

(51) International Patent Classification (IPC):

B22F 1/00 ^(2022.01) **C22C 33/02** ^(2006.01)
C22C 38/00 ^(2006.01) **C22C 38/50** ^(2006.01)

(21) Application number: **20869179.0**

(52) Cooperative Patent Classification (CPC):

B22F 1/00; C22C 33/02; C22C 38/00; C22C 38/50

(22) Date of filing: **16.06.2020**

(86) International application number:

PCT/JP2020/023645

(87) International publication number:

WO 2021/059621 (01.04.2021 Gazette 2021/13)

(84) Designated Contracting States:

**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

Designated Extension States:

BA ME

Designated Validation States:

KH MA MD TN

(30) Priority: **27.09.2019 JP 2019177923**

27.09.2019 JP 2019177920

27.09.2019 JP 2019177921

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(54) **ALLOY STEEL POWDER FOR POWDER METALLURGY, IRON-BASED MIXED POWDER FOR POWDER METALLURGY, AND SINTERED BODY**

(57) Provided is an alloyed steel powder for powder metallurgy which has excellent compressibility and can be used to produce a sintered body that obtains improved strength simply by sintering. The alloyed steel powder for powder metallurgy contains Cu: 1.0 mass% or more and 8.0 mass% or less, Mo: more than 0.50 mass% and

2.00 mass% or less, and at least one selected from the group consisting of V: 0.05 mass% or more and 0.50 mass% or less, Nb: 0.02 mass% or more and 0.40 mass% or less, and Ti: 0.02 mass% or more and 0.40 mass% or less, with the balance consisting of Fe and inevitable impurities.

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Description

TECHNICAL FIELD

5 **[0001]** This disclosure relates to an alloyed steel powder for powder metallurgy, an iron-based mixed powder for powder metallurgy, and a sintered body.

BACKGROUND

10 **[0002]** Powder metallurgical techniques enable producing parts with complicated shapes in shapes that are extremely close to product shapes (so-called near net shapes) with high dimensional accuracy, and consequently significantly reducing machining costs during the production of parts. Therefore, powder metallurgical products are widely used as all kinds of parts for machines. Further, to cope with demands for reductions in size and weight and increasing complexity of parts, requirements for powder metallurgical techniques are becoming more stringent.

15 **[0003]** Against this background, requirements for alloyed steel powders used in powder metallurgy are also becoming more stringent, and it is required that the alloyed steel powders have good compressibility and sintered bodies obtained by sintering the alloyed steel powders have excellent mechanical properties. Further, a reduction in production costs is strongly required. From such a viewpoint, it is desired that the alloyed steel powders can be produced by conventional metallurgical powder production processes without any additional step, and that the alloyed steel powders do not need to contain any expensive alloy component such as Ni.

20 **[0004]** For example, the following methods have been proposed to improve the strength of a sintered body: a method of mixing a steel powder with a specific metal powder to obtain a mixed powder, a method of diffusionally adhering a specific metal powder to the surface of a steel powder, a method of further combining with graphite powder, and a method of using an alloyed steel powder that has been alloyed with a specific metal element.

25 **[0005]** For example, JP2012520942A (PTL 1) proposes a steel powder alloyed with V and Mn, which may be mixed with Cu and Ni powders.

[0006] WO2016092827A (PTL 2) proposes an alloyed steel powder for powder metallurgy in which a Cu powder is diffusionally adhered to the surface of a steel powder alloyed with Cu.

30 **[0007]** JP2003500538A (PTL 3) proposes a mixed powder for powder metallurgy in which a steel powder alloyed with Mo is mixed with either or both of a Cu powder and a Ni powder.

[0008] JP2010529302A (PTL 4) proposes an alloyed steel powder alloyed with Ni, Mo and Mn.

[0009] JP2013508558A (PTL 5) proposes a method of binding graphite powder to an iron-based powder by a binder, where the iron-based powder may be alloyed with alloying elements such as Ni, Cr, Mo and Mn.

35 **[0010]** JP2013204112A (PTL 6) proposes a method of combining alloying elements such as Cr, Mo and Cu with a reduced amount of C.

CITATION LIST

Patent Literature

40 **[0011]**

PTL 1: JP2012520942A
 PTL 2: WO2016092827A
 45 PTL 3: JP2003500538A
 PTL 4: JP2010529302A
 PTL 5: JP2013508558A
 PTL 6: JP2013204112A

50 SUMMARY

(Technical Problem)

55 **[0012]** However, in PTL 1, the effect of improving the strength of a sintered body by precipitation strengthening of V is limited even if a Cu powder or the like is used as well. Further, containing Mn may cause a decrease in the strength of a sintered body due to oxidation, and further improvement in strength is required.

[0013] In PTL 2, the effect of improving the strength of a sintered body by the use of Cu alone is limited, and further improvement in strength is required.

[0014] In PTL 3, the effect of improving the strength of a sintered body by alloying of Mo is limited even if a Cu powder or the like is used as well, and further improvement in strength is required.

[0015] In PTL 4, containing Ni leads to a high cost, and containing Mn may cause a decrease in the strength of a sintered body due to oxidation.

[0016] In PTL 5, it is necessary to perform heat treatment such as carburizing, quenching and tempering after sintering to improve the mechanical properties of a sintered body.

[0017] PTL 6 only improves the compressibility of a mixed powder by reducing the amount of C (graphite powder or the like) to be mixed with an alloyed steel powder, which cannot improve the compressibility of the alloyed steel powder itself. Further, it is necessary to set the cooling rate in quenching after sintering to 2 °C/s or higher to ensure the hardness and tensile strength of a sintered body. To control the cooling rate as above, it is necessary to modify production apparatus, which increases production costs.

[0018] It could thus be helpful to provide an alloyed steel powder for powder metallurgy which has excellent compressibility and can be used to produce a sintered body that obtains improved strength simply by sintering (without further heat treatment). As used herein, the compressibility refers to the density (compressed density) of a formed body obtained by performing pressing at a given pressure, and the value is preferably as high as possible.

[0019] It is also helpful to provide an iron-base mixed powder for powder metallurgy containing the above-described alloyed steel powder for powder metallurgy.

[0020] Further, it is helpful to provide a sintered body using the above-described alloyed steel powder for powder metallurgy or the above-described iron-based mixed powder for powder metallurgy.

(Solution to Problem)

[0021] As a result of diligent studies, we found that an alloyed steel powder using Cu, Mo, and at least one of V, Nb and Ti, each in a specific amount, as alloying elements has excellent compressibility and can be used to provide a sintered body that obtains improved strength simply by sintering, thereby completing the present disclosure. The alloyed steel powder of the present disclosure can uniformize the distribution of Cu and Mo, which in turn can uniformize the distribution of Cu and Mo in the sintered body. Further, because at least one of V, Nb and Ti is contained, precipitates in the sintered body are refined, and consequently, the microstructure can be refined. It is presumed that all these factors can lead to a sintered body with improved strength.

[0022] We thus provide the following.

[1] An alloyed steel powder for powder metallurgy, comprising (consisting of)

Cu: 1.0 mass% or more and 8.0 mass% or less,

Mo: more than 0.50 mass% and 2.00 mass% or less, and

at least one selected from the group consisting of V: 0.05 mass% or more and 0.50 mass% or less, Nb: 0.02 mass% or more and 0.40 mass% or less, and Ti: 0.02 mass% or more and 0.40 mass% or less, with the balance consisting of Fe and inevitable impurities.

[2] The alloyed steel powder for powder metallurgy according to [1], comprising V: 0.05 mass% or more and 0.50 mass% or less.

[3] The alloyed steel powder for powder metallurgy according to [1] or [2], comprising Nb: 0.02 mass% or more and 0.40 mass% or less.

[4] The alloyed steel powder for powder metallurgy according to any one of [1] to [3], comprising Ti: 0.02 mass% or more and 0.40 mass% or less.

[5] An iron-based mixed powder for powder metallurgy, comprising the alloyed steel powder for powder metallurgy according to any one of [1] to [4] and a metal powder, wherein

the metal powder is either or both of a Cu powder of more than 0 mass% and 4 mass% or less and a Mo powder of more than 0 mass% and 4 mass% or less with respect to 100 mass% of the iron-based mixed powder for powder metallurgy.

[6] A sintered body using the alloyed steel powder for powder metallurgy according to any one of [1] to [4] or the iron-base mixed powder for powder metallurgy according to [5].

(Advantageous Effect)

[0023] The alloyed steel powder for powder metallurgy of the present disclosure has excellent compressibility and can be used to provide a sintered body that obtains improved strength simply by sintering.

[0024] In addition, the alloyed steel powder for powder metallurgy of the present disclosure is advantageous in that it

does not contain alloying elements that are easily oxidized, such as Cr and Mn, and thus does not cause a decrease in strength of a sintered body due to oxidation of alloying elements.

[0025] Further, the alloyed steel powder for powder metallurgy of the present disclosure does not contain elements such as Ni, which causes a high alloy cost, or Cr, which requires annealing in a special atmosphere, and it does not require additional production processes such as coating or plating. Therefore, it is advantageous in terms of cost and is also convenient in that it can be produced by conventional metallurgical powder production processes.

[0026] The iron-based mixed powder for powder metallurgy of the present disclosure also has excellent compressibility and can be used to provide a sintered body that obtains improved strength simply by sintering.

[0027] By using the alloyed steel powder for powder metallurgy or the iron-based mixed powder for powder metallurgy of the present disclosure, it is possible to produce a sintered body with improved strength at a low cost.

DETAILED DESCRIPTION

[0028] The following describes embodiments of the present disclosure in detail.

[Alloyed steel powder for powder metallurgy]

[0029] The alloyed steel powder for powder metallurgy of the present disclosure (hereinafter also referred to as "alloyed steel powder") contains iron-based alloy in which Cu, Mo, and at least one of V, Nb and Ti are contained as essential components. As used herein, the "iron-based" means containing 50 mass% or more of Fe. In the description of the chemical composition, "%" denotes "mass%" unless otherwise noted. The content of the chemical composition of the alloyed steel powder for powder metallurgy is an amount with respect to 100 mass% of the alloyed steel powder for powder metallurgy.

Cu: 1.0 % or more and 8.0 % or less

[0030] Cu is an element that improves hardenability, and Cu is superior to elements such as Si, Cr and Mn in that it is more resistant to oxidation. Cu is also advantageous in that it is cheaper than Ni. When the Cu content is less than 1.0 %, the effect of improving hardenability by Cu is insufficient. Therefore, the Cu content is set to 1.0 % or more. On the other hand, sintering is generally performed at about 1130 °C during the production of sintered bodies. According to the Fe-Cu phase diagram, when the Cu content exceeds 8.0 %, Cu precipitates in the austenite phase. The Cu precipitates formed during sintering do not function effectively to improve hardenability, but rather remain as a soft phase in the microstructure, which may lead to deterioration of mechanical properties. Therefore, the Cu content is set to 8.0 % or less. When Cu is added within the above range, it is possible to sufficiently improve tensile strength while suppressing a decrease in density. To effectively obtain a higher strength, the Cu content is preferably 2.0 % or more. The Cu content is preferably 6.0 % or less.

Mo: more than 0.50 % and 2.00 % or less

[0031] Mo is an element that improves hardenability, and Mo is superior to elements such as Si, Cr and Mn in that it is more resistant to oxidation. Further, Mo has a characteristic that a small amount of addition, which is less than that of Ni, is sufficient for obtaining an effect of improving hardenability. When the Mo content is 0.50 % or less, the strength-improving effect of Mo is insufficient. Therefore, the Mo content is set to more than 0.50 %. On the other hand, when the Mo content exceeds 2.00 %, the compressibility of the alloyed steel powder decreases, and a die for pressing is easily worn out. In addition, the effect of increasing the strength of a sintered body by containing Mo is saturated. Therefore, the Mo content is set to 2.00 % or less. To effectively obtain a higher strength, the Mo content is preferably 1.00 % or more. The Mo content is preferably 1.50 % or less.

[0032] The alloyed steel powder of the present disclosure contains at least one of V, Nb and Ti. The alloyed steel powder may contain only one of V, Nb and Ti, two of them, or all three of them. When two of them are contained, it may be any combination of V and Nb, V and Ti, or Nb and Ti. The content of each of V, Nb and Ti is as follows.

V: 0.05 % or more and 0.50 % or less

[0033] V is an element that acts extremely effectively to improve strength by precipitating as carbides in a solid portion of a sintered body. When the V content is less than 0.05 %, the amount of carbides formed is insufficient, and the strength of a sintered body cannot be sufficiently improved. Therefore, when V is contained, the V content is set to 0.05 % or more. On the other hand, when the V content exceeds 0.50 %, the carbides are coarsened, which deteriorates the strength-improving effect, and each particle of the alloyed steel powder is hardened, which causes a decrease in com-

pressibility. Further, it also is disadvantageous from an economic viewpoint. Therefore, the V content is set to 0.50 % or less. To effectively obtain a higher strength, the V content is preferably 0.10 % or more. The V content is preferably 0.40 % or less.

5 Nb: 0.02 % or more and 0.40 % or less

[0034] Nb is an element that not only greatly enhances hardenability but also acts effectively to improve strength by precipitating as carbides in a solid portion of a sintered body. When the Nb content is less than 0.02 %, the amount of carbides formed is insufficient, and the strength of a sintered body cannot be sufficiently improved. Therefore, when Nb is contained, the Nb content is set to 0.02 % or more. On the other hand, when the Nb content exceeds 0.40 %, the carbides are coarsened, which deteriorates the strength-improving effect, and each particle of the alloyed steel powder is hardened, which causes a decrease in compressibility. Further, it also is disadvantageous from an economic viewpoint. Therefore, when Nb is contained, the Nb content is set to 0.40 % or less. When Nb is contained, the Nb content is preferably 0.05 % or more to effectively obtain a higher strength. The Nb content is preferably 0.20 % or less to effectively obtain a higher strength.

Ti: 0.02 % or more and 0.40 % or less

[0035] Ti is an element that acts effectively to improve strength by precipitating as carbides in a solid portion of a sintered body. When the Ti content is less than 0.02 %, the amount of carbides formed is insufficient, and the strength of a sintered body cannot be sufficiently improved. Therefore, when Ti is contained, the Ti content is set to 0.02 % or more. On the other hand, when the Ti content exceeds 0.40 %, the carbides are coarsened, which deteriorates the strength-improving effect, and each particle of the alloyed steel powder is hardened, which causes a decrease in compressibility. Further, it also is disadvantageous from an economic viewpoint. Therefore, when Ti is contained, the Ti content is set to 0.40 % or less. When Ti is contained, the Ti content is preferably 0.05 % or more to effectively obtain a higher strength. The Ti content is preferably 0.20 % or less to effectively obtain a higher strength.

[0036] The balance of the alloyed steel powder other than the aforementioned components consists of Fe and inevitable impurities. The amount of inevitable impurities is not particularly limited as long as it is an amount inevitably mixed in. However, it is preferable to control inevitable impurities so that they are substantially not contained. Because Ni causes an increase in alloy costs, it is preferable to control the Ni content to 0.1 % or less. Because Cr is easily oxidized and it requires control of annealing atmosphere, it is preferable to control the Cr content to 0.1 % or less. For the same reason as for Cr, it is preferable to control the Si content to 0.1 % or less. It is preferable to suppress C to 0.01 % or less, O to 0.20 % or less, Mn to 0.15 % or less, P to 0.025 % or less, S to 0.025 % or less, N to 0.05 % or less, and other elements to 0.01 % or less.

[0037] The alloyed steel powder of the present disclosure includes the following embodiments.

[0038] An alloyed steel powder for powder metallurgy containing Cu: 1.0 mass% or more and 8.0 mass% or less, Mo: more than 0.50 mass% and 2.00 mass% or less, and V: 0.05 mass% or more and 0.50 mass% or less, with the balance consisting of Fe and inevitable impurities.

[0039] An alloyed steel powder for powder metallurgy containing Cu: 1.0 mass% or more and 8.0 mass% or less, Mo: more than 0.50 mass% and 2.00 mass% or less, and Nb: 0.02 mass% or more and 0.40 mass% or less, with the balance consisting of Fe and inevitable impurities.

[0040] An alloyed steel powder for powder metallurgy containing Cu: 1.0 mass% or more and 8.0 mass% or less, Mo: more than 0.50 mass% and 2.00 mass% or less, Ti: 0.02 mass% or more and 0.40 mass% or less, with the balance consisting of Fe and inevitable impurities.

[0041] An alloyed steel powder for powder metallurgy containing Cu: 1.0 mass% or more and 8.0 mass% or less, Mo: more than 0.50 mass% and 2.00 mass% or less, V: 0.05 mass% or more and 0.50 mass% or less, and Nb: 0.02 mass% or more and 0.40 mass% or less, with the balance consisting of Fe and inevitable impurities.

[0042] An alloyed steel powder for powder metallurgy containing Cu: 1.0 mass% or more and 8.0 mass% or less, Mo: more than 0.50 mass% and 2.00 mass% or less, V: 0.05 mass% or more and 0.50 mass% or less, and Ti: 0.02 mass% or more and 0.40 mass% or less, with the balance consisting of Fe and inevitable impurities.

[0043] An alloyed steel powder for powder metallurgy containing Cu: 1.0 mass% or more and 8.0 mass% or less, Mo: more than 0.50 mass% and 2.00 mass% or less, Nb: 0.02 mass% or more and 0.40 mass% or less, and Ti: 0.02 mass% or more and 0.40 mass% or less, with the balance consisting of Fe and inevitable impurities.

[0044] An alloyed steel powder for powder metallurgy containing Cu: 1.0 mass% or more and 8.0 mass% or less, Mo: more than 0.50 mass% and 2.00 mass% or less, V: 0.05 mass% or more and 0.50 mass% or less, Nb: 0.02 mass% or more and 0.40 mass% or less, and Ti: 0.02 mass% or more and 0.40 mass% or less, with balance consisting of Fe and inevitable impurities.

[0045] The method of producing the alloyed steel powder is not particularly limited, and the alloyed steel powder may

be produced with any method. For example, the alloyed steel powder may be an atomized powder produced with an atomizing method, and it is preferably a water atomized powder produced with a water atomizing method, which causes low production costs and is easy for mass production. In the case of producing the alloyed steel powder with an atomizing method, the alloyed steel powder can be obtained by, for example, atomizing molten steel, which has been adjusted to have the predetermined chemical composition, to obtain a powder, and reducing and/or classifying the powder as necessary.

[0046] The particle size of the alloyed steel powder is not particularly limited, and the alloyed steel powder may have any particle size. From the viewpoint of ease of production, it is preferable to have an average particle size of 30 μm or more and 150 μm or less. An alloyed steel powder having an average particle size within the above range can be produced industrially at low costs with a water atomizing method. As used here, the average particle size refers to the mass-based median size (D50). The average particle size can be determined by interpolation as a particle size for which a value of 50 % is reached when calculating the mass-based cumulative particle size distribution from particle size distribution measured with the dry sieving method described in JIS Z 2510.

[Iron-based mixed powder for powder metallurgy]

[0047] The alloyed steel powder can be used for powder metallurgy as it is, or it can be used as an iron-based mixed powder for powder metallurgy containing the alloyed steel powder and a metal powder (hereinafter also referred to as "mixed powder"). The metal powder in the mixed powder of the present disclosure is either or both of a Cu powder: more than 0 % and 4 % or less, and a Mo powder: more than 0 % and 4 % or less. The content of the chemical composition of the iron-based mixed powder for powder metallurgy is an amount with respect to 100 mass% of the iron-based mixed powder for powder metallurgy.

Cu powder: more than 0 % and 4 % or less

[0048] A Cu powder can be added to the alloyed steel powder to promote sintering and improve strength. However, when it exceeds 4 %, the amount of liquid phase formed during sintering increases, which decreases the density of a sintered body due to expansion and deteriorates the strength. Therefore, the amount of Cu powder added is set to 4 % or less. When a Cu powder is added, it is preferably 0.5 % or more to effectively improve the strength.

Mo powder: more than 0 % and 4 % or less

[0049] A Mo powder can be added to the alloyed steel powder to promote sintering and improve strength. However, when it exceeds 4 %, the alloyed steel powder is hardened, which decreases the compressive density and deteriorates the strength. Therefore, the amount of Mo powder added is set to 4 % or less. When a Mo powder is added, it is preferably 0.5 % or more to effectively improve the strength.

[0050] The method of producing the mixed powder is not particularly limited, and the mixed powder may be produced with any method. For example, it can be produced by mixing either or both of the Cu and Mo powders of the contents described above with the alloyed steel powder. The mixing can be performed with any method. Examples thereof include methods of mixing using a V-shaped mixer, a double cone mixer, a Henschel Mixer, or a Nauta Mixer. During the mixing, a binder such as a machine oil may be added to prevent segregation of either or both of the Cu and Mo powders. Alternatively, the mixed powder may be obtained by filling the alloyed steel powder, and either or both of the Cu and Mo powders of the contents described above in a mold for pressing.

[Sintered body]

[0051] The present disclosure also relates to a sintered body obtained by sintering a formed body containing the alloyed steel powder or the mixed powder.

[0052] The sintered body may be produced using the alloyed steel powder or the mixed powder (hereinafter also referred to as "raw material") as a raw material. The method of producing the sintered body is not particularly limited, and the sintered body may be produced with any production method. For example, the sintered body can be produced by adding any optional component as required to the raw material, and subjecting them to pressing and then sintering.

[Optional component]

[0053] The raw material of the sintered body may be the raw material as it is, or may also include an auxiliary raw material such as a carbon powder.

[0054] The carbon powder is not particularly limited and is preferably graphite powder (natural graphite powder, artificial

graphite powder, etc.) or carbon black. The addition of carbon powder can further improve the strength of the sintered body. When a carbon powder is added, the carbon powder is preferably 0.2 parts by mass or more with respect to 100 parts by mass of the raw material in terms of the strength-improving effect. The carbon powder is preferably 1.2 parts by mass or less with respect to 100 parts by mass of the raw material.

[0055] A lubricant may be added to the raw material. Containing a lubricant facilitates the extraction of a formed body from a press mold. The lubricant is not particularly limited, and examples thereof include metal soap (zinc stearate, lithium stearate, etc.) and amide-based wax (ethylene bis-stearate amide, etc.). The lubricant is preferably in powder form. When a lubricant is used, the lubricant is preferably 0.3 parts by mass or more with respect to 100 parts by mass of the raw material. The lubricant is preferably 1.0 part by mass or less with respect to 100 parts by mass of the raw material.

[0056] A machinability-improving powder may be added to the raw material. The machinability-improving powder is not particularly limited, and examples thereof includes a MnS powder and an oxide powder. When a machinability-improving powder is used, the machinability-improving powder is preferably 0.1 parts by mass or more with respect to 100 parts by mass of the raw material. The machinability-improving powder is preferably 0.7 parts by mass or less with respect to 100 parts by mass of the raw material.

(Pressing)

[0057] The raw material is blended with optional components such as an auxiliary raw material, a lubricant, and a machinability-improving powder as required and then subjected to pressing to obtain a formed body in a desired shape. The method of pressing is not particularly limited, and any method may be used. Examples thereof include a method of filling a press mold with the raw material and the like and performing pressing. A lubricant may be applied or adhered to the press mold. In this case, the amount of the lubricant is preferably 0.3 parts by mass or more with respect to 100 parts by mass of the raw material. The amount of the lubricant is preferably 1.0 part by mass or less with respect to 100 parts by mass of the raw material.

[0058] The pressure at which pressing is performed to obtain a formed body may be set to 400 MPa or more and 1000 MPa or less. Within this range, the density of the formed body is lowered, the density of the sintered body is reduced, an insufficient strength can be avoided, and burden on the press mold can also be suppressed. The raw material of the present disclosure can be pressed under a pressure of 588 MPa to obtain a formed body with a density (compressed density) of 6.75 Mg/m³ or more, for example. The density (compressed density) of the formed body is preferably 6.80 Mg/m³ or more.

(Sintering)

[0059] The resulting formed body is then sintered. The method of sintering is not particularly limited and can be any method. The sintering temperature may be 1100 °C or higher and is preferably 1120 °C or higher from the viewpoint of performing sintering sufficiently. On the other hand, the distribution of Cu and Mo becomes uniform in the sintered body as the sintering temperature increases, so that the upper limit of the sintering temperature is not particularly limited. However, the sintering temperature is preferably 1250 °C or lower and more preferably 1180 °C or lower from the viewpoint of controlling the production costs. Because the raw material is an alloyed steel powder obtained by alloying Cu, Mo and at least one of V, Nb and Ti, the distribution of Cu and Mo can be made uniform even at a sintering temperature within the above range. As a result, the strength of the sintered body can be effectively improved.

[0060] The sintering time may be 15 minutes or longer and 50 minutes or shorter. Within this range, insufficient sintering and insufficient strength can be avoided, and the production costs can be suppressed. The cooling rate during cooling after sintering may be 20 °C/min or higher and 40 °C/min or lower. At a cooling rate of lower than 20 °C/min, quenching cannot be performed sufficiently, and the tensile strength may be reduced. A cooling rate of 40 °C/min or higher requires ancillary equipment to accelerate the cooling rate, which increases the production costs.

[0061] In the case of using a lubricant, a degreasing process may be added in which the formed body is held in a temperature range of 400 °C or higher and 700 °C or lower for a certain period of time to decompose and remove the lubricant before sintering.

[0062] The conditions and equipment for the production of the sintered body other than the above are not particularly limited and may be any commonly known ones, for example.

[0063] The resulting sintered body may be subjected to treatment such as carburizing-quenching and tempering.

EXAMPLES

[0064] More detailed description of the present disclosure is given below based on examples. The following examples merely represent preferred examples of the present disclosure, and the present disclosure is not limited to these examples.

[0065] Alloyed steel powders and sintered bodies using the alloyed steel powders were produced by the following

procedures in the examples.

- Production of alloyed steel powder

[0066] Molten steels were adjusted to have the chemical compositions listed in Table 1 to Table 4, and alloyed steel powders were prepared with a water atomizing method. The amounts of Si, Mn, P, S and Cr contained in the alloyed steel powder as inevitable impurities were as follows: Si: less than 0.05 mass%, Mn: less than 0.15 mass%, P: less than 0.025 mass%, S: less than 0.025 mass%, and Cr: less than 0.03 mass%.

[0067] Each of the resulting alloyed steel powder was held at 920 °C in a hydrogen atmosphere for 30 minutes for finish-reduction. After finish-reduction, a heat-treated body, in which particles were sintered together to form a lump, was ground using a hammer mill and classified using a sieve with a mesh size of 180 μm, and the powder under the sieve was collected and used as an alloyed steel powder. The amounts of C, O and N contained in the alloyed steel powder as inevitable impurities were as follows: C: less than 0.01 mass%, O: less than 0.20 mass%, and N: less than 0.05 mass%. The chemical composition of the alloyed steel powder was equivalent to the chemical composition of the molten steel above.

- Production of diffusionally adhered alloy steel powder

[0068] A Cu powder (D50 of about 30 μm) or an oxidized Mo powder (D50 of about 3 μm) was added to the alloyed steel powder in such an amount that the content of Cu or Mo in a diffusionally adhered alloy steel powder was the value listed in Table 1 to Table 3, and the powders were mixed in a V-shaped mixer for 15 minutes and then held at 920 °C in a hydrogen atmosphere for 30 minutes for finish-reduction. After finish-reduction, a reduced body, in which particles were sintered together to form a lump, was ground using a hammer mill and classified using a sieve with a mesh size of 180 μm, and the powder under the sieve was collected and used as a diffusionally adhered alloy steel powder to which Cu or Mo was diffusionally adhered. The amounts of C, O and N contained in the diffusionally adhered alloy steel powder as inevitable impurities were as follows: C: less than 0.01 mass%, O: less than 0.20 mass%, and N: less than 0.05 mass%.

- Production of sintered body

[0069] The alloyed steel powder or diffusionally adhered alloy steel powder was added with 0.8 parts by mass of graphite powder, 0.6 parts by mass of a lubricant (zinc stearate), and a Cu powder (D50 of about 45 μm) or a Mo powder (D50 of about 25 μm) in an amount listed in Tables 1 to 3 or 5 with respect to 100 parts by mass of the alloyed steel powder or diffusionally adhered alloy steel powder, and the powders were mixed using a double-cone mixer to obtain an iron-based mixed powder. The iron-based mixed powder was pressed into a rectangular shape of 10 mm × 10 mm × 55 mm at a pressing pressure of 588 MPa to obtain a formed body. The density of the formed body was calculated by dividing the weight of the formed body by the volume of the rectangular body.

[0070] The formed body was held at 1130 °C for 20 minutes in a 10 % H₂-90 % N₂ atmosphere to obtain a sintered body. A test piece having a length of 50 mm and a diameter of 3 mm was cut out from the sintered body, and the maximum stress before breaking (tensile strength) was measured.

(Example 1)

[0071] This is an example relating to an alloyed steel powder in which Cu, Mo and V are added. Table 1 lists the chemical composition and the evaluation results. In the chemical composition, "-" means that the component is not added, and the same applies to the following description.

[0072] Iron-based powders prepared under the following four sets of conditions were also evaluated as comparative examples. In No. 1-10, Cu was diffusively adhered to the surface of an alloyed steel powder containing Mo and V as alloying elements, and the alloyed steel powder was mixed with graphite powder and a lubricant. In No. 1-11, an alloyed steel powder containing Mo and V as alloying elements was mixed with a Cu powder, graphite powder and a lubricant. In No. 1-12, Mo was diffusively adhered to the surface of an alloyed steel powder containing Cu and V as alloying elements, and the alloyed steel powder was mixed with graphite powder and a lubricant. In No. 1-13, an alloyed steel powder containing Cu and V as alloying elements was mixed with a Mo powder, graphite powder and a lubricant. Table 1 lists the amount adhered, the amount added and the evaluation results.

[0073] As indicated in Table 1, the tensile strength was significantly improved in No.1-2 containing Cu, Mo and V as compared to No.1-1 containing only Cu and V. Compared to No. 1-2, the tensile strength of No. 1-3, in which no V was added and Cu was increased, was not as high as that of No. 1-2. The tensile strength was significantly improved in No. 1-6 containing Cu, Mo and V as compared to No. 1-4 containing only Cu and V and No. 1-5 containing only Mo and V.

Compared to No. 1-6, a high tensile strength was obtained in No. 1-7 with increased Cu, No.1-8 with increased Mo, and No. 1-9 with increased V.

[0074] With regard to compressibility, it can be seen that Nos. 1-2 and 1-6 to 1-9, which are disclosed examples, all have a sufficiently high density and excellent compressibility. It can be seen from the results of Nos. 1-5 to 1-7 that Cu can improve the tensile strength by increasing the amount added while maintaining a high density.

[0075] The sintered body of No. 1-10 using a diffusionally adhered alloy steel powder, in which Cu was diffusively adhered to the surface of an alloyed steel powder containing Mo and V as alloying elements, and the sintered body of No. 1-11 using a mixed powder obtained by mixing the same alloyed steel powder with a Cu powder were inferior to the sintered body of No. 1-6 in terms of tensile strength, although they had the same contents of Cu, Mo and V. The sintered body of No. 1-12 using a diffusionally adhered alloy steel powder, in which Mo was diffusively adhered to the surface of an alloyed steel powder containing Cu and V as alloying elements, and the sintered body of No. 1-13 using a mixed powder obtained by mixing the same alloyed steel powder with a Mo powder were inferior to the sintered body of No. 1-6 in terms of tensile strength, although they had the same contents of Cu, Mo and V.

Table 1

No.	Alloyed steel powder			Diffusionally adhered powder		Metal powder		Formed body	Sintered body	Remarks
	Chemical composition *1 (mass%)			Amount adhered*2 (mass%)		Amount added*3 (mass%)		Density (Mg/m ³)	Tensile strength (MPa)	
	Cu	Mo	V	Cu	Mo	Cu powder	Mo powder			
1-1	1.0	-	0.05	-	-	-	-	7.07	461	Comparative example
1-2	1.0	0.51	0.05	-	-	-	-	7.00	572	Example
1-3	3.0	0.51	-	-	-	-	-	7.01	530	Comparative example
1-4	3.0	-	0.20	-	-	-	-	7.02	493	Comparative example
1-5	-	1.20	0.20	-	-	-	-	6.94	614	Comparative example
1-6	3.0	1.20	0.20	-	-	-	-	6.91	770	Example
1-7	8.0	1.20	0.20	-	-	-	-	6.96	765	Example
1-8	3.0	2.00	0.20	-	-	-	-	6.81	772	Example
1-9	3.0	1.20	0.50	-	-	-	-	6.82	719	Example
1-10	-	1.20	0.20	3.0	-	-	-	6.97	612	Comparative example
1-11	-	1.20	0.20	-	-	3.0	-	6.98	602	Comparative example
1-12	3.0	-	0.20	-	1.20	-	-	7.01	530	Comparative example
1-13	3.0	-	0.20	-	-	-	1.20	7.01	516	Comparative example
*1 The balance of the alloyed steel powder consists of Fe and inevitable impurities.										
*2 The total of the alloyed steel powder and the diffusionally adhered powder is taken as 100 mass%.										
*3 The total of the alloyed steel powder and the metal powder is taken as 100 mass%.										

(Example 2)

[0076] This is an example relating to an alloyed steel powder in which Cu, Mo and Nb are added. Table 2 lists the

chemical composition and the evaluation results.

[0077] Iron-based powders prepared under the following four sets of conditions were also evaluated as comparative examples. In No. 2-11, Cu was diffusively adhered to the surface of an alloyed steel powder containing Mo and Nb as alloying elements, and the alloyed steel powder was mixed with graphite powder and a lubricant. In No. 2-12, an alloyed steel powder containing Mo and Nb as alloying elements was mixed with a Cu powder, graphite powder and a lubricant. In No. 2-13, Mo was diffusively adhered to the surface of an alloyed steel powder containing Cu and Nb as alloying elements, and the alloyed steel powder was mixed with graphite powder and a lubricant. In No. 2-14, an alloyed steel powder containing Cu and Nb as alloying elements was mixed with a Mo powder, graphite powder and a lubricant. Table 2 lists the amount adhered, the amount added and the evaluation results.

[0078] As indicated in Table 2, the tensile strength was significantly improved in No. 2-2 containing Cu, Mo and Nb as compared to No. 2-1 containing only Cu and Nb. Compared to No. 2-2, the tensile strength of No. 2-3, in which no Nb was added and Cu was increased, was not as high as that of No. 2-2. The tensile strength was significantly improved in No. 2-6 containing Cu, Mo and Nb as compared to No. 2-4 containing only Cu and Nb and No. 2-5 containing only Mo and Nb. Compared to No. 2-6, a high tensile strength was obtained in No. 2-7 with increased Cu, No. 2-8 with increased Mo, and No. 2-9 with increased Nb. On the other hand, No. 2-10, in which the amounts of Cu, Mo and Nb were outside the range of the present disclosure, had a lowered density and a deteriorated tensile strength.

[0079] With regard to compressibility, it can be seen that Nos. 2-2 and 2-6 to 2-9, which are disclosed examples, all have a sufficiently high density and excellent compressibility. It can be seen from the results of Nos. 2-5 to 2-7 that Cu can improve the tensile strength by increasing the amount added while maintaining a high density.

[0080] The sintered body of No. 2-11 using a diffusionally adhered alloy steel powder, in which Cu was diffusively adhered to the surface of an alloyed steel powder containing Mo and Nb as alloying elements, and the sintered body of No. 2-12 using a mixed powder obtained by mixing the same alloyed steel powder with a Cu powder were inferior to the sintered body of No. 2-6 in terms of tensile strength, although they had the same contents of Cu, Mo and Nb. The sintered body of No. 2-13 using a diffusionally adhered alloy steel powder, in which Mo was diffusively adhered to the surface of an alloyed steel powder containing Cu and Nb as alloying elements, and the sintered body of No. 2-14 using a mixed powder obtained by mixing the same alloyed steel powder with a Mo powder were inferior to the sintered body of No. 2-6 in terms of tensile strength, although they had the same contents of Cu, Mo and Nb.

Table 2

No.	Alloyed steel powder			Diffusionally adhered powder		Metal powder		Formed body	Sintered body	Remarks
	Chemical *1 composition (mass%)			Amount adhered*2 (mass%)		Amount added*3 (mass%)		Density (Mg/m ³)	Tensile strength (MPa)	
	Cu	Mo	Nb	Cu	Mo	Cu powder	Mo powder			
2-1	1.0	-	0.02	-	-	-	-	7.06	458	Comparative example
2-2	1.0	0.51	0.02	-	-	-	-	7.01	570	Example
2-3	3.0	0.51	-	-	-	-	-	6.99	526	Comparative example
2-4	3.0	-	0.10	-	-	-	-	7.04	488	Comparative example
2-5	-	1.20	0.10	-	-	-	-	6.97	610	Comparative example
2-6	3.0	1.20	0.10	-	-	-	-	6.92	763	Example
2-7	8.0	1.20	0.10	-	-	-	-	6.98	758	Example
2-8	3.0	2.00	0.10	-	-	-	-	6.83	765	Example
2-9	3.0	1.20	0.40	-	-	-	-	6.85	720	Example
2-10	8.1	2.10	0.41	-	-	-	-	6.65	620	Comparative example

(continued)

No.	Alloyed steel powder			Diffusionally adhered powder		Metal powder		Formed body	Sintered body	Remarks
	Chemical *1 composition (mass%)			Amount adhered*2 (mass%)		Amount added*3 (mass%)		Density (Mg/m ³)	Tensile strength (MPa)	
	Cu	Mo	Nb	Cu	Mo	Cu powder	Mo powder			
2-11	-	1.20	0.20	3.0	-	-	-	6.97	608	Comparative example
2-12	-	1.20	0.20	-	-	3.0	-	6.98	598	Comparative example
2-13	3.0	-	0.20	-	1.20	-	-	7.04	518	Comparative example
2-14	3.0	-	0.20	-	-	-	1.20	7.03	510	Comparative example
*1 The balance of the alloyed steel powder consists of Fe and inevitable impurities. *2 The total of the alloyed steel powder and the diffusionally adhered powder is taken as 100 mass%. *3 The total of the alloyed steel powder and the metal powder is taken as 100 mass%.										

(Example 3)

[0081] This is an example relating to an alloyed steel powder in which Cu, Mo and Ti are added. Table 3 lists the chemical composition and the evaluation results.

[0082] Iron-based powders prepared under the following four sets of conditions were also evaluated as comparative examples. In No. 3-11, Cu was diffusively adhered to the surface of an alloyed steel powder containing Mo and Ti as alloying elements, and the alloyed steel powder was mixed with graphite powder and a lubricant. In No. 3-12, an alloyed steel powder containing Mo and Ti as alloying elements was mixed with a Cu powder, graphite powder and a lubricant. In No. 3-13, Mo was diffusively adhered to the surface of an alloyed steel powder containing Cu and Ti as alloying elements, and the alloyed steel powder was mixed with graphite powder and a lubricant. In No. 3-14, an alloyed steel powder containing Cu and Ti as alloying elements was mixed with a Mo powder, graphite powder and a lubricant. Table 1 lists the amount adhered, the amount added and the evaluation results.

[0083] As indicated in Table 3, the tensile strength was significantly improved in No. 3-2 containing Cu, Mo and Ti as compared to No. 3-1 containing only Cu and Ti. Compared to No. 3-2, the tensile strength of No. 3-3, in which no Ti was added and Cu was increased, was not as high as that of No. 3-2. The tensile strength was significantly improved in No. 3-6 containing Cu, Mo and Ti as compared to No. 3-4 containing only Cu and Ti and No. 3-5 containing only Mo and Ti. Compared to No. 3-6, a high tensile strength was obtained in No. 3-7 with increased Cu, No. 3-8 with increased Mo, and No. 3-9 with increased Ti. On the other hand, No. 3-10, in which the amounts of Cu, Mo and Ti were outside the range of the present disclosure, had a lowered density and a deteriorated tensile strength.

[0084] With regard to compressibility, it can be seen that Nos. 3-2 and 3-6 to 3-9, which are disclosed examples, all have a sufficiently high density and excellent compressibility. It can be seen from the results of Nos. 3-5 to 3-7 that Cu can improve the tensile strength by increasing the amount added while maintaining a high density.

[0085] The sintered body of No. 3-11 using a diffusionally adhered alloy steel powder, in which Cu was diffusively adhered to the surface of an alloyed steel powder containing Mo and Ti as alloying elements, and the sintered body of No. 3-12 using a mixed powder obtained by mixing the same alloyed steel powder with a Cu powder were inferior to the sintered body of No. 3-6 in terms of tensile strength, although they had the same contents of Cu, Mo and Ti. The sintered body of No. 3-13 using a diffusionally adhered alloy steel powder, in which Mo was diffusively adhered to the surface of an alloyed steel powder containing Cu and Ti as alloying elements, and the sintered body of No. 3-14 using a mixed powder obtained by mixing the same alloyed steel powder with a Mo powder were inferior to the sintered body of No. 3-6 in terms of tensile strength, although they had the same contents of Cu, Mo and Ti.

Table 3

No.	Alloyed steel powder			Diffusionally adhered powder		Metal powder		Formed body	Sintered body	Remarks
	Chemical *1 composition (mass%)			Amount adhered*2 (mass%)		Amount added*3 (mass%)		Density (Mg/m ³)	Tensile strength (MPa)	
	Cu	Mo	Ti	Cu	Mo	Cu powder	Mo powder			
3-1	1.0	-	0.02	-	-	-	-	7.07	455	Comparative example
3-2	1.0	0.51	0.02	-	-	-	-	7.01	567	Example
3-3	3.0	0.51	-	-	-	-	-	7.00	527	Comparative example
3-4	3.0	-	0.10	-	-	-	-	7.04	476	Comparative example
3-5	-	1.20	0.10	-	-	-	-	6.97	603	Comparative example
3-6	3.0	1.20	0.10	-	-	-	-	6.90	755	Example
3-7	8.0	1.20	0.10	-	-	-	-	6.99	751	Example
3-8	3.0	2.00	0.10	-	-	-	-	6.84	760	Example
3-9	3.0	1.20	0.40	-	-	-	-	6.82	690	Example
3-10	8.1	2.10	0.41	-	-	-	-	6.63	614	Comparative example
3-11	-	1.20	0.10	3.0	-	-	-	6.97	604	Comparative example
3-12	-	1.20	0.10	-	-	3.0	-	6.98	596	Comparative example
3-13	3.0	-	0.10	-	1.20	-	-	7.03	509	Comparative example
3-14	3.0	-	0.10	-	-	-	1.20	7.03	504	Comparative example
*1 The balance of the alloyed steel powder consists of Fe and inevitable impurities. *2 The total of the alloyed steel powder and the diffusionally adhered powder is taken as 100 mass%. *3 The total of the alloyed steel powder and the metal powder is taken as 100 mass%.										

(Example 4)

[0086] This is an example relating to an alloyed steel powder in which Cu, Mo, and two or three selected from V, Nb and Ti are added as alloy components. Table 4 lists the chemical composition and the evaluation results.

[0087] According to Nos. 4-1 to 4-3, 4-5 to 4-7, 4-9 to 4-11 and 4-13 to 4-15, it can be seen that the tensile strength is further improved by using an alloyed steel powder in which two or three selected from V, Ni and Ti were added in specific amounts. Further, all of these examples had a sufficiently high density and excellent compressibility. On the other hand, the tensile strength decreased in Nos. 4-4, 4-8, 4-12 and 4-16 where the amount added did not meet the specified conditions.

Table 4

No.	Alloyed steel powder					Formed body	Sintered body	Remarks
	Chemical composition * (mass%)					Density (Mg/m ³)	Tensile strength (MPa)	
	Cu	Mo	V	Nb	Ti			
4-1	3.0	1.20	0.20	0.02	-	6.93	794	Example
4-2	3.0	1.20	0.20	0.10	-	6.93	807	Example
4-3	3.0	1.20	0.20	0.40	-	6.89	784	Example
4-4	3.0	1.20	0.20	<u>0.50</u>	-	6.89	725	Comparative example
4-5	3.0	1.20	0.20	-	0.02	6.92	805	Example
4-6	3.0	1.20	0.20	-	0.10	6.92	806	Example
4-7	3.0	1.20	0.20	-	0.40	6.89	789	Example
4-8	3.0	1.20	0.20	-	<u>0.50</u>	6.89	734	Comparative example
4-9	3.0	1.20	-	0.10	0.02	6.94	797	Example
4-10	3.0	1.20	-	0.10	0.10	6.94	806	Example
4-11	3.0	1.20	-	0.10	0.40	6.91	781	Example
4-12	3.0	1.20	-	0.10	<u>0.50</u>	6.91	727	Comparative example
4-13	3.0	1.20	0.20	0.02	0.02	6.90	801	Example
4-14	3.0	1.20	0.20	0.10	0.10	6.89	812	Example
4-15	3.0	1.20	0.20	0.40	0.40	6.88	777	Example
4-16	3.0	1.20	0.20	<u>0.50</u>	<u>0.50</u>	6.88	659	Comparative example
* The balance consists of Fe and inevitable impurities.								

(Example 5)

[0088] This is an example relating to a mixed powder in which a Cu powder and/or a Mo powder is further added to an alloyed steel powder. Table 5 lists the amounts of the alloyed steel powder, Cu powder and Mo powder added, as well as the evaluation results.

[0089] Comparing No. 1-6 with Nos. 5-1, 5-3 to 5-4, and 5-6, comparing No. 2-6 with Nos. 5-8, 5-10 to 5-11, and 5-13, comparing No. 3-6 with Nos. 5-15, 5-17 to 5-18, and 5-20, comparing No. 4-10 with Nos. 5-22, 5-24 to 5-25, and 5-27, and comparing No. 4-14 with Nos. 5-29, 5-31 to 5-32, and 5-34, it can be seen that the tensile strength is further improved by mixing a Cu powder and/or a Mo powder in a specific amount. Further, all of these examples had a sufficiently high density and excellent compressibility. On the other hand, the tensile strength was decreased in Nos. 5-2, 5-5, 5-7, 5-9, 5-12, 5-14, 5-16, 5-19, 5-21, 5-23, 5-26, 5-28, 5-30, 5-33 and 5-35 where the amount of Cu powder and/or Mo powder added did not meet the specified conditions.

Table 5

No.	Mixed powder			Formed body	Sintered body	Remarks
	Alloyed steel powder	Amount added* (mass%)		Density (Mg/m ³)	Tensile strength (MPa)	
		Cu powder	Mo powder			
1-6	No. 1-6	-	-	6.91	770	Example
5-1		4	-	6.86	838	Example
5-2		<u>5</u>	-	6.83	763	Comparative example
5-3		-	2	6.85	825	Example
5-4		-	4	6.80	830	Example
5-5		-	<u>5</u>	6.75	764	Comparative example
5-6		4	4	6.76	855	Example
5-7		<u>5</u>	<u>5</u>	6.66	724	Comparative example
2-6	No.2-6	-	-	6.92	763	Example
5-8		4	-	6.87	830	Example
5-9		<u>5</u>	-	6.84	755	Comparative example
5-10		-	2	6.86	817	Example
5-11		-	4	6.81	822	Example
5-12		-	<u>5</u>	6.76	757	Comparative example
5-13		4	4	6.77	847	Example
5-14		<u>5</u>	<u>5</u>	6.66	715	Comparative example
3-6	No.3-6	-	-	6.90	755	Example
5-15		4	-	6.87	822	Example
5-16		<u>5</u>	-	6.84	747	Comparative example
5-17		-	2	6.86	809	Example
5-18		-	4	6.81	814	Example
5-19		-	<u>5</u>	6.76	749	Comparative example
5-20		4	4	6.77	839	Example
5-21		<u>5</u>	<u>5</u>	6.66	708	Comparative example

(continued)

No.	Mixed powder			Formed body	Sintered body	Remarks
	Alloyed steel powder	Amount added* (mass%)		Density (Mg/m ³)	Tensile strength (MPa)	
		Cu powder	Mo powder			
4-10	No.4-10	-	-	6.94	806	Example
5-22		4	-	6.89	861	Example
5-23		<u>5</u>	-	6.88	790	Comparative example
5-24		-	2	6.88	850	Example
5-25		-	4	6.83	854	Example
5-26		-	<u>5</u>	6.80	811	Comparative example
5-27		4	4	6.79	885	Example
5-28		<u>5</u>	<u>5</u>	6.75	755	Comparative example
4-14	No.4-14	-	-	6.89	812	Example
5-29		4	-	6.85	868	Example
5-30		<u>5</u>	-	6.84	796	Comparative example
5-31		-	2	6.84	856	Example
5-32		-	4	6.79	861	Example
5-33		-	<u>5</u>	6.77	810	Comparative example
5-34		4	4	6.75	891	Example
5-35		<u>5</u>	<u>5</u>	6.72	762	Comparative example
*3 The mixed powder is taken as 100 mass%.						

Claims

1. An alloyed steel powder for powder metallurgy, comprising

Cu: 1.0 mass% or more and 8.0 mass% or less,
 Mo: more than 0.50 mass% and 2.00 mass% or less, and
 at least one selected from the group consisting of V: 0.05 mass% or more and 0.50 mass% or less, Nb: 0.02 mass% or more and 0.40 mass% or less, and Ti: 0.02 mass% or more and 0.40 mass% or less,
 with the balance consisting of Fe and inevitable impurities.

2. The alloyed steel powder for powder metallurgy according to claim 1, comprising V: 0.05 mass% or more and 0.50 mass% or less.

3. The alloyed steel powder for powder metallurgy according to claim 1 or 2, comprising Nb: 0.02 mass% or more and 0.40 mass% or less.

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4. The alloyed steel powder for powder metallurgy according to any one of claims 1 to 3, comprising Ti: 0.02 mass% or more and 0.40 mass% or less.
5. An iron-based mixed powder for powder metallurgy, comprising the alloyed steel powder for powder metallurgy according to any one of claims 1 to 4 and a metal powder, wherein the metal powder is either or both of a Cu powder of more than 0 mass% and 4 mass% or less and a Mo powder of more than 0 mass% and 4 mass% or less with respect to 100 mass% of the iron-based mixed powder for powder metallurgy.
6. A sintered body using the alloyed steel powder for powder metallurgy according to any one of claims 1 to 4 or the iron-base mixed powder for powder metallurgy according to claim 5.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/023645

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. B22F1/00 (2006.01)i, C22C33/02 (2006.01)i, C22C38/00 (2006.01)i, C22C38/50 (2006.01)i
 FI: B22F1/00 T, B22F1/00 V, C22C33/02 B, C22C38/00 304, C22C38/00 302Z, C22C38/50, B22F1/00 U,
 C22C33/02 A

10

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)

Int. Cl. B22F1/00, C22C33/02, C22C38/00, C22C38/50

15

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2020

Registered utility model specifications of Japan 1996-2020

Published registered utility model applications of Japan 1994-2020

20

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

25

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 08-049047 A (KAWASAKI STEEL CORP.) 20 February	1-3, 5-6
Y	1996, paragraphs [0025], [0028]-[0047]	5
X	JP 06-081001 A (KAWASAKI STEEL CORP.) 22 March	1-4, 6
Y	1994, paragraphs [0011], [0015]-[0018]	5

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

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* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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Date of the actual completion of the international search
21.07.2020Date of mailing of the international search report
04.08.2020

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No. PCT/JP2020/023645
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Patent Documents referred to in the Report	Publication Date	Patent Family	Publication Date
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Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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