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(54) MIXED POWDER FOR POWDER METALLURGY

(57) Provided is a mixed powder for powder metallurgy that uses a fatty acid amide, which is a clean lubricant, and achieves excellent green compact ejectability and compressibility not only at room temperature but also after the die temperature has increased. A mixed powder for powder metallurgy comprises: an iron-based powder; and a fatty acid amide as a lubricant, wherein the fatty acid amide includes a saturated fatty acid bisamide, a saturated fatty acid monoamide, and an unsaturated fatty acid amide, the unsaturated fatty acid amide includes one or both of an unsaturated fatty acid bisamide and an unsaturated fatty acid monoamide, and the following Formulas (1) to (3) are satisfied:

$$0 < (b1) + (b2) + (b3) + (b4) \leq 2.0 \qquad \ldots (1)$$

$$0 < (b1)/(b2) < 0.45 \qquad \ldots (2)$$

$$0 < [(b3) + (b4)]/[(b1) + (b2) + (b3) + (b4)] \leq 0.35 \qquad \ldots (3)$$

where b1, b2, b3, and b4 respectively denote addition amounts of the saturated fatty acid bisamide, the saturated fatty acid monoamide, the unsaturated fatty acid bisamide, and the unsaturated fatty acid monoamide in parts by mass relative to 100 parts by mass of the iron-based powder.

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a mixed powder for powder metallurgy.

BACKGROUND

[0002] Powder metallurgy is a technology that produces parts with high dimensional accuracy by placing a metal powder into a die, compressing and solidifying the metal powder, and sintering it at high temperature. With powder metallurgy, even parts having complex shapes can be formed with high dimensional accuracy, so that machining costs can be significantly reduced as compared with shaping by cutting or the like. Thus, powder metallurgical products are widely used in various machines and parts.

[0003] In powder metallurgy, a mixed powder for powder metallurgy (hereafter also referred to as "mixed powder") obtained by mixing an iron-based powder, which is a main raw material, with an alloying powder such as copper powder, graphite powder, or iron phosphide powder, a powder for improving machinability such as MnS, and a lubricant according to need is used as a raw material powder.

[0004] The lubricant contained in the mixed powder for powder metallurgy plays an extremely important role when the mixed powder for powder metallurgy is subjected to compaction to yield a product. The lubricant is required to have the effect of reducing the friction between the particles contained in the mixed powder when the mixed powder is compacted in a die, and the effect of reducing the friction between the die used for compaction and the particles.

[0005] The effect of reducing the friction between the particles contained in the mixed powder when the mixed powder is compacted in the die is achieved, for example, by the lubricant being present between the particles during compaction. Reducing the friction between the particles promotes the rearrangement of the particles and improves formability (compactibility). The effect of reducing the friction between the die used for compaction and the particles is achieved, for example, by the lubricant on the die surface being present between the die and the particles. Reducing the friction between the die and the particles promotes the rearrangement of the particles on the surface of the green compact and improves formability (compactibility). With these two effects, the mixed powder can be compressed to high density during compaction. Moreover, reducing the friction between the die and the particles reduces the friction between the die and the green compact and improves the releasability of the green compact from the die. The green compact is ejected (removed) out of the die by, for example, pushing it out with a punch. If the friction between the die and the green compact is large, the ejection of the green compact out of the die may be difficult or the surface of the green compact may be damaged.

[0006] Although the lubricant plays an important role during the compaction of the mixed powder and the ejection of the green compact out of the die as mentioned above, it is required that the lubricant does not remain in the sintered body. Since the lubricant is no longer necessary after the green compact is ejected out of the die, for example, it is desirable that the lubricant disappears when the green compact is sintered.

[0007] A component that functions as a binder may also be added to the mixed powder for powder metallurgy. Herein, the binder is a component for adhering additive components such as an alloying powder to the surface of the iron particles of the iron-based powder which is the main component. In a mixed powder obtained by simply mixing an iron-based powder with additive components such as an alloying powder, a powder for improving machinability, and a lubricant, each component may segregate after mixing. In particular, graphite powder, which is typically used as an alloying powder, tends to segregate when the mixed powder is flowed or vibrated because it has a lower density than other components. In order to prevent such segregation, the additive components may be adhered to the particle surface of the iron-based powder via the binder. Such a mixed powder is sometimes called a segregation-free powder. The segregation-free powder has the additive components adhered to the iron-based powder, thereby preventing the foregoing segregation of the components.

[0008] Since the lubricant typically has stronger adhesive power than the iron-based powder, the lubricant deteriorates the fluidity of the mixed powder. Taking advantage of such adhesive power, however, a compound that also functions as the lubricant may be used as the binder in the segregation-free powder.

[0009] Typically, a mixed powder for powder metallurgy is subjected to press forming at a pressure of 300 MPa to 1000 MPa into a certain part shape, and then sintered at a high temperature of 1000 °C or more into a final part shape. Here, the total amount of lubricant and binder contained in the mixed powder is usually about 0.1 parts by mass to 2 parts by mass relative to 100 parts by mass of the iron-based powder. Since the lubricant and the binder have a lower density than the iron-based powder, adding a large amount of lubricant and binder causes a decrease in the density of the green compact (green density) and consequently causes a decrease in the density of the sintered body. In order to increase the green density, it is better to add less lubricant and binder. For example, the use of a binder that also has lubricity can reduce the total amount of binder and lubricant added to the mixed powder.

[0010] The lubricity of the lubricant is greatly influenced by the type of compound contained in the lubricant. Fatty acid amides and fatty acid metal soaps are typical compounds that are widely used as lubricants for powder metallurgy. Both fatty acid amides and fatty acid metal soaps are substances with excellent lubricity. However, fatty acid metal soaps may form metal oxides during sintering and contaminate the surface of the sintered body and the sintering furnace. In contrast, fatty acid amides decompose during sintering and all of their components volatilize, and thus are used as clean lubricants that do not cause contamination.

[0011] For example, JP 1993-148505 A (PTL 1) discloses using one or more selected from stearic acid, oleic acid monoamide, and stearic acid monoamide and one or more selected from ethylenebisstearamide and methylenebis-stearamide as a binder and lubricant.

[0012] JP 2011-184708 A (PTL 2) discloses using a combination of primary or secondary fatty acid amide and alkylene bis fatty acid amide or secondary or tertiary polyhydroxy fatty acid amide.

[0013] WO 2014/123106 A1 (PTL 3) discloses using: linear fatty acid bisamide and linear fatty acid monoamide; and unsaturated fatty acid bisamide or branched fatty acid bisamide or unsaturated fatty acid monoamide, at a predetermined ratio.

[0014] JP 2019-143200 A (PTL 4) discloses using a lubricant that combines unsaturated fatty acid bisamide and saturated hydroxy fatty acid.

CITATION LIST

Patent Literature

[0015]

PTL 1: JP 1993-148505 A
PTL 2: JP 2011-184708 A
PTL 3: WO 2014/123106 A1
PTL 4: JP 2019-143200 A

SUMMARY

(Technical Problem)

[0016] In a commercial powder metallurgy compaction process, hundreds to thousands of parts are formed continuously. In such a continuous compaction process, the temperature of the die increases gradually due to frictional heat. The degree of temperature increase of the die varies depending on the shape of the die and the part. For parts with a large side area, the temperature may increase to 70 °C to 80 °C. Lubricants for powder metallurgy are therefore required to exhibit high lubricity not only at room temperature during the initial compaction stage but also after the die temperature has increased. PTL 1 to PTL 4 only describe the green density and ejection force during compaction at room temperature, and do not mention performance when the die temperature increases.

[0017] It could therefore be helpful to provide a mixed powder for powder metallurgy that uses a fatty acid amide, which is a clean lubricant, and achieves excellent green compact ejectability and compressibility not only at room temperature but also after the die temperature has increased.

(Solution to Problem)

[0018] We thus provide the following.

[1] A mixed powder for powder metallurgy, comprising: an iron-based powder; and a fatty acid amide as a lubricant, wherein the fatty acid amide includes a saturated fatty acid bisamide, a saturated fatty acid monoamide, and an unsaturated fatty acid amide, the unsaturated fatty acid amide includes one or both of an unsaturated fatty acid bisamide and an unsaturated fatty acid monoamide, and the following Formulas (1) to (3) are satisfied:

$$0 < (b1) + (b2) + (b3) + (b4) \leq 2.0 \qquad \ldots \text{Formula (1)}$$

$$0 < (b1)/(b2) < 0.45 \qquad \ldots \text{Formula (2)}$$

$$0 < [(b3) + (b4)]/[(b1) + (b2) + (b3) + (b4)] \leq 0.35 \qquad \ldots \text{Formula (3)}$$

where b1, b2, b3, and b4 respectively denote addition amounts of the saturated fatty acid bisamide, the saturated fatty acid monoamide, the unsaturated fatty acid bisamide, and the unsaturated fatty acid monoamide in parts by mass relative to 100 parts by mass of the iron-based powder.

We also provide the following.

[2] The resin coated metal sheet according to [1], wherein the fatty acid amide has a long-chain alkyl group or alkenyl group having a carbon number of 11 or more and 21 or less.

[3] The resin coated metal sheet according to [1] or [2], wherein the fatty acid amide is a derivative of lauric acid, palmitic acid, stearic acid, behenic acid, oleic acid, or erucic acid.

[4] The resin coated metal sheet according to any one of [1] to [3], further comprising at least one of carbon black, metal oxide fine particles, and metal soap as a fluidity improver.

[5] The resin coated metal sheet according to any one of [1] to [4], further comprising one or both of an alloying powder and a machinability improver.

[6] The resin coated metal sheet according to [5], wherein one or both of the alloying powder and the machinability improver adhere to a particle surface of the iron-based powder via the fatty acid amide.

(Advantageous Effect)

[0019] It is thus possible to provide a mixed powder for powder metallurgy that achieves excellent green compact ejectability and compressibility not only at room temperature but also after the die temperature has increased.

DETAILED DESCRIPTION

[0020] A mixed powder for powder metallurgy according to an embodiment of the present disclosure will be described. The following description shows a preferred embodiment of the present disclosure, and the present disclosure is not limited to such.

[0021] First, an overview of the mixed powder for powder metallurgy according to this embodiment will be described.

[0022] The mixed powder for powder metallurgy according to this embodiment contains an iron-based powder and a fatty acid amide as a lubricant. The fatty acid amide includes a saturated fatty acid bisamide, a saturated fatty acid monoamide, and an unsaturated fatty acid amide. The unsaturated fatty acid amide includes one or both of an unsaturated fatty acid bisamide and an unsaturated fatty acid monoamide.

[0023] The mixed powder for powder metallurgy according to this embodiment satisfies the following Formulas (1) to (3) where b1, b2, b3, and b4 respectively denote the addition amounts of the saturated fatty acid bisamide, the saturated fatty acid monoamide, the unsaturated fatty acid bisamide, and the unsaturated fatty acid monoamide in parts by mass relative to 100 parts by mass of the iron-based powder.

$$0 < (b1) + (b2) + (b3) + (b4) \leq 2.0 \qquad \ldots \text{Formula (1).}$$

$$0 < (b1)/(b2) < 0.45 \qquad \ldots \text{Formula (2).}$$

$$0 < [(b3) + (b4)]/[(b1) + (b2) + (b3) + (b4)] \leq 0.35 \qquad \ldots \text{Formula (3).}$$

[0024] The mixed powder for powder metallurgy according to this embodiment uses a fatty acid amide, which is a clean lubricant, and achieves excellent green compact ejectability and compressibility not only at room temperature but also after the die temperature has increased.

[0025] The mixed powder for powder metallurgy according to this embodiment will be described in detail below.

[0026] The mixed powder for powder metallurgy (hereafter also simply referred to as "mixed powder") according to this embodiment may further contain at least one of a fluidity improver, an alloying powder, and a machinability improver, in addition to the iron-based powder and the fatty acid amide.

[0027] In this embodiment, the iron-based powder is a metal powder containing 50 mass% or more of Fe. In this embodiment, the term "iron powder" refers to a powder consisting of Fe and inevitable impurities. "Iron powder" is typically called "pure iron powder" in this technical field.

[0028] As the iron-based powder, any iron-based powder may be used without limitation. Examples of the iron-based powder include an iron powder and an alloyed steel powder. The alloyed steel powder may be, for example, any of a pre-alloyed steel powder obtained by pre-alloying an alloying element during smelting (fully alloyed steel powder), a partial diffusion-alloyed steel powder obtained by partially diffusing an alloying element in an iron powder to cause alloying, and a hybrid steel powder obtained by partially diffusing an alloying element in a pre-alloyed steel powder. As the alloying element, for example, one or more selected from the group consisting of C, Cu, Ni, Mo, Mn, Cr, V, and Si may be used.

[0029] The iron-based powder may be, for example, any of a reduced iron-based powder produced by reducing iron oxide and an atomized iron-based powder produced by an atomizing method.

[0030] The particle size of the iron-based powder is not limited, but it is preferable that the median size (50% particle size: D_{50}) of the iron-based powder is 30 μm to 120 μm.

[0031] The ratio of the mass of the iron-based powder to the total mass of the mixed powder is not limited, but is preferably 86 mass% or more and more preferably 90 mass% or more.

[0032] The mixed powder according to this embodiment contains a fatty acid amide as a lubricant. The fatty acid amide as a lubricant contained in the mixed powder according to this embodiment includes a saturated fatty acid bisamide, a saturated fatty acid monoamide, and an unsaturated fatty acid amide. The unsaturated fatty acid amide includes one or both of an unsaturated fatty acid bisamide and an unsaturated fatty acid monoamide.

[0033] The mixed powder according to this embodiment satisfies the foregoing Formulas (1) to (3) where b1, b2, b3, and b4 respectively denote the addition amounts of the saturated fatty acid bisamide, the saturated fatty acid monoamide, the unsaturated fatty acid bisamide, and the unsaturated fatty acid monoamide in parts by mass relative to 100 parts by mass of the iron-based powder.

[0034] In detail, the total amount of b1, b2, b3, and b4 is desirably more than 0 parts by mass and 2.0 parts by mass or less relative to the iron-based powder (see Formula (1)). As a result of the total amount being within this range, the green density when the mixed powder is subjected to compaction (compression formation) increases. If the total amount is more than 2.0 parts by mass, the green density during compression may decrease.

[0035] The ratio of b1 to b2 is desirably more than 0 and less than 0.45 (see Formula (2)). As a result of the ratio of b1 to b2 being within this range, the green density during compaction at room temperature and after the die temperature has increased can be increased and the ejection force of the green compact from the die can be reduced.

[0036] The ratio of the total amount of b3 and b4 to the total amount of b1, b2, b3, and b4 is desirably more than 0 and 0.35 or less. As a result of the ratio of the total amount of b3 and b4 being within this range, the green density after the die temperature has increased can be increased and the ejection force of the green compact from the die can be reduced. If the ratio of the total amount of b3 and b4 is excessively high, the green density after the die temperature has increased may decrease and the ejection force may increase.

[0037] The fatty acid amide desirably has a long-chain alkyl group or alkenyl group having a carbon number of 11 or more. This is because lubricity cannot be maintained if the alkyl chain or alkenyl chain is short. From the viewpoint of easy availability, the carbon number of the alkyl chain or alkenyl chain of the fatty acid amide is preferably 21 or less. Specifically, the fatty acid amide is preferably an amide made from a saturated or unsaturated fatty acid such as lauric acid, palmitic acid, stearic acid, behenic acid, oleic acid, or erucic acid. That is, the fatty acid amide is preferably a derivative of lauric acid, palmitic acid, stearic acid, behenic acid, oleic acid, or erucic acid.

[0038] The fluidity improver is carbon black, metal oxide fine particles, or metal soap. The mixed powder according to this embodiment preferably contains at least one of carbon black, metal oxide fine particles, and metal soap as a fluidity improver. This improves the fluidity of the mixed powder, and eases placing the mixed powder into the die during compaction. In addition, formability (compactibility) during compaction is improved.

[0039] The alloying powder is used to improve the strength of the green compact of the mixed powder. As the alloying powder, any powder that can be an alloy component may be used without limitation. As the alloying powder, for example, one or more powders selected from the group consisting of C, Cu, Ni, Mo, Mn, Cr, V, and Si may be used. In the case where C is used as an alloy component, it is preferable to use graphite powder as the alloying powder.

[0040] When the mixed powder containing the alloying powder is sintered, the alloying element dissolves in iron and forms an alloy. Thus, the use of the alloying powder can improve the strength of the finally obtained sintered body.

[0041] As the machinability improver, for example, one or more selected from the group consisting of MnS, CaF_2, and talc may be used. Adding the machinability improver can improve the machinability (workability) of the finally obtained sintered body.

[0042] The mixed powder need not necessarily contain the alloying powder and the machinability improver. The lower limit of the total amount of the alloying powder and the machinability improver relative to 100 parts by mass of the iron-based powder may be 0 parts by mass.

[0043] In the case where one or both of the alloying powder and the machinability improver are added to the mixed powder, the addition amount of the alloying powder and the machinability improver is not limited and may be any amount. The total amount of the alloying powder and the machinability improver is preferably 10 parts by mass or less, more preferably 7 parts by mass or less, and further preferably 5 parts by mass or less relative to 100 parts by mass of the iron-based powder. As a result of the total amount of the alloying powder and the machinability improver being within this range, the density of the sintered body can be further increased and the strength of the sintered body can be further improved.

[0044] In the case where the alloying powder and the machinability improver are contained, the total amount of the alloying powder and the machinability improver is preferably 0.1 parts by mass or more, more preferably 0.5 parts by mass or more, and further preferably 1 part by mass or more. As a result of the total amount of the alloying powder and the machinability improver being within this range, the effect of adding these components can be further enhanced.

[0045] A method of producing the mixed powder will be described below.

[0046] The mixed powder according to the present disclosure can be produced by any method without limitation. For example, the iron-based powder, lubricant (fatty acid amide), fluidity improver, alloying powder, and machinability improver may be mixed using a mixer to produce the mixed powder. The addition and mixing of the components may be performed once, or performed two or more times separately.

[0047] In the case of adhering the alloying powder and/or the machinability improver to the particle surface of the iron-based powder, for example, the iron-based powder and the lubricant (fatty acid amide) are heat-mixed with the alloying powder and/or the machinability improver to adhere the alloying powder and/or the machinability improver to the iron-based powder using the lubricant as a binder as follows. In detail, one or both of the alloying powder and the machinability improver are stirred and mixed together with the lubricant and the iron-based powder. This allows the alloying powder and/or the machinability improver to adhere to the particle surface of the iron-based powder via the fatty acid amide. Mixing by stirring is hereafter simply referred to as mixing. Here, the powder that is being mixed is heated to higher than or equal to the melting point of the lubricant and then gradually cooled while mixing.

[0048] In the case of performing the foregoing heat-mixing and also adding at least one of carbon black, metal oxide, and metal soap, after one or both of the alloying powder and the machinability improver are adhered to the particle surface of the iron-based powder as described above, at least one of carbon black, metal oxide, and metal soap is further added and mixed. The mixing operation after adding at least one of carbon black, metal oxide, and metal soap is carried out at a temperature lower than or equal to the melting point of the lubricant (fatty acid amide) so as to prevent the lubricant that has been fixed once from melting.

[0049] The mixing method or mixing device used to produce the mixed powder is not limited. As the mixing device used to produce the mixed powder, any mixing device such as various known mixers may be used. Examples of the mixing device include a V-shaped mixer, a high-speed bottom stirring mixer, an inclined rotating pan-type mixer, a rotating hoe-type mixer, and a conical planetary screw-type mixer. Two or more of these mixing devices may be used in combination.

[0050] Heat-mixing is not essential. Without performing any heat-mixing, all components may be mixed at room temperature to produce the mixed powder.

EXAMPLES

[Experimental Example 1]

[0051] The components of the composition of each mixed powder according to Experimental Example 1 shown in Table 1 were placed into a V-shaped mixer and mixed for 10 minutes to produce the mixed powder. The mixed powder was then compacted to obtain a green compact. In Table 1, the blending amount of the iron-based powder is 100 parts by mass, and the blending amount of each of the other components is expressed in parts by mass relative to 100 parts by mass of the iron-based powder.

[Table 1]

[0052]

Table 1

No.	Mixed powder for powder metallurgy														Evaluation				Remarks
	(a) Iron-based powder (parts by mass)	(f) Alloying powder		Lubricant											Compaction characteristics (30°C)		Compaction characteristics (70°C)		
		Copper powder (parts by mass)	Graphite powder (parts by mass)	(b1) Saturated fatty acid bisamide		(b2) Saturated fatty acid monoamide		(b3) Unsaturated fatty acid bisamide		(b4) Unsaturated fatty acid monoamide		(b1)+(b2)+(b3)+(b4)	(b1)/(b2)	[(b3)+(b4)]/[(b1)+(b2)+(b3)+(b4)]	Ejection force (MPa)	Green density (g/cm^3)	Ejection force (MPa)	Green density (g/cm^3)	
				Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)								
1	100	2.00	0.80	Ethylenebisstearamide	0.20	Lauramide	0.50	Erucamide	0.10			0.80	0.40	0.13	13.0	7.10	19.5	7.18	Example
2	100	2.00	0.80	Ethylenebisstearamide	0.20	Palmitamide	0.50	Erucamide	0.10			0.80	0.40	0.13	13.1	7.11	19.7	7.19	Example
3	100	2.00	0.80	Ethylenebisstearamide	0.20	Stearamide	0.50	Erucamide	0.10			0.80	0.40	0.13	13.0	7.12	20.0	7.20	Example
4	100	2.00	0.80	Ethylenebisstearamide	0.20	Behenamide	0.50	Erucamide	0.10			0.80	0.40	0.13	12.9	7.12	19.9	7.20	Example
5	100	2.00	0.80	Ethylenebisstearamide	0.20	Lauramide	0.50	Oleamide	0.10			0.80	0.40	0.13	13.0	7.12	19.7	7.18	Example
6	100	2.00	0.80	Ethylenebisstearamide	0.20	Palmitamide	0.50	Oleamide	0.10			0.80	0.40	0.13	13.1	7.11	19.6	7.18	Example
7	100	2.00	0.80	Ethylenebisstearamide	0.20	Stearamide	0.50	Oleamide	0.10			0.80	0.40	0.13	13.0	7.12	19.9	7.19	Example
8	100	2.00	0.80	Ethylenebisstearamide	0.20	Behenamide	0.50	Oleamide	0.10			0.80	0.40	0.13	12.9	7.12	19.8	7.19	Example
9	100	2.00	0.80	Ethylenebisbehenamide	0.20	Stearamide	0.50	Erucamide	0.10			0.80	0.40	0.13	12.8	7.12	19.8	7.20	Example

(continued)

No.	Mixed powder for powder metallurgy														Evaluation				Remarks
	(a) Iron-based powder (parts by mass)	(f) Alloying powder		Lubricant											Compaction characteristics (30°C)		Compaction characteristics (70°C)		
		Copper powder (parts by mass)	Graphite powder (parts by mass)	(b1) Saturated fatty acid bisamide		(b2) Saturated fatty acid monoamide		(b3) Unsaturated fatty acid bisamide		(b4) Unsaturated fatty acid monoamide		(b1)+(b2)+(b3)+(b4)	(b1)/(b2)	[(b3)+(b4)]/[(b1)+(b2)+(b3)+(b4)]	Ejection force (MPa)	Green density (g/cm^3)	Ejection force (MPa)	Green density (g/cm^3)	
				Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)								
10	100	2.00	0.80	Ethylenebisbehenamide	0.20	Stearamide	0.50	Oleamide	0.10			0.80	0.40	0.13	12.8	7.12	19.8	7.19	Example
11	100	2.00	0.80	Methylenebisstearamide	0.20	Stearamide	0.50	Oleamide	0.10			0.80	0.40	0.13	13.0	7.12	19.9	7.19	Example
12	100	2.00	0.80	Ethylenebisstearamide	0.20	Stearamide	0.50			Ethylenebisoleamide	0.10	0.80	0.40	0.13	13.0	7.12	19.9	7.20	Example
13	100	2.00	0.80	Ethylenebisstearamide	0.20	Stearamide	0.50			Ethylenebiserucamide	0.10	0.80	0.40	0.13	12.9	7.12	19.8	7.20	Example
14	100	2.00	0.80	Ethylenebisstearamide	0.25	Palmitamide	0.55					0.80	0.45	0	14.1	7.09	20.7	7.16	Comparative Example
15	100	2.00	0.80	Ethylenebisstearamide	0.60			Oleamide	0.20			0.80	-	0.25	14.0	7.12	21.5	7.19	Comparative Example
16	100	2.00	0.80			Stearamide	0.60	Erucamide	0.20			0.80	0	0.25	13.0	7.09	20.0	7.15	Comparative Example

[0053] In Table 1, each underlined value in the items "(b1) + (b2) + (b3) + (b4)", "(b1)/(b2)", and "[(b3) + (b4)]/[(b1) + (b2) + (b3) + (b4)]" does not satisfy the foregoing Formula (1), (2), or (3) and does not satisfy the requirements according to this embodiment.

[0054] As the iron-based powder, iron powder (pure iron powder: JIP301A produced by JFE Steel Corporation) produced by an atomizing method was used. The median size of this iron powder was 80 μm. The median size was measured using a laser diffraction particle size distribution measuring device.

[0055] As the alloying powder, copper powder and graphite powder were used.

[0056] The median sizes of the powder of fatty acid amide used as a lubricant and the alloying powder were measured in the same manner as for the iron powder. The median size of the copper powder used as the alloying powder was 25 μm. The median size of the graphite powder used as the alloying powder was 4.2 μm.

[0057] The following fatty acid amides were used. As the saturated fatty acid bisamide, ethylenebisstearamide or methylenebisstearamide was used. As the saturated fatty acid monoamide, lauramide, palmitamide, stearamide, or behenamide was used. As the unsaturated fatty acid bisamide, erucamide or oleamide was used. As the unsaturated fatty acid monoamide, ethylenebisoleamide was used.

[0058] Each mixed powder was compacted in a die, and the ejection force and the green density were evaluated. The evaluation results are shown in Table 1.

[0059] The ejection force was evaluated by the following procedure. Using each mixed powder, a cylindrical green compact with a diameter of 11.3 mm and a height of 10 mm was produced at a compaction pressure of 686 MPa in accordance with the method specified in JPMA P 13-2022. Here, a heater was set in the die to adjust the die temperature to 30 °C and 70 °C. In this evaluation, the maximum load when ejecting the green compact from the die was taken to be the ejection force. A lower ejection force indicates better ejectability. The die temperature of 70 °C simulates a case where the die temperature has increased due to frictional heat during continuous compaction in a commercial powder metallurgy compaction process.

[0060] The green density was calculated from the dimensions and weight of the green compact in accordance with the method specified in JIS Z 2508:2020. A higher green density indicates better compressibility of the mixed powder.

[0061] The green compacts of Nos. 1 to 13 according to this embodiment (corresponding to Examples) were superior in ejectability and/or compressibility to the green compacts of Nos. 14 to 16 not satisfying the requirements according to this embodiment.

[0062] In particular, even after the die temperature increase (compaction characteristics (70 °C)), the green compacts of Nos. 1 to 13 according to this embodiment had excellent ejectability and compressibility.

[Experimental Example 2]

[0063] As in Experimental Example 1, the components of the composition of each mixed powder according to Experimental Example 2 shown in Table 2 were placed into a V-shaped mixer and mixed for 10 minutes to produce the mixed powder. The mixed powder was then compacted to obtain a green compact. In Table 2, the blending amount of the iron-based powder is 100 parts by mass, and the blending amount of each of the other components is expressed in parts by mass relative to 100 parts by mass of the iron-based powder. The values not satisfying the requirements according to this embodiment are underlined in Table 2, as in Table 1.

[Table 2]

[0064]

Table 2

No.	Mixed powder for powder metallurgy														Evaluation				Remarks
	(a) Iron-based powder (parts by mass)	(f) Alloying powder		Lubricant											Compaction characteristics (30°C)		Compaction characteristics (70°C)		
		Copper powder (parts by mass)	Graphite powder (parts by mass)	(b1) Saturated fatty acid bisamide		(b2) Saturated fatty acid monoamide		(b3) Unsaturated fatty acid bisamide		(b4) Unsaturated fatty acid monoamide		(b1)+(b2) + (b3) +(b4)	(b1)/(b2)	[(b3) +(b4)]/ [(b1) +(b2)+ (b3) +(b4)]	Ejection force (MPa)	Green density (g/cm^3)	Ejection force (MPa)	Green density (g/cm^3)	
				Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)								
17	100	2.00	0.80	Ethylenebisstearamide	0.20	Behenamide	0.50	Oleamide	0.10			0.80	0.40	0.13	12.9	7.12	19.8	7.19	Example
18	100	2.00	0.80	Ethylenebisstearamide	0.35	Behenamide	0.35	Oleamide	0.10			0.80	1.00	0.13	12.9	7.13	21.0	7.20	Comparative Example
19	100	2.00	0.80	Ethylenebisstearamide	0.20	Stearamide	0.50	Oleamide	0.10			0.80	0.40	0.13	13.0	7.12	19.9	7.19	Example
20	100	2.00	0.80	Ethylenebisstearamide	0.40	Stearamide	0.30	Oleamide	0.10			0.80	1.33	0.13	13.5	7.13	21.5	7.20	Comparative Example
21	100	2.00	0.80	Ethylenebisstearamide	0.20	Behenamide	0.50	Erucamide	0.10			0.80	0.40	0.13	12.9	7.12	19.9	7.20	Example
22	100	2.00	0.80	Ethylenebisstearamide	0.10	Behenamide	0.40	Erucamide	0.30			0.80	0.25	0.38	12.9	7.13	21.0	7.17	Comparative Example
23	100	2.00	0.80	Ethylenebisstearamide	0.20	Stearamide	0.50			Ethylenebisoleamide	0.10	0.80	0.40	0.13	13.0	7.12	19.9	7.20	Example
24	100	2.00	0.80	Ethylenebisstearamide	0.50	Stearamide	0.20			Ethylenebisoleamide	0.10	0.80	2.50	0.13	13.5	7.13	21.5	7.21	Comparative Example

[0065] The following fatty acid amides were used. As the saturated fatty acid bisamide, ethylenebisstearamide was used. As the saturated fatty acid monoamide, stearamide or behenamide was used. As the unsaturated fatty acid bisamide, erucamide or oleamide was used. As the unsaturated fatty acid monoamide, ethylenebisoleamide was used.

[0066] Each mixed powder was compacted in a die, and the ejection force and the green density were evaluated in the same manner as in Experimental Example 1. The evaluation results are shown in Table 2.

[0067] The green compacts of Nos. 17, 19, 21, and 23 according to this embodiment were superior in ejectability and/or compressibility to the green compacts of Nos. 18, 20, 22, and 24 not satisfying the requirements according to this embodiment.

[0068] In particular, even after the die temperature increase (compaction characteristics (70 °C)), the green compacts of Nos. 17, 19, 21, and 23 according to this embodiment were superior in ejectability and/or compressibility respectively to the green compacts of Nos. 18, 20, 22, and 24 under the same conditions except for the condition related to "(b1)/(b2)".

[Experimental Example 3]

[0069] As in Experimental Examples 1 and 2, the components of the composition of each mixed powder according to Experimental Example 3 shown in Table 3 were placed into a V-shaped mixer and mixed for 10 minutes to produce the mixed powder. The mixed powder was then compacted to obtain a green compact. In Table 3, the blending amount of the iron-based powder is 100 parts by mass, and the blending amount of each of the other components is expressed in parts by mass relative to 100 parts by mass of the iron-based powder. In Experimental Example 3, carbon black, metal oxide (titanium oxide: TiO_2 or silica: SiO_2), or metal soap (zinc stearate or lithium stearate) was further added as a fluidity improver, unlike in Experimental Examples 1 and 2. The values not satisfying the requirements according to this embodiment are underlined in Table 3, as in Table 1.

[Table 3]

Table 3

No.	Mixed powder for powder metallurgy																Evaluation						Remarks
	(a) Iron-based powder (parts by mass)	(c), (d), (e) Fluidity improver		(f) Alloying powder		Lubricant											Powder characteristics		Compaction characteristics (30°C)		Compaction characteristics (70°C)		
		Substance name	Addition amount (parts by mass)	Copper powder (parts by mass)	Graphite powder (parts by mass)	(b1) Saturated fatty acid bisamide		(b2) Saturated fatty acid monoamide		(b3) Unsaturated fatty acid bisamide		(b4) Unsaturated fatty acid monoamide		(b1)+(b2)+(b3)+(b4)	(b1)/(b2)	[(b3)+(b4)]/[(b1)+(b2)+(b3)+(b4)]	Apparent density (g/cm^3)	Powder fluidity (sec/50g)	Ejection force (MPa)	Green density (g/cm^3)	Ejection force (MPa)	Green density (g/cm^3)	
						Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)										
25	100	Carbon black	0.05	2.00	0.80	Ethylenebisstearamide	0.20	Lauramide	0.50	Erucamide	0.10			0.80	0.40	0.13	3.33	27	13.5	7.09	20.0	7.17	Example
26	100	Carbon black	0.05	2.00	0.80	Ethylenebisstearamide	0.20	Palmitamide	0.50	Erucamide	0.10			0.80	0.40	0.13	3.32	26	13.6	7.10	20.2	7.18	Example
27	100	Carbon black	0.05	2.00	0.80	Ethylenebisstearamide	0.20	Stearamide	0.50	Erucamide	0.10			0.80	0.40	0.13	3.32	26	13.5	7.11	20.5	7.19	Example
28	100	Carbon black	0.05	2.00	0.80	Ethylenebisstearamide	0.20	Behenamide	0.50	Erucamide	0.10			0.80	0.40	0.13	3.31	27	13.4	7.11	20.4	7.19	Example
29	100	Carbon black	0.05	2.00	0.80	Ethylenebisstearamide	0.35	Behenamide	0.35	Oleamide	0.10			0.80	1.00	0.13	3.33	26	13.4	7.12	21.5	7.19	Comparative Example
30	100	SiO2	0.05	2.00	0.80	Ethylenebisstearamide	0.20	Stearamide	0.50			Ethylenebisoleamide	0.10	0.80	0.40	0.13	3.30	27	13.5	7.11	20.4	7.19	Example
31	100	SiO2	0.05	2.00	0.80	Ethylenebisstearamide	0.20	Stearamide	0.50			Ethylenebiserucamide	0.10	0.80	0.40	0.13	3.30	27	13.4	7.11	20.3	7.19	Example
32	100	TiO2	0.05	2.00	0.80	Ethylenebisstearamide	0.20	Stearamide	0.50	Oleamide	0.10			0.80	0.40	0.13	3.29	28	13.5	7.11	20.4	7.18	Example
33	100	TiO2	0.05	2.00	0.80	Ethylenebisstearamide	0.20	Behenamide	0.50	Oleamide	0.10			0.80	0.40	0.13	3.29	28	13.4	7.11	20.3	7.18	Example
34	100	SiO2	0.05	2.00	0.80	Ethylenebisstearamide	0.40	Stearamide	0.30	Oleamide	0.10			0.80	1.33	0.13	3.30	27	14.0	7.12	22.0	7.19	Comparative Example
35	100	Zinc stearate	0.10	2.00	0.80	Methylenebisstearamide	0.15	Stearamide	0.45	Oleamide	0.10			0.70	0.33	0.14	3.29	28	13.0	7.13	19.9	7.20	Example
36	100	Zinc stearate	0.10	2.00	0.80	Ethylenebisbehenamide	0.15	Stearamide	0.45	Erucamide	0.10			0.70	0.33	0.14	3.30	28	12.8	7.13	19.8	7.21	Example
37	100	Zinc stearate	0.10	2.00	0.80	Ethylenebisstearamide	0.05	Behenamide	0.35	Erucamide	0.30			0.70	0.25	0.38	3.28	29	12.9	7.14	21.0	7.18	Comparative Example
38	100	Lithium stearate	0.10	2.00	0.80	Ethylenebisstearamide	0.15	Stearamide	0.45	Erucamide	0.10			0.70	0.33	0.14	3.34	28	13.0	7.12	20.0	7.21	Example
39	100	Lithium stearate	0.10	2.00	0.80	Ethylenebisstearamide	0.15	Palmitamide	0.45	Erucamide	0.10			0.70	0.33	0.14	3.33	28	13.1	7.11	19.7	7.20	Example
40	100	Lithium stearate	0.10	2.00	0.80	Ethylenebisstearamide	0.45	Stearamide	0.15			Ethylenebisoleamide	0.10	0.70	2.50	0.13	3.35	26	13.5	7.13	21.5	7.22	Comparative Example

[0070] The following fatty acid amides were used. As the saturated fatty acid bisamide, ethylenebisstearamide or methylenebisstearamide was used. As the saturated fatty acid monoamide, lauramide, palmitamide, stearamide, or behenamide was used. As the unsaturated fatty acid bisamide, erucamide or oleamide was used. As the unsaturated fatty acid monoamide, ethylenebisoleamide was used.

[0071] The apparent density and fluidity of each mixed powder were evaluated as powder characteristics. The evaluation results are shown in Table 3.

[0072] The apparent density was evaluated using a funnel with a diameter of 2.5 mm in accordance with the method specified in JIS Z 2504:2020. A higher apparent density is better.

[0073] For the fluidity, the time taken for 50 g of the mixed powder to flow down was measured using a funnel with an orifice diameter of 2.5 mm in accordance with the method specified in JIS Z 2502:2020. A shorter time taken for the mixed powder to flow down indicates better fluidity.

[0074] Moreover, each mixed powder was compacted in a die, and the ejection force and the green density were evaluated in the same manner as in Experimental Example 1. The evaluation results are shown in Table 3.

[0075] The addition of carbon black, metal oxide, or metal soap as a fluidity improver contributed to good apparent density and fluidity. In the case of a powder with poor fluidity, the powder may be unable to be discharged from the funnel and measured by the method specified in JIS Z 2502:2020. The fluidity of each of the mixed powders of Nos. 25 to 40 was able to be measured, indicating that the mixed powder had good fluidity.

[0076] The green compacts of Nos. 25 to 28, 30 to 33, 35, 36, 38, and 39 according to this embodiment were superior in ejectability and/or compressibility to the green compacts of Nos. 29, 34, 37, and 40 not satisfying the requirements according to this embodiment.

[0077] In particular, after the die temperature increase (compaction characteristics (70 °C)), the green compacts of Nos. 25 to 28, 30 to 33, 35, 36, 38, and 39 according to this embodiment were superior in at least ejectability to the green compacts of Nos. 29, 34, 37, and 40 not satisfying the requirements according to this embodiment, although similar in compressibility in some cases.

[Experimental Example 4]

[0078] As in Experimental Example 3, the components of the composition of each mixed powder according to Experimental Example 4 shown in Table 4 were placed into a V-shaped mixer and mixed for 10 minutes to produce the mixed powder. The mixed powder was then compacted to obtain a green compact. In Table 4, the blending amount of the iron-based powder is 100 parts by mass, and the blending amount of each of the other components is expressed in parts by mass relative to 100 parts by mass of the iron-based powder. In Experimental Example 4, manganese sulfide (MnS) was further added as a machinability improver, unlike in Experimental Example 3.

[Table 4]

Table 4

No.	Mixed powder for powder metallurgy																	Evaluation						Remarks
	(a) Iron-based powder (parts by mass)	(c), (d), (e) Fluidity improver		(f) Alloying powder		(g) Machinability improver	Lubricant											Powder characteristics		Compaction characteristics (30°C)		Compaction characteristics (70°C)		
		Substance name	Addition amount (parts by mass)	Copper powder (parts by mass)	Graphite powder (parts by mass)	MnS (parts by mass)	(b1) Saturated fatty acid bisamide		(b2) Saturated fatty acid monoamide		(b3) Unsaturated fatty acid bisamide		(b4) Unsaturated fatty acid monoamide		(b1)+(b2)+(b3)+(b4)	(b1)/(b2)	[(b3)+(b4)]/[(b1)+(b2)+(b3)+(b4)]	Apparent density (g/cm^3)	Powder fluidity (sec/50g)	Ejection force (MPa)	Green density (g/cm^3)	Ejection force (MPa)	Green density (g/cm^3)	
							Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Substance name	Addition amount (parts by mass)										
41	100	Carbon black	0.05	2.00	0.80	0.10	Ethylenebis-stearamide	0.20	Lauramide	0.50	Erucamide	0.10			0.80	0.40	0.13	3.30	27	13.5	7.07	20.0	7.15	Example
42	100	Carbon black	0.05	2.00	0.80	0.10	Ethylenebis-stearamide	0.35	Behenamide	0.35	Oleamide	0.10			0.80	1.0	0.13	3.30	26	13.4	7.10	21.5	7.17	Comparative Example
43	100	SiO2	0.05	2.00	0.80	0.10	Ethylenebis-stearamide	0.20	Stearamide	0.50			Ethylenebis-oleamide	0.10	0.80	0.4	0.13	3.27	27	13.5	7.09	20.4	7.17	Example
44	100	SiO2	0.05	2.00	0.80	0.10	Ethylenebis-stearamide	0.40	Stearamide	0.30	Oleamide	0.10			0.80	1.3	0.13	3.27	27	14.0	7.10	22.0	7.17	Comparative Example
45	100	Zinc stearate	0.10	2.00	0.80	0.10	Methylenebis-stearamide	0.15	Stearamide	0.45	Oleamide	0.10			0.70	0.3	0.14	3.26	28	13.0	7.11	19.9	7.18	Example
46	100	Zinc stearate	0.10	2.00	0.80	0.10	Ethylenebis-stearamide	0.05	Behenamide	0.35	Erucamide	0.30			0.80	0.3	0.38	3.25	29	12.9	7.12	21.0	7.16	Comparative Example
47	100	Lithium stearate	0.10	2.00	0.80	0.10	Ethylenebis-stearamide	0.15	Stearamide	0.45	Erucamide	0.10			0.70	0.33	0.14	3.31	28	13.0	7.10	20.0	7.19	Example
48	100	Lithium stearate	0.10	2.00	0.80	0.10	Ethylenebis-stearamide	0.45	Stearamide	0.15			Ethylenebis-oleamide	0.10	0.80	2.5	0.13	3.32	26	13.5	7.11	21.5	7.20	Comparative Example

[0079] The following fatty acid amides were used. As the saturated fatty acid bisamide, ethylenebisstearamide or methylenebisstearamide was used. As the saturated fatty acid monoamide, lauramide, stearamide, or behenamide was used. As the unsaturated fatty acid bisamide, erucamide or oleamide was used. As the unsaturated fatty acid monoamide, ethylenebisoleamide was used.

[0080] In addition, carbon black, metal oxide (silica: SiO_2), or metal soap (zinc stearate or lithium stearate) was added as a fluidity improver.

[0081] The apparent density and fluidity of the mixed powder and the ejection force and green density of the green compact were evaluated in the same manner as in Experimental Example 3. The evaluation results are shown in Table 4.

[0082] In this experimental example in which the machinability improver was added, the mixed powders of Nos. 41, 43, 45, and 47 according to this embodiment had good apparent density and fluidity. The green compacts of Nos. 41, 43, 45, and 47 according to this embodiment were superior in ejectability and/or compressibility to the green compacts of Nos. 42, 44, 46, and 48 not satisfying the requirements according to this embodiment.

[0083] In particular, after the die temperature increase (compaction characteristics (70 °C)), the green compacts of Nos. 41, 43, 45, and 47 according to this embodiment were superior in at least ejectability to the green compacts of Nos. 42, 44, 46, and 48 not satisfying the requirements according to this embodiment, although similar in compressibility in some cases.

[Experimental Example 5]

[0084] The components of the composition of each mixed powder according to Experimental Example 5 shown in Table 5 were placed into a high-speed bottom stirring mixer and mixed to produce the mixed powder. The mixed powder was then compacted to obtain a green compact. In Table 5, the blending amount of the iron-based powder is 100 parts by mass, and the blending amount of each of the other components is expressed in parts by mass relative to 100 parts by mass of the iron-based powder. In Experimental Example 5, the lubricant was added in two separate times, unlike in Experimental Example 3.

[Table 5]

Table 5

No.	Mixed powder for powder metallurgy																					Evaluation						Remarks
	(a) Iron-based powder (parts by mass)	(c), (d), (e) Fluidity improver		(f) Alloying powder		Lubricant																Powder characteristics		Compaction characteristics (30°C)		Compaction characteristics (70°C)		
						(b1) Saturated fatty acid bisamide			(b2) Saturated fatty acid monoamide			(b3) Unsaturated fatty acid bisamide			(b4) Unsaturated fatty acid monoamide			(b1)+(b2)+(b3)+(b4)	(b1)/(b2)	[(b3)+(b4)]/[(b1)+(b2)+(b3)+(b4)]							
		Substance name	Addition amount (parts by mass)	Copper powder (parts by mass)	Graphite powder (parts by mass)	Substance name	Addition amount (parts by mass)	Secondary addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Secondary addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Secondary addition amount (parts by mass)	Substance name	Addition amount (parts by mass)	Secondary addition amount (parts by mass)				Apparent density (g/cm^3)	Powder fluidity (sec/50g)	Ejection force (MPa)	Green density (g/cm^3)	Ejection force (MPa)	Green density (g/cm^3)	
49	100	Carbon black	0.05	2.00	0.80	Ethylenebis-stearamide	0.10	0.10	Stearamide	0.25	0.25	Erucamide	0.10					0.80	0.40	0.13	3.28	28	14.0	7.11	21.0	7.19	Example
50	100	Carbon black	0.05	2.00	0.80	Ethylenebis-stearamide	0.17	0.18	Behenamide	0.10	0.25	Oleamide	0.10					0.80	1.00	0.13	3.29	28	13.9	7.12	22.0	7.19	Comparative Example
51	100	Zinc stearate	0.10	2.00	0.80	Ethylenebis-behenamide	0.07	0.08	Stearamide	0.20	0.25	Erucamide	0.10					0.70	0.33	0.14	3.26	30	13.3	7.13	20.3	7.21	Example
52	100	Zinc stearate	0.10	2.00	0.80	Ethylenebis-stearamide	0.03	0.03	Behenamide	0.15	0.20	Erucamide	0.30					0.70	0.14	0.38	3.24	31	13.4	7.14	21.5	7.18	Comparative Example
53	100	Lithium stearate	0.10	2.00	0.80	Ethylenebis-stearamide	0.07	0.08	Stearamide	0.20	0.25	Erucamide	0.10					0.70	0.33	0.14	3.30	30	13.5	7.12	20.5	7.21	Example
54	100	Lithium stearate	0.10	2.00	0.80	Ethylenebis-stearamide	0.20	0.25	Stearamide	0.07	0.08				Ethylenebis-oleamide	0.10		0.70	3.00	0.13	3.31	28	14.0	7.13	22.0	7.22	Comparative Example

[0085] The following fatty acid amides were used. As the saturated fatty acid bisamide, ethylenebisstearamide was used. As the saturated fatty acid monoamide, stearamide or behenamide was used. As the unsaturated fatty acid bisamide, erucamide or oleamide was used. As the unsaturated fatty acid monoamide, ethylenebisoleamide was used.

[0086] In addition, carbon black or metal soap (zinc stearate or lithium stearate) was added as a fluidity improver.

[0087] The lubricant was added as follows. First, the iron-based powder, the alloying powder, and part of the lubricant (the amount shown in the "Primary addition amount" column in Table 5) were placed in the high-speed bottom-stirring mixer and heat-mixed at a temperature higher than the melting points of all compounds contained in the primary added lubricant for 20 minutes, and then cooled to a temperature lower than the melting points. Thereafter, part of the lubricant (the amount shown in the "Secondary addition amount" column in Table 5) and the fluidity improver were added and mixed at room temperature for 1 minute to obtain the mixed powder according to Experimental Example 5.

[0088] The apparent density and fluidity of the mixed powder and the ejection force and green density of the green compact were evaluated in the same manner as in Experimental Example 3. The evaluation results are shown in Table 5.

[0089] The green compacts of Nos. 49, 51, and 53 according to this embodiment were superior in ejectability and/or compressibility after the die temperature increase (70 °C) to the green compacts of Nos. 50, 52, and 54 not satisfying the requirements according to this embodiment.

[0090] A mixed powder for powder metallurgy can be provided in this way.

[0091] The embodiments disclosed in this specification are illustrative, and the present disclosure is not limited to such embodiments and modifications can be made as appropriate without departing from the object of the present disclosure.

INDUSTRIAL APPLICABILITY

[0092] The present disclosure can be applied to mixed powders for powder metallurgy.

Claims

1. A mixed powder for powder metallurgy, comprising:

   an iron-based powder; and
   a fatty acid amide as a lubricant,
   wherein the fatty acid amide includes a saturated fatty acid bisamide, a saturated fatty acid monoamide, and an unsaturated fatty acid amide,
   the unsaturated fatty acid amide includes one or both of an unsaturated fatty acid bisamide and an unsaturated fatty acid monoamide, and
   the following Formulas (1) to (3) are satisfied:

$$0 < (b1) + (b2) + (b3) + (b4) \leq 2.0 \quad \ldots \text{Formula (1)}$$

$$0 < (b1)/(b2) < 0.45 \quad \ldots \text{Formula (2)}$$

$$0 < [(b3) + (b4)]/[(b1) + (b2) + (b3) + (b4)] \leq 0.35 \quad \ldots \text{Formula (3)}$$

   where b1, b2, b3, and b4 respectively denote addition amounts of the saturated fatty acid bisamide, the saturated fatty acid monoamide, the unsaturated fatty acid bisamide, and the unsaturated fatty acid monoamide in parts by mass relative to 100 parts by mass of the iron-based powder.

2. The mixed powder for powder metallurgy according to claim 1, wherein the fatty acid amide has a long-chain alkyl group or alkenyl group having a carbon number of 11 or more and 21 or less.

3. The mixed powder for powder metallurgy according to claim 1 or 2, wherein the fatty acid amide is a derivative of lauric acid, palmitic acid, stearic acid, behenic acid, oleic acid, or erucic acid.

4. The mixed powder for powder metallurgy according to any one of claims 1 to 3, further comprising at least one of carbon black, metal oxide fine particles, and metal soap as a fluidity improver.

5. The mixed powder for powder metallurgy according to any one of claims 1 to 4, further comprising one or both of an

alloying powder and a machinability improver.

6. The mixed powder for powder metallurgy according to claim 5, wherein one or both of the alloying powder and the machinability improver adhere to a particle surface of the iron-based powder via the fatty acid amide.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/012334

A. CLASSIFICATION OF SUBJECT MATTER

B22F 1/10(2022.01)i; ***B22F 1/00***(2022.01)i; ***B22F 1/105***(2022.01)i; ***B22F 1/17***(2022.01)i
FI: B22F1/10; B22F1/00 V; B22F1/105; B22F1/17

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)

B22F1/10; B22F1/00; B22F1/105; B22F1/17

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 09-263802 A (KAWASAKI STEEL CORP) 07 October 1997 (1997-10-07) entire text	1-6
A	JP 2013-194255 A (TOYOTA CENTRAL R&D LABS INC) 30 September 2013 (2013-09-30) entire text	1-6
A	JP 2002-155301 A (KAWASAKI STEEL CORP) 31 May 2002 (2002-05-31) entire text	1-6
A	WO 2020/217551 A1 (JFE STEEL CORP) 29 October 2020 (2020-10-29) entire text	1-6
A	JP 2017-036487 A (JFE STEEL CORP) 16 February 2017 (2017-02-16) entire text	1-6
A	JP 2013-503977 A (HOEGANAES AB) 04 February 2013 (2013-02-04) entire text	1-6

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

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"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

Date of the actual completion of the international search **21 April 2023**	Date of mailing of the international search report **16 May 2023**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/012334

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	WO 2022/260009 A1 (SHOWA DENKO MAT CO LTD) 15 December 2022 (2022-12-15) paragraphs [0077]-[0081], table 2, examples 29, 50	1-6

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/012334

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 09-263802 A	07 October 1997	(Family: none)	
JP 2013-194255 A	30 September 2013	(Family: none)	
JP 2002-155301 A	31 May 2002	(Family: none)	
WO 2020/217551 A1	29 October 2020	EP 3960331 A1 entire text CN 113710392 A	
JP 2017-036487 A	16 February 2017	(Family: none)	
JP 2013-503977 A	04 February 2013	US 2012/0187611 A1 entire text WO 2011/029759 A1	
WO 2022/260009 A1	15 December 2022	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 5148505 A **[0011] [0015]**
- JP 2011184708 A **[0012] [0015]**
- WO 2014123106 A1 **[0013] [0015]**
- JP 2019143200 A **[0014] [0015]**