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(54) Mixed powder for powder metallurgy and green compact using the same

(57) A mixed powder for powder metallurgy to be used as a feedstock of a green compact includes an iron powder and/or an iron alloy powder, a component for improving mechanical properties, and a thermosetting resin powder. In the mixed powder, the thermosetting resin powder is composed of at least one resin selected from the group consisting of an epoxy-polyester-based resin, an epoxy-based resin, and an acrylic-based resin. In addition, the average particle diameter of the thermosetting resin powder is 100 μm or less, and the content of the thermosetting resin powder relative to the total amount of the iron powder and/or the iron alloy powder is 0.05 to 1.0 mass percent.

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Description

[0001] The present invention relates to a mixed powder for powder metallurgy to be used as a feedstock of a green compact having an adequate density and strength even before the sintering process and having an excellent machinability, and a green compact using the mixed powder as a feedstock.

[0002] A powder metallurgy is a technology used for producing machine parts and oil-impregnated bearings from a metal powder. Since highly accurate products can be efficiently mass-produced, the powder metallurgy is indispensable particularly in the automobile industry and the like. In this powder metallurgy, in general, a mixed powder including a metal powder is molded by compression and the resultant green compact is then dewaxed. Subsequently, for example, in an iron-based powder metallurgy, the compact is sintered at a temperature of about 1,000°C to about 1,300°C. In this sintering process, the mixed metal powder forms an alloy, thereby increasing the strength of the compact. A cutting operation is then performed on the resultant sintered compact.

[0003] However, such a sintered compact has an excessively high strength from the viewpoint of a cutting operation. Furthermore, the lifetime of a cutting tool used is shortened because of the high strength of the sintered compact. On the other hand, a green compact cannot be subjected to a cutting operation prior to sintering because the green compact is brittle. Accordingly, a technology is desired by which the strength of a green compact prior to the sintering process is increased, so that the green compact can subsequently be subjected to a cutting operation and finally sintered.

[0004] A document by Tianjun Liu et al. (Funtai oyobi Funmatsu yakin (Journal of the Japan Society of Powder and Powder Metallurgy) Vol. 50, No. 11, pp. 832-836 (2003)) discloses an example of such a technology. According to this technology, a polymer lubricant is added to a mixed powder, which constitutes a feedstock, and a green compact made of the resultant mixed powder is heated at a temperature lower than the sintering temperature. Consequently, the strength of the compact can be increased only by this heat treatment and thus a cutting operation can be performed prior to the sintering process. However, since a polymer lubricant is used as a lubricant, its lubricity during compression molding may be insufficient. In addition, although the temperature is as relatively low as 190°C, it takes about an hour to complete the heat treatment before the cutting operation can be performed. Therefore, this heat treatment decreases the productivity.

[0005] In the powder metallurgy, when a mixed powder is discharged from a storage hopper or when a die is filled with the mixed powder, the fluidity of the mixed powder is one of its important characteristics. Specifically, a low fluidity of a mixed powder causes the following problems. For example, a bulging can occur at the upper part of a discharging hole of a hopper, resulting in a discharge failure. Also, the mixed powder can become clogged in a hose connecting from the hopper to a shoe box. Furthermore, even if a mixed powder having a low fluidity is compulsorily discharged from the hose, the powder may not satisfactorily fill a die, in particular, a die having thin walls. Consequently, a satisfactory compact may not be formed. For these reasons, a raw powder for powder metallurgy having excellent fluidity has been strongly desired.

[0006] Although the object is different from that of the present invention, the following technology for producing a bonded magnet is known: A thermosetting resin is added to a magnetic powder or the like, and a heat treatment is then performed. Thus, a compact is cured without sintering while the magnetic properties of the compact are ensured. The resultant compact is used without further treatment. Accordingly, this manufacturing technology of a bonded magnet may be applied to the powder metallurgy. However, known manufacturing technologies of bonded magnets cannot be applied to the powder metallurgy as they are.

[0007] For example, Japanese Unexamined Patent Application Publication Nos. 4-284602 (paragraph No. 0007, and Examples), 6-112022 (paragraph Nos. 0015 and 0016, and Examples), 6-188137 (paragraph Nos. 0015 and 0020, and Examples), and 8-31677 (paragraph Nos. 0031 and 0033, and Examples) disclose methods for producing a bonded magnet in which a mixture of an alloy powder and a thermosetting resin (binder) is used as a feedstock. However, the type and the particle diameter of the thermosetting resin are not studied in detail because these technologies relate to a bonded magnet and their objects are different from the object of the present invention. In addition, the content of thermosetting resin is relatively large from the viewpoint of application to the powder metallurgy. For example, according to Japanese Unexamined Patent Application Publication No. 4-284602, the content of a thermosetting resin binder is 0.5 to 4 mass percent based on an alloy. According to Japanese Unexamined Patent Application Publication No. 6-112022, 0.5 to 5 parts by weight (in particular, 1 to 3 parts by weight) of a thermosetting resin is added to 100 parts by weight of a magnetic powder. However, in Examples in these patent documents, the amount of a thermosetting resin relative to the total amount of an alloy powder is 2 mass percent or more. According to investigations made by the inventors of the present invention, when a thermosetting resin is excessively added to a mixed powder for powder metallurgy, the fluidity of the powder and the density of the green compact are decreased.

[0008] According to Japanese Unexamined Patent Application Publication No. 10-303009 (Claims), an epoxy resin powder having an average particle diameter of 50 μm or less, which is used as a resin binder, is mixed with a magnetic powder to mold a bonded magnet. The compounding ratio of the epoxy resin powder to the magnetic powder is 0.1 to 0.5 mass percent. An inorganic additive is added to the mixed powder in order to suppress the abrasion with a die during molding. However, in this mixed powder, a component that improves the strength or machinability of the compact is not considered. In addition, the content of this inorganic additive is very small (20 to 40 mass percent of the total amount of the resin binder, 0.02 to 0.2 mass percent of the total amount of the magnetic powder). Therefore, even if the inorganic additive has a function of enhancing the strength of the compact or the like, the function may not be fulfilled in such a small content.

[0009] In view of the above-described situation, it is an object of the present invention to provide a mixed powder for powder metallurgy to.be used as a feedstock of a green compact. Because of its excellent fluidity, the mixed powder provides a high productivity. Furthermore, a green compact using the mixed powder as a feedstock has an adequate density and strength, and is excellent in terms of machinability. Therefore, a cutting operation can be performed prior to the sintering process, and in addition, the lifetime of a cutting tool used can be extended. Also, it is an object of the present invention to provide a green compact using this mixed powder as a feedstock for powder metallurgy, the green compact having an excellent strength and the like even before sintering.

[0010] To solve the above-described problems, the inventors of the present invention have extensively studied, in particular, the composition of a mixed powder for powder metallurgy and found the following: When a component for improving mechanical properties and a thermosetting resin powder are added to a base powder, and in addition, an appropriate thermosetting resin powder is used, a green compact having an adequate density and strength can be produced. The present invention has been made on the basis of this finding.

[0011] Specifically, a mixed powder for powder metallurgy of the present invention is used as a feedstock of a green compact, and the mixed powder includes an iron powder and/or an iron alloy powder, a component for improving mechanical properties, and a thermosetting resin powder. In the mixed powder, the thermosetting resin powder is composed of at least one resin selected from the group consisting of an epoxy-polyester-based resin, an epoxy-based resin, and an acrylic-based resin. In addition, the average particle diameter of the thermosetting resin powder is 100 μm or less, and the content of the thermosetting resin powder relative to the total amount of the iron powder and/or the iron alloy powder is 0.05 to 1.0 mass percent.

[0012] The mixed powder for powder metallurgy preferably further includes a lubricant. This is because the lubricant can decrease the coefficient of friction between the green compact and a die. As a result, the generation of die galling and damage of the die can be suppressed. The lubricant is preferably at least one compound selected from the group consisting of ethylenebisstearamide, stearamide, zinc stearate, and lithium stearate. This is because these compounds are excellent as an additional component of the mixed powder for powder metallurgy.

[0013] The component for improving mechanical properties is preferably at least one substance selected from the group consisting of copper, nickel, chromium, molybdenum, graphite, and manganese sulfide. This is because these substances are diffused into.the iron powder or the like during the sintering process. Consequently, the hardness or the toughness of the compact can be improved or the machinability of the compact can be improved.

[0014] Furthermore, a green compact of the present invention is made of the above-described mixed powder for powder metallurgy.

[0015] The mixed powder for powder metallurgy of the present invention has excellent fluidity and the like and provides an excellent productivity. Furthermore, since a green compact using this mixed powder as a feedstock has an adequate density and strength even before sintering, the green compact can be subjected to a cutting operation. In addition, since the green compact does not have an excessively high strength, the lifetime of a cutting tool used can be extended. Accordingly, the mixed powder for powder metallurgy of the present invention and the green compact using the mixed powder as a feedstock are excellent for industrial application from the viewpoint that the productivity of powder metallurgy can be improved.

[0016] A mixed powder for powder metallurgy of the present invention includes an iron powder and/or an iron alloy powder, a component for improving mechanical properties, and a thermosetting resin powder. The thermosetting resin powder is composed of at least one resin selected from the group consisting of an epoxy-polyester-based resin, an epoxy-based resin, and an acrylic-based resin; the average particle diameter of the thermosetting resin powder is 100 μm or less; and the content of the thermosetting resin powder relative to the total amount of the iron powder and/or the iron alloy powder is 0.05 to 1.0 mass percent.

[0017] For example, commercially available normal iron powders and/or iron alloy powders used for a material for metallurgy can be used in the present invention.

[0018] The component for improving mechanical properties is added in order to improve the mechanical properties such as the hardness and the toughness of a compact or to improve the machinability of the compact by diffusing into a base iron powder or the like during the sintering process. Examples of the component for improving mechanical properties include metal powders used for alloys such as copper, nickel, chromium, and molybdenum powders; and inorganic powders such as graphite and manganese sulfide powders. These components may be used alone or in combinations of two or more powders. The component for improving mechanical properties may be mixed with an iron powder or the like when used. Alternatively, for example, graphite may be uniformly adhered to an iron powder or the like with a binder therebetween when used.

[0019] The content of metal powder used for alloys serving as a component for improving mechanical properties is 0.1 to 4 mass percent (hereinafter, unless otherwise stated, the "mass percent" is simply represented by "%") relative to the total amount of a base iron powder or the like. At a content of less than 0.1%, a satisfactory improvement of mechanical properties may not be achieved because of a small amount of diffusion in the base powder. On the other hand, at a content exceeding 4%, the improvement of mechanical properties is also decreased. In addition, at such an excessively high content, a green compact having a satisfactory density may not be produced because the compressibility is impaired. The content of inorganic powder such as graphite is 0.1% to 1% relative to the total amount of a base iron powder or the like. At a content of less than 0.1%, the improvement may not be satisfactory. At a content exceeding 1%, the mechanical properties may be impaired.

[0020] The thermosetting resin powder of the present invention is cured on the surface or inside of a green compact by a simple heat treatment to increase the bonding strength between base iron particles or the like. As a result, even prior to the sintering process, a cutting operation can be performed. Examples of the material of the thermosetting resin powder of the present invention mainly include (1) epoxy-polyester-based resins, (2) epoxy-based resins, (3) acrylic-based resins, and (4) mixtures including at least two of these.

[0021] The thermosetting resin powder is not a liquid but must be a powder because it must exhibit fluidity during the production process of a green compact. Accordingly, powder coatings that do not include a pigment and are colorless (i.e., clear powder coatings) can be used for the thermosetting resin powder.

[0022] The "epoxy-polyester-based resin" refers to an epoxy-group-containing resin crosslinked with a carboxylic-acid-group-containing polyester resin serving as a curing agent.

[0023] Examples of the epoxy-group-containing resin include compounds having at least two epoxy groups per molecule. More specifically, examples of the epoxy-group-containing resin include reaction products of a novolak-type phenolic resin and epichlorohydrin; reaction products of a bisphenol resin (A, B, F types, and the like) and epichlorohydrin; reaction products of a novolak-type phenolic resin, a bisphenol resin (A, B, F types, and the like), and epichlorohydrin; reaction products of a novolak-type phenolic resin and a bisphenol resin (A, B, F types, and the like); reaction products of a cresol compound such as cresol novolak, and epichlorohydrin; glycidyl ethers obtained by reacting an alcohol compound such as ethylene glycol, propylene glycol, 1,4-butanediol, polyethylene glycol, polypropylene glycol, neopentyl glycol, or glycerol with epichlorohydrin; glycidyl esters obtained by reacting a carboxylic acid such as succinic acid, adipic acid, phthalic acid, terephthalic acid, hexahydrophthalic acid, or trimellitic acid with epichlorohydrin; reaction products of a hydroxycarboxylic acid such as p-hydroxybenzoic acid or β-oxynaphthoic acid and epichlorohydrin; triglycidyl isocyanurate and derivatives thereof. These epoxy-group-containing resins may be used in combinations of two or more resins.

[0024] The "carboxylic-acid-group-containing polyester resin" includes at least two carboxylic acid groups or carboxylic anhydride groups. Examples of the carboxylic-acid-group-containing polyester resin include resins obtained by condensation polymerization using an acid component mainly composed of a polycarboxylic acid and an alcohol component mainly composed of a polyhydric alcohol.

[0025] Examples of the acid component include terephthalic acid, isophthalic acid, phthalic acid, and anhydrides thereof; aromatic dicarboxylic acid such as 2,6-naphthalenedicarboxylic acid, 2,7-naphthalenedicarboxylic acid, and anhydrides thereof; saturated aliphatic dicarboxylic acids such as succinic acid, adipic acid, azelaic acid, sebacic acid, dodecanedicarboxylic acid, 1,4-cyclohexanedicarboxylic acid, and anhydrides thereof; lactones such as γ-butyrolactone and ε-caprolactone; aromatic hydroxymonocarboxylic acids such as p-hydroxyethoxybenzoic acid; and hydroxycarboxylic acids corresponding to these. These acid components may be used in combinations of two or more components.

[0026] Examples of the alcohol component include ethylene glycol, diethylene glycol, triethylene glycol, 1,2-propanediol, 1,3-propanediol, 1,2-butanediol, 1,3-butanediol 1,4-butanediol, 1,2-pentanediol, 2,3-pentanediol, 1,4-pentanediol, 1,5-pentanediol, 1, 4-hexanediol, 1,5-hexanediol, 2,5-hexanediol, 1,4-cyclohexanediol, 1,4-cyclohexanedimethanol, alkylene oxide adducts of bisphenol A, alkylene oxide adducts of bisphenol S, neopentyl glycol, 3-methyl-1,5-pentanediol, 1,2-dodecanediol, 1,2-octadecanediol, trimethylolpropane, glycerin, and pentaerythritol. These alcohol components may be used in combinations, of two or more components.

[0027] The molar ratio of the total amount of epoxy group in the epoxy-group-containing resin to the total amount of acid group in the carboxylic-acid-group-containing polyester resin is appropriately determined according to the minimum melt viscosity. In general, the molar ratio is preferably 1/1 to 1/0.5, and more preferably 1/0.8 to 1/0.6.

[0028] The "epoxy-based resin" refers to an epoxy-group- containing resin crosslinked with an amine curing agent or an acid curing agent. The same epoxy-group-containing resins as those described as a component of the above epoxy-polyester-based resin can be used for this epoxy-group-containing resin.

[0029] Examples of the amine curing agent include chain aliphatic amines such as ethylenediamine, diethylenetriamine, triethylenetetramine, tetraethylenepentamine, dipropylenediamine, diethylaminopropylamine, and hexamethylenediamine; cyclic aliphatic amines such as menthanediamine, isophoronediamine, bis(4-amino-3-methylcyclohexyl)methane, diaminocyclohexylmethane, bis(aminomethyl)cyclohexane, N-aminoethylpiperazine, and 3,9-bis(3-aminopropyl) 2,4,8,10-tetraoxaspiro[5.5]undecane; and aromatic amines such as m-xylenediamine, metaphenylenediamine, diaminodiphenylmethane, diaminodiphenylsulfone, and diaminodiethyldiphenylmethane.

[0030] Examples of the acid curing agent include aliphatic acid anhydrides such as dodecenylsuccinic anhydride, polyadipic anhydride, polyazelaic anhydride, polysebacic anhydride, poly(ethyloctadecanedioic) anhydride, and poly (phenylhexadecanedioic) anhydride; alicyclic acid anhydrides such as methyltetrahydrophthalic anhydride, methylhexahydrophthalic anhydride, methyl himic anhydride, hexahydrophthalic anhydride, tetrahydrophthalic anhydride, a trialkyltetrahydrophthalic anhydride, and methylcyclohexenedicarboxylic anhydride; aromatic acid anhydrides such as phthalic anhydride, trimellitic anhydride, pyromellitic anhydride, benzophenonetetracarboxylic anhydride, ethylene glycol bistrimellitate, and glycerol tristrimellitate; and halogen-containing acid anhydrides such as chlorendic anhydride and tetrabromophthalic anhydride.

[0031] The "acrylic-based resin" refers to an acrylic resin having a glycidyl group in the side chain, the acrylic resin being crosslinked with a dibasic acid serving as a curing agent.

[0032] Examples of a monomer constituting the "acrylic resin having a glycidyl group in the side chain" include glycidyl acrylate, glycidyl methacrylate, β-methylglycidyl acrylate, and β-methylglycidyl methacrylate. These monomers may be used in combinations of two or more monomers. Alternatively, these monomers may be copolymerized with another monomer to prepare the acrylic resin. Examples of the other monomer include alkyl vinyl ethers such as ethyl vinyl ether, propyl vinyl ether, butyl vinyl ether, isobutyl vinyl ether, and cyclohexyl vinyl ether; esters of an alkyl carboxylic acid and vinyl alcohol such as vinyl acetate, vinyl propionate, vinyl butyrate, vinyl isobutyrate, vinyl valerate, and vinyl cyclohexanecarboxylate; alkyl allyl ethers such as ethyl allyl ether, propyl allyl ether, butyl allyl ether, isobutyl allyl ether, and cyclohexyl allyl ether; alkyl allyl esters such as ethyl allyl ester, propyl allyl ester, butyl allyl ester, isobutyl allyl ester, and cyclohexyl allyl ester; alkenes such as ethylene, propylene, butylene, and isobutylene; acrylics; esters of acrylic acid or methacrylic acid such as ethyl acrylate, propyl acrylate, butyl acrylate, isobutyl acrylate, 2-ethylhexyl acrylate, ethyl methacrylate, propyl methacrylate, butyl methacrylate, isobutyl methacrylate, and 2-ethylhexyl methacrylate; styrene and derivatives thereof such as styrene and α-methylstyrene; acrylamides such as acrylamide and methacrylamide; acrylonitriles such as acrylonitrile and methacrylonitrile; halogen-containing vinyl monomers; and silicon-containing vinyl monomers. These monomers may be used in combinations of two or more monomers.

[0033] The above-described monomers are polymerized and are then crosslinked with a dibasic acid to prepare the acrylic-based resin used in the present invention. The same acid curing agents as those used in the epoxy-based resin can be used as this dibasic acid.

[0034] In addition to the above resins, another resin may be added. Examples of the other resin include polyurethane-based resins prepared by curing a hydroxyl-group-containing polyester resin with an isocyanate curing agent, polyester-based resins prepared by curing a carboxyl-group-containing polyester resin with triglycidyl isocyanate or the like, resins prepared by curing a hydroxyl-group-containing polyester resin with an acrylic resin having an isocyanate group in the side chain, and resins prepared by curing a carboxyl-group-containing polyester resin with an acrylic resin having a glycidyl group in the side chain.

[0035] The average particle diameter of thermosetting resin powder is 100 μm or less. When a thermosetting resin powder having an average particle diameter of exceeding 100 μm is used, it is.difficult to coat entire base iron particles or the like with the resin melted by a heat treatment. In such a case, the strength of a compact may not be satisfactorily improved. The average particle diameter of thermosetting resin powder is more preferably 80 μm or less, particularly 60 μm or less. Although the lower limit is not particularly limited, the lower limit is generally about 30 μm. With respect to the "average particle diameter" in the present invention, when a commercially available resin powder is used, the value described in a catalog or the like should be referred to as the average particle diameter. When the average particle diameter is not known, the particle size distribution is measured by a normal particle size distribution analyzer. Subsequently, the particle diameter at the cumulative value of 50% (D_{50}) from the smallest particle diameter is determined from the result and defined as the average particle diameter.

[0036] The content of resin powder is 0.05% to 1.0% relative to the total amount of an iron powder and/or an iron alloy powder. At a resin powder content of less than 0.05%, the strength of a green compact cannot be satisfactorily improved and cutting operation prior to the sintering process cannot be performed. On the other hand, at a resin powder content exceeding 1.0%, the fluidity of a mixed powder is decreased, thus reducing the productivity. In such a case, the density of a green compact is also decreased.

[0037] Some of the commercially available resin powders include a pigment for the purpose of coloring. A commercially available resin powder including a pigment may be used for the resin powder in the present invention. However, since the pigment may have an adverse effect on the strength of a green compact, a pigment-free resin powder is preferably used.

[0038] A lubricant may be added to the mixed powder for powder metallurgy of the present invention. The lubricant decreases the coefficient of friction between the green compact and a die, thereby suppressing the generation of die galling and damage of the die. Preferable examples of the lubricant usable in the present invention include ethylenebisstearamide, stearamide, zinc stearate, lithium stearate, and mixtures of at least two of these. These lubricants should be selected according to the intended purpose of the compact when used.

[0039] The content of the lubricant is 0.05% to 1.0% relative to the total amount of a base iron powder or the like. At a content of less than 0.05%, the lubricity may be insufficient. At a content exceeding 1.0%, the curing of a resin powder may not be satisfactorily performed and the fluidity of mixed powder may be insufficient.

[0040] The above-described mixed powder for powder metallurgy of the present invention is molded by a normal method to produce a green compact. For example, a die is filled with the mixed powder and a pressure of 5 to 7 t/cm^2 (490 to 686 MPa) is applied. Subsequently, a heat treatment is performed in order that the thermosetting resin powder is cured to increase the strength of the green compact. Although the conditions for the heat treatment mainly depend on the type of thermosetting resin powder added, in general, the heat treatment is simply performed at about 150°C to about 200°C for 10 to 30 minutes (more preferably 15 to 20 minutes).

[0041] In general, a green compact cannot be subjected to a cutting operation prior to sintering because the green compact is brittle. However, for example, when the mixed powder for powder metallurgy of the present invention is molded at a pressure of 5 t/cm^2 (490.3 MPa), the resultant green compact has a strength of at least 30 MPa measured in accordance with Japan Powder Metallurgy Association (JPMA) Standard M09-1992. Thus, the use of the mixed powder for powder metallurgy of the present invention as a feedstock can provide a green compact capable of being subjected to a cutting operation. In other words, since the green compact of the present invention has an adequate density and strength even prior to the sintering process, the green compact can be subjected to a cutting operation, and in addition, the lifetime of a cutting tool used can be extended.

[0042] The present invention will now be described in more detail by way of examples, but the scope of the present invention is not limited to these examples.

EXAMPLES

EXAMPLE 1

[0043] A pure iron powder (trade name: "Atomel 300M", from Kobe Steel, Ltd.) was used as a base metal powder. A commercially available copper powder (2.0 mass percent of the amount of the pure iron powder) (hereinafter, the "mass percent" is simply referred to as "%"), a graphite powder (0.8%), ethylenebisstearamide (0.75%), and a clear powder coating (0.3%) composed of an epoxy-polyester-based resin (Konac No. 2700 from BASF NOF Coatings Co., Ltd., a resin produced by reacting an epoxy resin with a dibasic acid polyester, average particle diameter: 40 μm) were added to the pure iron powder. The mixture was agitated at a high speed with a mixer with blades. The apparent density of the resultant mixed powder was measured in accordance with Japanese Industrial Standard (JIS) Z2504. The flow rate was also measured in accordance with JIS Z2502.

[0044] A green compact having a diameter of 11.3 mm and a height of 10 mm was produced at a pressure of 5 t/cm^2 (490.3 MPa) in accordance with Japan Society of Powder and Powder Metallurgy (JSPM) Standard 1-64 (a metal powder compressibility testing method) using the above mixed powder as a feedstock. The green compact was heated at 170°C for 15 minutes. The density of the green compact was then measured. Also, the strength of the green compact was measured in accordance with JPMA M09-1992.

[0045] Furthermore, a green compact having a diameter of 25 mm and a height of 15 mm was produced at a surface pressure of 490 MPa using the above mixed powder as a feedstock to measure a ejection force, which is an indicator of lubricity. Specifically, the draw-out pressure was calculated by dividing a load required for drawing out the green compact from the die during molding by the area of contact between the die and the green compact. These samples are referred to as No. 1 and the results are shown in Table 1.

EXAMPLE 2

[0046] A mixed powder was produced as in Example 1 except that a clear powder coating composed of an acrylic-based resin (Konac No. 4600 from BASF NOF Coatings Co., Ltd., a resin produced by crosslinking an acrylic resin having a glycidyl group in the side chain with a dibasic acid, average particle diameter: 40 μm) was used instead of the clear powder coating composed of the epoxy-polyester-based resin used in Example 1. Furthermore, a green compact was produced as in Example 1 except that the green compact was heated at 180°C for 15 minutes. These samples are referred to as No. 2. The apparent density of the mixed powder, the density of the green compact, and the like were measured as in Example 1. Table 1 shows the results.

[0047] A mixed powder and a green compact made of the mixed powder were produced as in Example 1 except that a clear powder coating composed of an epoxy-based resin (Konac No. 3700 from BASF NOF Coatings Co., Ltd., a resin produced by curing an uncured epoxy resin with an amine curing agent, average particle diameter: 40 μm) was used as a thermosetting resin powder, and the green compact was heated at 160°C for 15 minutes. These samples are referred to as No. 3. The apparent density of the mixed powder and the like were measured by the same methods. Table 1 shows the results.

EXAMPLE 3

[0048] Mixed powders and green compacts made of the mixed powders were produced as in Example 1 except that the content of the clear powder coating composed of the epoxy-polyester-based resin (Konac No. 2700 from BASF NOF Coatings Co., Ltd., average particle diameter: 40 μm) was 1.0% (No. 4) or 0.1% (No. 5). The apparent density of the mixed powders and the like were measured as in Example 1. Table 1 shows the results.

COMPARATIVE EXAMPLE 1

[0049] Mixed powders and green compacts made of the mixed powders were produced as in Example 1 except that the clear powder coating composed of the-epoxy-polyester-based resin (Konac No. 2700 from BASF NOF Coatings Co., Ltd., average particle diameter: 40 μm) was not contained (No. 6), or the content of the clear powder coating composed of the epoxy-polyester-based resin (Konac No. 2700 from BASF NOF Coatings Co., Ltd., average particle diameter: 40 μm) was 0.03% (No. 7) or 1.2% (No. 8).

[0050] Furthermore, mixed powders and green compacts made of the mixed powders were produced as in Example 1 except that the average particle diameter of the clear powder coating composed of the epoxy-polyester-based resin was 150 μm (No. 9) or 250 μm (No. 10) instead of 40 μm.

[0051] The apparent density of these mixed powders and the like were measured as in Example 1. Table 1 shows the results.

Table 1

	Apparent density (g/cm^3)	Flow rate (sec/ 50g)	Density of green compact (g/cm^3)	Strength of green compact	Ejection force (Mpa) (MPa)
No. 1	3.14	27.8	6.87	52	12.0
No. 2	3.15	29.1	6.87	50	11.8
No. 3	3.16	28.3	6.86	48	12.1
No. 4	3.08	32.5	6.80	105	12.3
No. 5	3.16	28.2	6.92	35	11.7
No. 6	3.17	27.8	6.94	25	11.5
No. 7	3.16	28.1	6.93	26	11.8
No. 8	3.01	35.3	6.75	108	12.2
No. 9	3.13	29.7	6.85	29	11.9
No. 10	3.14	30.1	6.82	27	12.2

[0052] The results showed that the green compacts composed of a mixed powder for powder metallurgy that did not contain a resin powder or a mixed powder for powder metallurgy in which the content of a resin powder was less than the amount specified in the present invention had an insufficient strength and could not be subjected to a cutting operation (Nos. 6 and 7). The green compacts composed of a mixed powder in which the average particle diameter of the resin powder exceeded the range in the present invention also showed the same results (Nos. 9 and 10). In addition, when the content of the resin powder exceeded the range specified in the present invention, the green compact had a satisfactory strength, but had a low density. This green compact was also not suited for a cutting operation, and in addition, the mixed powder itself had a low fluidity (No. 8).

[0053] In contrast, the mixed powders for powder metallurgy containing a resin powder within the content range specified in the present invention had excellent fluidity, and green compacts made of these mixed powders had an adequate density and strength and thus were suited for a cutting operation. These examples demonstrates that, according to the present invention, since the green compact has an adequate density and strength even prior to the sintering process, the green compact can be subjected to a cutting operation, and in addition, the lifetime of a cutting tool used can be extended.

Claims

1. A mixed powder for powder metallurgy to be used as a feedstock of a green compact, the mixed powder comprising:

   an iron powder and/or an iron alloy powder;
   a component for improving mechanical properties; and
   a thermosetting resin powder,
   wherein the thermosetting resin powder comprises at least one resin selected from the group consisting of an epoxy-polyester-based resin, an epoxy-based resin, and an acrylic-based resin,
   the average particle diameter of the thermosetting resin powder is 100 μm or less, and
   the content of the thermosetting resin powder relative to the total amount of the iron powder and/or the iron alloy powder is 0.05 to 1.0 mass percent.

2. The mixed powder for powder metallurgy according to claim 1, further comprising a lubricant.

3. The mixed powder for powder metallurgy according to claim 2, wherein the lubricant is at least one compound selected from the group consisting of ethylenebisstearamide, stearamide, zinc stearate, and lithium stearate.

4. The mixed powder for powder metallurgy according to any one of claims 1 to 3, wherein the component for improving mechanical properties is at least one substance selected from the group consisting of copper, nickel, chromium, molybdenum, graphite, and manganese sulfide.

5. A green compact comprising the mixed powder for powder metallurgy according to any one of claims 1 to 4.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 02 0609

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	16 December 2005	Alvazzi Delfrate, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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