



US 20030103858A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2003/0103858 A1**

Baran et al.

(43) **Pub. Date: Jun. 5, 2003**

(54) **METALLURGICAL POWDER
COMPOSITIONS AND METHODS OF
MAKING AND USING THE SAME**

Publication Classification

(51) **Int. Cl.⁷** **C22C 32/00; B22F 9/00**

(76) **Inventors: Michael C. Baran, Croydon, PA (US);
K.S.V.L. Narasimhan, Moorestown, NJ
(US)**

(52) **U.S. Cl.** **419/30; 75/255; 75/343**

Correspondence Address:

**WOODCOCK WASHBURN LLP
ONE LIBERTY PLACE, 46TH FLOOR
1650 MARKET STREET
PHILADELPHIA, PA 19103 (US)**

(57) **ABSTRACT**

The present invention provides iron-based metallurgical powder compositions and a method of making and using the same. The metallurgical powder compositions of the present invention contain certain amounts of an iron-alloy powder having iron and at least one alloying additive; substantially pure iron powder; and a carbon powder, such as graphite. The metallurgical powder compositions are prepared by admixing the iron-alloy powder with the iron powder and carbon powder. The metallurgical powder compositions thus produce and when formed into metal parts have, for example, improved machinability properties.

(21) **Appl. No.: 10/266,316**

(22) **Filed: Oct. 8, 2002**

Related U.S. Application Data

(63) **Continuation of application No. 09/434,000, filed on
Nov. 4, 1999.**

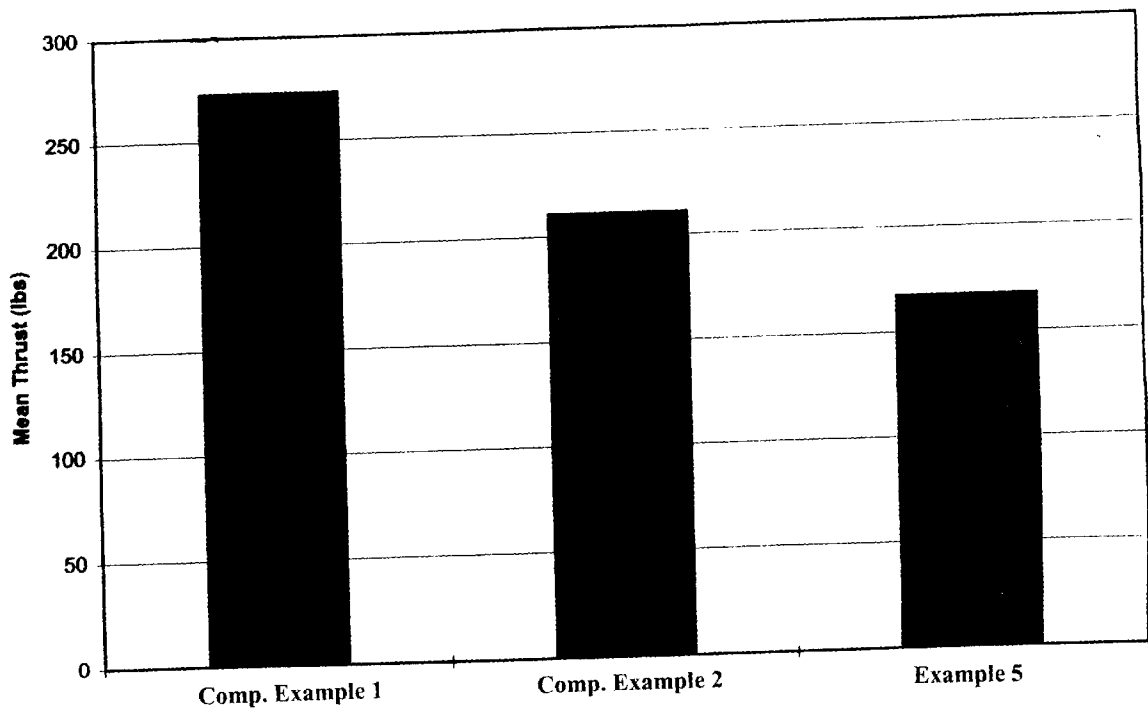
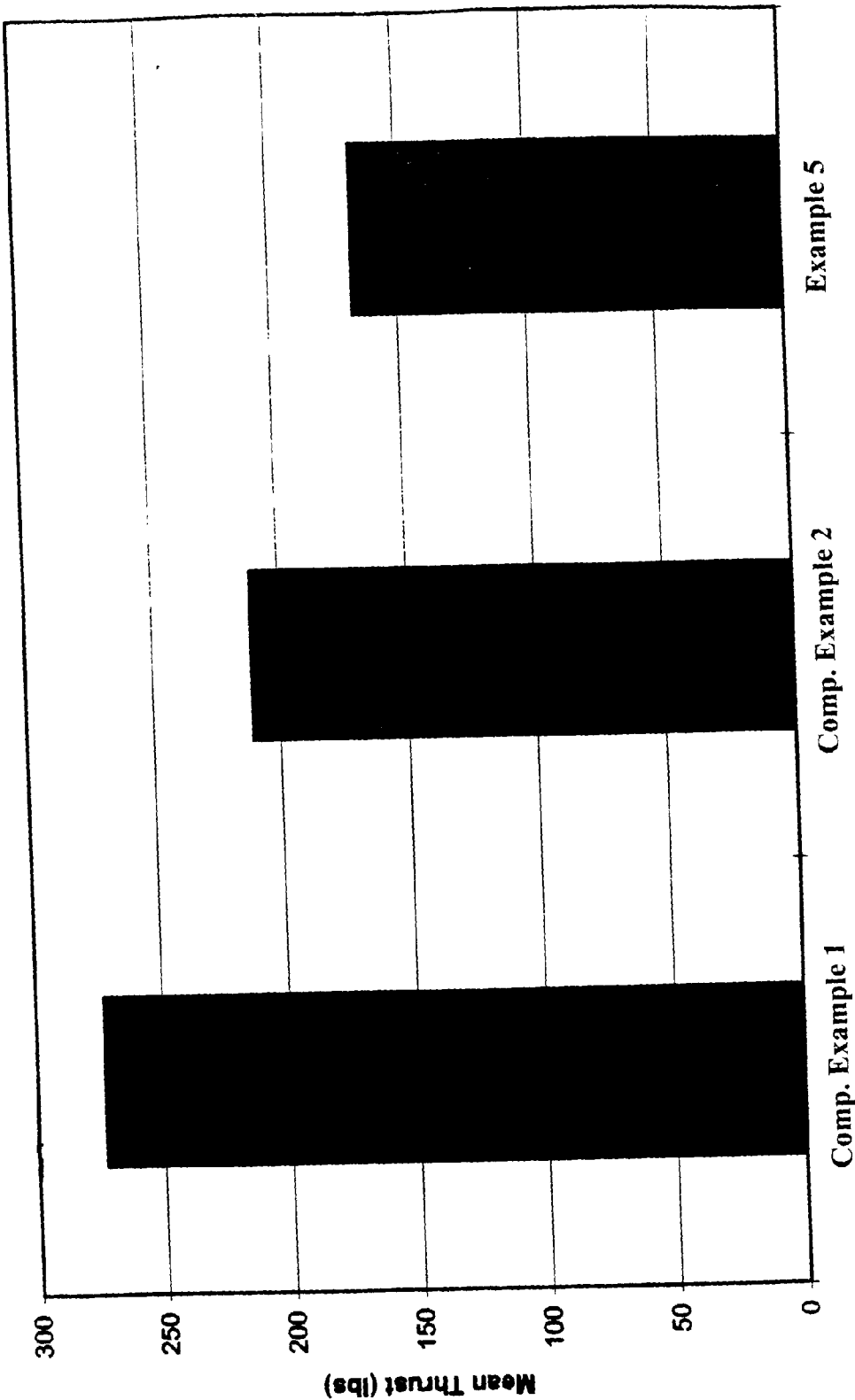


FIGURE 1



METALLURGICAL POWDER COMPOSITIONS AND METHODS OF MAKING AND USING THE SAME

FIELD OF THE INVENTION

[0001] The present invention relates to improved iron-based metallurgical powder compositions and methods of making and using the same. The iron-based powder compositions contain a mixture of substantially pure iron powder and an iron-alloy powder that preferably contains molybdenum as an alloying additive. The iron-based powder compositions thus produced have improved machinability when formed into metal parts.

BACKGROUND OF THE INVENTION

[0002] Industrial usage of metal parts manufactured by the compaction and sintering of metal powder compositions is expanding rapidly into a multitude of areas. In the manufacture of such parts, metal powder compositions are typically formed from metal-based powders and other additives such as lubricants, and binders. The metal-based powders are typically iron powders that optionally may be alloyed with one or more alloying components.

[0003] A common technique for preparing an iron-alloy powder is to form a homogeneous molten metal composition containing iron and one or more desired alloying components, and water atomizing the molten metal composition to form a homogeneous powder composition.

[0004] The metal-based powder, after any optional alloying, is often mixed with other additives to improve the properties of the final part. For example, the metal-based powder is often admixed with at least one other alloying additive that is in powder form ("alloying powder"). The alloying powder permits, for example, the attainment of higher strength and other mechanical properties in the final sintered part.

[0005] The mixture of metal-based powder and optional alloying powders are often also mixed with other additives such as lubricants and binding agents to form the final metal powder composition. This metal powder composition is typically poured into a compaction die and compacted under pressure (e.g., 5 to 70 tons per square inch (tsi)), and in some circumstances at elevated temperatures, to form the compacted, or "green" part. The green part is then usually sintered to form a cohesive metallic part and optionally finished. Examples of types of finishing steps include machining the metal part (e.g., cutting, shaving, drilling, turning, milling, etc.) to the desired specifications.

[0006] One problem that occurs in the finishing of metal parts is that the metal parts are often difficult to machine. For example, a metal part may be difficult to drill, leading to longer machining time, decrease in the life of the machine tool, and increased energy usage to operate the machining equipment.

[0007] One solution to increasing the machinability of iron-based metal parts is disclosed in U.S. Pat. No. 4,018, 632 to Schmidt (hereinafter "Schmidt"). Schmidt discloses that the machinability of an iron-based metal part can be improved through the use of a steel powder mixture of graphite and an iron-molybdenum-manganese alloy. The steel powder after compaction and sintering is heated and

cooled according to certain temperature profiles to improve the machinability of the metal part.

[0008] Another solution for increasing the machinability of iron-based metal parts is disclosed in U.S. Pat. No. 5,599,377 to Uenosono et al. (hereinafter "Uenosono"). Uenosono discloses a metal powder containing a mixture of iron powder having less than 0.1 weight percent manganese and from about 0.08 weight percent to about 0.15 weight percent sulfur; graphite; and from about 0.05 to about 0.70 weight percent of at least one compound selected from MoO_3 or WO_3 . The iron powder is disclosed to have excellent machinability and high strength due to the dissolution of molybdenum or tungsten compounds in the ferrite particles upon sintering of the compacted metal part in a hydrogen-containing atmosphere.

[0009] Another solution proposed for improving the machinability of metal parts is disclosed in U.S. Pat. No. 5,679,909 to Kaneko et al. (hereinafter "Kaneko"). Kaneko discloses a sintered material having good machinability, where the sintered material is prepared by compacting and sintering a powder containing a mixture of composite oxide of CaO-MgO-SiO_2 and an iron dominant metal matrix. The iron dominant metal matrix may be prepared from a mixture of pure iron and "hard" particles of FeMo, FeCr, FeW, or Tribaloy (containing Co—Ho—Cr and/or Co—Ho—Si). These hard particles are believed to contain at least 50 weight percent of the non-iron elements to provide the desired hardness.

[0010] Although the above compositions and/or methods provide ways of improving the machinability of a metal part, it would be desirable to develop alternate compositions and methods. Preferably such alternate compositions and methods would result in metal parts having comparable or improved machinability.

SUMMARY OF THE INVENTION

[0011] The present invention provides metallurgical powder compositions and methods of making and using the same. The metallurgical powder compositions, when formed into metal parts, exhibit improved machinability. This improved machinability is at least in part due to the presence of certain amounts of at least one iron-alloy powder in the metallurgical powder compositions.

[0012] In one embodiment of the present invention, a method is provided that includes providing an iron-alloy powder containing iron and at least one alloying additive, where the alloying additive is present in an amount of from about 0.01 weight percent to about 7.0 weight percent and the iron is present in an amount of at least 85 weight percent based on the total weight of the iron-alloy powder. Admixed with the iron-alloy powder is a substantially pure iron powder and carbon, typically a carbon powder, to form the metallurgical powder composition. The metallurgical powder composition preferably contains from about 5 weight percent to about 40 weight percent of the iron-alloy powder, at least 55 percent by weight of the iron powder, and at least 0.1 weight percent carbon based on the total weight of the metallurgical powder composition.

[0013] In another embodiment of the present invention, a metallurgical powder composition is provided that contains from about 5 weight percent to about 40 weight percent of

an iron-molybdenum alloy powder containing iron and molybdenum, where the amount of molybdenum is from about 0.10 weight percent to about 7.0 weight percent and the amount of iron is at least 85 weight percent based on the weight of the iron-molybdenum alloy powder. The metallurgical powder composition also contains at least 55 weight percent of substantially pure iron powder, and from about 0.1 weight percent to about 3.0 weight percent carbon.

[0014] The present invention also provides a method of forming a metal part that includes providing a metallurgical powder composition of the present invention and compacting the metallurgical powder composition at a pressure of at least about 5 tsi to form a metal part.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 is a graph showing the mean thrust (in pounds) produced in drilling a metal part formed from a metallurgical powder composition of the present invention (Example 5) in comparison to metal parts made from metallurgical powder compositions containing no iron-alloy powder (Comparative Examples 1 and 2).

DETAILED DESCRIPTION OF THE INVENTION

[0016] The present invention provides improved metallurgical powder compositions that when formed into metal parts have improved machinability. By "machinability" it is meant the ability of a metal part to be finished in some manner by machine operated tools. For example, metal parts produced in accordance with the methods of the present invention are preferably capable of being shaped, shaved, drilled, cut, turned, milled, or any combination thereof.

[0017] The metallurgical powder compositions of the present invention are iron-based powder compositions containing substantially pure iron powder, an iron-alloy powder, and carbon. These metallurgical powder compositions may also optionally contain alloying powders, one or more lubricants, one or more binders, any other conventional powder metallurgy additive, or any combination thereof.

[0018] It has been unexpectedly found that the machinability of iron-based metal parts can be significantly improved through the addition of certain amounts of iron-alloy powder in the metallurgical powder composition used to form the metal part. The iron-alloy powder useful in the present invention is preferably made by partially or completely alloying iron with at least one alloying additive (for example, molybdenum containing compounds) that can provide a hard phase for improving machinability.

[0019] By "alloying" it is meant that the alloying additives and iron are admixed in a manner to permit melting, diffusion bonding or chemical bonding of the iron and alloying additive. Suitable processes for alloying include for example "prealloying" and "diffusion bonding."

[0020] Prealloyed and diffusion bonded iron-alloy powder may be made according to any technique known to those skilled in the art. For example, prealloyed iron-alloy powder can be prepared from a melt of iron and one or more desired alloying additives. Preferably, the melt is then atomized so that the atomized droplets form a powder upon solidification. Diffusion bonded iron-alloy powder can be prepared

for example by blending iron powder with one or more alloying additives, preferably in oxide form, and annealing the resulting mixture at high temperatures (e.g., about 800 ° C. or greater). During annealing, the alloying compounds diffuse and partially alloy into the outer surfaces of the iron particles. A preferred diffusion bonding process is disclosed in GB 1,162,702, which is hereby incorporated by reference in its entirety.

[0021] In a preferred embodiment of the present invention the iron-alloy powder is formed by a prealloying process. Prealloying has the advantage of facilitating complete alloying of the iron and alloying additives.

[0022] Preferably, the iron-alloy powder is present in the metallurgical powder composition at a concentration that is effective in improving the machinability of the metal part in comparison to a composition containing no iron-alloy powder. Preferably, the amount of iron-alloy powder is from about 5 weight percent to about 40 weight percent, more preferably from about 10 weight percent to about 30 weight percent, and most preferably from about 12 weight percent to about 20 weight percent, based on the total weight of the metallurgical powder composition.

[0023] Iron that can be used to form the iron-alloy powder is preferably substantially pure iron containing not more than about 1.0% by weight, preferably no more than about 0.5% by weight, of normal impurities. The iron may be in any physical form prior to prealloying. For example, the iron may be in powder form or in the form of scrap metal. For diffusion bonding, the iron is preferably in powder form.

[0024] Examples of suitable alloying additives for forming the iron-alloy powder include, but are not limited to elements, compounds, or alloys of molybdenum, manganese, magnesium, tungsten, chromium, silicon, copper, nickel, gold, vanadium, columbium (niobium), or aluminum, or oxides thereof; binary alloys of copper and tin or phosphorus; carbides of tungsten or silicon; silicon nitride; sulfides of manganese or molybdenum, or combinations thereof. Preferably, the iron-alloy powder contains at least one alloying additive containing molybdenum, manganese, magnesium, tungsten, chromium, silicon, copper, nickel, vanadium, oxides thereof, or any combination thereof, and more preferably molybdenum, chromium, vanadium, tungsten, or combinations thereof.

[0025] The total amount of alloying additive in the iron-alloy powder will depend upon the alloying additive(s) chosen. Typically, the alloying additives are present in the iron-alloy powder in an amount of from about 0.01 weight percent to about 7.0 weight percent, preferably from about 0.10 weight percent to about 3.0 weight percent, and most preferably from about 0.10 weight percent to about 2.0 weight percent, based on the total weight of the iron-alloy powder.

[0026] The iron-alloy powder may also contain residual impurities, such as from the iron used to form the iron-alloy powder. Generally, the iron-alloy powder contains minimum residual impurities of at least about 0.15 weight percent and more preferably of at least about 0.25 weight percent, and preferably contains maximum residual impurities of up to about 1.0 weight percent, and more preferably up to about 0.9 weight percent, based on the total weight of the iron-alloy powder.

[0027] The balance of the iron-alloy powder is preferably iron. Iron is preferably present in the iron-alloy powder in an amount of at least 85.0 weight percent, more preferably at least about 90.0 weight percent, and most preferably from about 94.0 weight percent to about 99.8 weight percent.

[0028] In a preferred embodiment of the present invention, the iron is prealloyed with at least one alloying additive that contains molybdenum to form an iron-molybdenum prealloy powder. Molybdenum additive useful in forming an iron-molybdenum prealloy powder is any element, compound, or alloy that contains molybdenum and is capable of alloying with iron in the prealloying process. The molybdenum additive may be, for example, an oxide of molybdenum such as molybdenum trioxide or a ferromolybdenum alloy. The molybdenum additive may also be substantially pure elemental molybdenum (preferably having a purity of greater than about 90 wt %). Preferably, the molybdenum additive is an oxide of molybdenum such as molybdenum trioxide.

[0029] In a most preferred embodiment of the present invention, the iron-molybdenum prealloy powder preferably contains from about 0.40 weight percent to about 1.6 weight percent molybdenum, based on the total weight of the iron-molybdenum prealloy powder, and from about 97.4 weight percent to about 99.50 weight percent iron. The iron-molybdenum prealloy powder preferably contains maximum residual impurities of about 0.03 weight percent sulfur, about 0.02 weight percent silicon, and about 0.01 weight percent nitrogen based on the total weight of the prealloy powder.

[0030] Examples of suitable iron-molybdenum prealloy powders commercially available include Hoeganaes' ANCORSTEEL 150HP steel powder, 85 HP steel powder, 50HP steel powder, or combinations thereof. The amounts of molybdenum in the 150 HP, 85HP, and 50 HP steel powders are respectively about 1.5 weight percent, 0.85 weight percent, and 0.55 weight percent based on the total weight of the prealloy. These iron-molybdenum prealloy powders contain less than about 0.75 weight percent of materials such as manganese, chromium, silicon, copper, nickel, or aluminum, and less than about 0.02 weight percent carbon, with the balance being substantially iron. Another example of a commercially available iron-molybdenum prealloy powder is Hoeganaes' ANCORSTEEL 4600V steel powder, which contains about 0.5-0.6 weight percent molybdenum, about 1.5-2.0 weight percent nickel, about 0.1-0.25 weight percent manganese, less than about 0.02 weight percent carbon, and the balance preferably being substantially iron. Other ANCORSTEEL iron-molybdenum prealloy powders that are useful in the present invention include for example ANCORSTEEL 2000 and 737 steel powders. The 150HP, 85HP, or 50HP steel powders are preferred for use as the prealloy powder in the present invention.

[0031] The metallurgical powder compositions of the present invention also contain substantially pure iron powder. Preferably, the substantially pure iron powder is present in the metallurgical powder composition in an amount of at least about 55 weight percent, more preferably from about 60 weight percent to about 95 weight percent, and most preferably from about 70 weight percent to about 90 weight percent, based on the total weight of the metallurgical powder composition.

[0032] Substantially pure iron powder that can be used in the invention are powders of iron preferably containing not more than about 1.0% by weight, more preferably no more than about 0.5% by weight, of normal impurities. Examples of such highly compressible, metallurgical-grade iron powders are the ANCORSTEEL 1000 series of pure iron powders, e.g. 1000, 1000B, and 1000C, available from Hoeganaes Corporation, Riverton, N.J. For example, ANCORSTEEL 1000 iron powder, has a typical screen profile of about 22% by weight of the particles below a No. 325 sieve (U.S. series) and about 10% by weight of the particles larger than a No. 100 sieve with the remainder between these two sizes (trace amounts larger than No. 60 sieve). The ANCORSTEEL 1000 powder has an apparent density of from about 2.85-3.00 g/cm³, typically 2.94 g/cm³.

[0033] The particles of iron-alloy powder and substantially pure iron powder have a distribution of particle sizes. Typically, these powders are such that at least about 90% by weight of the powder sample can pass through a No. 45 sieve (U.S. series), and more preferably at least about 90% by weight of the powder sample can pass through a No. 60 sieve. These powders typically have at least about 50% by weight of the powder passing through a No. 70 sieve and retained above or larger than a No. 400 sieve, more preferably at least about 50% by weight of the powder passing through a No. 70 sieve and retained above or larger than a No. 325 sieve. Also, these powders typically have at least about 5 weight percent, more commonly at least about 10 weight percent, and generally at least about 15 weight percent of the particles passing through a No. 325 sieve. As such, these powders can have a weight average particle size as small as one micron or below, or up to about 850-1,000 microns, but generally the particles will have a weight average particle size in the range of about 10-500 microns. Preferred are iron-alloy particles or substantially pure iron particles having a maximum weight average particle size up to about 350 microns; more preferably the particles will have a weight average particle size in the range of about 25-150 microns, and most preferably 80-150 microns. Reference is made to MPFI Standard 05 for sieve analysis.

[0034] The metallurgical powder composition also preferably contains carbon. The carbon is preferably added as a substantially pure carbon powder, such as graphite. Preferably, the carbon powder has a purity of at least about 99.0 weight percent and more preferably a purity of at least about 99.5 weight percent. The carbon powder may be in crystalline and/or amorphous form. Carbon is preferably present in the metallurgical powder composition in an amount of from about 0.1 weight percent to about 3.0 weight percent, more preferably from about 0.2 weight percent to about 2.0 weight percent, and most preferably from about 0.3 weight percent to about 1.2 weight percent, based on the weight of the metallurgical powder composition.

[0035] The metallurgical powder compositions of the present invention may also optionally contain alloying powders in addition to the carbon powder. The term "alloying powder" as used herein refers to any particulate element, compound, or alloy powder physically blended with the metallurgical powder composition, whether or not that additive ultimately alloys or partially alloys with the metallurgical powder composition.

[0036] Examples of optional alloying powders that may be present in the metallurgical powder composition include

elements, compounds, or alloys containing molybdenum, manganese, copper, nickel, chromium, silicon, gold, vanadium, columbium (niobium), phosphorus, aluminum, boron, or oxides thereof; binary alloys of copper and tin, copper and nickel, or copper and phosphorous; ferro-alloys of manganese, chromium, boron, phosphorus, or silicon; low melting ternary and quaternary eutectics of carbon in combination with elements selected from iron, vanadium, manganese, chromium, molybdenum or combinations thereof; carbides of tungsten or silicon; silicon nitride; aluminum oxide; and sulfides of manganese or molybdenum, and combinations thereof. Preferred alloying powders include elements, compounds, or alloys containing molybdenum, manganese, copper, nickel, chromium, vanadium, phosphorus, or combinations thereof, and more preferably elements, compounds, or alloys containing copper, nickel, or combinations thereof.

[0037] The alloying powders are preferably present in the metallurgical powder composition in amounts of up to about 10 weight percent, and typically in the range of from about 0.25 to about 10 weight percent, preferably from about 0.25 to about 7 weight percent, and more preferably from about 0.5 to about 5 weight percent. The alloying powders generally have a weight average particle size below about 100 microns, preferably below about 75 microns, more preferably below about 30 microns, and most preferably in the range of about 5 microns to about 20 microns. The particle size of the alloying powders is generally relatively small and can be analyzed by laser light scattering technology as opposed to screening techniques. Laser light scattering technology reports the particle size distribution in d_x values, where it is said that "x" percent by volume of the powder has a diameter below the reported value. The alloying particles generally have a particle size distribution such that they have a d_{90} value of below about 100 microns, preferably below about 75 microns, and more preferably below about 50 microns; and a d_{50} value of below about 75 microns, preferably below about 50 microns, and more preferably below about 30 microns.

[0038] In a preferred embodiment of the present invention, the metallurgical powder composition contains an alloying powder containing copper. The copper provides hardenability properties to metal parts formed from the metallurgical powder compositions. The copper containing powder is preferably elemental copper having relatively few impurities. Preferably the copper containing powder contains at least 90 weight percent, more preferably at least 98 weight percent, and most preferably at least 99.5 weight percent copper based on the total weight of the copper containing powder.

[0039] Preferably, the amount of copper containing powder present in the metallurgical powder composition of the present invention is such that there is at least 0.2 weight percent, more preferably from about 0.5 weight percent to about 4.0 weight percent, and most preferably from about 1.0 to about 3.0 weight percent elemental copper, based on the total weight of the metallurgical powder composition.

[0040] The metallurgical powder compositions of the present invention may also include any special-purpose additive commonly used with metallurgical composition such as lubricants, machining agents, and plasticizers.

[0041] In a preferred embodiment of the present invention the metallurgical powder composition contains a lubricant to

reduce the ejection force required to remove a compacted part from the die cavity. Examples of typical powder metallurgy lubricants include the stearates, such as zinc stearate, lithium stearate, manganese stearate, or calcium stearate; synthetic waxes, such as ethylene bisstearamide or polyolefins; or combinations thereof. The lubricant may also be a polyamide lubricant, such as PROMOLD-450, disclosed in U.S. Pat. No. 5,368,630, particulate ethers disclosed in U.S. Pat. No. 5,498,276, to Luk, or a metal salt of a fatty acid disclosed in U.S. Pat. No. 5,330,792 to Johnson et al., the disclosures of which are hereby incorporated by reference in their entireties. The lubricant may also be a combination of any of the aforementioned lubricants described above.

[0042] The lubricant is generally added in an amount of up to about 2.0 weight percent, preferably from about 0.1 to about 1.5 weight percent, more preferably from about 0.1 to about 1.0 weight percent, and most preferably from about 0.2 to about 0.75 weight percent, of the metallurgical powder composition.

[0043] Preferred lubricants are ethylene bisstearamide, zinc stearate, Kenolube™ (supplied by Hoganäs Corporation, located in Hoganäs, Sweden), Ferrolube™ (supplied by Blanchford), and polyethylene wax. Preferably, these lubricants are added in an amount of from about 0.2 weight percent to about 1.5 weight percent based on the total weight of the metallurgical powder composition formed.

[0044] Other additives may also be present in the metallurgical powder compositions, such as plasticizers and machining agents. Preferably, these other additives are present in the metallurgical powder composition in an amount of from about 0.05 weight percent to about 1.5 weight percent, and more preferably from about 0.1 weight percent to about 0.5 weight percent based on the total weight of the metallurgical powder composition. Plasticizers, such as polyethylene-polypropylene copolymer, are typically used in connection with binders and/or lubricants. Machining agents, such as molybdenum sulfides, iron sulfides, boron nitride, boric acid, or combinations thereof are typically used to aid in final machining operations. In a preferred embodiment, manganese sulfide is present in the metallurgical powder composition in an amount of from about 0.1 weight percent to about 0.75 weight percent based on the weight of the metallurgical powder composition.

[0045] The metallurgical powder composition may also contain one or more binding agents to bond the different components present in the metallurgical powder composition so as to inhibit segregation. By "bond" as used herein, it is meant any physical or chemical method that facilitates adhesion of the components of the metallurgical powder composition.

[0046] In a preferred embodiment of the present invention, bonding is carried out through the use of at least one binding agent. Binding agents that can be used in the present invention are those commonly employed in the powder metallurgical arts. Examples of such binding agents are found in U.S. Pat. No. 4,834,800 to Semel, U.S. Pat. No. 4,483,905 to Engstrom, U.S. Pat. No. 5,154,881 to Rutz et al., and U.S. Pat. No. 5,298,055 to Semel et al., the disclosures of which are hereby incorporated by reference in their entireties.

[0047] Such binding agents include, for example, polyglycols such as polyethylene glycol or polypropylene glycol;

glycerine; polyvinyl alcohol; homopolymers or copolymers of vinyl acetate; cellulosic ester or ether resins; methacrylate polymers or copolymers; alkyd resins; polyurethane resins; polyester resins; or combinations thereof. Other examples of binding agents that are useful are the relatively high molecular weight polyalkylene oxide-based compositions described in U.S. Pat. No. 5,298,055 to Semel et al. Useful binding agents also include the dibasic organic acid, such as azelaic acid, and one or more polar components such as polyethers (liquid or solid) and acrylic resins as disclosed in U.S. Pat. No. 5,290,336 to Luk, which is incorporated herein by reference in its entirety. The binding agents in the '336 Patent to Luk can also advantageously act as lubricants. Additional useful binding agents include the cellulose ester resins, hydroxy alkylcellulose resins, and thermoplastic phenolic resins described in U.S. Pat. No. 5,368,630 to Luk, which is incorporated herein by reference in its entirety.

[0048] The binding agent can further be the low melting, solid polymers or waxes, e.g., a polymer or wax having a softening temperature of below 200° C. (390° F.), such as polyesters, polyethylenes, epoxies, urethanes, paraffins, ethylene bisstearamides, and cotton seed waxes, and also polyolefins with weight average molecular weights below 3,000, and hydrogenated vegetable oils that are C₁₄₋₂₄ alkyl moiety triglycerides and derivatives thereof, including hydrogenated derivatives, e.g. cottonseed oil, soybean oil, jojoba oil, and blends thereof, as described in WO 99/20689, published Apr. 29, 1999, which is hereby incorporated by reference in its entirety herein. These binding agents can be applied by the dry bonding techniques discussed in that application and in the general amounts set forth above for binding agents. Further binding agents that can be used in the present invention are polyvinyl pyrrolidone as disclosed in U.S. Pat. No. 5,069,714, which is incorporated herein in its entirety by reference, or tall oil esters. Preferred binding agents are polyethylene oxide and polyvinylacetate, or combinations thereof, which are binding agents disclosed in WO 99/20689,

[0049] The amount of binding agent present in the metallurgical powder composition depends on such factors as the density, particle size distribution and amounts of the iron-alloy powder, the iron powder and optional alloying powder in the metallurgical powder composition. Generally, the binding agent will be added in an amount of at least about 0.005 weight percent, more preferably from about 0.005 weight percent to about 2 weight percent, and most preferably from about 0.05 weight percent to about 1 weight percent, based on the total weight of the metallurgical powder composition.

[0050] In a preferred embodiment of the present invention, the metallurgical powder composition contains from about 10 weight percent to about 20 weight percent of an iron-molybdenum prealloy powder, from about 80 weight percent to about 90 weight percent substantially pure iron powder, from about 0.1 weight percent to about 1.2 weight percent carbon that is preferably graphite powder, and from about 0.1 to about 3.0 weight percent of copper that is preferably in the form of a copper containing powder. In this embodiment, the iron-molybdenum prealloy powder preferably contains from about 0.4 weight percent to about 2.0 weight percent molybdenum and from about 98 weight percent to about 99.6 weight percent iron. The percentages of iron,

molybdenum, carbon and copper in the metallurgical powder composition can be determined for example by an elemental analysis.

[0051] The present invention also provides methods of preparing metallurgical powder compositions. In the methods of the present invention, an iron-alloy powder that has preferably been prepared in accordance with the methods as previously described herein is provided. The iron-alloy powder is admixed with substantially pure iron powder and preferably carbon powder, in the amounts previously described herein, to form the metallurgical powder compositions of the present invention. Additionally other additives can be added to the metallurgical powder composition in the amounts previously described herein. For example, any combination of alloying powders, lubricants, binding agents, machining agents, plasticizers, or any other conventional metallurgical powder additive may be added.

[0052] The method of combining the iron-alloy powder, the substantially pure iron powder, the carbon powder, and other desired additives may be performed according to any technique well known to those skilled in the art. Preferably, the method used results in a uniformly mixed metallurgical powder composition that does not readily segregate. Moreover, the order of addition of the iron-alloy powder, the substantially pure iron powder, the carbon powder, and other desired additives is not critical. Preferably, however the order of addition is in a manner to achieve a uniform mixture of the metallurgical powder composition.

[0053] In a preferred embodiment, the methods of the present invention include adding a binding agent to the metallurgical powder composition to bond the iron-alloy powder, the substantially pure iron powder and other additives to inhibit segregation. The binding agent can be added to the powder mixture according to any technique known to those skilled in the art. For example, the procedures taught by U.S. Pat. Nos. 4,834,800 to Semel; 4,483,905 to Engstrom; 5,154,881 to Rutz et al.; and 5,298,055 to Semel et al.; and WO 99/20689, published Apr. 29, 1999, can be used, the disclosures of which are hereby incorporated by reference in their entireties. Preferably, the binding agent is added in a liquid form and mixed with the powders until good wetting of the powders is attained. Those binding agents that are in liquid form at ambient conditions can be added to the powder as such, but it is preferred that the binding agent, whether liquid or solid, be dissolved or dispersed in an organic solvent and added as a liquid solution, thereby providing substantially homogeneous distribution of the binding agent throughout the mixture. The wet powder is thereafter processed using conventional techniques to remove the solvent. Typically, if the mixes are small, generally 5 lbs. or less, the wet powder is spread over a shallow tray and allowed to dry in air. On the other hand, in the case of larger mixes, the drying step can be accomplished in the mixing vessel by employing heat and vacuum.

[0054] Also, the sequence of addition of the binding agent and a lubricant, if desired, can be varied to alter the final characteristics of the metallurgical powder composition. For example, the procedures taught in U.S. Pat. No. 5,256,185 to Semel et al., which is hereby incorporated by reference in its entirety, can be used. Also for example, the lubricant can be blended with the iron-alloy powder, the substantially pure iron powder, the carbon powder, the alloying powders and

other optional additives, and then, subsequently, the binding agent is applied to that composition. In another method, a portion of the lubricant, preferably from about 50 to about 99 weight percent, more preferably from about 75 to about 95 weight percent, is added to a mixture of the iron-alloy powder, the substantially pure iron powder, and other additives, then the binding agent is added, followed by removal of the solvent, and subsequently the rest of the lubricant is added to the metal powder composition. One further method is to add the binding agent first to a mixture of the iron-alloy powder and other additives, remove the solvent, and subsequently add the entire amount of the lubricant.

[0055] The metallurgical powder compositions of the present invention thus formed can be compacted in a die according to standard metallurgical techniques to form metal parts. Typical compaction pressures range between about 5 and 200 tons per square inch (tsi) (69-2760 MPa), preferably from about 20-100 tsi (276-1379 MPa), and more preferably from about 25-60 tsi (345-828 MPa).

[0056] Following compaction, the part can be sintered, according to standard metallurgical techniques at temperatures, sintering times, and other conditions appropriate to the metallurgical powder composition. For example, in a preferred embodiment, sintering temperatures range from about 1900° F. to about 2400° F. and are conducted for a time sufficient to achieve metallurgical bonding and alloying. The metallurgical powder composition may also be double pressed and double sintered by techniques well known to those skilled in the art.

[0057] Metal parts of various shapes and for various uses may be formed from the metallurgical powder compositions of the present invention. For example, the metal parts may be shaped for use in the automotive, aerospace, or nuclear energy industries.

[0058] It has been found that the metallurgical powder compositions made in accordance with the methods of the present invention have unexpectedly superior machinability properties. These improvements are especially observed when the metallurgical powder composition contains from about 10 weight percent to about 30 weight percent of an iron-molybdenum prealloy powder, from about 70 weight percent to about 90 weight percent of a substantially pure iron powder, from about 0.1 weight percent to about 3.0 weight percent of a carbon powder, and from about 0.1 weight percent to about 3.0 weight percent of a copper containing powder. Preferably, the iron molybdenum prealloy contains from about 0.40 to about 2.0 weight percent molybdenum and from about 98 weight percent to about 99.6 weight percent iron. The machinability can be further enhanced through the presence of a machining agent such as manganese sulfide in the metallurgical powder composition.

EXAMPLES

[0059] Some embodiments of the present invention will now be described in detail in the following Examples. Iron-based metallurgical powder compositions were prepared in accordance with the methods of the present invention. Comparative metal powder compositions were also prepared. The powder compositions prepared were compacted and sintered to form metal parts and evaluated for machinability.

Comparative Examples 1 to 2 and Examples 3 to 10

[0060] Metallurgical powder compositions having the compositions shown in Table 1 were prepared.

TABLE 1

Composition of Metal Powders Tested						
Examples	Fe Powder	Fe-Alloy Powder, wt %	Carbon wt %	Cu wt %	MnS wt %	Lubricant wt %
Control	Balance	0.0	0.5	2.0	0.0	0.0
Comp. Ex. 1	Balance	0.0	0.6	1.75	0.0	0.75
Comp. Ex. 2	Balance	0.0	0.6	1.75	0.35	0.75
Example 3	Balance	10.0	0.6	2.0	0.35	0.75
Example 4	Balance	15.0	0.6	2.0	0.35	0.75
Example 5	Balance	20.0	0.6	1.75	0.35	0.75
Example 6	Balance	20.0	0.6	2.0	0.35	0.75
Example 7	Balance	25.0	0.6	2.0	0.35	0.75
Example 8	Balance	30.0	0.6	2.0	0.35	0.75
Example 9	Balance	35.0	0.6	2.0	0.35	0.75
Example 10	Balance	40.0	0.6	2.0	0.35	0.75

[0061] The compositions were prepared by uniformly blending all the ingredients in the amounts shown in Table 1. The iron powder used in all examples was Ancorsteel 1000A available from Hoeganaes Corporation, located in Cinnaminson, N.J. The iron-alloy powder used in all examples was Ancorsteel™ 85HP steel powder also available from Hoeganaes Corporation. Ancorsteel 85HP is an iron-molybdenum prealloy powder containing about 0.85 weight percent molybdenum. The graphite used in all examples (shown as "Carbon" in Table 1) had a weight average particle size of about 6 to 8 microns and was obtained from Asbury Graphite Mills, Inc., located in Asbury, N.J. The copper powder (shown as "Cu" in Table 1) used in all examples was Accupowder from Accupowder Corporation. The copper powder had a weight average particle size of from about 10 microns to about 14 microns and a purity of 99.5 weight percent. The "MnS" shown in Table 1 is manganese sulfide, a machining agent. The lubricant shown in Table 1 was Acrawax™ C lubricant. Acrawax C is a synthetic wax and was obtained from Algroup Lonza located in Fair Lawn, N.J.

Example 11

[0062] The metal powder compositions of Comparative Examples 1 to 2 and Examples 3 to 10 were evaluated for machinability.

[0063] To evaluate machinability, each of the metallurgical powder compositions in Table 1 were compacted into 4 inch diameter by 1 inch thick discs having a density of 6.8 g/cm³. The discs were sintered at 2050° F. for 30 minutes in an atmosphere of 10% hydrogen and 90% nitrogen and allowed to cool to ambient temperature.

[0064] Prior to conducting the machinability tests, each drill bit was calibrated in the following manner. Twenty drill bits of 0.25 inch diameter were used to drill 0.95 inch deep holes in discs formed from the "Control" powder shown in Table 1. Each drill bit was used to drill approximately 2 to 3 holes for a total of about 40 to about 60 holes. The holes

were drilled at a feed rate of 0.005 inches per revolution and a cutting speed of 2220 rpm. During drilling the drill torque and drill thrust were measured automatically for each drill bit, and an average drill torque and thrust were calculated from all measurements. Only drill bits having a drill torque and thrust within ± 5 percent of the average were used in the machinability tests.

[0065] Using the same equipment used to calibrate the drill bits, discs formed from each of the metallurgical powder compositions shown in Table 1 were drilled with holes having a depth of 0.95 inches until the drill bit failed (e.g., wear exceeds a predetermined level). For each hole drilled, a feed rate of 0.005 inches per revolution and a cutting speed of 2220 rpm was used. The drill torque and drill thrust were measured throughout the test, and wear measurements on the drill bit were taken every ten holes drilled. The wear measurements were taken by a Microdynascope Model 5E Universal Inspection and Gauging System, supplied by Vision Engineering, located in Surrey, England. Table 2 shows the results of the machinability testing. The mean thrust was the mean value of thrust for all holes drilled prior to failure of the drill bit. Table 2 also shows the number of holes drilled to failure that was used for calculating the mean thrust. The number of holes drilled to failure depended in part on the strength of the material (increasing the strength decreases the number of holes to failure).

TABLE 2

Machinability Results			
Composition of Disc	Wt % of Preloy Powder	Number of Holes Drilled to Failure	Mean Thrust, (lbs)
Comp. Ex. 1	0.0	95	273.0
Comp. Ex. 2	0.0	775	210.6
Example 3	10.0	34	161.6
Example 4	15.0	622	166.0
Example 5	20.0	838	167.2
Example 6	20.0	398	195.5
Example 7	25.0	550	223.3
Example 8	30.0	383	140.7
Example 9	35.0	435	129.5
Example 10	40.0	476	131.0

[0066] The results in Table 2 show that the addition of the iron-alloy powder in an metallurgical powder composition reduces the mean thrust of a drill bit during the drilling of a disc. For example, although the mean thrust can be reduced somewhat by the addition of manganese sulfide to an iron based powder composition (see comparative Example 1 in comparison to Comparative Example 2), further improvement can be achieved by addition of a iron-alloy powder. The results for mean thrust obtained for Comparative Examples 1 to 2 and Example 5 are shown in FIG. 1. FIG. 1 is a bar graph showing mean thrust for discs prepared from Comparative Examples 1 to 2 and Example 5. By reducing the mean thrust, there is less wear on the drill bit leading to such benefits as increased lifetime of the drill bit.

[0067] There have thus been described certain preferred embodiments of the improved metallurgical powder compositions of the present invention, and methods of making and using the same. While preferred embodiments have been disclosed and described, it will be recognized by those with skill in the art that variations and modifications are within

the true spirit and scope of the invention. The appended claims are intended to cover all such variations and modifications.

What is claimed is:

1. A method of making a metallurgical powder composition comprising the steps of:

- (a) providing an iron-alloy powder comprising iron and at least one alloying additive, wherein the alloying additive is present in an amount of from about 0.01 weight percent to about 7 weight percent and the iron is present in an amount of at least 85 weight percent based on the total weight of the iron-alloy powder; and
- (b) admixing with the iron-alloy powder a substantially pure iron powder and carbon to form a metallurgical powder composition, wherein the metallurgical powder composition comprises from about 5 weight percent to about 40 weight percent of the iron-alloy powder, at least 55 percent by weight of the substantially pure iron powder, and at least 0.1 weight percent of the carbon based on the total weight of the metallurgical powder composition.

2. The method of claim 1 wherein the alloying additive in the iron-alloy powder is selected from the group consisting of molybdenum, chromium, vanadium, tungsten, and combinations thereof.

3. The method of claim 2 wherein the alloying additive is molybdenum.

4. The method of claim 3 wherein the molybdenum is present in the iron-alloy powder in an amount of from about 0.1 to about 2.0 weight percent, based on the total weight of the iron-alloy powder.

5. The method of claim 1 wherein the metallurgical powder composition further comprises at least one alloying powder.

6. The method of claim 5 wherein the alloying powder comprises copper, nickel, or combinations thereof.

7. The method of claim 1 wherein the metallurgical powder composition further comprises copper, nickel, graphite, manganese sulfide, or combinations thereof.

8. The method of claim 1 wherein the metallurgical powder composition comprises from about 10 weight percent to about 30 weight percent of the iron-alloy powder based on the total weight of the metallurgical powder composition and wherein the iron-alloy powder comprises from about 0.1 weight percent to about 2 weight percent molybdenum based on the total weight of the iron-alloy powder.

9. The method of claim 8 wherein the metallurgical powder composition comprises from about 70 weight percent to about 95 weight percent of the substantially pure iron powder, from about 0.1 weight percent to about 3 weight percent carbon, and from about 0.10 to about 3.0 weight percent copper, based on the total weight of the metallurgical powder composition.

10. An improved metallurgical powder composition comprising:

- (a) from about 5 weight percent to about 40 weight percent of an iron-molybdenum alloy powder comprising iron and molybdenum, wherein the amount of molybdenum is from about 0.10 weight percent to about 7.0 weight percent and the amount of iron is at

least 85 weight percent based on the weight of the iron-molybdenum alloy powder;

(b) at least 55 weight percent of a substantially pure iron powder; and

(c) from about 0.1 weight percent to about 3 weight percent of carbon.

11. The metallurgical powder composition of claim 10 wherein the metallurgical composition further comprises at least one alloying powder.

12. The metallurgical powder composition of claim 10 wherein the metallurgical composition further comprises nickel, copper, graphite, manganese sulfide, or combinations thereof.

13. The metallurgical powder composition of claim 10 wherein the metallurgical powder composition comprises from about 10 weight percent to about 30 weight percent of the iron-molybdenum alloy powder, from about 70 weight percent to about 95 weight percent of the substantially pure iron, from about 0.1 weight percent to about 2 weight percent of the carbon, and from about 0.10 to about 3.0 weight percent copper, based on the total weight of the metallurgical powder composition.

14. A method of forming a metal part comprising the steps of:

(a) providing a metallurgical powder composition comprising a mixture of:

(i) from about 5 weight percent to about 40 weight percent, based on the weight of the metallurgical powder composition, of a iron-alloy powder comprising iron and at least one alloying additive, wherein the alloying additive is present in an amount of from about 0.01 weight percent to about 7 weight percent and the iron is present in an amount of at least 85 weight percent, based on the total weight of the iron-alloy powder;

(ii) at least 55 weight percent of substantially pure iron powder; and

(iii) at least about 0.1 weight percent of carbon; and

(b) compacting the metallurgical powder composition at a pressure of at least about 5 tsi to form a metal part.

15. The method of claim 14 wherein the alloying additive is molybdenum and is present in the iron-alloy powder in an amount of from about 0.1 to about 3.0 weight percent, based on the total weight of the iron-alloy powder.

16. The method of claim 15 further comprising the step of sintering the compacted metal part at a temperature of at least 1900° F. to form a machinable metal sintered part.

* * * * *