IRON-BASED SINTERED ALLOY MATERIAL FOR VALVE SEAT AND VALVE SEAT MADE OF IRON-BASED SINTERED ALLOY

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ABSTRACT

An iron-based sintered alloy material for a valve seat, in which hard particles are dispersed in a base matrix phase, is characterized in that the base matrix phase is comprised of 5 to 40 vol. % of a pearlite phase and 10 to 40 vol. % of a high-alloy diffused phase and particles having hardness of Hv 600 to 1300 and particle diameter of 10 to 150 μm are dispersed as the hard particles, by the amount of 10 to 30 vol. %, in the base matrix phase. The hard particles are preferably at least one type of particles selected from the group consisting of intermetallic compound particles of Cr—Mo—Co; intermetallic compound particles of Cr—Mo—Co; Fe—Mo alloy particles; and carbide-precipitated particles.
Fig. 1

(a)

(b)

ST
HC
R
P
H
Fig. 2

(a)

(b) ST
    P
    R
    HC
    H
Fig. 3

(a)

(b)

H
R
P
HC
ST
Fig. 4

(a)

(b)

ST
P
C
R
H
Fig. 5

The diagram shows the amount of abrasion of a valve seat (μm) for both present and comparative examples. The present examples include samples labeled 1 to 13, and the comparative examples include samples labeled 8 to 13.
IRON-BASED SINTERED ALLOY MATERIAL FOR VALVE SEAT AND VALVE SEAT MADE OF IRON-BASED SINTERED ALLOY

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a sintered alloy material, and specifically to an iron-based sintered alloy material suitable for a valve seat used in an internal combustion engine.

[0003] 2. Description of Prior Art

[0004] A sintered alloy is produced by a method including the steps of: blending and mixing alloy powder; filling the blended alloy powder in a mold and compressing the alloy powder for molding; and sintering the molding in an atmosphere at a predetermined temperature. By this method, according to a sintered alloy, a metal or an alloy which is difficult to obtain by an ordinary melting and casting method can be easily produced. In addition, as the various functions can be easily imparted to the product in a combined manner, a member having unique functions can be produced according to this method. Further, a sintered alloy is suitable for producing a porous material, a hard-machining material or a mechanical member having a complicated shape. Due to such reasons, a sintered alloy has recently been applied to a valve seat of an internal combustion engine which must have high wear resistance.

[0005] In recent years, in the field of automobile engine, a demand for improvement, such as prolonging the product life, increasing the power, purifying exhaustion and enhancing fuel consumption thereof has been increasing. As a result, a valve seat for an automobile engine is now required to have a more excellent durability than is required in the conventional model so that the valve seat can bear a harsher application environment. Accordingly, there has increasingly been a demand for further improvement of the heat resistance property and the wear resistance property of a valve seat.

[0006] As the sintered alloy material for a valve seat, for example, JP-B 51-13093 Laid-Open discloses an iron-based sintered alloy material for a valve seat, which simultaneously exhibits excellent wear resistance, heat resistance and corrosion resistance even when lead-free gasoline is used. JP-B 51-13093 Laid-Open discloses a sintered alloy containing Cr, Ni, Cr, Mo, Co and W by relatively large amounts, in which specific alloy particles comprised of Co—Cr—W—Co and ferromolybdenum particles are dispersed in the pearlite base matrix, and Co and Ni are diffused around these particles. In other words, in the sintered alloy described in JP-B 51-13093 Laid-Open, specifically large amounts of W and Co must be added in order to provide the sintered alloy with excellent heat resistance, wear resistance, corrosion resistance and the like. As a result, the valve seat made of such a sintered alloy is quite expensive and problematic in terms of production cost.

[0007] Further, JP-A 9-53158 Laid-Open discloses an iron-based sintered alloy of the hard-phase-dispersion-type. The iron-based sintered alloy described in JP-A 9-53158 Laid-Open has an iron-based matrix which contains: 3 to 15 wt % of Ni; 3 to 15 wt % of Mo; 0.5 to 5 wt % of Cr; 0.5 to 1.2 wt % of C; and Fe as the remainder. Hard phase particles are dispersed by the amount of 3 to 20 wt % in the iron-based matrix. As the hard phase particles, at least one type of hard phase particles selected from the group consisting of: hard phase particles containing 50 to 57 wt % of Cr, 18 to 22 wt % of Mo, 8 to 12 wt % of Co, 0.1 to 1.4 wt % of C, 0.8 to 1.3 wt % of Si, and Fe as the remainder; hard phase particles containing 27 to 33 wt % of Cr, 22 to 28 wt % of W, 8 to 12 wt % of Co, 1.7 to 2.3 wt % of C, 1.0 to 2.0 wt % of Si, and Fe as the remainder; hard phase particles containing 60 to 70 wt % of Mo, no more than 0.01 wt % of C, and Fe as the remainder, are used.

[0008] JP-A 2000-199040 Laid-Open discloses an iron-based sintered alloy for a valve seat, in which 3 to 20% of hard particles are dispersed in a base matrix phase, the base matrix phase being comprised of 5 to 40% of the pearlite phase; 20 to 60% of the carbide-dispersed phase including fine carbides dispersed therein; and 5 to 20% of the high-alloy diffused phase.

OBJECT AND SUMMARY OF THE INVENTION

[0009] However, in the iron-based sintered alloy described in JP-A 9-53158 Laid-Open, Cr, Mo, Ni, Co and W must be added by relatively large amounts, in order to provide the sintered alloy with excellent heat resistance property, wear resistance property, corrosion resistance property and the like. As a result, the valve seat made of such a sintered alloy is quite expensive and causes a problem in terms of production cost. Further, in producing this iron-based sintered alloy, the influence of Ni and Co powder on human body remains as a problem to be solved.

[0010] As the iron-based sintered alloy described in JP-A 2000-199040 Laid-Open includes the carbide dispersed phase having relatively high hardness therein by a high proportion the iron-based sintered alloy is quite hard and causes a problem when the sintered alloy is utilized in an application in which excellent toughness is required.

[0011] An object of the present invention is to propose an iron-based sintered alloy material for a valve seat, as well as a valve seat made of the iron-based sintered alloy for the use in an internal combustion engine, which solves the aforementioned problems in an advantageous manner, does not contain the alloy elements by large amounts and thus is inexpensive, and exhibits excellent toughness and wear resistance.

[0012] The inventors of the present invention, as a result of the keen study for achieving the aforementioned object, have discovered that, by constituting the base matrix phase of the iron-based sintered alloy material with the pearlite phase and the high-alloy diffused phase and dispersing hard particles in the base matrix phase, the wear resistance of the resulting sintered alloy can be significantly increased and toughness thereof can be enhanced without adding a large amount of alloy elements. The present invention has been completed on the basis of this discovery. In the present invention, “a high-alloy diffused phase” represents a phase which is characteristically formed around hard particles due to the diffusion of the alloy elements of the hard particles, contributes to the excellent heat resistance, wear resistance and corrosion resistance of the sintered alloy and has hardness of Hv 350 to 600.

[0013] Specifically, the gist of the present invention is as follows.
An iron-based sintered alloy material for a valve seat, in which hard particles are dispersed in a base matrix phase and which is characterized in that the base matrix phase is comprised of 5 to 40 vol. % of a pearlite phase and 10 to 40 vol. % of a high-alloy diffused phase and having hardness of Hv 600 to 1300 and particle diameter of 10 to 150 μm are dispersed as the hard particles, by the amount of 10 to 30 vol. %, in the base matrix phase.

An iron-based sintered alloy material for a valve seat, in which hard particles are dispersed in a base matrix phase, characterized in that a base matrix portion which includes the hard particles has a composition comprised of: 0.2 to 2.0 wt % of C; 1.0 to 9.0 wt % of Cr; 1.0 to 9.0 wt % of Mo; 0.1 to 1.0 wt % of Si; 1.0 to 3.0 wt % of W; 0.1 to 1.0 wt % of V; 3.0 to 15.0 wt %, as the sum, of at least one type of element selected from the group consisting of Cu, Co and Ni; and the remainder which is substantially Fe, the base matrix phase is comprised of 5 to 40 vol. % of a pearlite phase and 10 to 40 vol. % of a high-alloy diffused phase and particles having hardness of Hv 600 to 1300 and particle diameter of 10 to 150 μm are dispersed as the hard particles, by the amount of 10 to 30 vol. %, in the base matrix phase.

An iron-based sintered alloy material for a valve seat described in the aforementioned (1) or (2), wherein the hard particles are at least one type of particles selected from the group consisting of: intermetallic compound particles of Mo–Ni–Cr–Si–Co; intermetallic compound particles of Cr–Mo–Co; Fe–Mo alloy particles; and carbide-precipitated particles.

An iron-based sintered alloy material far a valve seat described in the aforementioned (3), wherein the carbide-precipitated particles have a composition which is comprised of 0.2 to 2.0 wt % of Cr; 2.0 to 10.0 wt % of W; 0.2 to 5.0 wt % of V; and Fe and inevitable impurities as the remainder.

An iron-based sintered alloy material for a valve seat described in the aforementioned (4), wherein the content of the carbide-precipitated particles, as is expressed as the proportion by volume thereof present in the base matrix phase, is less than 20 vol. %.

An iron-based sintered alloy material for a valve seat described in the aforementioned (5), wherein fine carbides having particle diameter of 1 to 10 μm have been precipitated on said carbide-precipitated particles.

An iron-based sintered alloy material for a valve seat described in any one of the aforementioned (1) to (6), wherein the base matrix phase contains solid lubricant particles by the amount of 0.1 to 10.0 vol. %.

An iron-based sintered alloy material for a valve seat described in the aforementioned (7), wherein the solid lubricant particles made of are at least one type of compound selected from the group consisting of a sulfide, a fluoride and graphite.

An iron-based sintered alloy material for a valve seat described in any one of the aforementioned (1) to (8), wherein sintered pores are infiltrated with one of the material selected from the group consisting of Cu, Cu alloy, Pb and Pb alloy or with a phenol-based resin.

A valve seat made of an iron-based sintered alloy, characterized in that the valve seat is made of the iron-based sintered alloy material for a valve seat of any one of the aforementioned (1) to (9).

**BRIEF DESCRIPTION OF THE DRAWINGS**

**FIG. 1(a)** is a optical micrograph of a sintered alloy material (the sintered body No. 3) of an example of the present invention.

**FIG. 1(b)** is a sketch of FIG. 1(a).

**FIG. 2(a)** is a optical micrograph of a sintered alloy material (the sintered body No. 6) of an example of the present invention.

**FIG. 2(b)** is a sketch of FIG. 2(a).

**FIG. 3(a)** is a optical micrograph of a sintered alloy material (the sintered body No. 10) of a comparative example of the present invention.

**FIG. 3(b)** is a sketch of FIG. 3(a).

**FIG. 4(a)** is a optical micrograph of a sintered alloy material (the sintered body No. 12) of a comparative example of the present invention.

**FIG. 4(b)** is a sketch of FIG. 4(a).

**FIG. 5** is a graph which shows the result of the single piece wear test on rig of the examples.

**FIG. 6** is a schematic view of a tester of the single piece wear test on rig.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The iron-based sintered alloy material of the present invention is comprising of a base matrix phase, hard particles dispersed in the base matrix phase, and optionally a solid lubricant particles dispersed in the hard matrix. The base matrix phase has a structure which includes a pearlitic phase and a high-alloy diffused phase. The high-alloy used phase is formed of the alloy elements which have been diffused from the hard particles to the surrounding of the hard particles.

In the structure of the base matrix, the pearlite phase occupies 5 to 40 vol. % and the high-alloy diffused phase occupies 10 to 40 vol. % of the sintered alloy material as a whole.

When the proportion by volume of the pearlite phase is less than 5%, hardness of the base matrix phase increases and the machinability thereof may be deteriorated. On the other hand, when the proportion by volume of the pearlite phase exceeds 40%, hardness of the base matrix phase is decreased, whereby the wear resistance and the heat resistance may deteriorate. The high-alloy diffused phase contributes to enhancing the heat resistance, the wear resistance and the corrosion resistance properties, whereby the properties of the iron-based sintered alloy material as a whole are improved. When the proportion by volume of the high-alloy diffused phase is less than 10%, improvement of the aforementioned properties of the iron-based sintered alloy material is reduced. On the other hand, when the proportion by volume of the high-alloy diffused phase
The hard particles dispersed in the base matrix phase are particles having hardness in a range of Hv 600 to 1300 and particle diameter in a range of 10 to 150 \( \mu \text{m} \). When hardness of the hard particles exceeds Hv 1300, toughness of the resulting sintered alloy material is reduced and the generation rate of chip and crack thereof increases. When the particle diameter of the hard particles is smaller than 10 \( \mu \text{m} \), the components of the hard particles tend to be diffused in the base matrix phase in an excessive manner at the time of sintering, whereby hardness of the particles is lowered. On the other hand, when the particle diameter of the hard particles exceed 150 \( \mu \text{m} \), the machinability of the sintered body may be deteriorated and the aggressiveness to mated materials increases.

The high temperature diffusion of the carbide-precipitated particles is suppressed to less than 20 vol. %, whereby softness of the sintered alloy material increases, whereas toughness of the particles deteriorates, the machinability thereof may be disturbed, and the opposite aggressiveness to mated materials.

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In the present invention, at least one type of the aforementioned hard particles is dispersed in the base matrix phase such that the total amount thereof is 10 to 30 vol. %. When the total content of the hard particles is less than 10 vol. %, the content of the hard particles is too small and the wear resistance thereof will deteriorate. On the other hand, when the total content of the hard particles exceeds 30 vol. %, the strength of the sintered alloy material is lowered, the aggressiveness to mated materials increases, and the machinability of the sintered alloy material may be deteriorated.

The composition of the base matrix portion including the base matrix phase and the hard particles dispersed in the base matrix phase is preferably comprised of: 0.2 to 2.0 wt % of C; 1.0 to 9.0 wt % of Cr; 1.0 to 9.0 wt % of Mo; 0.1 to 1.0 wt % of Si; 1.0 to 3.0 wt % of W; 0.1 to 1.0 wt % of V, 3.0 to 15.0 wt %, as the sum, of at least one type of elements selected from the group consisting of Cu, Co and Ni; and the remainder which is substantially Fe.

Next, the preferable contents of the respective alloy elements of the base matrix portion will be described hereafter.

Carbon is an element which is solid-solved in the base matrix phase, thereby increasing hardness of the base matrix phase. In addition, carbon is reacted with other alloy elements and forms a carbide, thereby increasing hardness of the base matrix phase and improving the wear resistance thereof. When the content of carbon is less than 0.2 wt %, the base matrix phase cannot have the predetermined hardness and the wear resistance thereof deteriorates. When the content of carbon exceeds 2.0 wt %, not only the resulting carbide becomes coarse and the toughness thereof deteriorates, but also the diffusion of the components of the hard particles proceeds excessively and hardness of the particles is lowered. Accordingly, the content of C is preferably restricted to 0.2 to 2.0 wt %.

Cr: 1.0 to 9.0 wt %

Cr is an element which is contained in the base matrix phase and the hard particles and contributes to increasing hardness, the wear resistance and the corrosion resistance of the sintered alloy material. When the content of Cr exceeds 9.0 wt %, the content of the hard particles becomes too high or the hardness of the base matrix phase increases too high, whereby the aggressiveness to mated materials of the sintered alloy materials increases. On the other hand, when the content of Cr is less than 1.0 wt %, the content of the hard particles is not high enough and the wear resistance of the sintered alloy material deteriorates. Accordingly, the content of Cr is preferably in a range of 1.0 to 9.0 wt %.

Mo: 1.0 to 9.0 wt %

Mo is contained in the base matrix phase and the hard particles and contributes to enhancing hardness and the wear resistance of the sintered alloy material. However,
when the content of Mo exceeds 9.0 wt %, the content of the hard particles becomes too high or the hardness of the base matrix phase increases too high, whereby the aggressiveness to mated materials increases. On the other hand, when the content of Mo is less than 1.0 wt %, the content of the hard particles is not high enough and the hardness of the base portion is lowered, whereby the wear resistance of the sintered alloy material is likely to be deteriorate. Accordingly, the content of Mo is preferably in a range of 1.0 to 9.0 wt %.

[0052] Si: 0.1 to 1.0 wt %

[0053] Si is an element which is contained mainly in the hard particles and contributes to enhancing the wear resistance of the sintered alloy material. When the content of Si is less than 0.1 wt %, the content of the hard particles is not high enough and the effect of improving the wear resistance is not clearly observed. On the other hand, when the content of Si exceeds 1.0 wt %, the content of the hard particles becomes too high or the hardness of the base matrix phase increases too high, whereby the aggressiveness to mated materials increases. Accordingly, the content of Si is preferably restricted to a range of 0.1 to 1.0 wt %.

[0054] W: 1.0 to 3.0 wt %

[0055] W is an element which is contained in the base matrix phase and/or the hard particles and contributes to strengthening the base matrix phase and enhancing hardness and the wear resistance of the sintered alloy material. When the content of W is less than 1.0 wt %, the content of the hard particles is not high enough and the effect of improving the wear resistance is not clearly observed. On the other hand, when the content of W exceeds 3.0 wt %, the content of the hard particles becomes too high or the hardness of the base matrix phase increases too high, whereby the aggressiveness to mated materials increases. Accordingly, the content of W is preferably restricted to a range of 1.0 to 3.0 wt %.

[0056] V: 0.1 to 1.0 wt %

[0057] V is an element which is contained in the base matrix phase and/or the hard particles and contributes to strengthening the base matrix phase and enhancing hardness and the wear resistance of the sintered alloy material. When the content of V is less than 0.2 wt %, the effect of improving the wear resistance is not clearly observed. On the other hand, when the content of V exceeds 1.0 wt %, the content of the hard particles becomes too high or the hardness of the base matrix phase increases too high, whereby the aggressiveness to mated materials increases. Accordingly, the content of V is preferably restricted to a range of 0.1 to 1.0 wt %.

[0058] At least one type of elements selected from the group consisting of Cu, Co and Ni; the total content thereof being 3.0 to 15.0 wt %

[0059] Cu, Co and Ni are all contained in the base matrix phase and the hard particles and contributes to strengthening the base matrix phase and enhancing hardness and the wear resistance of the sintered alloy material. However, when the total content of Cu, Co and Ni is less than 3.0 wt %, the effect thereof is not clearly observed. On the other hand, when the total content of added Cu, Co and Ni is too large, the hardness of the base matrix phase increases too high and the aggressiveness to mated material increases. Accordingly, the total content of Cu, Co and Ni is preferably in a range of 3.0 to 15.0 wt %.

[0060] In the base matrix portion which includes the base matrix phase and the hard particles, the remainder other than the aforementioned components is substantially Fe.

[0061] In the iron-base sintered alloy material of the present invention, the solid lubricant particles may optionally be dispersed in the base matrix phase. The solid lubricant particles are preferably at least one type of compound selected from the group consisting of sulfide, fluoride and graphite. Examples of the sulfide include MnS, MoS2, and W2S. Examples of the fluoride include CaF2 and LiF. By dispersing the solid lubricant particles in the base matrix phase, the machinability of the sintered alloy material is facilitated, the wear resistance of the sintered alloy material is enhanced and the aggressiveness to mated materials decreases.

[0062] It is preferable that the solid lubricant particles are dispersed in the base matrix phase, by the total amount thereof of 0.1 to 10.0 wt %, with respect to the total amount of the base matrix phase, the hard particles and the solid lubricant particles. When the content of the solid lubricant particles is less than 0.1 wt %, the content of the solid lubricant particles is not high enough, whereby the sliding lubricity of the sintered alloy material deteriorates and the machinability of the sintered alloy material may be decreased. Further, when the content of the solid lubricant particles is less than 0.1 wt %, occurrence of adhesion is accelerated and the wear resistance of the sintered alloy material deteriorates. On the other hand, when the content of the solid lubricant particles exceeds 10.0 wt %, the powder-compression property (compatibility), the diffusion property during sintering and the strength of the sintered alloy material deteriorate.

[0063] The particle diameter of the solid lubricant particles is preferably in a range of 2 to 50 μm. In a case in which the particle diameter of the solid lubricant particles is smaller than 2 μm, the aforementioned effect of the solid lubricant particles cannot be expected. On the other hand, in a case in which the particle diameter of the solid lubricant particles exceeds 50 μm, the sintering and powder-compression properties (compatibility) will be adversely affected.

[0064] The iron-based sintered alloy material of the present invention may contain pores by the proportion by volume of no higher than 10.0%. When the content of pores exceeds 10.0 vol. %, the strength at a high temperature and the heat conductivity are lowered and drop-out resistance of the sintered alloy material deteriorates.

[0065] In order to obtain the iron-based sintered alloy material of the present invention, first, at least one type of powder selected from the group consisting of pure iron powder, alloy iron powder and alloy elements powder is blended with powder of the hard particles (and optionally with powder of the solid lubricant powder) such that the aforementioned composition of the base matrix portion is satisfied, to prepare raw material powder as the mixture of the components powders.

[0066] Preferable examples of combination of at least one type of powder selected from the group consisting of pure iron powder, alloy iron powder and alloy elements powder include the following 1) to 5). In each of 1) to 5), "wt%" represents "wt %" with respect to the total amount of pure iron powder, alloy iron powder, alloy elements powder, powder of the hard particles and powder of the solid lubricant.
1) 40.0 to 85.0% of pure iron powder and 8.0 to 35.0% of alloy elements powder which contains at least one type of element selected from the group consisting of C, Cr, Mo, Si, W, V, Cu, Co and Ni (i.e., the total content of C, Cr, Mo, Si, W, V, Cu, Co and Ni is in a range of 8.0 to 35.0%).

2) At least one type of alloy iron powder, each type of alloy iron powder containing at least one type of elements selected from C, Cr, Mo, Si, W, V, Cu, Co and Ni by the amount of 20% or less each, as well as Fe and inevitable impurities as the remainder, the content of each type of alloy iron powder being adjusted such that the total content thereof is within a range of 70.0 to 95.0%.

3) 20.0 to 70.0% of pure iron powder and at least one type of alloy iron powder, each type of alloy iron powder containing at least one type of elements selected from C, Cr, Mo, Si, W, V, Cu, Co and Ni by the amount of 20% or less each, as well as Fe and inevitable impurities as the remainder, the content of each type of alloy iron powder being adjusted such that the total content thereof is within a range of 5.0 to 70.0%.

4) At least one type of alloy iron powder, each type of alloy iron powder containing at least one type of elements selected from C, Cr, Mo, Si, W, V, Cu, Co and Ni by the amount of 20% or less each, as well as Fe and inevitable impurities as the remainder, and alloy elements powder which contains at least one type of element selected from the group consisting of Cr, Mo, Si, W, V, Cu, Co and Ni, the total content of the alloy iron powder(s) being in a range of 45.0 to 90.0% and the content of the alloy elements powder, i.e., the total content of the alloy elements being in a range of 5.0 to 30.0%.

5) 15.0 to 65.0% of pure iron powder, at least one type of alloy iron powder, each type of alloy iron powder containing at least one type of element selected from C, Cr, Mo, Si, W, V, Cu, Co and Ni by the amount of 20% or less each, as well as Fe and inevitable impurities as the remainder, alloy elements powder which contains at least one type of element selected from the group consisting of Cr, Mo, Si, W, V, Cu, Co and Ni, the total content of the alloy iron powder(s) being in a range of 5.0 to 65.0% and the content of the alloy elements powder, i.e., the total content of the alloy elements being in a range of 5.0 to 25.0%.

The mixed powder as the raw material powder is preferably prepared by blending and mixing at least one type of powder selected from the group consisting of the pure iron powder, the alloy iron powder and the alloy elements powder, with the hard particles (and optionally with the solid lubricant powder), such that the content of the added hard particles is in a range of 3 to 20 wt% and the content of the added solid lubricant powder is in a range of 0.1 to 10 wt% with respect to the total amount of the pure iron powder, the alloy iron powder, the alloy elements powder, the hard particles and the solid lubricant powder. As the lubricant, zinc stearate and the like may further be added.

The mixed powder is preferably at least one type of powder selected from the group consisting of: intermetallic compound particles of Mo—Ni—Cr—Si—Co; intermetallic compound particles of Cr—Mo—Co; Fe—Mo alloy particles; and carbide-precipitated particles. The solid lubricant powder is preferably at least one type of powder selected from the group consisting of a sulfide, a fluoride and graphite.

The mixed powder as the raw material powder prepared as described above is filled in a mold and subjected to compression and molding by a molding press, whereby a compressed powder body is obtained (the molding process), and the compressed powder body is heated to a temperature in a range of 1,000 to 1,200°C in a protective atmosphere and sintered, whereby a sintered body is obtained (the sintering process). The sintered body may be further subjected to infiltration or impregnation (the infiltration-impregnation process). As a result, an iron-based sintered alloy material for a valve seat is produced.

When the temperature at the sintering process is below 1,000°C, the diffusion during sintering does not occur in a sufficient manner and the formation of the base is insufficient. On the other hand, when the temperature at the sintering process exceeds 1,200°C, excessive diffusion occurs at the hard particles and the base matrix, whereby the wear resistance of the sintered alloy material deteriorates. It is preferable that the sintering atmosphere is a protective atmosphere and specifically NH3 gas, a mixture of N2 and H2 gases or the like.

The infiltration-impregnation process is optionally carried out in order to seal the sintered pores (air pores). The pore sealing process may be carried out by setting a low-melting point metal such as Cu, Cu alloy, Pb or Pb alloy on the sintered body, heating the metal and allow the metal to infiltrate the sintered body. Alternatively, the pore sealing process may be carried out by allowing a phenol-based resin to impregnate the sintered body.

The produced sintered body is then subjected to cutting and grinding, so that a valve seat having a desired dimension and shape is obtained.

EXAMPLES

At least one type of powder selected from the group consisting of the iron powder, the alloy iron powder and the alloy elements powder was blended and kneaded with powder of the hard particles (and optionally with the solid lubricant powder) as shown in Table 1, whereby the mixed powder was obtained. The blended amount of each component powder was indicated as wt% with respect to the total amount of the mixed powder.

The types of the alloy iron powder which was used are: (A) alloy steel powder containing 1.0% of Cr, 0.5% of Mn, 0.3% of Mo and Fe as the remainder; (B) alloy steel powder containing 3.0% of Cr, 0.2% of Mo and Fe as the remainder; (C) alloy steel powder containing 4.0% of Ni, 1.5% of C, 0.5% of Mo and Fe as the remainder. Here, “%” represents “wt%”.

The types of the hard particles which were used are: (a) powder of carbide-precipitated particles (the average particle diameter being 80 µm, the average particle diameter of carbide being 3 µm) of SKD 11 (1.5% of C, 12% of Cr, 0.8% of V, 1% of Mo and Fe as the remainder); (b) powder of carbide-precipitated particles (the average particle diameter being 80 µm, the average particle diameter of carbide being 3 µm) of SKH 51 (0.8% of C, 4% of Cr, 5% of Mo, 2% of V, 6% of W and Fe as the remainder); (c) powder of carbide-precipitated particles (the average particle diameter being 80 µm, the average particle diameter of carbide being 4 µm) of SKH 57 (1.2% of C, 4% of Cr, 3% of Mo, 10% of
W, 3% of V, 10% of Co and Fe as the remainder; (d) powder of intermetallic compound particles containing 9% of Cr, 30% of Mo and Co as the remainder (the average particle diameter being 100 μm); (e) powder of intermetallic compound particles containing 24% of Mo, 10% of Ni, 24% of Cr, 2% of Si and Co as the remainder (the average particle diameter being 100 μm). "%" represents "wt. %".

[0081] The types of the solid lubricant powder which was used are MnS (X), CaF₂ (Y) and Graphite(Z).

[0082] The mixed powder as described above was filled in a mold and subjected to compression and molding by a molding press, whereby a compressed powder body was obtained. Each compressed powder body was subjected to sintering in a reducing atmosphere (NH₃ gas) at a temperature of 1,000 to 1,200°C for 15 to 45 minutes, whereby a sintered body was obtained. Some of the sintered body samples were subjected to the infiltration process in which each sample was heated with an infiltration agent (lead) at 500°C.

[0083] The composition of the base matrix portion, as well as the structural proportions, of each of the obtained sintered body samples are shown in Table 2.

[0084] FIG. 1(a), FIG. 2(a), FIG. 3(a) and FIG. 4(a) show the optical micrographs of the sintered body No. 3, the sintered body No. 6, the sintered body No. 10 and the sintered body No. 12, respectively. FIGS. 1(b) to 4(b) are sketches of FIGS. 1(a) to 4(a), respectively. "P" represents the pearlitic phase, "P" represents the high-alloy diffused phase, "H" represents the hard particles (other than the carbide-precipitated particles), "HC" represents the carbide-precipitated particles (the hard particles), "ST" represents the solid lubricant particles.

[0085] Next, each sintered body was processed to form a valve seat (having a dimension of φ41.4±φ38.6±7.0 mm), whereby a single piece wear test on rig was carried out as described below.

[0086] 1) A single piece wear test on rig wear resistance test

[0087] The wear resistance was investigated by using a single piece wear test on rig shown in FIG. 6. The single piece wear test on rig was carried out by: pressingly inserting the valve seat 1 into a jig 2 which simulated a cylinder head, moving up/down the valve 4 in the vertical direction with heating the valve 4 and the valve seat 1 by using a heat source (LP+Ar) 3 provided in the testing device; and measuring the amount of wear as the amount of sinking of the valve. The conditions at the test were as follows.

- [0088] Temperature: 400°C. (at the seat surface)
- [0089] Testing time: 9.0 hr
- [0090] Number of cam rotation: 3000 rpm
- [0091] Number of valve rotation: 20 rpm
- [0092] Load of spring: 35 kgf (at the time of setting)
- [0093] Valve material: SUH3
- [0094] The result of the single piece wear test on rig are shown in Tables 2 and FIG. 5.

[0095] Table 1

[0096] Table 2

[0097] The amount of wear of the valve seat in each of the sintered bodies No. 1 to No. 9, No.14 to No.17 of the present examples was in a range of 11 to 19 μm. In these examples, the amount of wear of the mated material was in a range of 4 to 11 μm. The amount of wear of the valve seat in each of the sintered bodies No. 10 to No. 13 of the comparative examples, which were beyond the scope of the present invention, was in a range of 29 to 48 μm. In these comparative examples, the amount of wear of the mated material was in a range of 15 to 47 μm. Accordingly, it is understood that the amount of wear is decreased, the wear resistance is improved and the aggressiveness to mated materials is lowered in the present examples, as compared with the comparative examples.

[0098] As described above, according to the present invention, a sintered alloy material which is inexpensive and excellent in toughness and wear resistance can be obtained. This sintered alloy material exhibits excellent durability in a harsh operation when used as a valve seat for an automobile and achieves a significantly excellent effect in the industrial terms.

### Table 1

<table>
<thead>
<tr>
<th>Sintered body No.</th>
<th>Alloy powder**</th>
<th>Powder of solid particles*</th>
<th>Amount to be blended (wt %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powder Type</td>
<td>wt %</td>
<td>C</td>
<td>Others</td>
</tr>
<tr>
<td>1</td>
<td>28.5</td>
<td>B</td>
<td>45.0</td>
</tr>
<tr>
<td>2</td>
<td>31.8</td>
<td>A</td>
<td>50.0</td>
</tr>
<tr>
<td>3</td>
<td>31.5</td>
<td>C</td>
<td>40.0</td>
</tr>
<tr>
<td>4</td>
<td>62.8</td>
<td>—</td>
<td>12.0</td>
</tr>
<tr>
<td>5</td>
<td>59.0</td>
<td>C</td>
<td>10.0</td>
</tr>
<tr>
<td>6</td>
<td>21.8</td>
<td>A</td>
<td>53.0</td>
</tr>
<tr>
<td>7</td>
<td>29.7</td>
<td>B</td>
<td>45.0</td>
</tr>
<tr>
<td>8</td>
<td>40.9</td>
<td>A</td>
<td>35.0</td>
</tr>
<tr>
<td>9</td>
<td>30.5</td>
<td>A</td>
<td>40.0</td>
</tr>
<tr>
<td>10</td>
<td>28.5</td>
<td>B</td>
<td>34.5</td>
</tr>
</tbody>
</table>
TABLE 1—continued

<table>
<thead>
<tr>
<th>Sintered body No.</th>
<th>Iron powder*</th>
<th>Alloy elements powder (wt %)</th>
<th>Powder of hard particles**</th>
<th>Powder of solid lubricant particles</th>
<th>Infiltration agent</th>
<th>Amount to be blended (wt %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>Others</td>
<td>amount</td>
<td>Type</td>
<td>wt %</td>
</tr>
<tr>
<td>11</td>
<td>73.2</td>
<td>C</td>
<td>10.0</td>
<td>1.3</td>
<td>0.7</td>
<td>Co:3.0, Ni:2.0</td>
</tr>
<tr>
<td>12</td>
<td>20.0</td>
<td>A</td>
<td>22.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>13</td>
<td>25.0</td>
<td>C</td>
<td>40.0</td>
<td>—</td>
<td>a</td>
<td>10.0</td>
</tr>
<tr>
<td>14</td>
<td>32.8</td>
<td>A</td>
<td>40.0</td>
<td>1.2</td>
<td>a</td>
<td>20.0</td>
</tr>
<tr>
<td>15</td>
<td>26.4</td>
<td>C</td>
<td>40.0</td>
<td>1.1</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>16</td>
<td>28.4</td>
<td>C</td>
<td>45.0</td>
<td>1.1</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>17</td>
<td>28.4</td>
<td>B</td>
<td>40.0</td>
<td>1.1</td>
<td>C</td>
<td>4.0</td>
</tr>
</tbody>
</table>

* Alloy iron powder
A: 1.0% of Cr-5% of Mo-0.3% of Mo-Fe
B: 3.0% of Cr-0.2% of Mo-Fe
C: 4.0% of Ni-1.5% of Cr-0.5% of Mo-Fe

**Hard particles:
a: SKD11 (carbide-precipitated particles)
b: SKH51 (carbide-precipitated particles)
c: SKH57 (carbide-precipitated particles)
d: An intermetallic compound containing 9% of Cr-30% of Mo-Co
e: An intermetallic compound containing 24% of Mo-10% of Ni-24% of Cr-2% of Si-Co
f: An alloy containing 60% of Mo-Fe

Solid lubricant agent
X: MoS2
Y: C6F6
Z: Graphite

[0099]

TABLE 2

<table>
<thead>
<tr>
<th>Sintered body No.</th>
<th>Composition of the base matrix portion (wt %)</th>
<th>Pearlite phase (vol %)</th>
<th>High-alloy diffused phase (vol %)</th>
<th>Particle diameter (μm)</th>
<th>Hardness (HV)</th>
<th>Carbide-precipitated particles vol. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C 1.6 Cr 2.8 Mo 4.0 Si 0.3 W 0.5 V 0.3 Ni 0.5 Cu 0.5</td>
<td>35</td>
<td>35</td>
<td>4</td>
<td>650</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>C 1.3 Cr 1.5 Mo 2.8 Si 0.2 W 0.2 V 0.2 Ni 0.2 Cu 0.2</td>
<td>39</td>
<td>39</td>
<td>3</td>
<td>630</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>C 1.6 Cr 2.8 Mo 3.1 Si 0.2 W 0.2 V 0.2 Ni 0.2 Cu 0.2</td>
<td>38</td>
<td>37</td>
<td>4</td>
<td>650</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>C 1.4 Cr 4.9 Mo 3.3 Si 0.3 W 0.3 V 0.3 Ni 3.3 Cu 0.2</td>
<td>35</td>
<td>33</td>
<td>3</td>
<td>620</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>C 1.1 Cr 0.4 Mo 9.4 Si 0.1 W 0.9 V 0.9 Ni 0.9 Cu 0.9</td>
<td>35</td>
<td>36</td>
<td>4</td>
<td>660</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>C 1.3 Cr 4.5 Mo 4.2 Si 0.5 W 0.5 V 0.5 Ni 0.5 Cu 0.5</td>
<td>32</td>
<td>38</td>
<td>3</td>
<td>630</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>C 1.4 Cr 4.2 Mo 2.9 Si 0.2 W 0.2 V 0.2 Ni 0.2 Cu 0.2</td>
<td>36</td>
<td>37</td>
<td>4</td>
<td>660</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>C 1.2 Cr 2.8 Mo 2.9 Si 0.2 W 0.2 V 0.2 Ni 0.2 Cu 0.2</td>
<td>37</td>
<td>37</td>
<td>4</td>
<td>660</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>C 1.1 Cr 2.2 Mo 5.0 Si 0.4 W 0.7 V 0.7 Ni 2.0 Cu 2.0</td>
<td>26.5</td>
<td>39</td>
<td>3</td>
<td>630</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>C 1.7 Cr 5.5 Mo 4.7 Si 0.4 W 0.4 V 0.4 Ni 2.0 Cu 2.0</td>
<td>11.5</td>
<td>45</td>
<td>4</td>
<td>600</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>C 1.4 Cr 1.4 Mo 1.5 Si 0.1 W 0.3 V 0.3 Ni 0.9 Cu 0.9</td>
<td>56.5</td>
<td>30</td>
<td>4</td>
<td>630</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>C 0.4 Cr 4.9 Mo 5.2 Si 0.4 W 0.9 V 0.9 Ni 1.2 Cu 4.8</td>
<td>9.5</td>
<td>20</td>
<td>2</td>
<td>500</td>
<td>45</td>
</tr>
<tr>
<td>13</td>
<td>C 0.1 Cr 7.2 Mo 6.3 Si 0.5 W 0.5 V 0.5 Ni 0.1 Cu 0.1</td>
<td>27</td>
<td>30</td>
<td>2</td>
<td>450</td>
<td>10</td>
</tr>
<tr>
<td>14</td>
<td>C 3.6 Cr 3.4 Mo 0.4 Si 0.2 W 0.2 V 0.2 Ni 0.2 Cu 0.2</td>
<td>38</td>
<td>38</td>
<td>2</td>
<td>620</td>
<td>20</td>
</tr>
<tr>
<td>15</td>
<td>C 1.1 Cr 2.4 Mo 6.2 Si 0.7 W 0.7 V 0.7 Ni 1.1 Cu 1.1</td>
<td>39.5</td>
<td>39.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>16</td>
<td>C 1.1 Cr 6.0 Mo 6.2 Si 0.5 W 0.5 V 0.5 Ni 4.3 Cu 0.3</td>
<td>36</td>
<td>33.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>17</td>
<td>C 1.1 Cr 1.2 Mo 15.7 Si 0.1 W 0.1 V 0.1 Ni 0.4 Cu 0.4</td>
<td>32</td>
<td>35.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
What is claimed is:

1. An iron-based sintered alloy material for a valve seat, in which hard particles are dispersed in a base matrix phase, characterized in that the base matrix phase is comprised of 5 to 40 vol. % of a pearlite phase and 10 to 40 vol. % of a high-alloy used phase and particles having hardness of Hv 600 to 1300 and particle diameter of 10 to 150 μm are dispersed as the hard particles, by the amount of 10 to 30 vol. %, in the base matrix phase.

2. An iron-based sintered alloy material for a valve seat, in which hard particles are dispersed in a base matrix phase, characterized in that a base portion which includes the hard particles has a composition comprised of 0.2 to 2.0 wt % of C; 1.0 to 9.0 wt % of Cr; 1.0 to 9.0 wt % of Mo; 0.1 to 1.0 wt % of Si; 1.0 to 3.0 wt % of W; 0.1 to 1.0 wt % of V; 3.0 to 15.0 wt %, as the total, of at least one type of element selected from the group consisting of Cu, Co and Ni; and the remainder which is substantially Fe, the base matrix phase is comprised of 5 to 40 vol. % of a pearlite phase and 10 to 40 vol. % of a high-alloy diffused phase and particles having hardness of Hv 600 to 1300 and particle diameter of 10 to 150 μm are dispersed as the hard particles, by the amount of 10 to 30 vol. %, in the base matrix phase.

3. An iron-based sintered alloy material for a valve seat according to claim 1 or 2, wherein the hard particles are at least one type of particles selected from the group consisting of intermetallic compound particles of Mo—Ni—Cr—Si—Co; intermetallic compound particles of Cr—Mo—Co; Fe—Mo alloy particles; and carbide-precipitated particles.

4. An iron-based sintered alloy material for a valve seat according to claim 3, wherein the carbide-precipitated particles have a composition which is comprised of: 0.2 to 2.0 wt % of C; 2.0 to 10.0 wt % of Cr; 2.0 to 10.0 wt % of Mo; 2.0 to 10.0 wt % of W; 0.2 to 5.0 wt % of V; and Fe and inevitable impurities as the remainder.

5. An iron-based sintered alloy material for a valve seat according to claim 4, wherein the content of the carbide-precipitated particles, as is expressed as the proportion by volume thereof present in the base matrix phase, is less than 20 vol. %.

6. An iron-based sintered alloy material for a valve seat according to claim 4 or 5, wherein fine carbides having...
particle diameter of 1 to 10 $\mu$m have been precipitated on said carbide-precipitated particles.

7. An iron-based sintered alloy material for a valve seat according to any one of claims 1 to 6, wherein the base matrix phase contains solid lubricant particles by the amount of 0.1 to 10.0 vol. %.

8. An iron-based sintered alloy material for a valve seat according to claim 7, wherein the solid lubricant particles made of are at least one type of compound selected from the group consisting of a sulfide, a fluoride and graphite.

9. An iron-based sintered alloy material for a valve seat according to any one of claims 1 to 8, wherein sintered pores are infiltrated with one of the material selected from the group consisting of Cu, Cu alloy, Pb and Pb alloy or with a phenol-based resin.

10. A valve seat made of an iron-based sintered alloy, characterized in that the valve seat is made of the iron-based sintered alloy material for a valve seat of any one of claims 1 to 9.

* * * * *