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(54) ALLOY CAST IRON AND MANUFACTURING METHOD OF VANE USING THE SAME

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Description

Technical Field

[0001] This specification relates to an alloy cast iron a vane for a compressor and a manufacturing method of a vane for a rotary compressor using the same.

Background Art

[0002] Generally, a compressor includes a driving motor for generating a driving force at an inner space of a shell, and a compression unit coupled to the driving motor and compressing a refrigerant. The compressor may be categorized into various types according to a refrigerant compression method. For instance, in case of a rotary compressor, the compression unit includes a cylinder for forming a compression space, a vane for dividing the compression space of the cylinder into a suction chamber and a discharge chamber, a plurality of bearing members for supporting the vane and forming the compression space together with the cylinder, and a rolling piston rotatably mounted in the cylinder.

[0003] The vane is inserted into a vane slot of the cylinder, and the compression space is divided into two parts as the end of the vane is fixed to the outer circumference of the rolling piston. During a compression process, the vane continuously slides in the vane slot. Here, the vane should have a high strength and a high abrasion resistance, because it should continuously contact a refrigerant of high temperature and high pressure, and maintain an attached state to the rolling piston and the bearing for prevention of refrigerant leakage.

[0004] Especially, a new refrigerant, such as Hydroflurocarbon (HFC), which replaces Chloroflurocarbon (CFC) prohibited from use due to ozone depletion, has a lower lubricative property than the CFC, and exhibits a more increased abrasion resistance, which is required for a vane because of the use of an inverter to reduce energy consumption, as compared with the related art.

[0005] To satisfy these conditions, in recent time, vanes are manufactured by machining high speed steel or stainless steel into predetermined shapes, followed by a post-processing, such as surface treatment or the like.

Disclosure of Invention

Technical Problem

[0006] However, the vanes excessively contain Cr, W, Mo, V, Co and the like, which are high-priced rare earth metals and are machined into the predetermined shapes through forging, thereby having low productivity and high prices. In particular, the vane has a high hardness for an increase in the abrasion resistance, but this makes it difficult to perform the processing operation through the forging.

[0007] CN 1 876 878 A relates to a CrMoCu alloy grain continuous casting section and its manufacturing process.

[0008] GB 1 248 610 A discloses a piston ring made of grey cast iron with a customary content of carbon, silicon, manganese, and phosphorus.

[0009] GB 1 119 759 A describes improvements of internal combustion engine valve components.

Solution to Problem

[0010] Therefore, to overcome the drawbacks of the related art, an aspect of the detailed description is to provide an alloy cast iron capable of increasing productivity and reducing manufacturing costs with satisfying requirements for strength and abrasion resistance necessary to a vane.

[0011] Another aspect of the detailed description is to provide a manufacturing method of such vane.

[0012] To achieve these and other advantages and in accordance with the purpose of this specification, as embodied and broadly described herein, there is provided an alloy cast iron consisting of by weight, 3.2 to 3.8% C, 2.0 to 2.6% Si, 0.5 to 1.0% Mn, 0.2 to 0.6% Cr, 0.1 to 0.6% Mo, 0.04 to 0.15% Ti, P less than 0.3%, S less than 0.1% optionally 0.01 to 0.5% Nb and/or 0.1 to 0.5% V, optionally 0.02 to 0.1% B, optionally 0.2 to 0.5% Cu, and balance Fe and inevitable impurities, wherein the alloy cast comprises a martensitic matrix structure, flake graphite, and 15 to 30% carbide in volume ratio.

[0013] The alloy cast iron may be added with an inoculant in a state of a molten metal taken out of a melting furnace. Here, the inoculant may be a barium-based inoculant (Fe-Si-Ba). The inoculant may be added by 0.4 to 1.0% of the mass of the molten mass.

[0014] The alloy cast iron may be formed by cooling the molten metal in a cast to transform into a martensitic matrix structure through quenching and tempering. Here, the quenching may be carried out by keeping the alloy cast iron at temperature of 860 to 950°C for 0.5 to 1.5 hours and oil-cooling the alloy cast iron down to room temperature. The

tempering may be carried out by keeping the quenched alloy cast iron at temperature of 180 to 220°C for 0.5 to 1.5 hours, and air-cooling the alloy cast iron down to room temperature.

[0015] The alloy cast iron may further comprise a sulfurized layer which is 0.005 to 0.015 mm thick. Here, the sulfurized layer may be formed by carrying out ion-sulfurizing for the alloy cast iron transformed into the martensitic matrix structure.

[0016] The alloy cast iron may further comprise 0.01 to 0.5% by weight of niobium (Nb).

[0017] The alloy cast iron may further comprise 0.1 to 0.5% by weight of vanadium (V).

[0018] The alloy cast iron may further comprise 0.02 to 0.1% by weight of boron (B).

[0019] The alloy cast iron may further comprise 0.2 to 0.5% by weight of copper (Cu).

[0020] In accordance with another aspect of the detailed description, there is provided a method for manufacturing a vane for a compressor including a smelting step of preparing a molten metal consisting of, by weight, 3.2 to 3.8% C, 2.0 to 2.6% Si, 0.5 to 1.0% Mn, 0.2 to 0.6% Cr, 0.1 to 0.6% Mo, 0.04 to 0.15% Ti, P less than 0.3%, S less than 0.1%, optionally 0.01 to 0.5% Nb and/or 0.1 to 0.5% V, optionally 0.02 to 0.1% B, optionally 0.2 to 0.5% Cu, and the balance Fe and inevitable impurities, a casting step of obtaining a semi-product comprising flake graphite and 15 to 30% by volume of carbide by injecting the molten metal in a cast and cooling the molten metal, a grinding step of grinding the cooled semi-product into a predetermined shape, and a heat treatment step of carrying out a heat treatment for the ground semi-product to transform into a martensitic matrix structure, as defined in the claims.

[0021] The method further includes an inoculation step of taking out the molten metal and injecting an inoculant into the molten metal.

[0022] The heat treatment step includes a quenching process of keeping the ground semi-product at temperature of 860 to 950°C for 0.5 to 1.5 hours and oil-cooling the semi-product down to room temperature, and a tempering process of keeping the quenched semi-product at temperature of 180 to 220°C for 0.5 to 1.5 hours and air-cooling the semi-product down to room temperature.

[0023] The method further includes a fine grinding step of finely grinding the semi-product completely processed through the heat treatment.

[0024] The method further includes an ion-sulfurizing step of forming a sulfurized layer on a surface of the completely heat-treated semi-product. Here, the sulfurized layer is 0.005 to 0.015 mm thick.

[0025] The alloy cast iron may further comprise 0.01 to 0.5% by weight of niobium (Nb).

[0026] The alloy cast iron may further comprise 0.1 to 0.5% by weight of vanadium (V).

[0027] The alloy cast iron may further comprise 0.02 to 0.1 % by weight of boron (B).

[0028] The alloy cast iron may further comprise 0.2 to 0.5% by weight of copper (Cu).

[0029] In accordance with another aspect of the detailed description, there is provided a vane for a compressor manufactured using the alloy cast iron.

Advantageous Effects of Invention

[0030] In accordance with the aspects, the present disclosure with the configuration provides an alloy cast iron capable of simultaneously improving abrasion resistance and tensile strength by virtue of elements mixed by an adequate ratio and combination of a martensitic matrix structure, a flake graphite structure and carbide. This facilitates a member, such as a compressor vane, which is used under high temperature and high pressure atmosphere, to be manufactured with low costs.

[0031] Instead of high-priced rare earth elements, which have been added to satisfy requirements for a compressor vane in the related art, relatively low-priced elements may be used to fabricate the vane for the compressor, resulting in reduction of raw material costs.

[0032] According to another aspect of the present disclosure, the vane is manufactured through casting other than forging used in the related art. Accordingly, post-treatments may be remarkably decreased and a plurality of vanes may be manufactured at the same time, resulting in remarkable improvement of productivity. In addition, the manufacturing using the relatively how-priced alloy cast iron, other than a high-priced high speed steel which is used for the forging, may remarkably reduce the raw material cost.

Brief Description of Drawings

[0033]

FIG. 1 is a front view schematically showing a sample (test piece) for testing a tensile strength of an alloy cast iron in accordance with one exemplary embodiment of the present disclosure; and

FIGS. 2 to 12 are enlarged photos obtained by capturing surface structures of alloy cast irons in accordance with 1st to 11th exemplary embodiments of the present disclosure.

Mode for the Invention

[0034] Description will now be given in detail of the exemplary embodiments, with reference to the accompanying drawings. For the sake of brief description with reference to the drawings, the same or equivalent components will be provided with the same reference numbers, and description thereof will not be repeated.

[0035] In general, a cast iron has properties, such as high resistance to abrasion by virtue of its high hardness and excellent machinability. However, the cast iron has low tensile strength and high brittleness, accordingly, it is not well used as a member exposed to a high pressure atmosphere. Especially, the vane for the compressor needs a higher abrasion resistance than the related art because it is not only exposed to the high pressure atmosphere but also slid with being closely adhered to adjacent components in order to prevent leakage of a compressed refrigerant. The present disclosure provides an alloy cast iron, which is manufactured by mixing various elements contained in a cast iron with adequate contents so as to raise a tensile strength and an abrasion resistance high enough to be used for various purposes. Hereinafter, each element will be described. Here, each content is based on a weight ratio if not particularly expressed.

(1) Carbon (C): 3.2 ~ 3.8%

[0036] Carbon within a cast iron exists as graphite or in form of carbide designated as Fe3C. Hence, when the carbon content is low, most of carbons are present in the form of carbide, so a flake graphite structure is not well observed. More precisely, graphite with a net shape is distributed when C content is 1.7 ~ 2.0%, crystalline graphite is exhibited when the C content is 2.0 ~ 2.6%, thin graphite flake is normally exhibited when the C content is 2.6 ~ 3.5%, and coarse thick graphite flake is exhibited when the C content is more than 3.5%. When the carbon content within the alloy cast iron is limited to the range of 2.7 ~ 3.8%, the carbons are generally present in the flake graphite structure. For a high carbon cast iron, its metal structure contains ferrite and coarse thick flake graphite, and has relatively high mechanical strength and hardness but its mechanical properties are lowered if the carbon content is excessive.

[0037] Hence, an addition of carbon more than 3.2% may result in acquisition of an overall uniform flake graphite structure. Meanwhile, a high carbon content lowers a solidifying point. This is helpful to improve castability. However, an amount of graphite precipitates excessively increases to thereby increase brittleness and badly influence on a tensile strength. That is, when a carbon saturation (Cs) is approximately in the range of 0.8 to 0.9, the highest tensile strength may be acquired. Therefore, a satisfactory tensile strength may be obtained by fixing a maximum limit of the carbon content to 3.8%.

(2) Silicon (Si): 2.0 ~ 2.6%

[0038] Silicon serves to decompose a carbide as a graphitizer to obtain graphite precipitates. That is, an addition of silicon may provide an effect such as an increase of a carbon content. In addition, the silicon serves to grow graphite microstructure existing within a cast iron into a flake graphite structure. In general, when a Si-C content is low, relatively high mechanical strength and hardness are obtained but fluidity is relatively low. On the contrary, when the Si-C content is high, the fluidity is high but the mechanical strength and the hardness are low.

[0039] However, when a large amount of silicon is added, it also functions to increase a tensile strength by reinforcing (strengthening) a matrix structure of the cast iron. That is, an increased Si/C may reduce the amount of graphite and improve a tensile strength due to the effect of reinforcing the matrix structure using the high silicon content. This is remarkably observed when an inoculation of a molten metal is carried out. From this perspective, the silicon content is decided in the range of 2.0 to 2.6%.

(3) Manganese (Mn): 0.5 ~1.0%

[0040] Manganese is an element which promotes the formation of a white (carbidic) cast iron interfering with graphitization of carbon, and serves to stabilize combined carbons (i.e., cementites). Also, the manganese interferes with precipitation of ferrite and refines pearlite, so as to be useful when transforming a matrix structure of a cast iron into pearlite. Especially, the manganese forms manganese sulfide by being combined with sulfur within the cast iron. The manganese sulfide is floated to the surface of a molten metal to be removed as slag, or remains in the cast iron as a nonmetallic inclusion after solidification to prevent the formation of iron sulfide. That is, the manganese also acts as an element which detoxifies the sulfur.

[0041] As described above, the manganese stabilizes and refines the pearlite. Here, as the manganese content increases, strength and hardness of the cast iron increase and plasticity and toughness decrease. In addition, the manganese may remarkably lower a transformation start point (Ms) of martensite. However, when a large quantity of manganese is added, it forms a carbide, thereby increasing brittleness and affecting a mechanical properties of the alloy

cast iron.

[0042] Further, when the manganese content is adequate, the manganese does not have a great influence on the structure of the cast iron. Therefore, the manganese content is decided in the range of 0.5 to 1.0% for facilitation of the formation of the pearlite and desulfurization.

(4) Chromium (Cr): 0.2 ~ 0.6%

[0043] Chromium is an element which promotes the formation of carbide and interferes with graphitization of carbon. When it is much added, the chromium forms a white cast iron and excessively increases hardness, causing machinability to be lowered. On the contrary, the chromium stabilizes the carbide and contributes to an increase in heat resistance. The chromium is also an element which prevents the formation of ferrite within the cast iron, decreases a distance between pearlite flake layers, and facilitates the formation of pearlite. The chromium also increases and stabilizes an amount of pearlite and refines the pearlitic structure. However, when a chromium content is excessive, excessive cementites are formed, which may result in the formation of a chilled structure.

[0044] Therefore, 0.2 to 0.6% chromium, more preferably, 0.1 to 0.3% chromium is added to improve the mechanical properties and heat resistance.

(5) Molybdenum (Mo): 0.1 ~ 0.6%

[0045] Molybdenum stabilizes carbide and refines pearlite and graphite when its content is less than 0.6%. When the molybdenum is added, an amount of phosphorous (P) should be reduced. If not, P-Mo quaternary eutectic is formed and brittleness increases. In the meantime, the molybdenum improves uniformity of a sectional structure, increases properties, such as strength, hardness, impact strength, fatigue strength and high temperature (less than 550°C), decreases shrinkage, and improve a heat treatment property and a quenching property. In accordance with those properties, the molybdenum content is decided in the range of 0.1 to 0.6%, more preferably, in the range of 0.4 to 0.6%.

(6) Vanadium (V): 0.1 - 0.5%

[0046] Vanadium also serves to refine a pearlitic structure and graphite, and easily forms carbide and nitride within a cast iron, and allows the carbide and nitride to be widely evenly dispersed in a particle form. This allows for acquisition of even properties all over the cast iron. In addition, the vanadium does not lower machinability even with improving hardness and tensile strength of the cast iron. The vanadium especially has a good affection on abrasion resistance but, if excessively contained, the cast iron is chilled. Therefore, the vanadium content is decided in the range of 0.1 to 0.5% vanadium, preferably, 0.2 to 0.4%.

(7) Boron (B): 0.02 ~ 0.1%

[0047] Boron refines graphite but acts to reduce the amount of graphite and facilitate the formation of carbide. Especially, when less boron is added, the boron precipitates in the state of boron carbide. The boron carbide remarkably increases hardness and abrasion resistance of the cast iron. Especially, the boron carbide forms a net shape. The boron carbide forms an intermittent net when less boron is added, but forms a continuous net when the boron is excessively added, which results in lowering the mechanical properties.

[0048] When the boron is added into the cast iron, a relation between Si and B has to be taken into account. In general, the boron carbide may precipitate in the cast iron when Si/B<80, a small amount of boron carbide may precipitate when 80<Si/B<130, and no boron carbide may precipitate when Si/B>130. It has been observed in one example of the present disclosure that a relatively large amount of boron carbide is present when Si/B = 36.6, and in this case, the cast iron exhibits a very strong abrasion resistance.

[0049] When the boron-containing alloy cast iron is corroded, the boron carbide with high hardness forms a first sliding surface to support a load, and pearlite or the like with a relatively low hardness is corroded to form a second sliding surface which is concave. A slot between the first sliding surface and the second sliding surface functions to store oil therein. This may allow lubricating oil to be continuously supplied to the boron carbide, thereby reducing the degree of corrosion and improving abrasion resistance of the boron cast iron. Simultaneously, when the boron content increases, the boron carbide also increases. This accordingly improves the support operation of the boron carbide so as to reduce pressure applied onto the first sliding surface per unit area, thereby reducing the degree of abrasion and thus improving the abrasion resistance.

[0050] However, when the boron content is too high, a diameter of the boron carbide increases and thereby a coupling force with the matrix structure is lowered. Accordingly, when a frictional force is applied, the boron carbide is easily separated. The separated boron carbide acts as a hard abrasion particle on a frictional surface, aggravating the abrasion

of the cast iron. Also, in this case, the hardness of the cast iron excessively increases, which causes machinability to be lowered. In view of those properties, the boron content is decided in the range of 0.02 to 0.1%.

(8) Titanium (Ti): 0.04 ~ 0.15%

[0051] Titanium refines graphite, facilitates the formation of pearlite, and increases high temperature stability of the pearlite. When the titanium content is relatively low, it facilitates graphitization and improves graphite distribution and shape of the cast iron. However, as the content increases, the titanium precipitates near a crystal interface in the form of compounds, such as TiN, TiC or the like, becoming a solidification nucleus of an austenite crystal. This results in increasing the hardness of the cast iron and simultaneously deteriorating the machinability of the cast iron. For a relatively low content, the titanium (Ti) facilitates the graphitization, and increases the amount of ferrite of a gray cast iron structure to lower hardness. On the contrary, for a high content, the titanium refines a cast iron crystal, and strengthens (reinforces) an alloy structure. Simultaneously, the hardness of the gray cast iron further increases because of precipitation of TiC2 on the crystal interface.

[0052] The Ti is one of alloy elements for manufacturing a D-type graphite cast iron. The D-type graphite cast iron has higher hardness and abrasion resistance than those of an A-type graphite cast iron. When the Ti content is less than 0.1%, the Ti is partially melted in ferrite, and mostly precipitates in the form of TiC2 or TiN. Accordingly, the Ti well deoxidizes and denitrifies a molten metal. In the meantime, when TiC2 or TiN is undercooled, A-type graphite becomes fine and D-type graphite appears. Also, A and D mixed structure is formed due to relatively high graphite content and ferrite content, lowering strength and hardness of the gray cast iron.

[0053] When the Ti content is higher than 0.1%, the Ti increases the strength of the D-type graphite and makes the amount of D-type graphite exceed 95%. Simultaneously, relatively low graphite content and ferrite content increase an amount of Ti melted in the ferrite, and the ferrite is strengthened to increase the strength and hardness of the gray cast iron. Therefore, to acquire the D-type graphite content and improve machinability, the titanium content is decided in the range of 0.04 to 0.15%.

(9) Niobium (Nb): 0.01 ~ 0.5%

[0054] Niobium further refines the metal crystal and makes a structure uniform. Especially, when the Nb content is less than 0.5%, the niobium forms an Nb enriched phase in a shape of band, so as to further refine the graphite, increase high temperature structure stability of an alloy, and increase a P eutectic hardness. Here, when exceeding 0.5%, the niobium forms a cubic Nb enriched phase to thereby lower mechanical properties. Therefore, the niobium content is decided in the range of 0.01 to 0.5%.

(10) Copper (Cu): 0.2 ~ 0.5%

[0055] Copper makes graphite thick and short in shape, and is an element which reduces D-type and E-type undercooled graphites and facilitates the formation of A-type flake graphite. Also, the copper has an excellent function of improving the graphite shape, and prevents graphitization and reduces chilling of the cast iron during an eutectic process. In addition, the copper improves carbide distribution, forms pearlite, and refines the structure.

[0056] Further, the copper refines the pearlite by facilitating the pearlite formation and reducing a distance between the pearlites. The copper also improves castability by increasing fluidity of the molten metal, thereby lowering a residual stress.

[0057] In addition, the copper makes the structure fine and slightly improves tensile strength, hardness and the like of the cast iron. These effects are remarkably exhibited when the carbon content is about 0.3%, and better effects may be expected when 0.3 to 0.5% chromium is added. Therefore, as described above, the copper content is decided in the range of 0.2 to 0.5%.

(11) Phosphorous (P): Less than 0.3%

[0058] Phosphorous forms a compound of iron phosphide (Fe3P) so as to exist as a ternary eutectic steadite together with ferrite and cementite. The iron phosphide is easy to be undercooled and easily causes segregation in casting. Accordingly, as the phosphorous content increases, brittleness increases and a tensile strength is drastically lowered. Therefore, the phosphorous content is decided below 0.3%.

(12) Sulfur (S): Less than 0.1%

[0059] As a large quantity of sulfur is added, fluidity of a molten metal is lowered, a shrinkage of an alloy cast iron

increases, and generation of cavity or crack is likely to be caused. Therefore, the sulfur content is preferably as low as possible. Here, when the sulfur content is less than 0.1%, such bad influence by the sulfur does not greatly appear, so it should be managed to be maintained in the content.

[0060] An alloy cast iron according to the present disclosure may be produced by mixing those elements having the properties, to be used for manufacturing a vane for a compressor. Hereinafter, description will be given of processes of manufacturing a vane for a compressor, which is made of the alloy cast iron.

(1) Smelting

[0061] Those elements are mixed by an adequate ratio to prepare a raw material. The raw material is put into a middle frequency induction furnace, heated up to be completely melted, and then smelted into a molten metal. Here, a temperature at which the molten metal is taken out of the furnace is approximately in the range of 1500 to 1550°C.

(2) Inoculation

[0062] An inoculant is injected into the molten metal which was smelted at the smelting step. The inoculation generates many graphite nuclei to facilitate graphitization, and contributes to a uniform distribution of the graphite and an increase in a strength thereof. Here, barium silicon ferroalloy (FeSi72Ba2) is used as the inoculant and its content may be 0.4 to 1.0% of a mass of the molten metal.

(3) Casting

[0063] The molten metal, which was inoculated at the inoculation step, is injected into a premanufactured cast to have a cavity with a desired shape. Here, the casting is carried out using a shell mold process using a resin-coated sand or an investment mold process. The cooled semiprocessed vane contains flake graphite and carbide, and the carbide content may occupy 15% to 30% of the total volume of the vane. Here, the carbide indicates that an added component is coupled to carbons. An example of the carbide may comprise Fe3C, so-called iron carbide, or the like.

(4) Grinding

[0064] The semiprocessed vane obtained at the casting step is ground into a desired shape.

(5) Heat Treatment

[0065] The heat treatment may include a quenching process and a tempering process.

- Quenching: The ground semiprocessed vane is heated up to 860 to 950°C using an electrical resistance furnace which can control air temperature, and remains in that state for 0.5 to 1.5 hours. The heated semiprocessed vane is quickly put into oil whose temperature is in the range of 10 to 30°C to cool down to room temperature. The quenching may allow a pearlitic matrix structure to be transformed to a martensitic matrix structure, resulting in improvement of hardness. That is, when the quenching is completed, a vane which contains the martensitic matrix structure, the carbide and the flake graphite is acquired.
- Tempering: The vane of the martensitic cast iron containing the carbide and the flake graphite obtained through the quenching is heated up to 180 to 220°C using an electrical resistance furnace which can control air temperature, and remains in that state for 0.5 to 1.5 hours. The heated vane is air-cooled down to room temperature, so as to slightly lower strength and hardness, which increased by the quenching, and rather increase ductility. This results in lowering brittleness.

(6) Fine Grinding and Polishing

[0066] The vane of the carbidic cast iron, which was obtained through the quenching and tempering of the heat treatment, is processed to have the final shape and a desired surface quality through fine grinding and polishing.

(7) Ion-Sulfurizing (sulphurizing)

[0067] An ion-sulfurizing is undertaken for the vane of the carbidic cast iron obtained through the fine grinding and polishing, to form a sulfurized layer, which is 0.005 to 0.015 mm thick, on the surface of the vane. The sulfurized layer may operate together with the flake graphite which exists within the vane, and further improve lubricity and abrasion

resistance which the vane itself has.

Example 1

[0068] Example 1 was manufactured through the following processes.

[0069] A raw material, which comprises, by weight, the following elements, namely, C:3.4%, Si:2.2%, Mn:0.7%, Cr:0.4%, Mo:0.4%, V: 0.3%, B:0.06%, Ti:0.1%, Nb: 0.25%, Cu: 0.25%, P<0.3%, S<0.1%, and the rest percentage of Fe, is prepared. The prepared raw material is put into a middle frequency induction furnace, whose temperature is increased until the raw material is completely melted such that the alloy cast iron is smelted into a molten metal, The molten metal of the alloy cast iron is taken out of the furnace at temperature of 1525°C.

[0070] The molten metal of the alloy cast iron which was taken out of the furnace after smelted, is inoculated by injecting an inoculant. Here, the inoculant is a barium silicon ferroalloy, namely, FeSi72Ba2, and its content is 0.7% of the mass of the molten metal.

[0071] The molten metal of the alloy cast iron, which was inoculated at the previous step, is casted through a shell mold process or an investment mold process, acquiring a vane of a pearlitic cast iron which contains flake graphite and carbide. Here, the carbide content is 25% of the total volume of the vane.

[0072] The acquired vane is ground into a desired shape.

[0073] Afterwards, the vane is heated up to 910°C and maintained at the same temperature for 0.7 hours. The heated vane is put into an oil of 20°C and cooled down to room temperature, thereby transforming a matrix structure into a martensitic structure. The vane acquired through the quenching is heated up to 210°C, maintained for 0.7 hours, and air-cooled down to room temperature.

[0074] The thusly obtained semiprocessed vane undergoes fine grinding and polishing, followed by ion-sulfurizing, so as to form a sulfurized layer, which is 0.008 mm thick, on the surface of the vane.

Example 2

[0075] A raw material, which comprises, by weight, the following elements, namely, C:3.2%, Si:2.0%, Mn:0.5%, Cr:0.2%, Mo:0.1%, Ti:0.04%, P<0.3%, S<0.1% and the rest percentage of Fe, is melted into a molten metal. The molten metal is then taken out at temperature of 1500°C. FeSi72Ba2 is added as an inoculant into the molten metal by 0.4% of the mass of the molten metal. Afterwards, the inoculated molten metal is casted through the shell mold process or investment mold process, thereby obtaining a semiprocessed vane in which 15% carbide is contained in volume ratio.

[0076] After grinding the semiprocessed vane, the ground semiprocessed vane is heated up to 860°C, maintained at the same temperature for 0.5 hours, put into oil of 10°C to be cooled down to room temperature, thereby being transformed into a martensitic structure. The semiprocessed vane with the martensitic structure is heated up to 180°C, maintained at the same temperature for 0.5 hours, and air-cooled down to room temperature. The air-cooled vane is processed sequentially through the fine grinding and polishing and the ion-sulfurizing, so as to form a sulfurized layer, which is 0.005 mm thick, on the surface of the vane.

Example 3

[0077] A raw material, which comprises, by weight of, the following elements, namely, C: 3.8%, Si: 2.6%, Mn: 1.0%, Cr: 0.6%, Mo: 0.6%, V: 0.5%, B: 0.1%, Ti: 0.15%, Nb: 0.5%, Cu: 0.5%, P<0.3%, S<0.1% and the rest percentage of Fe, is melted into a molten metal. The molten metal is then taken out at temperature of 1550°C. FeSi72Ba2 is added as an inoculant by 1.0% of the mass of the molten metal. Afterwards, the inoculated molten metal is casted through the shell mold process or investment mold process, to contain a carbide corresponding to 30% of the vane in volume ratio, thereby being ground into a desired shape.

[0078] The ground vane is heated up to 950°C, and maintained for 1.5 hours. The heated vane is put into oil of 30°C to be cooled down to room temperature, thereby obtaining a vane which contains a martensitic matrix structure, carbide and flake graphite. The obtained vane is heated up to 220°C, maintained for 1.5 hours and then air-cooled down to room temperature, thereby lowering brittleness. Afterwards, the fine grinding and polishing is carried out to acquire the final shape of the vane, and the ion-sulfurizing is carried out to form a sulfurized layer, which is 0.015 mm thick, on the surface of the vane.

Example 4

[0079] In accordance with Example 4, a raw material, which comprises, by weight, C:3.3%, Si:2.1%, Mn:0.6%, Cr:0.3%, Mo:0.2%, V:0.2%, B:0.02%, Ti: 0.05%, P<0.3%, S<0.1% and the rest percentage of Fe, is melted into a molten metal. The molten metal is taken out at temperature of 1515°C. The other steps are the same as those in Example 1.

Example 5

[0080] In accordance with Example 5, a raw material, which comprises, by weight, C:3.3%, Si:2.2%, Mn:0.7%, Cr:0.4%, Mo:0.3%, V: 0.2%, Ti: 0.04~0.15%, Nb: 0.1%, P<0.3%, S<0.1% and the rest percentage of Fe, is melted into a molten metal. The molten metal is taken out at temperature of 1510°C. The other steps are the same as those in Example 1.

Example 6

[0081] In accordance with Example 6, a raw material, which comprises, by weight, C:3.4%, Si:2.3%, Mn:0.8%, Cr:0.4%, Mo:0.3%, V: 0.3%, Ti: 0.06%, Cu: 0.2%, P<0.3%, S<0.1% and the rest percentage of Fe, is melted into a molten metal. The molten metal is taken out at temperature of 1520°C. The other steps are the same as those in Example 1.

Example 7

[0082] In accordance with Example 7, a raw material, which comprises, by weight, C:3.6%, Si:2.4%, Mn:0.9%, Cr:0.5%, Mo:0.5%, B: 0.05%, Ti: 0.12%, Cu: 0.3%, P<0.3%, S<0.1% and the rest percentage of Fe, is melted into a molten metal. The molten metal is taken out at temperature of 1530°C. The other steps are the same as those in Example 1.

Example 8

[0083] In accordance with Example 8, a raw material, which comprises, by weight, C:3.3%, Si:2.2%, Mn:0.7%, Cr:0.4%, Mo:0.3%, Ti: 0.04~0.15%, Nb: 0.1%, P<0.3%, S<0.1% and the rest percentage of Fe, is melted into a molten metal. The molten metal is taken out at temperature of 1510°C. The other steps are the same as those in Example 2.

Example 9

[0084] In accordance with Example 9, a raw material, which comprises, by weight, C:3.4%, Si:2.3%, Mn:0.8%, Cr:0.4%, Mo:0.3%, Ti: 0.06%, Cu: 0.2%, P<0.3%, S<0.1% and the rest percentage of Fe, is melted into a molten metal. The molten metal is taken out at temperature of 1520°C. The other steps are the same as those in Example 2.

Example 10

[0085] In accordance with Example 10, a raw material, which comprises, by weight, C:3.4%, Si:2.2%, Mn:0.7%, Cr:0.4%, Mo:0.4%, V: 0.3%, B:0.06%, Ti:0.1%, Cu: 0.25%, P<0.3%, S<0.1% and the rest percentage of Fe, is melted into a molten metal. The molten metal is taken out at temperature of 1535°C. The other steps are the same as those in Example 3.

Example 11

[0086] In accordance with Example 11, a raw material, which comprises, by weight, C: 3.8%, Si: 2.6%, Mn: 1.0%, Cr: 0.6%, Mo: 0.6%, B: 0.1%, Ti: 0.15%, Nb: 0.5%, Cu: 0.5%, P<0.3%, S<0.1% and the rest percentage of Fe, is melted into a molten metal. The molten metal is taken out at temperature of 1545°C. The other steps are the same as those in Example 3.

[0087] The foregoing Examples are listed in Table 1.

Table 1

[0088]

[Table 1]

	C	Si	Mn	Cr	Mo	V	B	Ti	Nb	Cu	P	S
1	3.4	2.2	0.7	0.4	0.4	0.3	0.06	0.1	0.25	0.25	<0.3	<0.1
2	3.2	2.0	0.5	0.2	0.1			0.04			<0.3	<0.1
3	3.8	2.6	1.0	0.6	0.6	0.5	0.1	0.15	0.5	0.5	<0.3	<0.1
4	3.3	2.1	0.6	0.3	0.2	0.2	0.02	0.05			<0.3	<0.1

(continued)

	C	Si	Mn	Cr	Mo	V	B	Ti	Nb	Cu	P	S
5	3.3	2.2	0.7	0.4	0.3	0.2		0.04	0.1		<0.3	<0.1
6	3.4	2.3	0.8	0.4	0.3	0.3		0.06		0.2	<0.3	<0.1
7	3.6	2.4	0.9	0.5	0.5		0.05	0.12		0.3	<0.3	<0.1
8	3.3	2.2	0.7	0.4	0.3			0.04	0.1		<0.3	<0.1
9	3.4	2.3	0.8	0.4	0.3			0.06		0.2	<0.3	<0.1
10	3.4	2.2	0.7	0.4	0.4	0.3	0.06	0.1		0.25	<0.3	<0.1
11	3.8	2.6	1.0	0.6	0.6		0.1	0.15	0.5	0.5	<0.3	<0.1

[0089] In addition, a hardness test using HR-150A type Rockwell hardometer was also carried out with respect to completely heat-treated samples. After deciding, as test positions, upper and lower two points, which were adjacent to an injection hole of a casting solution, upper and lower two points, located away from the injection hole of the casting solution, and one point therebetween, the hardness test was carried out with respect to those five points.

[0090] Test samples each having the shape shown in FIG. 1 were manufactured by using the same material as each Example, and their tensile strengths were measured. The test results were shown in the following Table 2.

Table 2

[0091]

[Table 2]

	1	2	3	4	5	6	7	8	9	10	11
Hardness (HRC)	60.8	55.2	52.2	60.7	54.4	60.3	60.0	59.5	57.2	58.5	59.0
TensileStr ength(MP a)	394.2	385.9	408.1	385.2	377.3	389.5	387.4	387.7	399.2	372.7	388.0

[0092] Also, the following Table 3 shows test results for machinability and abradability for those Examples.

Table 3

[0093]

[Table 3]

	Details	Examples	High speed steel
Machinability	Load factor	75%	100%
	Tool lifespan(per unit)	200	100
grinding workability	Load factor	75%	100%
	Grinding stone dressing period	800/dressing	500/dressing

[0094] Also, in terms of the grinding workability, the grinding load of the alloy cast iron may correspond to 75% of the high speed steel, 800 vanes may be ground per one-time dressing for the grinding stone. It may thusly be understood that the grinding property remarkably increases as compared with the high speed steel.

[0095] Also, a vane using the high speed steel has a low productivity because of the use of forging other than casting, whereas the vane according to the present disclosure is manufactured by casting so as to have relatively excellent machinability even with abrasion resistance, which is similar to that of the high speed steel. Accordingly, the productivity and manufacturing costs for the vane according to the present disclosure may be remarkably reduced.

[0096] The foregoing embodiments and advantages are merely exemplary and are not to be construed as limiting the present disclosure. The present teachings can be readily applied to other types of apparatuses. This description is intended to be illustrative, and not to limit the scope of the claims. Many alternatives, modifications, and variations will

be apparent to those skilled in the art. The features, structures, methods, and other characteristics of the exemplary embodiments described herein may be combined in various ways to obtain additional and/or alternative exemplary embodiments.

[0097] As the present features may be embodied in several forms without departing from the characteristics thereof, it should also be understood that the above-described embodiments are not limited by any of the details of the foregoing description, unless otherwise specified, but rather should be construed broadly within its scope as defined in the appended claims, and therefore all changes and modifications that fall within the metes and bounds of the claims, or equivalents of such metes and bounds are therefore intended to be embraced by the appended claims.

Claims

1. A vane for a compressor composed of an alloy cast iron, the alloy cast iron consists of, by weight:

3.2 to 3.8% carbon (C);
2.0 to 2.6% silicon (Si);
0.5 to 1.0% manganese (Mn);
0.2 to 0.6% chromium (Cr);
0.1 to 0.6% molybdenum (Mo);
0.04 to 0.15% titanium(Ti);
less than 0.3% phosphorus (P);
less than 0.1% sulphur (S);
optionally 0.01 to 0.5% niobium (Nb) and/or
0.1 to 0.5% vanadium (V);
optionally 0.02 to 0.1% boron (B);
optionally 0.2 to 0.5% copper (Cu); and
Fe balance and inevitable impurities,
wherein the alloy cast iron comprises a martensitic matrix structure, flake graphite, and 15 to 30% carbide in volume ratio, wherein the vane has on its surface a sulfurized layer having a thickness of 0.005 to 0.015 mm.

2. A vane for a compressor of claim 1, wherein the sulfurized layer is formed by carrying out ion-sulfurizing.

3. A method for manufacturing a vane for a compressor according to claims 1 or 2, comprising:

a smelting step of preparing a molten metal consisting of, by weight, 3.2 to 3.8% carbon (C), 2.0 to 2.6% silicon (Si), 0.5 to 1.0% manganese (Mn), 0.2 to 0.6% chromium (Cr), 0.1 to 0.6% molybdenum (Mo), 0.04 to 0.15% titanium (Ti), less than 0.3% phosphorus (P), less than 0.1 % sulphur (S), optionally 0.01 to 0.5% niobium (Nb) and 0.1 to 0.5% vanadium (V), optionally 0.02 to 0.1% boron (B), optionally 0.2 to 0.5% copper (Cu) and Fe balance and inevitable impurities, and taking out the molten metal from a furnace in the range of 1500 to 1550 °C;
an inoculation step of injecting FeSi72Ba2 as an inoculant by 0.4 to 1.0% of mass of the molten metal;
a casting step of obtaining a semi-product comprising flake graphite and 15 to 30% by volume of carbide by injecting the molten metal in a cast and cooling the molten metal;
a grinding step of grinding the cooled semi-product into a predetermined shape;
a heat treatment step of carrying out a heat treatment for the ground semi-product to transform into a martensitic matrix structure;
a fine grinding step of finely grinding the heat-treated semi-product; and
an ion-sulfurizing step of forming a sulfurized layer 0.005-0.015 mm on a surface of the heat-treated semi-product, wherein the heat treatment step comprises:

a quenching process of keeping the ground semi-product at a temperature of 860 to 950 °C for 0.5 to 1.5 hours and oil-cooling the semi-product to room temperature; and
a tempering process of keeping the quenched semi-product at a temperature of 180 to 220 °C for 0.5 to 1.5 hours and air cooling the semi-product to room temperature.

Patentansprüche

1. Kolben für einen Verdichter, der sich aus einem legierten Gusseisen zusammensetzt, wobei das legierte Gusseisen

gewichtsbezogen besteht aus: 3,2 bis 3,8 % Kohlenstoff (C);

2,0 bis 2,6 % Silizium (Si);
0,5 bis 1,0 % Mangan (Mn);
0,2 bis 0,6 % Chrom (Cr);
0,1 bis 0,6 % Molybdän (Mo);
0,04 bis 0,15 % Titan (Ti);
unter 0,3 % Phosphor (P);
unter 0,1 % Schwefel (S);
optional 0,01 bis 0,5 % Niob (Nb) und/oder 0,1 bis 0,5 % Vanadium (V);
optional 0,02 bis 0,1 % Bor (B);
optional 0,2 bis 0,5 % Kupfer (Cu); und
als Rest Eisen und unvermeidliche Verunreinigungen,
wobei das legierte Gusseisen eine martensitische Matrixstruktur, Lamellengraphit und 15 bis 30 % Carbid im Volumenverhältnis aufweist, wobei der Kolben auf seiner Oberfläche eine geschwefelte Schicht mit einer Dicke von 0,005 bis 0,015 mm hat.

2. Kolben für einen Verdichter nach Anspruch 1, wobei die geschwefelte Schicht durch Durchführen von Ionenverschwefelung gebildet ist.

3. Verfahren zur Herstellung eines Kolbens für einen Verdichter nach Anspruch 1 oder 2, das aufweist:

einen Schmelzschritt des Erzeugens einer Metallschmelze, die gewichtsbezogen besteht aus: 3,2 bis 3,8 % Kohlenstoff (C), 2,0 bis 2,6 % Silizium (Si), 0,5 bis 1,0 % Mangan (Mn), 0,2 bis 0,6 % Chrom (Cr), 0,1 bis 0,6 % Molybdän (Mo), 0,04 bis 0,15 % Titan (Ti), unter 0,3 % Phosphor (P), unter 0,1 % Schwefel (S), optional 0,01 bis 0,5 % Niob (Nb) und 0,1 bis 0,5 % Vanadium (V), optional 0,02 bis 0,1 % Bor (B), optional 0,2 bis 0,5 % Kupfer (Cu) und als Rest Eisen und unvermeidliche Verunreinigungen, und des Entnehmens der Metallschmelze aus einem Ofen im Bereich von 1500 bis 1550 °C;
einen Impfschritt des Einspritzens von FeSi72Ba2 als Impfzusatz mit 0,4 bis 1,0 Masse-% der Metallschmelze;
einen Gießschritt des Erhaltens eines Halbzeugs, das Lamellengraphit und 15 bis 30 Vol.-% Carbid aufweist, durch Einspritzen der Metallschmelze in eine Form und Abkühlen der Metallschmelze;
einen Schleifschritt des Schleifens des abgekühlten Halbzeugs in eine vorbestimmte Form;
einen Wärmebehandlungsschritt des Durchführens einer Wärmebehandlung für das geschliffene Halbzeug, um es in eine martensitische Matrixstruktur zu überführen;
einen Feinschleifschritt des Feinschleifens des wärmebehandelten Halbzeugs; und
einen Ionenverschwefelungsschritt des Bildens einer geschwefelten Schicht von 0,005 bis 0,015 mm auf einer Oberfläche des wärmebehandelten Halbzeugs, wobei der Wärmebehandlungsschritt aufweist:

einen Abschreckvorgang des 0,5 bis 1,5 stündigen Haltens des geschliffenen Halbzeugs auf einer Temperatur von 860 bis 950 °C und des Ölkühlens des Halbzeugs auf Raumtemperatur; und
einen Anlassvorgang des 0,5 bis 1,5 stündigen Haltens des abgeschreckten Halbzeugs auf einer Temperatur von 180 bis 220 °C und des Luftkühlens des Halbzeugs auf Raumtemperatur.

Revendications

1. Aube pour un compresseur composée d'une fonte alliée, la fonte alliée consistant en, en poids :

3,2 à 3,8 % de carbone (C) ;
2,0 à 2,6 % de silicium (Si) ;
0,5 à 1,0 % de manganèse (Mn) ;
0,2 à 0,6 % de chrome (Cr) ;
0,1 à 0,6 % de molybdène (Mo) ;
0,04 à 0,15 % de titane (Ti) ;
moins de 0,3 % de phosphore (P) ;
moins de 0,1 % de soufre (S) ;
optionnellement 0,01 à 0,5 % de niobium (Nb) et/ou
0,1 à 0,5 % de vanadium (V) ;

optionnellement 0,02 à 0,1 % de bore (B) ;
optionnellement 0,2 à 0,5 % de cuivre (Cu) ; et
le reste étant du Fe et les inévitables impuretés,
dans laquelle la fonte alliée comprend une structure de matrice martensitique, du graphite lamellaire, et de 15 à 30 % de carbure en rapport volumique, dans laquelle l'aube présente sur sa surface une couche sulfurée présentant une épaisseur de 0,005 à 0,015 mm.

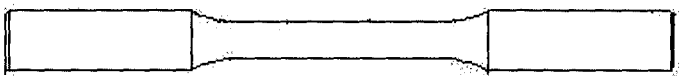
2. Aube pour un compresseur selon la revendication 1, dans laquelle la couche sulfurée est formée en réalisant une sulfuration ionique.

3. Procédé de fabrication d'une aube pour un compresseur selon les revendications 1 ou 2, comprenant :

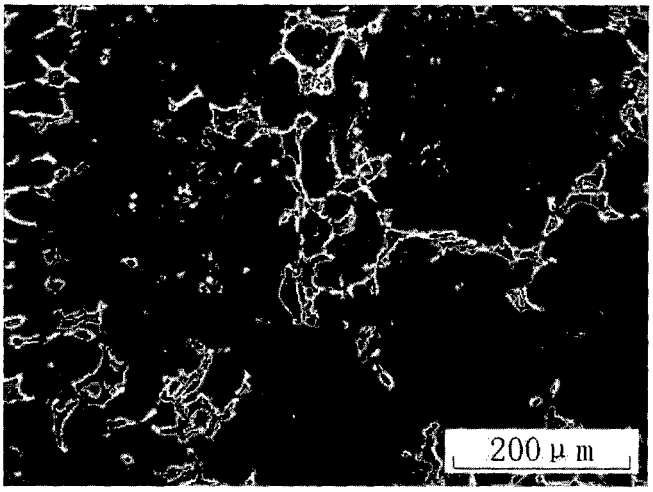
une étape de fusion consistant à préparer un métal en fusion consistant en, en poids, 3,2 à 3,8 % de carbone (C), 2,0 à 2,6 % de silicium (Si), 0,5 à 1,0 % de manganèse (Mn), 0,2 à 0,6 % de chrome (Cr), 0,1 à 0,6 % de molybdène (Mo), 0,04 à 0,15 % de titane (Ti), moins de 0,3 % de phosphore (P), moins de 0,1 % de soufre (S), optionnellement 0,01 à 0,5 % de niobium (Nb) et 0,1 à 0,5 % de vanadium (V), optionnellement 0,02 à 0,1 % de bore (B), optionnellement 0,2 à 0,5 % de cuivre (Cu) et le reste étant du Fe et les inévitables impuretés, et extraire le métal en fusion d'un four dans la plage de 1 500 à 1 550 °C ;
une étape d'inoculation consistant à injecter du FeSi72Ba2 en tant qu'inoculant en une proportion de 0,4 à 1,0 % en masse du métal en fusion ;
une étape de coulée consistant à obtenir un demi-produit comprenant du graphite lamellaire et 15 à 30 % en volume de carbure par injection du métal en fusion dans un moule et refroidissement du métal en fusion ;
une étape de meulage consistant à meuler le demi-produit refroidi en une forme prédéterminée ;
une étape de traitement thermique consistant à effectuer un traitement thermique pour le demi-produit meulé afin de le transformer en une structure de matrice martensitique ;
une étape de meulage fin consistant à meuler finement le demi-produit traité thermiquement ; et
une étape de sulfuration ionique consistant à former une couche sulfurée de 0,005 à 0,015 mm sur une surface du demi-produit traité thermiquement,
dans laquelle l'étape de traitement thermique comprend :

un processus de trempe consistant à maintenir le demi-produit meulé à une température de 860 à 950 °C pendant 0,5 à 1,5 heures et refroidir à l'huile le demi-produit à la température ambiante ; et
un processus de revenu consistant à maintenir le demi-produit trempé à une température de 180 à 220 °C pendant 0,5 à 1,5 heures et refroidir à l'air le demi-produit à la température ambiante.

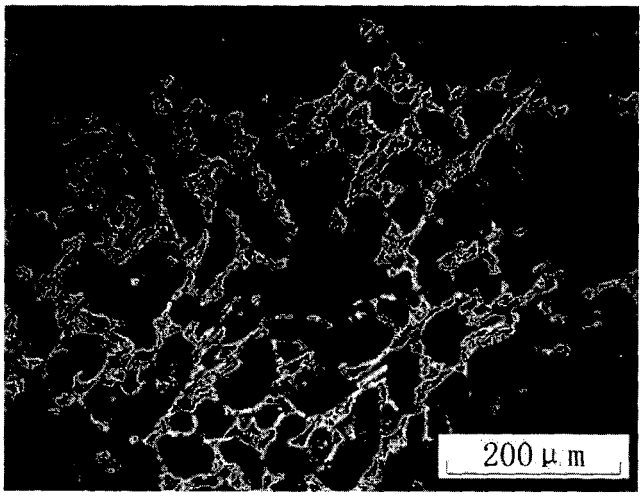
[Fig. 1]



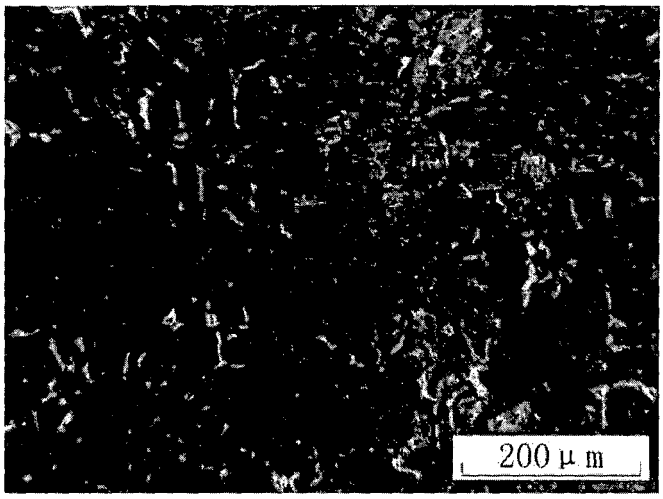
[Fig. 2]



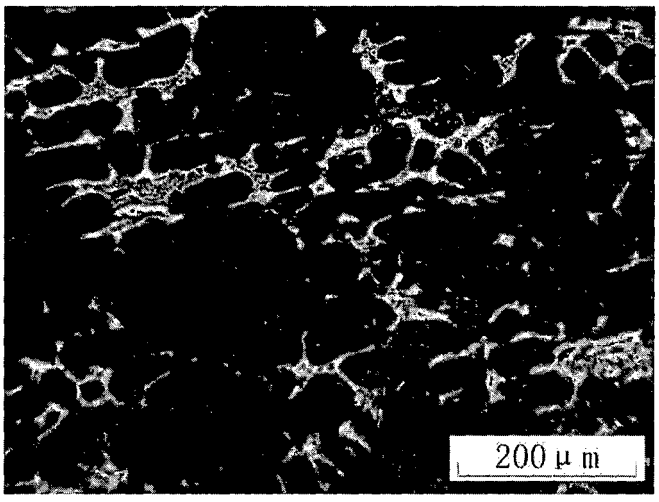
[Fig. 3]



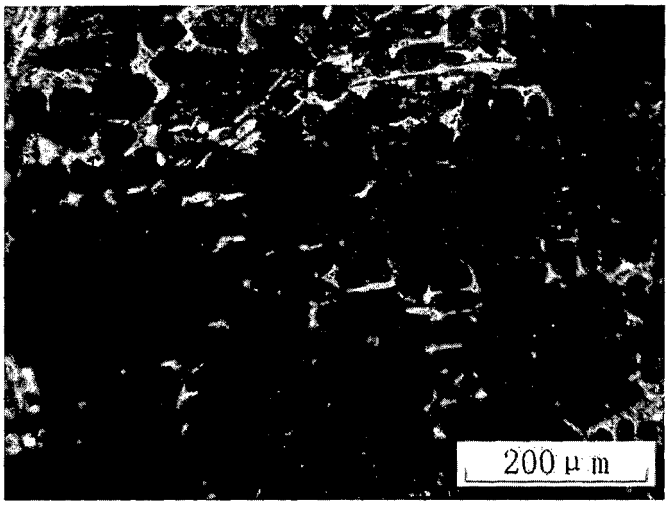
[Fig. 4]



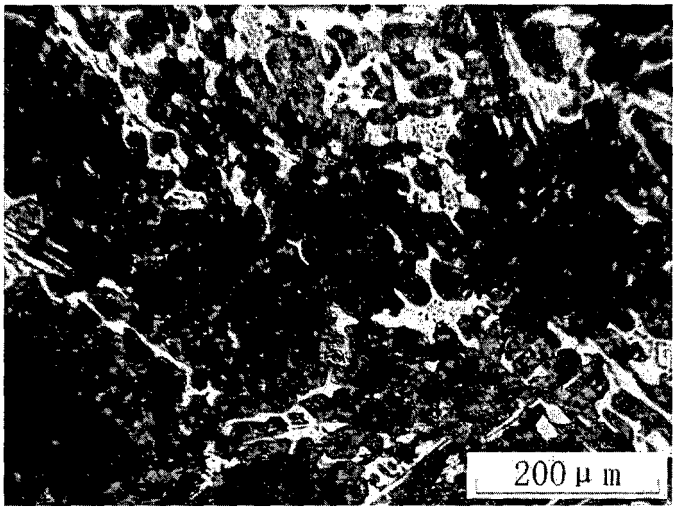
[Fig. 5]



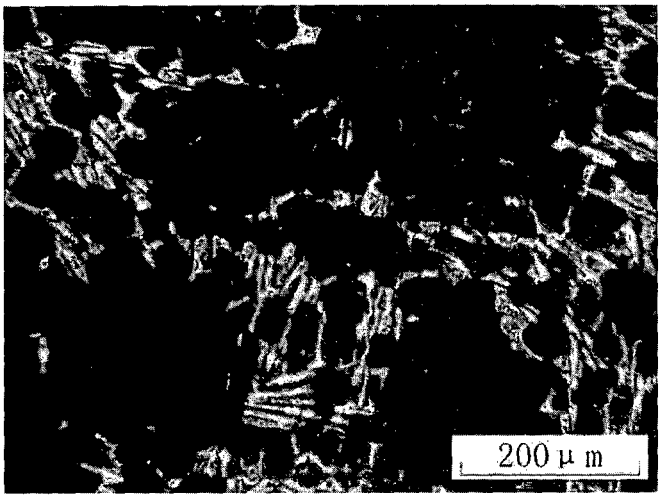
[Fig. 6]



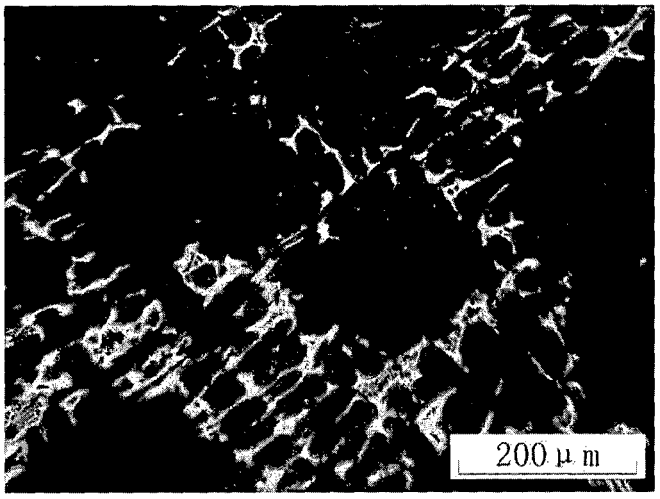
[Fig. 7]



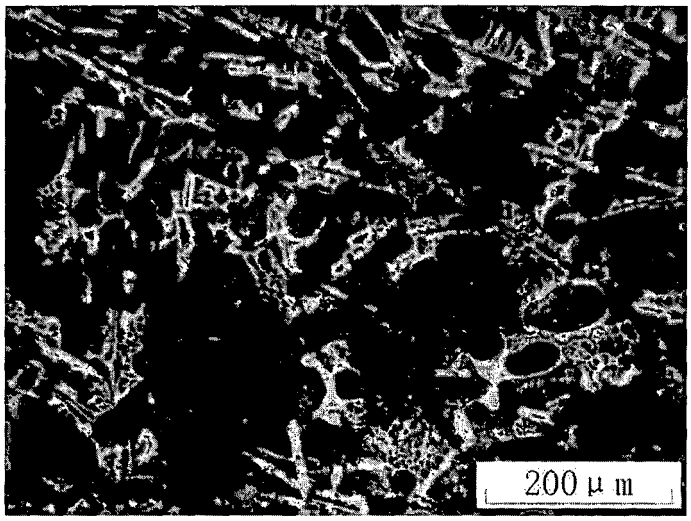
[Fig. 8]



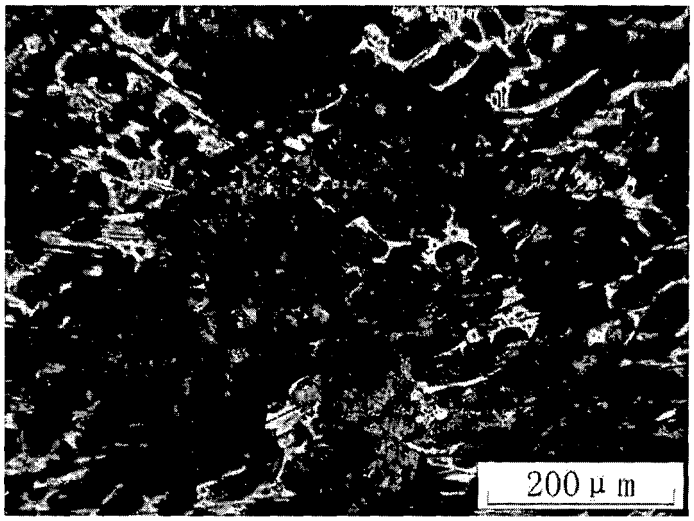
[Fig. 9]



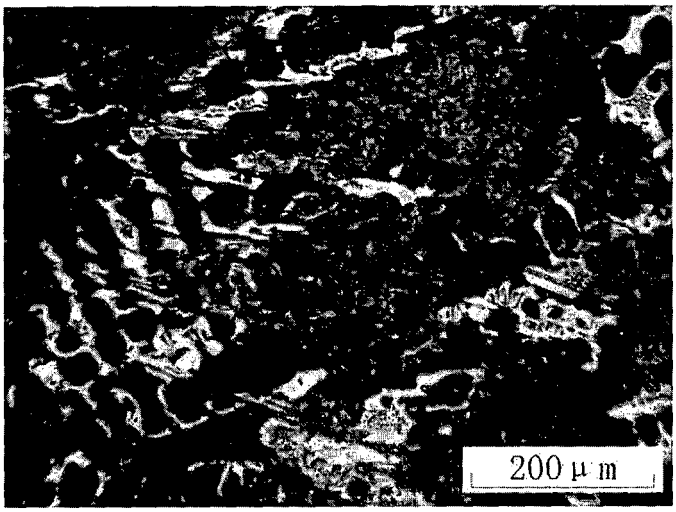
[Fig. 10]



[Fig. 11]



[Fig. 12]



REFERENCES CITED IN THE DESCRIPTION

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