A cam ring of a vane pump and a method of manufacturing a cam ring are provided. The cam ring may be formed of a material including approximately 3.0% to 3.5% of carbon (C), approximately 2.0% to 2.5% of silicon (Si), approximately 0.5% to 1.0% of manganese (Mn), approximately 0.5% to 1.0% of chromium (Cr), approximately 0.2% to 0.5% of copper (Cu), approximately 0.1% to 0.3% of phosphorus (P), approximately 0.02% to 0.06% of boron (B), approximately 0.06% to 0.1% of sulfur (S), and approximately 0.043% or more of titanium (Ti) by weight ratio, and iron (Fe) and any inevitable impurity for the remainder, and may have a tempered martensite matrix including a carbide.
FIG. 1
RELATED ART
CAM RING OF VANE PUMP AND METHOD OF MANUFACTURING CAM RING

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] Pursuant to 35 U.S.C. §119(a), this application claims priority to Korean Application No. 10-2013-0025244, filed in Korea on Mar. 8, 2013, the contents of which is incorporated by reference herein in its entirety.

BACKGROUND

[0002] 1. Field

[0004] 2. Background
[0005] Various devices have been utilized to provide double steering force in a steering device of vehicles. In the case of a hydraulic steering device, a power steering pump to supply oil pressure may be used. Various types of pumps may be utilized as a power steering pump, and in general, a vane pump having high efficiency, small volume, and weight, and generating less vibrations is utilized.

[0006] FIG. 1 is a schematic cross-sectional view of a related art vane pump. The vane pump may include a body 1 and a pump cartridge 3 installed in the body 1. The pump cartridge 3 may include a rotor 31 rotatably installed within the body 1 and a cam ring 30 in which the rotor 31 may be installed. In addition, a plurality of slots may be formed in the rotor 31, and a vane 32 may be slidably installed within each of the plurality of slots. The vane 32 may be pressurized toward an inner wall of the cam ring 30, thus preventing leakage between an end portion of the vane 32 and an inner wall surface of the cam ring 30.

[0007] The rotor 31 may be coupled to a rotational shaft 50 rotated by a driving force from an engine, so that the rotor 31 is rotated together with a driving of the engine. When the rotor 31 is rotated, the vane 32 may also be rotated together to force-feed a fluid within a space defined by outer surfaces of the vane 32, cam ring 30, and rotor 31.

[0008] Thus, the cam ring needs to have high abrasion resistance and impact resistance. Conventionally, cam rings have been manufactured through a heat treatment, such as quenching (or hardening), or tempering, for example, using low-alloy steel, such as 20CrMo, or Cr12MoV, for example. However, this manufacturing method involves complicated processing, and as bar-shaped continuous casting should be severed and processed, large amounts of material may be consumed and a process time lengthened.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Embodiments will be described in detail with reference to the following drawings in which like reference numerals refer to like elements, and wherein:

[0010] FIG. 1 is a schematic cross-sectional view of a related art vane pump; and
[0011] FIG. 2 is a photograph illustrating internal structure of a cam ring of a vane pump according to an embodiment.

DETAILED DESCRIPTION

[0012] Description will now be given in detail to 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.

[0013] Hereinafter, a vane pump according to an embodiment will be described in detail with reference to the accompanying drawings. The embodiments are directed to a material of a cam ring included in a vane pump, rather than being related to a configuration thereof, and thus, the embodiments are not limited by a configuration of a cam ring. Hereinafter, the vane pump will be described based on the configuration illustrated in FIG. 1.

[0014] In general, cast iron has high hardness and excellent abrasion resistance and machinability, but has low tensile strength and strong brittleness, so cast iron is rarely used as a material of a member exposed to a high pressure atmosphere. In particular, the cam ring of a vane pump as mentioned above slides upon being tightly attached with an end portion of the vane to prevent leakage of a liquid, and thus, the cam ring is required to have high abrasion resistance, relative to the related art. In the present disclosure, alloy cast iron is formed by mixing various elements included in cast iron in appropriate contents to obtain high tensile strength and abrasion resistance so as to be used for various purpose. Hereinafter, each element will be described, and each content is expressed by weight ratio, unless otherwise mentioned.

[0015] (1) Carbon (C): approximately 3.0–3.5%

[0016] In alloy cast iron according to an embodiment, a content of carbon (C) may be approximately 3.0–3.5% by weight ratio. Or, the content of carbon (C) may be approximately 3.2–3.5% by weight ratio. Or, the content of carbon (C) may be approximately 3.2–3.8% by weight ratio.

[0017] In cast iron, carbon (C) may exist as graphite or in the form of carbide represented by Fe3C. Thus, in a case in which the content of carbon is small, as most carbon exists in the form of carbide, a flake graphite structure rarely appears. In more detail, when the content of carbon (C) ranges from approximately 1.7% to 2.0%, graphite is distributed in a net shape; when the content of carbon (C) ranges from approximately 2.6% to 3.5%, graphite has a normal thin flake shape, and when the content of carbon (C) is more than approximately 3.5%, graphite having a coarse (or rough) and thick flake structure appears. In the alloy cast iron, when the content of carbon (C) is limited to approximately 3.0% to 3.5%, carbon mainly exists in a graphite state having a flake structure, and a metal structure of a high carbon alloy cast iron includes ferrite and graphite having coarse, thick flake structure and has relatively high mechanical strength and hardness, but when carbon (C) is excessive, mechanical performance is degraded.

[0018] Thus, carbon (C) may be added by an amount equal to or more than approximately 3.0% to obtain an entirely uniform flake graphite structure. As the content of carbon (C) is higher, a freezing point is lowered, assisting to improve castability, but a deposition amount of graphite is too excessive to increase brittleness and negatively affect tensile strength. Namely, the highest tensile strength may be obtained when carbon saturation (Sc) ranges from approximately 0.8 to 0.9, and thus, a maximum limitation may be set to approximately 3.5% to obtain good tensile strength.

[0019] (1) Silicon (Si): approximately 2.0% to 2.5%

[0020] In alloy cast iron according to an embodiment, a content of silicon (Si) may be approximately 2.0–2.5% by weight ratio. Or, the content of silicon (Si) may be approxi-
approximately 2.11–2.5% by weight ratio. Or, the content of silicon (Si) may be approximately 2.2–2.34% by weight ratio.

Silicon (Si), a graphitizing, may serve to decompose a carbide to precipitate graphite. Namely, addition of silicon (Si) may provide an effect of increasing an amount of carbon. In addition, silicon (Si) may serve to allow a micro-graphite structure existing in cast iron to grow as a flake graphite structure. In general, when the content of Si–C is low, relatively high mechanical strength and hardness may be obtained, while fluidity is relatively low. Conversely, when the content of Si–C is high, good fluidity may be obtained, but mechanical strength and hardness are low.

However, an addition of a large amount of silicon (Si) may strengthen a matrix structure of cast iron to increase tensile strength. Namely, when Si/C is increased, an amount of graphite may be reduced and tensile strength may be enhanced by an effect of strengthening the matrix structure due to high silicon. This may be remarkable when inoculation is performed on a molten metal. In this point of view, the content of silicon is determined to range from approximately 2.0% to 2.5%.

(3) Manganese (Mn): approximately 0.5% to 1.5%

In alloy cast iron according to an embodiment, a content of manganese (Mn) may be approximately 0.5–1.0% by weight ratio. Or, the content of manganese (Mn) may be approximately 0.62–1.0% by weight ratio. Or, the content of manganese (Mn) may be approximately 0.66–1.0% by weight ratio.

Manganese (Mn), a white cast iron acceleration element that hampers graphitizing of carbon, may stabilize combined carbon (namently, cementite). Also, manganese (Mn) may hinder precipitation of ferrite and refine pearlite, so it is advantageous to make a matrix structure of cast iron or pearlite. In particular, manganese (Mn) may be combined with sulfur of cast iron to create manganese sulfide. Manganese sulfide may float to a surface of a molten metal so as to be removed as slag, or may remain in cast iron as a non-metallic inclusion to prevent generation of iron sulfide. Namely, manganese (Mn) may act as an element that neutralizes harm of sulfur.

As mentioned above, manganese (Mn) may stabilize and subdivide pearlite, but in this case, as the content of manganese (Mn) is increased, strength and hardness of cast iron may be increased and plasticity and toughness lowered. Also, when manganese (Mn) is combined with sulfur, manganese sulfide may form because of the state change of manganese, but if a large amount of manganese (Mn) is added, it forms a carbide to increase brittleness and affect mechanical performance of alloy cast iron.

In addition, in a case in which silicon (Si) is sufficiently provided, manganese (Mn) may not greatly affect a structure of cast iron, and thus, in order to accelerate pearlite and remove a sulfur component, manganese (Mn) may be provided in an amount of approximately 0.5% to 1.0%.

Chromium (Cr): approximately 0.5% to 1.0%

In alloy cast iron according to an embodiment, a content of chromium (Cr) may be approximately 0.5–1.0% by weight ratio. Or, the content of chromium (Cr) may be approximately 0.77–1.0% by weight ratio. Or, the content of chromium (Cr) may be approximately 0.77–0.842% by weight ratio.

Chromium (Cr) is an element that accelerates formation of a carbide and hampers graphitizing of carbon (C). Addition of a large amount of chromium (Cr) may produce white cast iron and excessively enhance hardness to degrade workability. Meanwhile, chromium (Cr) may assist stabilization of a carbide and enhancement of heat resistance. Also, chromium (Cr) is an element that prevents generation of ferrite in cast iron, reduces a distance between pearlite flake layer (flake layer), and accelerates formation of pearlite. In addition, chromium (Cr) may serve to increase an amount of pearlite and stabilize pearlite, and also sub-divide a pearlite structure. However, if the content of chromium (Cr) is excessive, cementite is formed to form a chilled structure.

Thus, chromium (Cr) may be added in an amount of approximately 0.5% to 1.0% to enhance mechanical performance and heat resistance.

(5) Copper (Cu): approximately 0.2% to 0.5%

In alloy cast iron according to an embodiment, a content of copper (Cu) may be approximately 0.2–0.5% by weight ratio. Or, the content of copper (Cu) may be approximately 0.2–0.45% by weight ratio. Or, the content of copper (Cu) may be approximately 0.35–0.45% by weight ratio.

Copper (Cu) is an element that thickens and shortens a shape of graphite, reduces D and E-type undercooled graphite, and accelerates A-type flake graphite. Also, copper (Cu) may play an excellent role to improve a form of graphite, hamper graphitizing and reduce chilling tendency during a eutectoiding process. In addition, copper (Cu) may improve a distribution of carbide, form pearlite, and sub-divide the structure.

In addition, while accelerating formation of pearlite, copper (Cu) may reduce a distance between pearlites to subdivide the pearlite. Also, copper (Cu) may increase fluidity of a molten metal, enhancing castability and thus lowering residual stress.

In addition, copper (Cu) may densify the structure and slightly enhance tensile strength, or hardness, for example, of cast iron. Such effects may be conspicuous when carbon is provided in an amount of approximately 3.0%, and addition of chromium (Cr) may obtain better effects. Thus, copper (Cu) may be provided in an amount of approximately 0.2% to 0.5% as mentioned above.

(6) Phosphor (P): approximately 0.1% to 0.3%

In alloy cast iron according to an embodiment, a content of phosphor (P) may be approximately 0.1–0.3% by weight ratio. Or, the content of phosphor (P) may be approximately 0.15–0.3% by weight ratio. Or, the content of phosphor (P) may be approximately 0.169–0.3% by weight ratio.

Phosphor (P) may form a compound of iron phosphide (FeP3) and exists as a ternary eutectic steady together with an iron carbide. The iron phosphide may be easily undercooled and easily cause segregation in casting. Thus, as the content of phosphor (P) is increased, brittleness may be increased and tensile strength rapidly degraded. Thus, the content of phosphor (P) may be determined as approximately 0.1% to 0.3.

(7) Sulfur (S): approximately 0.06% to 0.1%

In alloy cast iron according to an embodiment, a content of sulfur (S) may be approximately 0.06–0.1% by weight ratio. Or, the content of sulfur (S) may be approximately 0.07–0.096% by weight ratio. Or, the content of sulfur (S) may be approximately 0.083–0.096% by weight ratio.

Addition of a large amount of sulfur (S) may degrade fluidity of a molten metal, increase shrinkage, and cause a shrinkage cavity or cracks. Thus, content of sulfur (S) may be as small as possible. In this case, when sulfur (S) is provided in an amount of approximately 0.06% to 0.1%, such
a bad influence is not greatly exerted, so sulfur (S) may be provided to be within this amount.  

**[0043]** Boron (B): approximately 0.02% to 0.06%

**[0044]** In alloy cast iron according to an embodiment, a content of boron (B) may be approximately 0.02–0.06% by weight ratio. Or, the content of boron (B) may be approximately 0.035–0.06% by weight ratio. Or, the content of boron (B) may be approximately 0.035–0.043% by weight ratio.

**[0045]** Boron (B) may serve to subdivide graphite, but it reduces an amount of graphite and instigates formation of a carbide. In particular, when a small amount of boron (B) is added, a boron carbide may be precipitated, and such a boron carbide may greatly increase hardness and abrasion resistance of cast iron. In particular, the boron carbide has a net shape, and in this case, when the content of boron is small, the net shape is a disconnected shape, but if an excessive amount of boron is provided, a continuously connected net may be formed to degrade mechanical performance.

**[0046]** When boron (B)-containing alloy cast iron is abraded, the boron carbide having a high hardness may form a first sliding surface to support a load, and pearlite, for example, having relatively low hardness may be abraded to form a second concave sliding surface. A slot between the second sliding surface and the first sliding surface may serve to store oil, so the boron carbide may be continuously provided with a lubricant to reduce an amount of abrasion and enhance abrasion resistance of boron cast iron. When the content of boron (B) may be increased, the boron carbide is increased, and thus, supporting action of the boron carbide may be increased to reduce pressure applied to the first sliding surface per unit area to reduce a degree of abrasion to thus increase abrasion resistance.

**[0047]** However, when the content of boron (B) is too high, a particle diameter of the boron carbide may be increased to have a degraded bonding force with the matrix structure. In this case, when frictional force is applied, the boron carbide may be easily separated, and the separated boron carbide may act as a hard abrasion particle on a friction surface to cause cast iron to be severely abraded. Also, in such a case, hardness of cast iron may be so high that workability is degraded. Thus, the content of boron (B) may be determined to be in a range from approximately 0.02% to 0.06%.

**[0048]** Titanium (Ti): approximately 0.043% or less

**[0049]** In alloy cast iron according to an embodiment, a content of titanium (Ti) may be approximately 0.043% or less by weight ratio or approximately 0.001–0.043% by weight ratio. Or, the content of titanium (Ti) may be approximately 0.038% or less by weight ratio. Or, the content of titanium (Ti) may be approximately 0.035% or less by weight ratio.

**[0050]** Titanium (Ti) may serve to subdivide graphite, accelerate formation of pearlite, and increase high temperature stability of pearlite. When the content of titanium is relatively low, graphitizing may be accelerated and a distribution and form of graphite of cast iron may be improved. However, as the content of titanium (Ti) is increased, compounds TiN, or TiC, for example, may be precipitated around an interface of crystal to become nucleus of austenite crystal solidification. Accordingly, hardness of cast iron may be increased and machining performance may be degraded. In a case in which the content of titanium (Ti) is relatively low, titanium (Ti) may accelerate formation of graphitizing and increase an amount of ferrite of a gray cast iron structure to lower hardness, and conversely, when the content of titanium (Ti) is increased, titanium (Ti) may subdivide cast iron crystal and strengthen the alloy structure, and as TiC, is precipitated from an interface of the crystal, hardness of the gray cast iron may be further increased.

**[0051]** Titanium (Ti) is one of alloy elements to manufacture D-type graphite cast iron. The D-type graphite cast iron has strength higher than that of D0 type graphite cast iron and better abrasion resistance. When the content of titanium (Ti) is approximately 0.1% or less, titanium (Ti) may be partially melted in ferrite and mostly precipitated in the form of TiC2 or TiN. Thus, titanium (Ti) has strong deoxidation and denitrification with respect to a molten metal. When TiC2 and TiN are undercooled, A-type graphite may be refined and D-type graphite appears. As the content of graphite and the content of ferrite are large, A/D mixed-type structure may be formed to reduce strength and hardness of gray cast iron.

**[0052]** When the content of titanium is greater than approximately 0.1%, titanium (Ti) may increase a strength of D-type graphite formation, and an amount of D-type graphite may exceed approximately 95%. At the same time, an amount of graphite and an amount of ferrite are small, and thus, titanium (Ti) melted in ferrite is increased, and as ferrite is strengthened, strength and hardness of gray cast iron may be increased.

**[0053]** Thus, in order to secure an amount of D-type graphite and enhance machining performance, titanium (Ti) may be provided in an amount less than approximately 0.04%.

**[0054]** By mixing the elements having the foregoing characteristics, a camring formed of the alloy cast iron may be produced. Hereinafter, a process for manufacturing a camring formed of the foregoing alloy cast iron will be described.

**[0055]** (1) Smelting

**[0056]** The foregoing elements may be selected in appropriate ratios to prepare a raw material, and the raw material may be put into a middle frequency induction furnace and heated to be melted, and subsequently smelted to obtain a crude liquid molten metal of alloy cast iron. At this time, the crude liquid molten metal of alloy cast iron may be taken out at a temperature ranging from approximately 1500°C to 1550°C.

**[0057]** (2) Inoculation

**[0058]** An inoculant is inoculated to the crude liquid molten metal of alloy cast iron smelted in the smelting process. In this case, inoculation may generate a large amount of graphite nucleus to accelerate graphitizing, make a distribution of graphite uniform, and help to increase strength. In this case, as an inoculant, a barium silicon iron alloy (FeSi72Bi2) may be used and a content of inoculant may be approximately 0.3–0.5% of a mass of the crude liquid molten metal of alloy cast iron.

**[0059]** (3) Casting

**[0060]** The inoculated molten metal may be injected into a mold manufactured in advance to have a cavity having a desired shape. Casting may be performed using a green sand mold. Steam inoculation may be performed immediately when the molten metal is injected into the mold, the injection may be a sulfur oxygen injection, and the content thereof may be approximately 0.05–0.15% of the mass of the crude liquid molten metal of alloy cast iron. A cooled cam ring semi-product has a pearlite structure of A-type flake graphite and carbide. The content of the carbide amounts to approximately 3–10% of a total volume of the cam ring.
MACHINING

The cam ring semi-product obtained in the casting process may be machined and ground to have an intended shape.

HEAT TREATMENT

A heat treatment may include quenching and tempering.

Quenching: The cam ring semi-product ground using an electric resistance furnace capable of controlling an air temperature may be heated to reach a temperature of approximately 800-930°C, maintained for approximately 1.5-2.5 hours, quickly put into oil having a temperature of approximately 50-90°C, so as to be cooled, and subsequently cooled to reach approximately room temperature in the air. Through such quenching, the pearlitic matrix structure may be changed into a martensite matrix structure, and thus, hardness may be considerably enhanced. Namely, when quenching is completed, a cam ring including the martensite matrix structure and containing carbide and A-type flake graphite may be obtained.

Tempering: The cam ring of martensite cast iron containing carbide and A-type flake graphite obtained from the quenching using the electric resistance furnace capable of controlling an air temperature is heated to reach a temperature of approximately 220-250°C, and maintained for approximately 1.5-2.5 hours. Air may be cooled to reach approximately room temperature in the air to slightly lower strength and hardness which has been increased through the quenching, to increase ductility instead to lower brittleness. Through tempering, a metal structure may be changed into a tempered martensite structure.

FINE GRINDING AND POLISHING

The cam ring of carbide alloy cast iron obtained through quenching and tempering in the heat treatment process is ground and polished to have a final shape and required surface quality.

EMBODIMENT 1

Embodiment 1 was manufactured through the following process.

A raw material including C: approximately 3.2%, Si: approximately 2.11%, Mn: approximately 0.63%, Cr: approximately 0.77%, Cu: approximately 0.4%, P: approximately 0.15%, B: approximately 0.023%, S: approximately 0.07%, Ti: approximately 0.038% by weight ratio and Fe comprising the remainder was prepared, and the prepared raw material was put into a medium frequency induction furnace. The raw material was entirely melted at a high temperature so as to be smelted into a crude liquid molten metal of alloy cast iron, and the crude liquid molten metal was taken out of the electric furnace at a temperature of approximately 1520°C.

The crude liquid molten metal of the alloy cast iron taken out of the furnace after being smelted was inoculated. The inoculant was FeSi72B2a as a barium silicon iron alloy, and the content thereof was approximately 0.35% of a mass of the crude liquid molten metal.

The molten metal of the alloy cast iron inoculated in the above process was injected into a green sand mold, and sulfur oxygen injection corresponding to approximately 0.1% of the mass of the crude liquid molten metal was injected. Accordingly, a pearlitic alloy cast iron cam ring containing A-type flake graphite and carbide was obtained, and in this case, the content of carbide was approximately 4% of a total volume of the cam ring.

The cam ring obtained in this process is ground to have an intended shape.

The vane was heated to reach a temperature of approximately 895°C, maintained for approximately 2 hours, put into oil having a temperature of approximately 55°C so as to be cooled, and cooled to reach approximately room temperature in the air to change the matrix structure into martensite. The cam ring obtained from quenching was heated to reach approximately 230°C, maintained for approximately 2 hours, and subsequently air-cooled to reach approximately room temperature.

The obtained cam ring semi-product was fine-ground and polished so as to be completed.

FIG. 2 is a photograph illustrating internal structure of Embodiment 1, and it can be seen that carbide and A-type flake graphite is evenly precipitated.

EMBODIMENT 2

A raw material including C: approximately 3.3%, Si: approximately 2.2%, Mn: approximately 0.62%, Cr: approximately 0.842%, Cu: approximately 0.35%, P: approximately 0.171%, B: approximately 0.035%, S: approximately 0.083%, Ti: approximately 0.035% by weight ratio and Fe comprising the remainder was melted and the crude liquid molten metal was taken out at a temperature of approximately 1530°C. Thereafter, FeSi72B2a was added in an amount of approximately 0.4% of a mass of the crude liquid molten metal as an inoculant. Thereafter, the inoculated molten metal was cast by a green sand mold, and the sulfur oxygen injection corresponding to approximately 0.15% of the mass of the crude liquid molten metal was injected to obtain a cam ring semi-product. In this case, the content of carbide was approximately 4.5% of a total volume of the cam ring by volume ratio.

The cam ring semi-product was heated to reach a temperature of approximately 900°C, maintained at the temperature for approximately two hours, put into oil having a temperature of approximately 57°C so as to be cooled to reach approximately room temperature in the air to become martensite, and the cam ring semi-product was heated to reach a temperature of approximately 225°C, maintained at the temperature for approximately two hours, air-cooled at approximately room temperature, and subsequently fine-ground and polished.

EMBODIMENT 3

A raw material including C: approximately 3.38%, Si: approximately 2.34%, Mn: approximately 0.66%, Cr: approximately 0.8289%, Cu: approximately 0.45%, P: approximately 0.169%, B: approximately 0.043%, S: approximately 0.096%, Ti: approximately 0.043% by weight ratio and Fe comprising the remainder was melted and the crude liquid molten metal was taken out at a temperature of approximately 1525°C. Thereafter, FeSi72B2a was added as an inoculant in an amount of approximately 0.38% of a mass of the crude liquid molten metal. Thereafter, the inoculated molten metal was cast by a green sand mold, and sulfur oxygen injection corresponding to approximately 0.13% of the mass of the crude liquid molten mass was injected to
obtain a cam ring semi-product. Here, the content of carbide was approximately 6% of a total volume of the cam ring by volume ratio.

[0080] The cam ring semi-product was heated to a temperature of approximately 905° C., maintained at the temperature for approximately two hours, put into oil having a temperature of approximately 60° C. so as to be cooled to reach approximately room temperature in the air to become martensite, and the cam ring semi-product was heated to reach a temperature of approximately 235° C., maintained at the temperature for approximately two hours, air-cooled at approximately room temperature, and subsequently fine-ground and polished.

EMBODIMENT 4

[0081] A raw material including C: approximately 3.38%, Si: approximately 2.34%, Mn: approximately 0.66%, Cr: approximately 0.829%, Cu: approximately 0.45%, P: approximately 0.169%, B: approximately 0.043%, S: approximately 0.096%, Ti: approximately 0.043% by weight ratio and Fe comprising the remainder was melted and the crude liquid molten metal was taken out at a temperature of approximately 1528° C. A subsequent procedure is the same as that of Embodiment 1.

[0082] Embodiments disclosed herein provide a cam ring having excellent abrasion resistance and impact resistance and easily manufactured. Embodiments disclosed herein also provide a method for manufacturing a cam ring.

[0083] Embodiments disclosed herein provide a cam ring of a vane pump that may be formed of a material including approximately 3.0% to 3.5% of carbon (C), approximately 2.0% to 2.5% of silicon (Si), approximately 0.5% to 1.0% of manganese (Mn), approximately 0.5% to 1.0% of chromium (Cr), approximately 0.2% to 0.5% of copper (Cu), approximately 0.1% to 0.3% of phosphor (P), approximately 0.2% to 0.06% of boron (B), approximately 0.06% to 0.1% of sulfur (S), and approximately 0.04% or more of titanium (Ti) by weight ratio, and iron (Fe) and any inevitable impurity for the remainder, and have a tempered martensite matrix structure including a carbide. The cam ring may include approximately 3% to 10% of carbide by volume ratio. Also, the tempered martensite matrix structure of the cam ring may be a structure in which a carbide and A-type flake graphite are precipitated.

[0084] Embodiments disclosed herein provide a method for manufacturing a cam ring of a vane pump that may include a smelting operation of mixing raw materials including approximately 3.0% to 3.5% of carbon (C), approximately 2.0% to 2.5% of silicon (Si), approximately 0.5% to 1.0% of manganese (Mn), approximately 0.5% to 1.0% of chromium (Cr), approximately 0.2% to 0.5% of copper (Cu), approximately 0.1% to 0.3% of phosphor (P), approximately 0.02% to 0.06% of boron (B), approximately 0.06% to 0.1% of sulfur (S), and approximately 0.043% or more of titanium (Ti) by weight ratio, and iron (Fe) comprising the remainder and melting the mixture to obtain a crude liquid molten metal; a casting operation of injecting the crude liquid molten metal into a mold to cast the same to obtain a semi-product; and a machining operation of machining the casted semi-product into a form of a cam ring; and a heat treatment operation of heat-treating the machined cam ring. In the smelting operation, the crude liquid molten metal may be taken out at a temperature ranging from approximately 1500° C. to 1550° C.

[0085] The method may further include an inoculating operation of injecting an inoculant into the crude liquid molten metal. The inoculant may be a barium silicon iron alloy (FeSi72Ba2) and may inoculate approximately 0.3% to 0.5% of a mass of the crude liquid molten metal.

[0086] During the heat treatment process, after quenching (or hardening), tempering may be performed. The quenching may include heating the cam ring semi-product at a temperature ranging from approximately 890° C. to 930° C. and maintaining the heated cam ring semi-product for approximately 1.5 to 2.5 hours; cooling the cam ring semi-product with a quenching oil having a temperature ranging from approximately 50° C. to 90° C.; and cooling the cam ring semi-product to reach approximately room temperature in the atmosphere.

[0087] The tempering may include heating the quenched cam ring semi-product at a temperature ranging from approximately 220° C. to 250° C. and maintaining the heated cam ring semi-product for approximately 1.5 to 2.5 hours; and cooling the cam ring semi-product to reach approximately room temperature in the atmosphere.

[0088] During the casting operation, a stream injection may be performed with a sulfur oxygen injection, and the content of the sulfur oxygen injection may be approximately 0.05 to 0.15% of a mass of the crude liquid molten metal. Also, the method may further include a grinding operation of grinding the heat-treated cam ring to have final dimensions and shape.

[0089] According to embodiments, with martensite having high hardness, toughness may be increased, while maintaining strength as is, through tempering, and thus, abrasion resistance and impact resistance may be enhanced, and hardness may be further enhanced by a carbide. In addition, as the cam ring may be formed of components that may be easily obtained at relatively low costs, and thus, manufacturing costs may be reduced. Also, due to lubricating properties of the A-type flake graphite, abrasion resistance may be further enhanced. In addition, high hardness equivalent to a Rockwell hardness (HRC) ranging from approximately 50 to 55 may be obtained through a quenching and tempering process.

[0090] Further scope of applicability will become more apparent from the detailed description. However, it should be understood that the detailed description and specific examples, while indicating embodiments, are given by way of illustration only, as various changes and modifications within the spirit and scope will become apparent to those skilled in the art from the detailed description.

[0091] The foregoing embodiments and advantages are merely exemplary and are not to be considered as limiting. The 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 embodiments described herein may be combined in various ways to obtain additional and/or alternative embodiments.

[0092] 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 considered 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 equiva-
lents of such metes and bounds are therefore intended to be embraced by the appended claims.

[0093] Any reference in this specification to “one embodiment,” “an embodiment,” “example embodiment,” etc., means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The appearances of such phrases in various places in the specification are not necessarily all referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with any embodiment, it is submitted that it is within the purview of one skilled in the art to effect such feature, structure, or characteristic in connection with other ones of the embodiments.

[0094] Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this disclosure. More particularly, various variations and modifications are possible in the component parts and/or arrangements of the subject combination arrangement within the scope of this disclosure, the drawings and the appended claims. In addition to variations and modifications in the component parts and/or arrangements, alternative uses will also be apparent to those skilled in the art.

What is claimed is:

1. A cam ring of a vane pump formed of a material including approximately 3.0% to 3.5% of carbon (C), approximately 2.0% to 2.5% of silicon (Si), approximately 0.5% to 1.0% of manganese (Mn), approximately 0.5% to 1.0% of chromium (Cr), approximately 0.2% to 0.5% of copper (Cu), approximately 0.02% to 0.06% of phosphorus (P), approximately 0.02% to 0.06% of boron (B), approximately 0.06% to 0.1% of sulfur (S), and approximately 0.043% or more of titanium (Ti) by weight ratio, and iron (Fe) and any inevitable impurity comprising the remainder.

2. The cam ring of claim 1, wherein the cam ring includes approximately 3% to 10% of carbide by volume ratio.

3. The cam ring of claim 2, wherein the tempered martensite matrix structure of the cam ring is a structure in which a carbide and a type flake graphite are precipitated.

4. The cam ring of claim 1, wherein the material includes approximately 3.2% to 3.5% of carbon (C), approximately 2.11% to 2.5% of silicon (Si), approximately 0.62% to 1.0% of manganese (Mn), approximately 0.77% to 1.0% of chromium (Cr), approximately 0.2% to 0.45% of copper (Cu), approximately 0.15% to 0.3% of phosphorus (P), approximately 0.035% to 0.06% of boron (B), approximately 0.07% to 0.096% of sulfur (S), and approximately 0.038% or more of titanium (Ti) by weight ratio, and iron (Fe) and any inevitable impurity comprising the remainder.

5. The cam ring of claim 1, wherein the material includes approximately 3.2% to 3.38% of carbon (C), approximately 2.2% to 2.34% of silicon (Si), approximately 0.66% to 1.0% of manganese (Mn), approximately 0.77% to 0.842% of chromium (Cr), approximately 0.35% to 0.45% of copper (Cu), approximately 0.069% to 0.3% of phosphorus (P), approximately 0.035% to 0.043% of boron (B), approximately 0.083% to 0.096% of sulfur (S), and approximately 0.053% or more of titanium (Ti) by weight ratio, and iron (Fe) and any inevitable impurity comprising the remainder.

6. A method for manufacturing a cam ring of a vane pump, the method comprising:

mixing raw materials including approximately 3.0% to 3.5% of carbon (C), approximately 2.0% to 2.5% of silicon (Si), approximately 0.5% to 1.0% of manganese (Mn), approximately 0.5% to 1.0% of chromium (Cr), approximately 0.2% to 0.5% of copper (Cu), approximately 0.02% to 0.06% of phosphorus (P), approximately 0.02% to 0.06% of boron (B), approximately 0.06% to 0.1% of sulfur (S), and approximately 0.043% or more of titanium (Ti) by weight ratio, and iron (Fe) comprising the remainder and melting the mixture to obtain a crude liquid molten metal;
injecting the crude liquid molten metal into a mold so as to be cast to obtain a semi-product;
machining the casted semi-product to form a cam ring; and
heat-treating the machined cam ring.

7. The method of claim 6, wherein, in the mixing, the crude liquid molten metal is taken out at a temperature ranging from approximately 1500°C to 1550°C.

8. The method of claim 6, further comprising injecting an inoculant into the crude liquid molten metal.

9. The method of claim 8, wherein the inoculant is a barium silicon iron alloy (FeSi72B3a2) and inoculates approximately 0.3% to 0.5% of a mass of the crude liquid molten metal.

10. The method of claim 6, wherein during the heat-treating, after quenching, tempering is performed.

11. The method of claim 10, wherein the quenching comprises:

heating the cam ring semi-product at a temperature ranging from approximately 890°C to 930°C and maintaining the heated cam ring semi-product for approximately 1.5 to 2.5 hours;
cooling the cam ring semi-product with a quenching oil having a temperature ranging from approximately 50°C to 90°C; and
cooling the cam ring semi-product to reach approximately room temperature in the atmosphere.

12. The method of claim 10, wherein the tempering comprises:

heating the quenched cam ring semi-product at a temperature ranging from approximately 220°C to 250°C and maintaining the heated cam ring semi-product for approximately 1.5 to 2.5 hours; and
cooling the cam ring semi-product to reach approximately room temperature in the atmosphere.

13. The method of claim 6, wherein, during the injecting, stream inoculation is performed with a sulfur oxygen injection.

14. The method of claim 13, wherein a content of the sulfur oxygen injection is approximately 0.05-0.15% of a mass of the crude liquid molten metal.

15. The method of claim 6, further comprising:

grinding the heat-treated cam ring to have final dimensions and shape.

16. The method of claim 6, wherein the raw materials include approximately 3.2% to 3.5% of carbon (C), approximately 2.11% to 2.5% of silicon (Si), approximately 0.62% to 1.0% of manganese (Mn), approximately 0.77% to 1.0% of chromium (Cr), approximately 0.2% to 0.45% of copper (Cu), approximately 0.15% to 0.3% of phosphorus (P), approximately 0.035% to 0.06% of boron (B), approximately 0.07% to 0.096% of sulfur (S), and approximately 0.038% or more
of titanium (Ti) by weight ratio, and iron (Fe) and any inevitable impurity comprising the remainder.

17. The method of claim 6, wherein the raw materials include approximately 3.2% to 3.38% of carbon (C), approximately 2.2% to 2.34% of silicon (Si), approximately 0.66% to 1.0% of manganese (Mn), approximately 0.77% to 0.842% of chromium (Cr), approximately 0.35% to 0.45% of copper (Cu), approximately 0.069% to 0.3% of phosphorus (P), approximately 0.035% to 0.043% of boron (B), approximately 0.083% to 0.096% of sulfur (S), and approximately 0.035% or more of titanium (Ti) by weight ratio, and iron (Fe) and any inevitable impurity comprising the remainder.

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