A rotor of a vane pump and a method of manufacturing a rotor are provided. The rotor may be formed to include a plurality of radially formed slots and having a disk shape, and may include approximately 20% to 70% of pig iron, approximately 0.2% to 0.5% of copper (Cu), and approximately 0.1% to 0.4% of iron (Fe) by weight ratio, and scraps and steel wastes for the remainder, and may be formed of a nodular graphite cast iron including precipitated spheroidal graphite and having an austenite structure.
FIG. 2
ROTOR OF VANE PUMP AND METHOD OF MANUFACTURING ROTOR
CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] Pursuant to 35 U.S.C. §119(a), this application claims the priority to Korean Application No. 10-2013-0025242, 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 may be 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 rotor needs to have high abrasion resistance and impact resistance. Conventionally, cam rings have been manufactured through a heat treatment, such as carburizing and quenching, for example, using low-alloy steel, such as 20CrMo, Cr12MoV, for example. However, this manufacturing method involves complicated processing, and it is difficult to manufacture a cam ring.

[0009] In particular, a carburizing and quenching treatment consumes a large amount of raw material. Further, after quenching, dimensions of a component may be significantly changed, making it difficult to manufacture a cam ring.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Embodiments will be described in detail with reference to the following drawings in which like reference numerals refer to like elements, and wherein:
[0011] FIG. 1 is a schematic cross-sectional view of a related art vane pump; and
[0012] FIG. 2 is a photograph illustrating structure of a rotor according to an embodiment.

DETAILED DESCRIPTION

[0013] 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.

[0014] 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 rotor included in a vane pump, rather than being related to a configuration thereof, and thus, embodiments are not limited by a configuration of a rotor. Hereinafter, the vane pump will be described based on the configuration illustrated in FIG. 1.

[0015] 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 rotor of a vane pump as mentioned above slides upon being tightly attached with a lateral surface portion of the vane, and thus, the rotor is required to have high abrasion resistance, relative to the related art. In the present disclosure, in order to overcome shortcomings of cast iron, nodular graphite cast iron having an austenite structure obtained by precipitating spheroidal graphite may be utilized as a material of the rotor.

[0016] In the nodular graphite cast iron as a material of a rotor of a vane pump according to an embodiment, the content of pig iron is approximately 20-70% by weight ratio. Or, the content of pig iron may be approximately 30-60%. Or, the content of pig iron may be approximately 40-50%.

[0017] Pig iron, a type of iron immediately produced from iron ore, may contain impurities, such as sulfur, and phosphor, for example, besides approximately 2.2% to 7% (approximately 2.5% to 4.5% in most cases) of carbon (C). Due to brittleness, pig iron may not be rolled or forged. However, as pig iron has a low melting point, pig iron may be appropriate to be utilized as a raw material of casting.

[0018] Meanwhile, scrap, remanufactured, and various materials, for example, produced while steel is machined has characteristics identical to those of the base material. In addition, steel wastes remaining after steel is utilized in construction sites or various structures and ends its life retain ductility and toughness of the original steel. Thus, steel wastes may be mixed with pig iron during a casing process to improve characteristics of the pig iron.

[0019] In the nodular graphite cast iron as a material of a rotor of a vane pump according to an embodiment, the content of iron (Fe) may be approximately 0.1-0.4% by weight ratio. Or, the content of iron may be approximately 0.15-0.35%. Or, the content of iron may be approximately 0.25-0.35%.

[0020] In the nodular graphite cast iron as a material of a rotor of a vane pump according to an embodiment, copper (Cu) may be added in an amount of approximately 0.2% to 0.5%. Copper (Cu) is an element thickening and shortening graphite in shape, reducing D and E type undercooled graphite, and accelerating A type flake graphite. Also, copper (Cu) may positively serve to improve a shape of graphite and hamper graphitizing and reduce a chilled tendency of cast iron during a eutectoiding process. In addition, copper (Cu) may improve a carbide distribution, form pearlites, and sub-divide the structure.
In addition, copper (Cu) may subdivide pearlitic by reducing a distance between pearlitic, while acceleration formation of pearlitic. Also, copper (Cu) fluidity of molten metal may enhance castability and lower residual stress. In addition, copper (Cu) may densify the structure and enhance tensile strength and hardness of cast iron more or less. Copper (Cu) may be added in an amount of approximately 0.2–0.5% by weight ratio. Or, the content of copper may be approximately 0.3–0.5% by weight ratio. Or, the content of copper may be approximately 0.3–0.5% by weight ratio.

Hereinafter, a process for manufacturing a rotor according to an embodiment will be described.

(1) Smelting

The foregoing pig iron, scrap, steel wastes, copper, and iron (Fe) 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. At this time, the crude liquid molten metal may be taken out at a temperature ranging from approximately 1500°C to 1550°C.

(2) Spheroidization and Inoculation

A nodularizer to nodularize graphite and an inoculant may be inoculated to the crude liquid molten metal smelted in the smelting process. In this case, magnesium (Mg), calcium (Ca), and rare earth resources (RE), known to accelerate nodularization of graphite, may be used as the nodularizer. In more detail, a nodularizer having components such as Mg: approximately 5.5–6.5%, Si: approximately 44–48%, Cu: approximately 0.5–2.5%, Al: approximately 1.5%, RE: approximately 0.8–1.5%, MgO: approximately 0.7% may be used. For example, FeSiMg6RE1 may be added in an amount of approximately 1.0–1.2% of a mass of the crude liquid molten metal.

Meanwhile, inoculation generates a large amount of graphite nucleus to accelerate graphitizing, and makes a distribution of graphite uniform, and helps to increase strength. As an inoculant, a barium silicon iron alloy (FeSi72Ba2) may be used, and the content of inoculant may be approximately 0.4–0.8% of the mass of the crude liquid molten metal.

(3) Casting

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, and a temperature of the molten metal during the injection process may be controlled to range from approximately 1380–1420°C. Stream inoculation may be performed simultaneously when the molten metal is injected into the mold, and here, an injection may be a sulfur oxygen injection, and the content may be approximately 0.05–0.2% of the mass of the crude liquid molten metal. The molten metal injected into the mold may be cooled to obtain a nodular cast iron rotor.

(4) Machining

The rotor semi-product obtained in the casting process may be first cleaned to remove sand and an oxide layer attached to a surface thereof, and machined to have an intended shape.

(5) Isothermal Hardening

Isothermal hardening (heat treatment process) may be performed on the machined rotor semi-product. The isothermal hardening may be performed to austenitize the matrix structure. In more detail, the machined rotor semi-product having a pearlite matrix structure may be heated by using an electrical resistance furnace capable of controlling an air temperature to reach approximately 890–920°C, maintained for approximately 60–90 minutes, and put into a nitrate solution having a temperature ranging from approximately 280–340°C, maintained for approximately 1–3 hours, taken out, and cooled to reach approximately room temperature in the air. Through this heat treatment, a pearlite matrix of the rotor semi-product may be transformed into an austenite matrix structure, and thus, toughness and impact resistance may be significantly enhanced.

A solution in which KNO3 and NaNO3 are mixed in a weight ratio of approximately 1:1 may be used as the nitrate solution. Concentration of the nitrate solution and concentration of KNO3 and NaNO3 constituting the nitrate solution are not particularly limited. The nitrate solution, as a quenching medium, is advantageous, compared with general quenching oil. Advantages of the nitrate solution are as follows.

There is no steam membrane process during a nitrate solution quenching process, and a high temperature section cooling speed is very high, and thus, a quenching structure having excellent thick part may be obtained.

The nitrate solution has a cooling speed close to 0 in a case of low temperature section isothermal, and thus, quenching strain is very low.

A cooling speed of nitrate may be adjusted by adjusting a content of water (which is between fourfold of hot oil cooling speed and oil cooling speed).

A surface of a part has a stress pressure state, and a crack of the part is reduced, and a lifespan of the part is lengthened.

After quenching, the part has uniform metal gloss and navy color, and after cleaning, it is not required to perform channeling or peening, and corrosion-resistance performance is high.

(6) Fine Grinding and Polishing

The rotor of the nodular graphite cast iron of carbide obtained through the heat treatment may be fine-ground and polished to have a final shape and required surface quality.

Hereinafter, embodiments of a rotor of a vane pump will be described.

Embodiment 1

Approximately 40% of pig iron, approximately 30% of scrap, approximately 30% of steel waste, approximately 0.4% of Cu, and approximately 0.25% of Fe were mixed by weight ratio and put into a middle frequency induction furnace, and smelted to obtain a crude liquid molten metal of nodular graphite cast iron, and the crude liquid molten metal was taken out of the furnace at a temperature of approximately 1530°C.

The crude liquid molten metal of nodular graphite cast iron taken out of the furnace was spheroidized and inoculated, and rare earth resource silicon iron magnesium alloy (FeSiMg6RE1) was added as a nodularizer in an amount of approximately 1.0% of the mass of the crude liquid molten metal, and barium silicon iron (FeSi72Ba2) was added as an inoculant in an amount of approximately 0.5% of the mass of the crude liquid molten metal.

The spheroidized and inoculated molten metal were injected into a green sand mold manufactured in advance. After a temperature thereof was controlled to approximately 1390°C, the molten metal was cooled to obtain a nodular cast iron rotor containing spheroidal graphite, ferrite, and pearlite.

The nodular cast iron rotor was processed to have a rotor shape, heated to reach approximately 900°C.
by using a furnace capable of continuously heating, maintained for approximately 60 minutes, and quickly put into a nitrate solution having a temperature of approximately 300°C for approximately two hours. Thereafter, the nodular cast iron rotor was taken out and cooled to reach approximately room temperature to obtain austenite nodular graphite cast iron rotor.

[0047] Finally, fine grinding and polishing were performed to allow the rotor to have required surface roughness.

Embodiment 2

[0048] Approximately 50% of pig iron, approximately 40% of scrap, approximately 10% of steel waste, approximately 0.3% of Cu, and approximately 0.35% of iron were mixed and melted, and the crude liquid molten metal was drawn out at a temperature of approximately 1540°C, to which approximately 1.1% of FeSiMg6RE1 of a mass of the crude liquid molten metal and approximately 0.6% of FeSi72Ba2 of the mass of the crude liquid molten metal were applied. Thereafter, the molten metal was injected to a green sand mold at a temperature of approximately 1400°C, and subsequently cooled. The obtained rotor semi-product was machined and isothermally-hardened. Here, the rotor semi-product was heated to reach approximately 920°C, maintained for approximately 70 minutes, and put into a nitrate solution having a temperature of approximately 290°C for approximately two hours. Thereafter, the rotor semi-product was cooled to reach approximately room temperature and fine-ground and polished.

Embodiment 3

[0049] Approximately 60% of pig iron, approximately 25% of scrap, approximately 15% of steel waste, approximately 0.3% of Cu, and approximately 0.35% of Fe were mixed and melted, and the crude liquid molten metal was taken out at a temperature of approximately 1550°C, and FeSiMg6RE1 in an amount of approximately 1.15% of the mass of the crude liquid molten metal and FeSi72Ba2 in an amount of approximately 0.65% of a mass of the crude liquid molten metal were applied. Thereafter, the molten metal was injected into a green sand mold at a temperature of approximately 1410°C, and subsequently cooled. The obtained rotor semi-product was machined and isothermally-hardened. The rotor semi-product was heated to reach approximately 915°C, maintained for approximately 70 minutes, and put into a nitrate solution having a temperature of approximately 290°C for two hours. Thereafter, the rotor semi-product was cooled to reach approximately room temperature and fine-ground and polished.

Embodiment 4

[0050] Approximately 30% of pig iron, approximately 30% of scrap, approximately 40% of steel waste, approximately 0.2% of Cu, and approximately 0.15% of Fe were mixed and melted, and the crude liquid molten metal was taken out at a temperature of approximately 1545°C, and FeSiMg6RE1 in an amount of approximately 1.2% of the mass of the crude liquid molten metal and FeSi72Ba2 in an amount of approximately 0.7% of a mass of the crude liquid molten metal were applied. Thereafter, the molten metal was injected into a green sand mold at a temperature of approximately 1410°C, and subsequently cooled. The obtained rotor semi-product was machined and isothermally-hardened. Here, the rotor semi-product was heated to reach approximately 905°C, maintained for approximately 90 minutes, and put into a nitrate solution having a temperature of approximately 320°C, for approximately two hours. Thereafter, the rotor semi-product was cooled to reach approximately room temperature and fine-ground and polished.

[0051] Fig. 2 is a photograph illustrating internal structure of Embodiment 1. Referring to Fig. 2, it can be seen that Embodiment 1 is comprised of austenite and spheroidal graphite.

[0052] Embodiments disclosed herein provide a rotor of a vane pump having excellent abrasion resistance and impact resistance and easily manufactured. Embodiments disclosed herein further provide a method for manufacturing a rotor of a vane pump. Embodiments disclosed herein provide a rotor of a vane pump, that may include a plurality of radially formed slots and having a disk shape, being formed of a material including approximately 20% to 70% of pig iron, approximately 0.2% to 0.5% of copper (Cu), and approximately 0.1% to 0.4% of iron (Fe) by weight ratio, and scraps and steel wastes for the remainder, and formed of a nodular graphite cast iron including precipitated spheroidal graphite and having an austenite structure.

[0053] Scraps refer to fragments, for example, produced during mechanical working, and steel waste refers to steel discarded after being used. The rotor of a vane pump may be formed of the nodular graphite cast iron to have sufficient strength and abrasion resistance, and as scraps and steel wastes may be used, manufacturing costs may be reduced. The weight ratio of the steel wastes may be equal to or smaller than that of the scraps, and more specifically, a weight ratio between the scraps and the steel wastes may be approximately 1:1 to 5:1 by weight ratio.

[0054] Embodiments disclosed herein provide a method for manufacturing a rotor of a vane pump that may include mixing raw materials including approximately 20% to 70% of pig iron, approximately 0.2% to 0.5% of copper (Cu), and approximately 0.1% to 0.4% of iron (Fe), and scraps and steel wastes for the remainder and smelting the crude liquid molten metal; applying a nodularizer and an inoculant to the smelted crude liquid molten metal; a casting operation of injecting the molten metal into a mold to obtain a rotor semi-product; machining the rotor semi-product to have a predetermined shape; and isothermal-hardening the machined rotor semi-product. In the operation of smelting the crude liquid molten metal, the crude liquid molten metal may be taken out at a temperature ranging from approximately 1500°C to 1550°C.

[0055] A silicon-iron-magnesium alloy (FeSiMg6RE1), a rare earth element, may be applied as the nodularizer in an amount of approximately 1.0% to 1.2% of a mass of the crude liquid molten metal.

[0056] The isothermal-hardening may include heating the rotor semi-product to reach a temperature ranging from approximately 890°C to 950°C and maintaining the heated rotor semi-product for approximately 60 minutes to 90 minutes; applying the rotor semi-product to a liquid having a temperature ranging from approximately 280°C to 340°C and maintaining the rotor semi-product in the liquid for approximately one to three hours; and cooling the rotor semi-product to reach approximately room temperature in the atmosphere. The liquid may be a nitrate solution obtained by mixing KNO₃ and NaNO₃ in a ratio of approximately 1:1.
method may further include grinding the hardening-completed rotor semi-product to have a final shape.

[0057] According to embodiments, nodular graphite cast iron including precipitated spheroidal graphite and having an austenite structure may be used. The austenite structure has high impact resistance and abrasion resistance, and due to work hardening, surface hardness may be further enhanced during a production process. In addition, due to high lubricating performance of the spheroidal graphite, abrasion resistance may be further enhanced. Also, as scraps or steel wastes may be used, without using a rare earth element or a high-priced material, manufacturing costs may be considerably reduced.

[0058] 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.

[0059] The foregoing embodiments and advantages are merely exemplary and are not to be considered 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.

[0060] 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 equivalents of such metes and bounds are therefore intended to be embraced by the appended claims.

[0061] 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.

[0062] 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 the 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 rotor of a vane pump including a plurality of radially formed slots and having a disk shape, wherein the rotor is formed of a material comprising approximately 20% to 70% of pig iron, approximately 0.2% to 0.5% of copper (Cu), and approximately 0.1% to 0.4% of iron (Fe) by weight ratio, and scraps and steel wastes comprising the remainder, and formed of a nodular graphite cast iron including precipitated spheroidal graphite and having an austenite structure.

2. The rotor of claim 1, wherein a weight ratio of the steel wastes is equal to or smaller than a weight ratio of the scraps.

3. The rotor of claim 2, wherein a weight ratio between the scraps and the steel wastes is approximately 1:1 to 5:1 by weight ratio.

4. The rotor of claim 1, wherein the material comprises approximately 30% to 60% of pig iron, approximately 0.3% to 0.5% of copper (Cu), and approximately 0.15% to 0.35% of iron (Fe) by weight ratio, and scraps and steel wastes comprising the remainder, and formed of a nodular graphite cast iron including precipitated spheroidal graphite and having an austenite structure.

5. The rotor of claim 1, wherein the material comprises approximately 40% to 50% of pig iron, approximately 0.3% to 0.4% of copper (Cu), and approximately 0.25% to 0.35% of iron (Fe) by weight ratio, and scraps and steel wastes comprising the remainder, and formed of a nodular graphite cast iron including precipitated spheroidal graphite and having an austenite structure.

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

mixing raw materials including approximately 20% to 70% of pig iron, approximately 0.2% to 0.5% of copper (Cu), and approximately 0.1% to 0.4% of iron (Fe), and scraps and steel wastes comprising the remainder and smelting the crude liquid molten metal;

applying a nodularizer and an inoculant to the smelted crude liquid molten metal to obtain a molten metal;

injecting the molten metal to a cast to obtain a rotor semi-product;

machining the rotor semi-product to have a predetermined shape; and

isothermal-hardening the machined rotor semi-product.

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

8. The method of claim 6, wherein a silicon-iron-magnesium alloy (FeSiMg6RE1), a rare earth element, is applied as the nodularizer in an amount of approximately 1.0% to 1.2% of a mass of the crude liquid molten metal.

9. The method of claim 6, wherein the isothermal-hardening comprises:

heating the rotor semi-product to reach a temperature ranging from approximately 890°C to 950°C and maintaining the heated rotor semi-product for approximately 60 minutes to 90 minutes;

applying the rotor semi-product to a liquid having a temperature ranging from approximately 280°C to 340°C and maintaining the rotor semi-product in the liquid for approximately one to three hours; and

cooling the rotor semi-product to reach approximately room temperature in the atmosphere.
10. The method of claim 9, wherein the liquid is a nitrate solution obtained by mixing KNO₃ and NaNO₃ in a ratio of approximately 1:1.

11. The method of claim 6, further comprising:
   grinding the hardening-completed rotor semi-product to have a final shape.

12. The method of claim 6, wherein the raw materials include approximately 30% to 60% of pig iron, approximately 0.3% to 0.5% of copper (Cu), and approximately 0.15 to 0.35% of iron (Fe), and scraps and steel wastes comprising the remainder and smelting the crude liquid molten metal.

13. The method of claim 6, wherein the raw materials include approximately 40% to 50% of pig iron, approximately 0.3% to 0.4% of copper (Cu), and approximately 0.25% to 0.35% of iron (Fe), and scraps and steel wastes comprising the remainder and smelting the crude liquid molten metal.

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