(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 121 303 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
03.01.2018 Bulletin 2018/01

(21) Application number: **15764543.3**

(22) Date of filing: **11.03.2015**

(51) Int Cl.:
C22C 21/12 $^{(2006.01)}$
B22C 9/02 $^{(2006.01)}$
B22C 9/22 $^{(2006.01)}$
B22D 18/04 $^{(2006.01)}$
B22D 21/04 $^{(2006.01)}$
C22F 1/057 $^{(2006.01)}$
F02B 39/00 $^{(2006.01)}$
F04D 29/30 $^{(2006.01)}$

(86) International application number:
PCT/JP2015/001340

(87) International publication number:
WO 2015/141191 (24.09.2015 Gazette 2015/38)

(54) COMPRESSOR IMPELLER CAST FROM AL ALLOY AND METHOD FOR PRODUCING SAME

AUS AL-LEGIERUNG GEGOSSENES VERDICHTERLAUFRAD UND VERFAHREN ZUR HERSTELLUNG DAVON

HÉLICE DE COMPRESSEUR COULÉE À PARTIR D'UN ALLIAGE D'AL ET SON PROCÉDÉ DE PRODUCTION

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **15.03.2014 JP 2014052840**

(43) Date of publication of application:
25.01.2017 Bulletin 2017/04

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Printed by Jouve, 75001 PARIS (FR)

Description

Technical Field

[0001] The present invention relates to a compressor impeller cast from aluminum alloy for use in turbochargers of the internal combustion engines of automobiles and ships, and to a method for producing same.

Background Art

[0002] The turbochargers used for the internal combustion engines of automobiles and ships include a compressor impeller that compresses and supplies air into the internal combustion engine by rotating at high speed. The compressor impeller can reach temperatures as high as about 150°C during its high-speed rotation, and receives high stress, such as the torsional stress from the rotating shaft, and the centrifugal force, near the center of rotation, particularly at the disc section.

[0003] Various materials are used for the compressor impeller according to the required performance of the turbocharger. Hot forged materials of an aluminum alloy machined into an impeller shape are typically used in large-scale applications such as ships. Mass production efficiency and costs are more important in relatively smaller applications such as in automobiles (e.g., cars, and trucks), and boats. Such applications commonly use easily castable aluminum alloys of primarily silicon additive such as JIS-AC4CH (Al-7% Si-0.3% Mg alloy), ASTM-354.0 (Al-9% Si-1.8% Cu-0.5% Mg alloy), and ASTM-C355.0 (Al-5% Si-1.3% Cu-0.5% Mg alloy) of desirable castability. These materials are then cast with a plaster mold by using techniques such as low-pressure casting, vacuum casting, and gravity casting, and are strengthened by a solution treatment or an aging treatment before use. A basic method of such procedures is disclosed in detail in Patent Document 1.

[0004] Lately, the need for high-speed turbochargers has increased with the increase in the demand for higher compression ratios of air necessitated by smaller engines, higher output, and increased exhaust recirculation. However, faster rotation speeds increase the amount of heat generated by air compression, and at the same time increase the temperature of the exhaust turbine impeller. The temperature of the compressor impeller is increased by a heat transfer due to heat generation. It has been found that conventional compressor impellers made of easily castable aluminum alloys of primarily silicon additive tend to cause problems such as deformation and fatigue failure during use, and fail to keep rotating normally. Specifically, these existing compressor impellers have an operating temperature of at most about 150°C, and there is a strong need for the development of a compressor impeller that can withstand an operating temperature of about 200°C to meet the demand for high speed rotations.

[0005] It may be possible to use an aluminum alloy composition of more desirable high-temperature strength, for example, such as JIS-AC1B (Al-5% Cu-0.3% Mg alloy). However, as described in Patent Document 2, the problem of the alloy such as JIS-AC1B is that the molten metal lacks desirable fluidity, and tends to cause misruns (underfilling) of the molten metal in thin section of vane sections when used to make articles that have complex shapes and thin vane sections such as in compressor impellers.

[0006] Patent Document 2 addresses this problem by proposing a method that uses an Al-Si easily castable alloy such as AC4CH for the vane section for which misruns of a molten metal are of concern, and an Al-Cu high-strength alloy such as AC1B for the boss and disk sections that are connected to the rotating shaft and thus require strength. These are coalesced by being poured in two separate sections to form a compressor impeller.

[0007] Patent Document 3 proposes a method that uses an alloy of desirable castability for the vane section, and in which a strengthened composite material prepared by impregnating a strengthening material such as a 25%-B (boron) aluminum whisker with aluminum is used for the stressed boss section and the central section of the disk section. These are then joined to each other to form a compressor impeller.

[0008] Patent Document 4 proposes a method in which a vane section and a boss section (and a disk section) are joined to each other by friction welding. However, methods such as this that use different materials for different sections are problematic in terms of productivity and cost, and are currently not usable in industrial applications.

[0009] Patent Document 5 addresses the problem of using different materials by proposing a compressor impeller that can be cast from a single alloy, specifically an Al-Cu-Mg-base alloy for which the additive elements and the combination range of these elements are optimized. The resulting compressor impeller has a proof stress value of 250 MPa or more at 180°C. Patent Document 6 proposes improving the casting yield by controlling the crystal grain size of an Al-Cu-Mg-base alloy through optimization of the additive elements and the combination range of these elements. The compressor impeller has a proof stress value of 260 MPa or more at 200°C.

[0010] Finally, Patent Document 7 discloses a compressor impeller cast from an Al alloy comprising Cu: 1.4 to 3.2 mass%, Mg: 1.0 to 2.0 mass%, Ni: 0.5 to 2.0 mass%, Fe: 0.5 to 2.0 mass%, Ti: 0.01 to 0.35 mass%, B: 0.002 to 0.070 mass % and a balance of Al and unavoidable impurities. However, a problem remains that the products of the single alloy casting using the Al-Cu-Mg-base alloy still need to stably withstand high temperatures in the vicinity of 200°C over extended time periods if these were to be used for ever faster turbochargers. Another unsolved problem is that the casting yield needs to be improved for stable production.

Citation List

Patent Document

[0011]

Patent Document 1: US Patent No. 4,556,528
Patent Document 2: JP-A-10-58119
Patent Document 3: JP-A-10-212967
Patent Document 4: JP-A-11-343858
Patent Document 5: JP-A-2005-206927
Patent Document 6: JP-A-2012-25986
Patent Document 7: JP-5415655B

Summary of The Invention

Problems to Be Solved by The Invention

[0012] The present invention has been made in view of the foregoing problems, and it is an obj ect of the present invention to provide a compressor impeller cast from an aluminum alloy (hereinafter, "Al alloy") that remains stably strong over extended time periods even under operating temperatures of about 200°C, and that excels in productivity. The invention is also intended to provide a method for producing such impellers.

Solution to Problem

[0013] With regard to the foregoing problems, the present inventors focused on the disc section of compressor impellers that receives high stress, and found that the strength of the disc section greatly improves when the intermetallic compounds at the end section of the disc section are finely dispersed. The present inventors also diligently studied a method of production for finely dispersing intermetallic compounds, and found that refining primary phase aluminum crystal grains is important for fine dispersal of intermetallic compounds, and that controlling the cooling rate of Al alloy molten metal, and controlling the distribution of refined particles in a compressor impeller are important to achieve this. The present invention was completed on the basis of these findings.

[0014] In claim 1, the present invention is directed to a compressor impeller cast from an Al alloy comprising a boss section, a plurality of vane sections and a disc section,
wherein the boss section, the plurality of vane sections, and the disc section excluding an end section comprise an Al alloy comprising Cu: 1.4 to 3.2 mass%, Mg: 1.0 to 2.0 mass%, Ni: 0.5 to 2.0 mass%, Fe: 0.5 to 2.0 mass%, Ti: 0.01 to 0.35 mass%, and B: 0.002 to 0.070 mass% and a balance of Al and unavoidable impurities,
wherein the end section of the disc section comprises an Al alloy comprising Cu: 1.4 to 3.2 mass%, Mg: 1.0 to 2.0 mass%, Ni: 0.5 to 2.0 mass%, Fe: 0.5 to 2.0 mass%, Ti: 0.005 to 0.175 mass%, and B: 0.001 to 0.035 mass% and a balance of Al and unavoidable impurities, and
wherein at least 10000/mm^2 of intermetallic compounds having a circle- equivalent diameter of 1 to 6 μm, and no greater than 500/mm^2 of intermetallic compounds having a circle-equivalent diameter exceeding 6 μm exist in the end section of the disc section.

[0015] In claim 2 of the present invention, the compressor impeller is for use in large-scale applications including ships, and the boss section has a height of 200 to 80 mm, the disc section has a diameter of 300 to 100 mm and the vane sections have a height of 180 to 60 mm with 30 to 10 vanes measuring 4.0 to 0.4 mm in thickness at the vane tip in claim 1.

[0016] In claim 3 of the present invention, the compressor impeller is for use in small-scale applications including automobiles, and the boss section has a height of 100 to 20 mm, the disc section has a diameter of 120 to 25 mm, and the vane sections have a height of 90 to 5 mm with 20 to 4 vanes measuring 3.0 to 0.1 mm in thickness at the vane tip in claim 1.

[0017] In claim 4, the present invention is directed to a method for producing a compressor impeller cast from an Al alloy, comprising:

a step of preparing a 720 to 780°C Al alloy molten metal comprising Cu: 1.4 to 3.2 mass%, Mg: 1.0 to 2.0 mass%, Ni: 0.5 to 2.0 mass%, Fe: 0.5 to 2.0 mass% and a balance of Al and unavoidable impurities, and adding a refining agent to an Al alloy molten metal to incorporate Ti: 0.01 to 0.35 mass% and B: 0.002 to 0.070 mass% in the alloy composition;

a step of casting the Al alloy casting by pressure casting whereby the Al alloy molten metal prepared is injected through a molten metal inlet into a space having a product shape configured from a plaster mold having the molten metal inlet at the bottom of the plaster mold, and a 100 to 250°C chill disposed on a surface that contacts with an impeller disc surface, the space being formed by disposing the plaster mold and the chill so that the chill is at upper position and the plaster mold is at below position, and an inflow rate at the molten metal inlet into the space being 0.12 to 1.00 m/s;

a step of solution treating by subjecting the Al alloy casting to a solution treatment; and

a step of aging treating by subjecting the Al alloy casting to aging after the solution treatment.

[0018] In claim 5 of the present invention, the end section of the disc section has a cooling rate of 0.1 to 200°C/s in the casting step in claim 4.

[0019] In claim 6 of the present invention, the Al alloy casting is heat treated for 2 hours or more at a temperature 5 to 25°C below the solidus temperature of the Al alloy in the solution treatment step, and the solution-treated Al alloy casting is subjected to a heat treatment at 180 to 230°C for 3 to 30 hours in the aging treatment step in claim 4 or 5.

[0020] The present invention can provide an aluminum alloy cast impeller for compressors that shows stable high-temperature strength even in a high temperature range in the vicinity of 200°C over extended time periods, and that has excellent productivity such as casting yield.

Brief Description of Drawings

[0021]

FIG. 1 is a perspective view representing an exemplary structure of an Al alloy cast impeller for compressors according to the present invention.

FIG. 2 is an explanatory diagram representing the measurement areas of intermetallic compound distribution in the Al alloy cast impeller for compressors according to the present invention.

FIG. 3 is an explanatory diagram representing how a plaster mold and a chill are disposed, and the pour direction of molten metal upwardly poured into a space configured from the plaster mold and the chill in a method for producing the Al alloy cast impeller for compressors according to the present invention.

FIG. 4 is an explanatory diagram representing how the plaster mold and the chill are disposed, and the pour direction of molten metal laterally poured into the space configured from the plaster mold and the chill.

FIG. 5 is an explanatory diagram representing how the plaster mold and the chill are disposed, and the pour direction of molten metal downwardly poured into the space configured from the plaster mold and the chill.

Description of Embodiments

[0022] An embodiment of the present invention is described below in detail.

A. Features of Aluminum Alloy Cast Impeller for Compressors According to the Present Invention

[0023] After a series of various experimental studies conducted to solve the foregoing problems, the present inventors found that a compressor impeller that stably maintains excellent high-temperature strength over extended time periods without involving damage to the disc section can be obtained by optimizing the size and the surface density of intermetallic compounds at the end section of the disc section of the compressor impeller, even when the compressor impeller is used under high temperatures of about 200°C. It was also found that the size and the surface density of intermetallic compounds at the end section of the disc section of the compressor impeller can be optimized, and that the casting yield can improve from conventional yields by optimizing the Al alloy composition, controlling the cooling rate of casting through adjustments of molten metal temperature and chill temperature, and controlling the pour rate of molten metal into a compressor impeller mold.

[0024] As used herein, "stably maintain desirable high-temperature strength over extended time periods" means that deformation and fatigue failure do not occur over extended time periods even under operating temperatures of about 200°C. Specifically, it means that no damage occurs in a turbo assembly durability test conducted at 200°C for 150, 000 rpm × 200 hours.

B. Shape of Al Alloy Cast Impeller for Compressors

[0025] FIG. 1 shows an example of the shape of the aluminum alloy cast impeller for compressors (hereinafter, simply referred to "compressor impeller") according to the present embodiment. A compressor impeller 1 includes a rotational center shaft (boss section) 2, a disk section 3 continuous from the boss section 2, and a plurality of thin vanes 4 projecting outwardly from the disk section 3. The compressor impeller 1 reaches a temperature as high as about 200°C during high-speed rotation, and receives high repeated stress along a vertical direction, particularly at the disk section end.

C. Al Alloy Composition

[0026] The composition of the Al alloy used in the present invention is described below along with the reasons for limiting the Al alloy components.

C-1. Cu, Mg:

[0027] Cu and Mg dissolve into the Al matrix and show an effect that a mechanical strength is improved by the solid solution strengthening. By existing together, Cu and Mg also contribute to improving strength through precipitation strengthening such as by Al_2Cu, and Al_2CuMg. Because these two elements widen the solidification temperature range, excess addition of these elements is detrimental to castability.

[0028] When the Cu content is less than 1.4 mass% (hereinafter, simply referred to "%"), and/or Mg content is less than 1.00%, the required mechanical strength at high temperatures of around 200°C may not be obtained. On the other hand, when the Cu content is above 3.2%, and/or Mg content is in excess of 2.0%, the castability of the compressor impeller is impaired, and may cause an underfill as the molten metal fails to sufficiently run into the vane end section in particular. For these reasons, the Cu content should preferably be 1.4 to 3.2%, and the Mg content should preferably be 1.0 to 2.0%. The Cu content is more preferably 1.7 to 2.8%, and the Mg content is more preferably 1.3 to 1.8% in terms of surely preventing defects such as deformation during use, and practically preventing generation of an underfill during casting and obtaining an industrially preferable yield.

C-2. Ni, Fe:

[0029] Ni and Fe form an intermetallic compound with Al, and disperse into the Al matrix to improve the high-temperature strength of the Al alloy. To this end, the Ni content should be 0.5% or more, and the Fe content should be 0.5% or more. However, when contained in excess, these elements not only coarsen the intermetallic compound, but reduce the amount of the solid solution Cu in the Al matrix, and lower strength by forming Cu_2FeAl_7 and Cu_3NiAl_6 at high temperatures. The presence of coarsened intermetallic compounds at the end section of the disc section causes damage to the compressor impeller as the intermetallic compounds become a starting point of damage under the repeatedly applied stress on the end section of the disc section, as will be described later. It is therefore preferable to contain Ni in a content of 2.0% or less, and Fe in a content of 2.0% or less. Taken together, the Ni content should preferably be 0.5 to 2.0%, and the Fe content should preferably be 0.5 to 2.0%. Preferably, the Ni content is 0.5 to 1.4%, and the Fe content is 0.7 to 1.5%. The lower limits of these preferred ranges are provided as indications for stably mass producing products in industrial settings by reducing production variation, whereas the upper limits are indications above which the effects will be saturated, and the elements will be wasted.

C-3. Ti, B:

[0030] Ti and B have the effect to inhibit the growth of primary phase aluminum crystal grains during casting, and are added to reduce the size of the solid structure in the casting, and improve the supply and the run of molten metal. These effects may not be sufficiently obtained when the Ti content is less than 0.01%, and/or the B content is less than 0.002% in the boss section, the vane sections, and the disc section other than the end section, or when the Ti content is less than 0.005%, and/or the B content is less than 0.001% in the end section of the disc section. On the other hand, the refining agent particles aggregate, and fatigue cracking occurs from the aggregates when the Ti content exceeds 0.35%, and/or the B content exceeds 0.070% in the boss section, the vane sections, and the disc section other than the end section, or when the Ti content exceeds 0.175%, and/or the B content exceeds 0.035% in the end section of the disc section. When contained in excess of 0.35% in these sections, Ti forms coarse intermetallic compounds of several ten to several hundred micrometers with Al. Such coarse intermetallic compounds become a starting point of fatigue cracking, and lowers the reliability of the compressor impeller. For these reasons, the Ti content should be 0.01 to 0.35%, and the B content should be 0.002 to 0.070%, preferably the Ti content is 0.15 to 0.30%, and the B content is 0.003 to 0.060% in the boss section, the vane sections, and the disc section other than the end section. At the end section of the disc section, the Ti content should be 0.005 to 0.175%, and the B content should be 0.001 to 0.035%, preferably the Ti content is 0.010 to 0.165%, and the B content is 0.002 to 0.033%.

[0031] The Al alloy may contain unavoidable impurities, such as about 0.3% or less of Si, and about 0.2% or less of each of Zn, Mn, and Cr. These unavoidable impurities are acceptable because these do not affect the characteristics of the compressor impeller.

D. Intermetallic Compound

[0032] The aluminum alloy used in the present invention is cast into a shape of the compressor impeller with a plaster mold by pressure casting (low-pressure casting, vacuum casting, or differential pressure casting) according to a conventional Al-Si aluminum alloy casting producing method.

[0033] In the pressure casting using a plaster mold, producing conditions need to be controlled with regard to the distribution of the intermetallic compounds inside each casting in such a manner that the number of intermetallic compounds having a circle-equivalent diameter of 1 to 6 μm is at least 10000/mm^2 at the end section of the disc section, and that the number of intermetallic compounds having a circle-equivalent diameter exceeding 6 μm is no greater than 500/mm^2 at the end section of the disc section.

[0034] After studying the damaging behavior of the compressor impeller, the present inventors found that end section of the disc section receives repeatedly occurring high normal stress due to acceleration and deceleration of compressor impeller rotation, and becomes damaged as the coarse intermetallic compounds having a circle-equivalent diameter exceeding 6 μm at the end section of the disc section become a starting point of cracking and develop cracks. After further studies, it was also found that cracking originating from such intermetallic compounds, and propagation of cracks, when present, can be inhibited when the intermetallic compounds having a circle-equivalent diameter exceeding 6 μm at the end section of the disc section has a surface density of no greater than 500/mm^2. It was also found that generation of the coarse intermetallic compounds can be inhibited when the number of intermetallic compounds having a circle-equivalent diameter of 1 to 6 μm at the end section of the disc section is at least 10000/mm^2.

[0035] The generated amounts of intermetallic compounds depend on the composition under typical casting conditions. Here, "under typical casting conditions" means under the cooling rate of low-pressure casting, specifically 0.1 to 200°C/s. Studies of intermetallic compound changes after a post-casting heat treatment revealed that the heat treatment does not have a large effect on the size of the intermetallic compounds generated during casting. By generating large amounts of fine intermetallic compounds during casting, it then becomes possible to inhibit generation of coarse intermetallic compounds in the subsequent heat treatment.

[0036] The reason that the intermetallic compounds having a circle-equivalent diameter of 1 to 6 μm are made to have a surface density of at least 10000/mm^2 is as follows. Intermetallic compounds having a circle-equivalent diameter of less than 1 μm do not affect the compressor impeller strength. When the surface density of the intermetallic compounds having a circle-equivalent diameter of 1 to 6 μm is less than 10000/mm^2, the generation of intermetallic compounds having a circle-equivalent diameter exceeding 6 μm accelerates, and cracking occurs from the generated intermetallic compounds having a circle-equivalent diameter exceeding 6 μm. The upper limit of the surface density is not particularly limited, and is determined by the composition of the Al alloy, and the producing conditions. In the present invention, the upper limit is 30000/mm^2.

[0037] The reason that intermetallic compounds having a circle-equivalent diameter exceeding 6 μm is made to have a surface density of no greater than 500/mm^2 is as follows. Intermetallic compounds having a circle-equivalent diameter exceeding 6 μm are of interest for the reason described above. When the surface density exceeds 500/mm^2, cracking propagates as the distances between the intermetallic compounds become shorter. The lower limit of the surface density is not particularly limited, and depends on the composition of the Al alloy, and the producing conditions. In the present invention, the lower limit is preferably 100/mm^2, most preferably 0/mm^2.

[0038] Examples of the intermetallic compounds generated in the present invention include Al-Fe-Ni-Cu, Al-Fe-Cu-Ni-Mg, Al-Cu-Mg, Al-Cu, Al-Cu-Mg-Si, Al-Cu-Fe, Al-Ni, Al-Mg, and Mg-Si intermetallic compounds. The circle equivalent size of the generated intermetallic compounds has a distribution in a range of from 0.1 to 20.0 μm, though it depends on the composition of the Al alloy, and the producing conditions. As used herein, "circle equivalent size" means "circle equivalent diameter."

E. Controlling Amounts of Refining Agent Components in End Section of Disc Section

[0039] Controlling the size of primary phase aluminum crystal grains is important in controlling the distribution of the intermetallic compounds. This is because the intermetallic compounds are generated at the grain boundary of primary phase aluminum crystal grains. Factors that are important in controlling the size of primary phase aluminum crystal grains are amounts of the refining agent components, and the cooling rate which will be described later.

[0040] The appropriate amounts of the Ti and B components in the end section of the disc section are 0.005 to 0.175%

for Ti, and 0.001 to 0.035% for B. In order to achieve these refining agent contents, a refining agent comprised of Al, Ti, and B is added in the molten metal preparation step to make the amounts of the Ti and B components 0.01 to 0.35% and 0.002 to 0.070%, respectively, in the aluminum alloy molten metal after the molten metal preparation step. The product-shape space configured from the plaster mold and the chill is formed by vertically disposing these members so that the chill is higher in position than the plaster mold having a molten metal inlet at the bottom. The prepared Al alloy molten metal is poured into the space through the molten metal inlet. The molten metal is poured into the space at a pour rate of 0.12 to 1.00m/s at the molten metal inlet. The casting step of pressure casting the Al alloy casting by injecting the prepared molten metal into the space is adapted to satisfy the foregoing requirements.

[0041] One of the reasons for specifying the foregoing requirements is that only a section of the refining agent amount in the molten metal preparation step reaches the end section of the disc section under the effect of the molten metal flow inside the space. The present inventors have confirmed that this is due to the refining agent particles failing to follow the moving molten metal during pressure casting in accordance with the law of inertia. The following describes this in detail.

[0042] The refining agent comprised of Al, Ti, and B is added in the molten metal preparation step. When the amount of the Ti component is less than 0.01%, and/or the amount of the B component is less than 0.002% in the aluminum alloy molten metal after the molten metal preparation step, the primary phase aluminum crystal grains coarsen, which, in turn, coarsens the intermetallic compounds at the grain boundary to lower the strength of the Al alloy material. When the amount of the Ti component exceeds 0.35%, and/or the amount of the B component exceeds 0.070% in the aluminum alloy molten metal after the molten metal preparation step, coarse TiB_2 aggregates are generated, and become a starting point of fracture. The amounts of the Ti and B components in the aluminum alloy molten metal after adding the refining agent in the molten metal preparation step are therefore 0.01 to 0.35% for Ti, and 0.002 to 0.070% for B.

[0043] The product-shape space configured from the plaster mold and the chill is described below. As shown in FIG. 3, the product-shape space 10 configured from a plaster mold 7 and a chill 6 is formed by vertically disposing these members so that the chill 6 is higher in position than the plaster mold 7. A molten metal inlet 8 for pouring molten metal into the space 10 is provided at the bottom on the plaster mold 7 side. Molten metal is charged into the space 10 by being poured into the space, from the bottom to the top of the figure, through the molten metal inlet 8 along the molten metal pour direction 9.

[0044] Without the space 10 configured as above, balancing during high-speed rotations of the compressor impeller suffers as a result of the nonuniform solidification occurring in the circumferential direction of the compressor impeller, and operation of the device becomes limited as the casting machine becomes complex. For example, as shown FIG. 4, when the plaster mold 7 and the chill 6 are horizontally disposed to form the product-shape space 10 configured from these members, the molten metal is charged into the space 10 by being laterally poured into the space 10, from the right to left in the figure, through the molten metal inlet 8 along the molten metal pour direction 9. In this case, the molten metal poured into the space 10 solidifies as it fills the space 10 from the bottom to the top. The molten metal thus solidifies earlier in the circumferential section at the bottom side of the space 10 than in the upper circumferential section in the circumferential direction of the compressor impeller, and fails to produce a uniform solid state in the circumferential direction. The nonuniform solidification in the circumferential direction of the compressor impeller causes a bend in the shaft section, and produces an imbalance during high-speed rotations.

[0045] On the other hand, for example, as shown in FIG. 5, when the product-shape space 10 configured from the plaster mold 7 and the chill 6 is formed by vertically disposing these members so that the plaster mold 7 is higher in position than the chill 6, the molten metal is charged into the space 10 by being poured into the space 10 through the molten metal inlet 8 along the molten metal pour direction 9 from the top to the bottom of the figure. This complicates the piping of the pipes (stalks) used to charge the molten metal in a furnace into the space 10. Specifically, a stalk needs to be piped to create a vertically downward flow of the molten metal vertically discharged upward from inside of a furnace in pressure casting. This inevitably complicates the stalk piping. Further, because the stalk distance increases, a lowered molten metal temperature or an increased pressure loss of the molten metal flow makes the casting difficult.

[0046] When the product-shape space 10 is formed by disposing the plaster mold 7 and the chill 6 as shown in FIG. 3, the nonuniform solid state in circumferential direction seen in the configuration of FIG. 4, or the complex stalks, decrease of molten metal temperature, and increase in the pressure loss of the molten metal flow seen in the configuration of FIG. 5 do not occur.

[0047] The pour rate of molten metal at the molten metal inlet is an important factor in controlling the refining agent content at the disc section end. As described above, the content of the refining agent particles comprised of Ti and B reaching the end section of the disc section decreases from the content of refining agent particles in the molten metal preparation step. This is due to the refining agent particles failing to follow the moving molten metal during pressure casting in accordance with the law of inertia. When the pour rate of molten metal at the molten metal inlet exceeds 1.00 m/s, the excessively fast pour rate of the molten metal makes it even more difficult for the inertial movement of the refining agent particles to follow the pour rate of the molten metal, and the refining agent particles cannot reach the end section of the disc section in amounts that are necessary for grain refining. On the other hand, when the pour rate of the molten metal at the molten metal inlet is less than 0.12 m/s, the excessively slow pour rate of the molten metal increases the time it takes for the molten metal to reach the plaster mold through the stalk. This lowers the molten metal temperature, and causes solidification failure. The pour rate of molten metal at the molten metal inlet is preferably 0.20 to 0.85 m/s.

F. Controlling Cooling Rate at End Section of Disc Section

[0048] In order to obtain the intermetallic compound distribution above, the cooling rate at the end section of the disc section of the compressor wheel needs to be controlled. Specifically, the molten metal temperature is controlled between 720 and 780°C, and the temperature of the chill (chill plate) disposed on the surface that contacts the compressor disc surface is controlled between 100 and 250°C. The cooling rate at the end section of the disc section is adjusted in a preferred range of 0.1 to 200°C/s by specifying the molten metal temperature and the chill temperature as above. When the cooling rate is less than 0.1°C/s, the primary phase aluminum crystal grain coarsens, which coarsens the intermetallic compounds generated at the grain boundary. Further, shrinkage cavity occurs, and productivity suffers as the cooling rate decreases. On the other hand, when the cooling rate is above 200°C/s, early solidification occurs inside the product-shape space. This causes misruns, and the intended product shape cannot be ensured. The cooling rate at the end section of the disc section is further preferably 3 to 150°C/s.

[0049] When the molten metal temperature is below 720°C, the injected molten metal solidifies early inside the product-shape space. This causes misruns, and the intended product shape cannot be ensured. On the other hand, with a molten metal temperature above 780°C, the molten metal progressively undergoes oxidation, and increased porosity numbers due to hydrogen gas absorption, and increased oxides impair the quality of the molten metal. This makes it difficult to ensure product strength.

[0050] When the chill temperature is below 100°C, solidification proceeds at an excessive rate, and misruns occur. On the other hand, when the chill temperature is above 250°C, solidification from the chill slows down, and the slow cooling rate coarsens the primary phase aluminum crystal grains, which coarsens the intermetallic compounds generated at the grain boundary. Further, a chill temperature above 250°C causes burr defects, which occur when the molten metal enters between the plaster mold and the chill.

[0051] In the present invention, it is preferable to control the preheating temperature of the plaster mold between 200 and 350°C, though the temperature is not particularly limited. When the preheating temperature of the plaster mold is less than 200°C, solidification takes place before the charged molten metal fills the mold end. This causes misruns, and the intended product shape cannot be ensured. On the other hand, when the preheating temperature of the plaster mold exceeds 350°C, the solidification slows down inside the plaster mold, and a shrinkage cavity failure occurs.

[0052] The chill material is preferably copper or a copper alloy, which has high thermal conductivity. However, materials such as steel, and stainless steel also may be used. Preferably, the chill temperature is adjusted by using a mechanism by which superheating in the casting is reduced with a coolant such as water passed inside the chill.

G. Producing Method

[0053] A method for producing the Al alloy cast impeller for compressors according to the present invention is described below. The producing method includes a molten metal adjusting step, a casting step, and a heat treatment step.

Molten Metal Preparation Step:

[0054] Each component element is melted under heat to make the Al alloy composition above by using an ordinary method, and molten metal processes such as processing of dehydrogenated gas, and removal of inclusions are performed. The temperature is adjusted to make the final molten metal temperature 720 to 780°C. The hydrogen gas amount in the molten metal is also adjusted. A rotary gas blower is used to adjust the hydrogen gas amount in the molten metal. However, the method is not limited to this.

Casting Step:

[0055] In the casting step, the molten metal adjusted to 720 to 780°C is cast into a shape of the compressor impeller by pressure casting using a plaster mold. As described above, the temperature of the chill disposed on the surface that contacts the disc surface is adjusted to 100°C to 250°C. As for the product-shape space configured from the plaster mold and the chill, the product-shape space configured from the plaster mold and the chill is formed by vertically disposing these members so that the chill is higher in position than the plaster mold, as shown in FIG. 3. The molten metal inlet through which the molten metal is poured into the space in molten metal pour direction is provided at the bottom on the plaster mold 7 side. The pour rate of the molten metal into the space through the molten metal inlet is adjusted to 0.12 to 1.00 m/s. The Al alloy casting is cast by pressure casting whereby the prepared Al alloy molten metal is injected into the space as above.

Heat Treatment Step:

[0056] The Al alloy casting is subjected to a heat treatment step. The heat treatment step includes a solution treatment step and an aging treatment step. The heat treatment step can effectively take advantage of the solid solution strengthening by Cu; the precipitation strengthening by Cu and Mg; and the dispersion strengthening by the intermetallic compounds formed by Al and Fe and by Al and Ni.

Solution Treatment Step:

[0057] The solution treatment is performed preferably in a temperature range that is 5 to 25°C lower than the solidus temperature. In the preferred Al alloys for use in the present invention, a temperature range of 510 to 530°C represents such a temperature range that is 5 to 25°C lower than the solidus temperature. The risk of melting the second phase of crystal grain boundaries increases, and it becomes difficult to ensure strength at temperatures above the temperature range that is 5 to 25°C lower than the solidus temperature. On the other hand, the elements do not diffuse sufficiently, and the solution treatment becomes insufficient at temperatures below the temperature range that is 5 to 25°C lower than the solidus temperature. Preferably, the solution treatment is performed for at least 2 hours. The elements do not diffuse sufficiently, and the solution treatment becomes insufficient when the solution treatment is less than 2 hours. Considering mass production, the solution treatment by element diffusion is performed for preferably 30 hours or less, though the treatment time is not particularly limited as long as the solution treatment is performed for at least 2 hours.

Aging Treatment:

[0058] The aging treatment involves a heat treatment performed preferably at 180 to 230°C for 3 to 30 hours, more preferably 190 to 210°C for 5 to 20 hours. The precipitation strengthening for improving strength may become insufficient when the process temperature is below 180°C, or when the process time is less than 3 hours. On the other hand, the precipitated phase formed may coarsen (overaging), and may fail to provide a sufficient strengthening effect, and the solid solution strengthening capability of Cu weakens when the process temperature exceeds 230°C, or when the process time exceeds 30 hours.

H. Shape of Compressor Wheel

[0059] The shape and the dimensions of the compressor impeller according to the present invention, and the number of vanes of the compressor impeller are not particularly limited, and the compressor impeller is applicable to many different applications, ranging from large-scale applications such as ships to small-scale applications such as automobiles. Taking a large scale application such as ships as an example, the boss section has a height of 200 to 80 mm, preferably 180 to 100 mm, the disc section has a diameter of 300 to 100 mm, preferably 260 to 120 mm, and the vane sections have a height of 180 to 60 mm, preferably 160 to 90 mm. The thickness at the tip of the vane is 4.0 to 0.4 mm, preferably 3.0 to 0.6 mm. The number of vanes is 30 to 10, preferably 26 to 12. In the case of smaller applications such as automobiles, the boss section has a height of 100 to 20 mm, preferably 90 to 25 mm, the disc section has a diameter of 120 to 25 mm, preferably 100 to 30 mm, and the vane sections have a height of 90 to 5 mm, preferably 80 to 8 mm. The thickness at the tip of the vane is 3.0 to 0.1 mm, preferably 2.0 to 0.2 mm. The number of vanes is 20 to 4, preferably 18 to 6.

Examples

[0060] The present invention is described below in greater detail using Examples.

First Example (Present Examples 1 to 7, and Comparative Examples 1 to 20)

[0061] Each Al alloy of the composition shown under the column "Components" in Table 1 was melted by using a common molten metal process, and the molten metal was adjusted to the temperature shown in Table 1 by a molten metal preparation step. In the molten metal preparation step, 150 kg of the Al alloy of the composition shown under the column "Components" in Table 1 was melted to obtain a molten metal. Thereafter, a blow degassing process was performed by blowing argon gas into the molten metal for 30 minutes with a rotary gas blower operated at a rotation speed of 400 rpm, and a gas flow rate of 2.5 Nm^3/h. The whole molten metal was held still for 1 hour to remove the slag. After the slag removal, a refining agent was added to the molten metal in the metal preparation step to make the amounts of Ti and B components as shown under the column "Amounts of refining agent components after molten metal preparation" in Table 1.

[Table 1]

No.	Components (mass%)					Casting conditions					Amounts of refining agent components after molten metal preparation (mass%)		Heat treatment conditions	
	Cu	Mg	Ni	Fe	Al	Molten metal temp. (°C)	Chill temp. (°C)	Plaster mold temp. (°C)	Pour rate of molten metal into mold (m/s)	Molten metal pour direction	Ti	B	Solution treatment temp. × time (°C × hour)	Aging treatment temp. × time (°C × hour)
Present Ex. 1	3.2	2.0	1.9	2.0		760	210	206	0.15	Upward	0.10	0.020		
Present Ex. 2	3.1	1.9	1.4	1.5		780	250	201	0.90	Upward	0.20	0.040		
Present Ex. 3	2.2	1.6	0.8	1.0		760	110	267	0.35	Upward	0.15	0.030		
Present Ex. 4	1.6	1.4	0.6	0.7		740	220	250	0.12	Upward	0.35	0.070		
Present Ex. 5	2.6	1.6	0.8	1.1		750	130	240	1.00	Upward	0.13	0.020		
Present Ex. 6	1.4	1.2	1.2	1.0		720	240	210	0.85	Upward	0.08	0.015		
Present Ex. 7	2.4	1.0	0.5	0.5		740	230	350	0.20	Upward	0.01	0.002		
Com. Ex. 1	2.9	1.7	1.6	1.1		770	260	304	0.45	Upward	0.05	0.010		
Com. Ex. 2	2.0	1.1	1.2	0.9		740	90	341	0.75	Upward	0.27	0.050		
Com. Ex. 3	2.1	1.2	1.4	1.5		710	160	319	0.80	Upward	0.21	0.040		
Com. Ex. 4	2.5	1.3	1.7	1.3		790	200	239	0.90	Upward	0.12	0.020		

(continued)

No.	Components (mass%)					Casting conditions					Amounts of refining agent components after molten metal preparation (mass%)		Heat treatment conditions	
	Cu	Mg	Ni	Fe	Al	Molten metal temp. (°C)	Chill temp. (°C)	Plaster mold temp. (°C)	Pour rate of molten metal into mold (m/s)	Molten metal pour direction	Ti	B	Solution treatment temp. × time (°C × hour)	Aging treatment temp. × time (°C × hour)
Com. Ex. 5	1.3	1.9	1.4	1.2	Remainder excluding Ti and B	730	180	312	0.45	Upward	0.07	0.012	530 × 8	200 × 20
Com. Ex. 6	2.8	0.9	1.1	1.4		750	190	330	0.30	Upward	0.15	0.030		
Com. Ex. 7	3.0	1.4	1.4	0.4		760	170	230	0.20	Upward	0.23	0.045		
Com. Ex. 8	2.9	1.3	0.4	1.7		770	200	235	0.30	Upward	0.18	0.035		
Com. Ex. 9	2.6	1.4	0.9	1.2		765	210	197	0.50	Upward	0.01	0.001		
Com. Ex. 10	3.3	1.8	1.1	1.2		740	185	316	0.80	Upward	0.23	0.045		
Com. Ex. 11	2.5	2.1	0.9	1.1		750	150	231	0.90	Upward	0.19	0.036		
Com. Ex. 12	2.9	1.5	1.4	2.1		730	225	279	0.30	Upward	0.26	0.050		
Com. Ex. 13	2.2	1.6	2.1	1.2		760	190	289	0.80	Upward	0.18	0.036		
Com. Ex. 14	2.9	1.3	1.2	1.2		740	210	366	1.20	Upward	0.38	0.075		
Com. Ex. 15	2.8	1.1	1.7	0.9		750	220	260	1.50	Upward	0.02	0.003		

(continued)

No.	Components (mass%)					Casting conditions					Amounts of refining agent components after molten metal preparation (mass%)		Heat treatment conditions	
	Cu	Mg	Ni	Fe	Al	Molten metal temp. (°C)	Chill temp. (°C)	Plaster mold temp. (°C)	Pour rate of molten metal into mold (m/s)	Molten metal pour direction	Ti	B	Solution treatment temp. × time (°C × hour)	Aging treatment temp. × time (°C × hour)
Com. Ex. 16	3.0	1.6	0.8	1.0		740	190	296	0.90	Upward	0.37	0.072		
Com. Ex. 17	2.0	1.1	1.2	0.9		760	180	244	0.11	Upward	0.27	0.050		
Com. Ex. 18	2.9	1.3	1.7	1.2		730	240	231	1.01	Upward	0.23	0.015		
Com. Ex. 19	2.5	1.3	1.1	1.2		740	170	348	0.75	Lateral	0.26	0.050		
Com. Ex. 20	3.1	1.6	0.9	1.1		770	200	256	0.20	Downward	0.20	0.040		

[0062] The Al alloy molten metal prepared in the molten metal preparation step was then subjected to low-pressure casting to produce an Al alloy casting, whereby the molten metal was pressure injected into a predetermined space configured from a plaster mold that had been adjusted to 250°C, and a copper chill that had been adjusted to the temperature shown in Table 1 and disposed on the surface that contacts the impeller disc surface. Here, the molten metal was injected through the molten metal inlet provided at the bottom of the lower plaster mold (FIG. 3), the side of the side plaster mold (FIG. 4), or the top of the upper plaster mold (FIG. 5). The Al alloy casting was intended as a turbocharger compressor impeller for cars, and had a shape with a disc section measuring 40 mm in diameter, a boss section measuring 40 mm in height, vane sections measuring 35 mm in height and having 12 vanes that were 0.3 mm in thickness at the vane tip. The molten metal was pressure injected into the space configured from the plaster mold and the chill in the directions shown in Table 1 through the molten metal inlet at the pour rates shown in Table 1, and the pressure was maintained until the whole Al alloy casting solidified.

[0063] The Al alloy casting was removed from the plaster mold, and subjected to a solution treatment at 530°C for 8 hours, and thereafter to an aging treatment at 200°C for 20 hours. In this way, a sample Al alloy cast impeller for compressors was prepared.

[0064] The samples produced in the manner described above were each evaluated with respect to the surface density of intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section, the surface density of intermetallic compounds having a circle equivalent size of more than 6 μm at the end section of the disc section, amounts of the refining agent components (Ti, B) at the end section of the disc section, amounts of the refining agent components (Ti, B) in sections other than the end section of the disc section, high-temperature characteristics (durability test evaluation), and productivity (casting yield evaluation), as follows.

1. Surface Density Measurement of Intermetallic Compounds

[0065] The samples were cut along the central axis to determine the size and the surface density of intermetallic compounds at the end section of the disc section. FIG. 2 shows a cross section on one side of the central axis 5 of the compressor impeller. The end section 31 of the disc section in the cross section was cut and polished, and imaged with an optical microscope at 100 × magnification. Here, the end section 31 of the disc section represents 20% of the disc section from the circumference of the disc section of the compressor impeller to the central axis 5 along the radial direction. The image was fed to an image analyzer, and measured for the surface density of intermetallic compounds having a circle equivalent size of 1 to 6 μm, and the surface density of intermetallic compounds having a circle equivalent size of more than 6 μm. The measurements were made at arbitrarily selected 10 measurement points, and the arithmetic mean value was calculated as surface density. Each measurement point had a view area of 1 mm^2. The results are presented in Table 2.

[Table 2]

No.	Intermetallic compounds at end section of disc section		Amounts of refining agent components at end section of disc section		Amounts of refining agent components in sections other than end section of disc section		High-temperature characteristics	Productivity			
	Surface density of intermetallic compounds having circle equivalent size of 1 to 6 μm (Number of intermetallic compounds/mm^2)	Surface density of intermetallic compounds having circle equivalent size of more than 6 μm (Number of intermetallic compounds/mm^2)	Ti content (mass%)	B content (mass%)	Ti content (mass%)	B content (mass%)	Durability test evaluation	Casting yield evaluation	Percentage of products with internal defects (%)	Percentage of products with misrun defects (%)	Percentage of products with shrinkage cavity defects (%)
Present Ex. 1	14546	250	0.047	0.009	0.10	0.019	Good	Good	1.0	0.3	0.8
Present Ex. 2	15460	393	0.029	0.006	0.13	0.026	Good	Good	2.2	0.1	1.2
Present Ex. 3	29970	101	0.060	0.012	0.14	0.027	Good	Good	1.8	0.2	0.4
Present Ex. 4	12318	469	0.175	0.035	0.35	0.070	Good	Good	1.1	1.0	0.6
Present Ex. 5	14948	390	0.008	0.002	0.06	0.012	Good	Good	1.4	0.4	1.6
Present Ex. 6	15727	230	0.012	0.002	0.05	0.010	Good	Acceptable	2.5	2.1	1.8
Present Ex. 7	22814	110	0.005	0.001	0.01	0.002	Good	Acceptable	2.1	0.8	3.4
Com. Ex. 1	9386	670	0.017	0.003	0.04	0.008	Poor	Poor	2.8	0.2	9.5
Com. Ex. 2	24385	197	0.052	0.010	0.18	0.035	Good	Poor	4.2	30.4	4.6
Com. Ex. 3	17715	227	0.038	0.008	0.14	0.028	Acceptable	Poor	2.6	38.6	12.2

(continued)

No.	Intermetallic compounds at end section of disc section		Amounts of refining agent components at end section of disc section		Amounts of refining agent components in sections other than end section of disc section		High-temperature characteristics	Productivity			
	Surface density of intermetallic compounds having circle equivalent size of 1 to 6 μm (Number of intermetallic compounds/mm^2)	Surface density of intermetallic compounds having circle equivalent size of more than 6 μm (Number of intermetallic compounds/mm^2)	Ti content (mass%)	B content (mass%)	Ti content (mass%)	B content (mass%)	Durability test evaluation	Casting yield evaluation	Percentage of products with internal defects (%)	Percentage of products with misrun defects (%)	Percentage of products with shrinkage cavity defects (%)
Com. Ex. 4	8659	471	0.012	0.002	0.06	0.012	Poor	Poor	5.5	0.7	20.1
Com. Ex. 5	19094	207	0.018	0.004	0.05	0.010	Good	Poor	1.2	25.1	1.3
Com. Ex. 6	19429	199	0.063	0.013	0.14	0.028	Acceptable	Good	1.6	0.6	1.7
Com. Ex. 7	10934	405	0.104	0.021	0.22	0.043	Acceptable	Good	0.8	0.8	1.8
Com. Ex. 8	11170	397	0.072	0.014	0.16	0.032	Poor	Good	1.0	0.7	2.6
Com. Ex. 9	7472	577	0.004	0.000	0.00	0.001	Poor	Poor	3.5	36.0	1.0
Com. Ex. 10	12773	356	0.044	0.009	0.16	0.031	Poor	Acceptable	2.1	2.3	1.1

No.	Intermetallic compounds at end section of disc section		Amounts of refining agent components at end section of disc section		Amounts of refining agent components in sections other than end section of disc section		High-temperature characteristics	Productivity			
	Surface density of intermetallic compounds having circle equivalent size of 1 to 6 μm (Number of intermetallic compounds/mm²)	Surface density of intermetallic compounds having circle equivalent size of more than 6 μm (Number of intermetallic compounds/mm²)	Ti content (mass%)	B content (mass%)	Ti content (mass%)	B content (mass%)	Durability test evaluation	Casting yield evaluation	Percentage of products with internal defects (%)	Percentage of products with misrun defects (%)	Percentage of products with shrinkage cavity defects (%)
Com. Ex. 11	16344	247	0.016	0.003	0.11	0.021	Good	Poor	1.6	47.1	7.1
Com. Ex. 12	40896	713	0.101	0.020	0.23	0.045	Acceptable	Acceptable	4.1	2.4	2.5
Com. Ex. 13	31311	565	0.034	0.007	0.12	0.025	Acceptable	Acceptable	2.6	2.3	3.3
Com. Ex. 14	12130	360	0.150	0.030	0.36	0.072	Poor	Poor	46.9	0.3	0.2
Com. Ex. 15	6386	583	0.000	0.000	0.01	0.002	Poor	Poor	50.1	0.2	0.2
Com. Ex. 16	27598	173	0.180	0.036	0.36	0.071	Poor	Good	1.3	0.1	1.4
Com. Ex. 17	14208	328	0.128	0.026	0.25	0.051	Acceptable	Poor	2.3	37.3	2.2
Com. Ex. 18	14625	271	0.004	0.001	0.04	0.008	Acceptable	Poor	39.3	3.7	0.2
Com. Ex. 19	11412	363	0.051	0.010	0.18	0.035	Poor	Poor	21.6	0.3	1.4
Com. Ex. 20	26824	191	0.086	0.017	0.19	0.037	Acceptable	Poor	1.9	11.6	1.8

2. Measurement of Refining Agent Component Amounts

[0066] The refining agent content was measured at the end section of the disc section, and in sections other than the end section of the disc section. 5 g of sample was collected for analysis from the end section 31 of the disc section, the boss section 2, the vane section 4, and the disc section 32 other than the end section shown in FIG. 2, and the Ti and B contents were analyzed using an ICP emission spectrometer. The amounts of the refining agent components in sections other than the end section of the disc section given in Table 2 were calculated as mean values of the refining agent component amounts determined at the boss section, the vane sections, and the disc section other than the end section. The results are presented in Table 2.

3. High Temperature Characteristics

[0067] High-temperature fatigue strength was evaluated in a high-temperature durability test (turbo assembly; 150,000 rpm × 200 h, outlet temperature 200°C). The results are presented in Table 2. The durability test evaluation results in Table 2 followed the following notation.

Poor: Fractured

[0068]

Acceptable: No fracture, but cracking is occurred
Good: No fracture or cracking, and the sample remained intact

[0069] The parentheses following Acceptable and Poor indicate the location of the occurred cracks and fractures.

4. Casting Yield Evaluation

[0070] Casting yield was evaluated for 1,000 samples produced in each Example. Each sample was tested for external appearance failure due to misruns and shrinkage cavity failure, and internal failure based on the detected internal blow holes in an X-ray examination. The proportions (%) of samples with misruns, shrinkage cavity failure, and internal failure in all samples were determined. The proportion (%) of non-defective products was then determined by subtracting the sum of the proportions of these defective products from the total 100%. The results are presented in Table 2.

Poor: The proportion of non-defective products is less than 90% (worse than in existing products)
Acceptable: The proportion of non-defective products is 90% or more and less than 95% (same as in existing products)
Good: The proportion of non-defective products is 95% to 100% (great improvement over existing products)

[0071] In Present Examples 1 to 7, the surface density of intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section, the surface density of intermetallic compounds having a circle equivalent size of more than 6 μm at the end section of the disc section, and the refining agent contents in the end section of the disc section and in sections other than the end section fell in the specified ranges, and because of this, the high-temperature characteristics, and the casting yield were both desirable.

[0072] In Comparative Example 1, with a high chill temperature, the surface density was low in the intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section, and was high in the intermetallic compounds having a circle equivalent size of more than 6 μm at the end section of the disc section. Because of this, fracture occurred at the end section of the disc section, and the sample was inferior in terms of high-temperature characteristics. Further, multiple shrinkage cavity failures occurred at the boss section, and the casting yield was considerably poor.

[0073] In Comparative Example 2, with a low chill temperature, multiple defects occurred in the appearance of the disc section due to misruns, and the casting yield was poor.

[0074] In Comparative Example 3, there was a decrease in the molten metal temperature. As a result, multiple defects occurred in the appearance of the vane sections due to misruns and shrinkage cavity, and the casting yield was considerably poor. Further, cracking occurred in the vane sections, and the high-temperature characteristics were poor.

[0075] In Comparative Example 4, the molten metal temperature was high, and the cooling rate was low. The surface density was therefore low in the intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section. As a result, multiple defects occurred in the appearance of the boss section due to shrinkage cavity, and the casting yield was considerably poor. Further, cracking occurred in the end section of the disc section, and the high-temperature characteristics were poor.

[0076] In Comparative Example 5, with the low Cu content, the high-temperature characteristics were desirable. However, there was a high incidence of misruns in the vane sections, and the casting yield was poor.

[0077] In Comparative Example 6, with the low Mg content, cracking occurred in the boss section, and the high-temperature characteristics were poor.

[0078] In Comparative Example 7, with the low Fe content, cracking occurred in the vane sections, and the high-temperature characteristics were poor.

[0079] In Comparative Example 8, with the low Ni content, fracture occurred in the disc section, and the high-temperature characteristics were poor.

[0080] In Comparative Example 9, with the small amount of refining agent component (B) in the molten metal preparation, the amounts of the Ti and B components became small in the end section of the disc section, and in sections other than the end section of the disc section. The grain refining effect was therefore insufficient, and the surface density was low in the intermetallic compounds having a circle equivalent size of 1 to 6 μm in the end section of the disc section, and was high in the intermetallic compounds having a circle equivalent size of more than 6 μm. As a result, multiple defects occurred in the appearance of the vane sections due to misruns, and the casting yield was considerably poor. Further, fracture occurred in the disc section, and the high-temperature characteristics were poor.

[0081] In Comparative Example 10, with the high Cu content, fracture occurred in the disc section, and high-temperature characteristics were poor.

[0082] In Comparative Example 11, with the high Mg content, multiple misruns occurred in the vane sections, and the casting yield was poor, though the high-temperature characteristics were desirable.

[0083] In Comparative Example 12, with the high Fe content, the intermetallic compounds having a circle equivalent size of more than 6 μm had a high surface density. Because of this, cracking occurred in the disc section, and the high-temperature characteristics were poor.

[0084] In Comparative Example 13, with the high Ni content, the intermetallic compounds having a circle equivalent size of more than 6 μm had a high surface density. Because of this, cracking occurred in the disc section, and the high-temperature characteristics were poor.

[0085] In Comparative Example 14, the amounts of the Ti and B components were high in sections other than the end section of the disc section because of the large amounts of the Ti and B components in the molten metal preparation, and the high pour rate of molten metal into the space mold (here and below, "space mold" refers to the product-shape space configured from the plaster mold and the chill). Because of this, fracture occurred in the boss section, and the high-temperature characteristics were poor. There was also a disturbed molten metal flow in the space mold, and the casting yield was considerably poor because of multiple internal failures.

[0086] In Comparative Example 15, the amounts of the Ti and B components in the end section of the disc section were small (0%) because of the high pour rate of molten metal into the space mold, though the amounts of the Ti and B components in the molten metal preparation were in the specified ranges. Because of this, the grain refining effect was insufficient, and the surface density was low in the intermetallic compounds having a circle equivalent size of 1 to 6 μm in the end section of the disc section, and was high in the intermetallic compounds having a circle equivalent size of more than 6 μm. As a result, fracture occurred in the disc section, and the high-temperature characteristics were poor. There was also a disturbed molten metal flow in the space mold, and the casting yield was considerably poor because of multiple internal failures.

[0087] In Comparative Example 16, because of the large amounts of the Ti and B components in the molten metal preparation, the amounts of the Ti and B components were large in the end section of the disc section, and in sections other than the end section of the disc section. This caused aggregation of refining agent particles. Further, fracture occurred in the disc section, and the high-temperature characteristics were poor.

[0088] In Comparative Example 17, because of the slow pour rate of molten metal into the plaster mold, the molten metal temperature decreased in the process of delivering the molten metal to the plaster mold. This caused multiple failures in the appearance of the vane sections due to misruns, and the casting yield was considerably poor. Further, cracking occurred in the vane sections, and the high-temperature characteristics were poor.

[0089] In Comparative Example 18, because of the high pour rate of molten metal into the plaster mold, the inertial movement of the refining agent particles had difficulties following the pour rate of the molten metal. Because of this, the Ti content was low in the end section of the disc section, and the refining agent particles failed to reach the end section of the disc section in sufficient amounts. Refining of crystal grains therefore did not take place, and coarse intermetallic compounds were created. This caused cracking in the end section of the disc section, and the high-temperature characteristics were poor. There was also a disturbed molten metal flow in the space mold, and the casting yield was considerably poor because of multiple internal failures.

[0090] In Comparative Example 19, because of the lateral pour direction of molten metal into the space mold, nonuniform solidification occurred in the circumferential direction of the compressor impeller. This caused cracking in the boss section due to an axial runout, and the high-temperature characteristics were poor. Further, because the molten metal was nonuniformly charged into the space mold, multiple internal failures occurred, and the casting yield was considerably poor.

[0091] In Comparative Example 20, because of the downward pour direction of molten metal into the space mold, the molten metal temperature decreased in the process of delivering the molten metal to the plaster mold. This caused multiple failures in the appearance of the disc section due to misruns, and the casting yield was considerably poor. Further, cracking occurred in the disc section, and the high-temperature characteristics were poor.

Second Example (Present Examples 8 to 18, and Comparative Examples 21 to 26)

[0092] Each Al alloy of the composition shown under the column "Components" in Table 3 was melted by using a common molten metal process, and the molten metal was adjusted to the temperature shown in Table 3 by a molten metal preparation step. In the molten metal preparation step, 150 kg of the Al alloy of the composition shown under the column "Components" in Table 3 was melted to obtain a molten metal. Thereafter, a blow degassing process was performed by blowing argon gas into the molten metal for 20 minutes with a rotary gas blower operated at a rotation speed of 400 rpm, and a gas flow rate of 2.5 Nm^3/h. The whole molten metal was held still for 1 hour to remove the slag. After the slag removal, a refining agent was added to the molten metal in the metal preparation step to make the amounts of the Ti and B components as shown under the column "Amounts of refining agent components after molten metal preparation" in Table 3.

[Table 3]

No.	Components (mass%)					Casting conditions		Amounts of refining agent components after molten metal preparation (mass%)		Heat treatment conditions	
	Cu	Mg	Ni	Fe	Al	Molten metal temp. (°C)	Chill temp. (°C)	Ti	B	Solution treatment temp. × time (°C × hour)	Aging treatment temp. × time (°C × hour)
Present Ex. 8	2.6	1.6	1.1	0.9	Remainder excluding Ti and B	780	200	0.15	0.03	525 × 5	190 × 16
Present Ex. 9						760	170			515 × 10	190 × 24
Present Ex. 10						770	240			515 × 10	190 × 24
Present Ex. 11						720	150			530 × 4	230 × 9
Present Ex. 12						740	160			505 × 10	230 × 9
Present Ex. 13						740	140			535 × 2	230 × 9
Present Ex. 14						750	210			520 × 8	200 × 2
Present Ex. 15						750	220			520 × 8	200 × 34
Present Ex. 16						740	180			520 × 8	170 × 24
Present Ex. 17						740	200			520 × 8	240 × 24
Present Ex. 18						760	110			525 × 1	200 × 20
Com. Ex. 21						715	200			520 × 6	200 × 16

(continued)

No.	Components (mass%)					Casting conditions		Amounts of refining agent components after molten metal preparation (mass%)		Heat treatment conditions	
	Cu	Mg	Ni	Fe	Al	Molten metal temp. (°C)	Chill temp. (°C)	Ti	B	Solution treatment temp. × time (°C × hour)	Aging treatment temp. × time (°C × hour)
Com. Ex. 22						785	220			520 × 6	200 × 16
Com. Ex. 23						740	90			520 × 6	200 × 16
Com. Ex. 24						750	260			520 × 6	200 × 16
Com. Ex. 25						760	190			None	190 × 24
Com. Ex. 26						740	200			530 × 6	None

[0093] The Al alloy molten metal prepared in the molten metal preparation step was then subjected to low-pressure casting to produce an Al alloy casting, whereby the molten metal was pressure injected into a predetermined space configured from a plaster mold that had been adjusted to 220°C, and a copper chill that had been adjusted to the temperature shown in Table 3 and disposed on the surface that contacts the impeller disc surface. The Al alloy casting was intended as a turbocharger compressor impeller for trucks, and had a shape with a disc section measuring 80 mm in diameter, a boss section measuring 70 mm in height, vane sections measuring 60 mm in height and having 14 vanes that were 0.4 mm in thickness at the vane tip. As shown in FIG. 3, the space configured from the plaster mold and the chill was formed by vertically disposing the plaster mold and the chill so that the chill was higher in position than the plaster mold having a molten metal inlet at the bottom. The pour direction of molten metal was upward. The molten metal was pressure injected into the space at a pour rate of 0.75 m/s at the molten metal inlet, and the pressure was maintained until the whole Al alloy casting solidified.

[0094] The Al alloy casting was removed from the plaster mold, and subjected to a solution treatment under the conditions shown in Table 3, and thereafter an aging treatment under the conditions of Table 3. In this way, a sample Al alloy cast impeller for compressors was prepared.

[0095] The samples produced in the manner described above were each evaluated in the same manner as in First Example with respect to the surface density of intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section, the surface density of intermetallic compounds having a circle equivalent size of more than 6 μm at the end section of the disc section, amounts of the refining agent components (Ti, B) at the end section of the disc section, amounts of the refining agent components (Ti, B) in sections other than the end section of the disc section, high-temperature characteristics (durability test evaluation), and productivity (casting yield evaluation). The results are presented in Table 4. For high-temperature characteristics, samples that scored "Good" in the evaluation of First Example were further tested for 100 hours for a total of 300 hours under the same conditions (turbo assembly, 150000 rpm, output temperature 200°C). Samples that produced desirable results after the 300-hour test were evaluated as "Excellent."

[Table 4]

No.	Intermetallic compounds at end section of disc section		Amounts of refining agent components at end section of disc section		Amounts of refining agent components in sections other than end section of disc section		High-temperature characteristics	Productivity			
	Surface density of intermetallic compounds having circle equivalent size of 1 to 6 μm (Number of intermetallic compounds/mm^2)	Surface density of intermetallic compounds having circle equivalent size of more than 6 μm (Number of intermetallic compounds/mm^2)	Ti content (mass %)	B content (mass %)	Ti content (mass %)	B content (mass %)	Durability test evaluation	Casting yield evaluation	Percentage of products with internal defects (%)	Percentage of products with misrun defects (%)	Percentage of products with shrinkage cavity defects (%)
Present Ex. 8	15576	284	0.048	0.010	0.12	0.025	Excellent	Good	1.3	0.4	1.1
Present Ex. 9	11382	410	0.018	0.004	0.09	0.019	Excellent	Good	1.9	0.2	2.0
Present Ex. 10	12225	387	0.066	0.013	0.14	0.028	Excellent	Good	1.5	0.3	2.3
Present Ex. 11	11837	404	0.011	0.002	0.09	0.017	Excellent	Good	2.3	0.8	1.2
Present Ex. 12	15759	252	0.024	0.005	0.10	0.020	Good	Good	2.1	0.9	1.2
Present Ex. 13	12905	359	0.012	0.002	0.09	0.017	Good	Good	1.3	1.1	1.3
Present Ex. 14	13780	317	0.053	0.011	0.13	0.026	Good	Good	1.8	0.4	2.1
Present Ex. 15	15647	283	0.057	0.011	0.13	0.026	Good	Good	1.6	0.2	2.3
Present Ex. 16	10027	424	0.024	0.005	0.10	0.020	Good	Good	1.5	1.2	1.5
Present Ex. 17	16027	235	0.038	0.008	0.11	0.023	Good	Good	2.1	0.3	2.1

(continued)

No.	Intermetallic compounds at end section of disc section		Amounts of refining agent components at end section of disc section		Amounts of refining agent components in sections other than end section of disc section		High-temperature characteristics	Productivity			
	Surface density of intermetallic compounds having circle equivalent size of 1 to 6 μm (Number of intermetallic compounds/mm^2)	Surface density of intermetallic compounds having circle equivalent size of more than 6 μm (Number of intermetallic compounds/mm^2)	Ti content (mass %)	B content (mass %)	Ti content (mass %)	B content (mass %)	Durability test evaluation	Casting yield evaluation	Percentage of products with internal defects (%)	Percentage of products with misrun defects (%)	Percentage of products with shrinkage cavity defects (%)
Present Ex. 18	15633	303	0.023	0.004	0.09	0.019	Good	Good	1.2	0.6	2.1
Com. Ex. 21	14007	299	0.032	0.006	0.11	0.021	Acceptable	Poor	6.3	26.3	2.3
Com. Ex. 22	6448	766	0.063	0.013	0.14	0.028	Poor	Poor	2.5	1.2	17.3
Com. Ex. 23	13743	332	0.009	0.002	0.08	0.017	Acceptable	Poor	1.5	38.1	4.1
Com. Ex. 24	8335	549	0.075	0.015	0.15	0.030	Poor	Acceptable	2.0	1.1	5.2
Com. Ex. 25	16103	232	0.032	0.006	0.11	0.021	Poor	Good	1.6	0.3	1.5
Com. Ex. 26	16187	231	0.045	0.009	0.12	0.024	Poor	Good	1.1	1.0	1.2

[0096] In Present Examples 8 to 18, the surface density of intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section, the surface density of intermetallic compounds having a circle equivalent size of more than 6 μm at the end section of the disc section, and the amounts of the refining agent components in the end section of the disc section and in sections other than the end section fell in the specified ranges, and because of this, the high-temperature characteristics, and the casting yield were both desirable.

[0097] On the other hand, in Comparative Example 21, the molten metal temperature was low, and the casting yield was poor with multiple failures occurring in the appearance of the vane sections due to misruns. Further, cracking occurred in the vane sections, and the high-temperature characteristics were poor.

[0098] In Comparative Example 22, the molten metal temperature was high, and the cooling rate was low. The surface density was therefore low in the intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section, and was high in the intermetallic compounds having a circle equivalent size of more than 6 μm at the end section of the disc section. This caused multiple failures in the appearance of the boss section due to shrinkage cavity, and the casting yield was considerably poor. Further, fracture occurred in the disc section, and the high-temperature characteristics were poor.

[0099] In Comparative Example 23, with a low chill temperature, multiple misruns occurred in the disc section, and the casting yield was poor. Further, cracking due to misruns occurred in the disc, and the high-temperature characteristics were poor.

[0100] In Comparative Example 24, the chill temperature was high, and the surface density was low in the intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section, and was high in the intermetallic compounds having a circle equivalent size of more than 6 μm at the end section of the disc section. This caused fractures in the disc section, and the high-temperature characteristics were poor.

[0101] The solution treatment step was not performed in Comparative Example 25. The aging treatment step was not performed in Comparative Example 26. As a result, fracture occurred in the disc section, and the high-temperature characteristics were poor.

Third Example (Present Examples 19 to 28, and Comparative Examples 27 to 32)

[0102] Each Al alloy of the composition shown under the column "Components" in Table 5 was melted by using a common molten metal process, and the molten metal was adjusted to the temperature shown in Table 5 by a molten metal preparation step. In the molten metal preparation step, 200 kg of the Al alloy of the composition shown under the column "Components" in Table 5 was melted to obtain a molten metal. Thereafter, a blow degassing process was performed by blowing argon gas into the molten metal for 40 minutes with a rotary gas blower operated at a rotation speed of 400 rpm, and a gas flow rate of 2.5 Nm^3/h. The whole molten metal was held still for 1.5 hours to remove the slag. After the slag removal, a refining agent was added to the molten metal in the metal preparation step to make the amounts of the Ti and B components as shown under the column "Amounts of refining agent components after molten metal preparation" in Table 5.

[Table 5]

No.	Components (mass%)					Casting conditions		Amounts of refining agent components after molten metal preparation (mass%)		Heat treatment conditions	
	Cu	Mg	Ni	Fe	Al	Molten metal temp. (°C)	Chill temp. (°C)	Ti	B	Solution treatment temp. × time (°C × hour)	Aging treatment temp. × time (°C × hour)
Present Ex. 19	2.9	1.7	1.1	1.1	Remainder excluding Ti and B	770	200	0.17	0.02	525 × 6	190 × 22
Present Ex. 20						780	230			510 × 8	190 × 22
Present Ex. 21						760	240			515 × 10	190 × 22
Present Ex. 22						740	190			530 × 4	200 × 12
Present Ex. 23						760	180			505 × 8	200 × 12
Present Ex. 24						730	150			535 × 3	200 × 12
Present Ex. 25						750	220			515 × 8	220 × 2
Present Ex. 26						720	250			515 × 8	220 × 32
Present Ex. 27						730	120			515 × 8	175 × 24
Present Ex. 28						720	100			515 × 8	235 × 20
Com. Ex. 27						785	200			530 × 4	195 × 18
Com. Ex. 28						715	180			530 × 4	195 × 18

(continued)

No.	Components (mass%)					Casting conditions		Amounts of refining agent components after molten metal preparation (mass%)		Heat treatment conditions	
	Cu	Mg	Ni	Fe	Al	Molten metal temp. (°C)	Chill temp. (°C)	Ti	B	Solution treatment temp. × time (°C × hour)	Aging treatment temp. × time (°C × hour)
Com. Ex. 29						740	95			530 × 4	195 × 18
Com. Ex. 30						750	255			530 × 4	195 × 18
Com. Ex. 31						760	180			None	195 × 18
Com. Ex. 32						750	210			530 × 4	None

[0103] The Al alloy molten metal prepared in the molten metal preparation step was then subjected to low-pressure casting to produce an Al alloy casting, whereby the molten metal was pressure injected into a predetermined space configured from a plaster mold that had been adjusted to 220°C, and a copper chill that had been adjusted to the temperature shown in Table 5 and disposed on the surface that contacts the impeller disc surface. The Al alloy casting was intended as a turbocharger compressor impeller for ships, and had a shape with a disc section measuring 150 mm in diameter, a boss section measuring 160 mm in height, vane sections measuring 120 mm in height and having 16 vanes that were 0.6 mm in thickness at the vane tip. As shown in FIG. 3, the space configured from the plaster mold and the chill was formed by vertically disposing the plaster mold and the chill so that the chill was higher in position than the plaster mold having a molten metal inlet at the bottom. The pour direction of molten metal was upward. The molten metal was pressure injected into the space at a pour rate of 0.95 m/s at the molten metal inlet, and the pressure was maintained until the whole Al alloy casting solidified.

[0104] The Al alloy casting was removed from the plaster mold, and subjected to a solution treatment under the conditions shown in Table 5, and thereafter to an aging treatment under the conditions of Table 5. In this way, a sample Al alloy cast impeller for compressors was prepared.

[0105] The samples produced in the manner described above were each evaluated in the same manner as in First Example with respect to the surface density of intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section, the surface density of intermetallic compounds having a circle equivalent size of more than 6 μm at the end section of the disc section, amounts of the refining agent components (Ti, B) at the end section of the disc section, amounts of the refining agent components (Ti, B) in sections other than the end section of the disc section, high-temperature characteristics (durability test evaluation), and productivity (casting yield evaluation). The results are presented in Table 6.

[Table 6]

No.	Intermetallic compounds at end section of disc section		Amounts of refining agent components at end section of disc section		Amounts of refining agent components in sections other than end section of disc section		High-temperature characteristics	Productivity			
	Surface density of intermetallic compounds having circle equivalent size of 1 to 6 μm (Number of intermetallic compounds/mm^2)	Surface density of intermetallic compounds having circle equivalent size of more than 6 μm (Number of intermetallic compounds/mm^2)	Ti content (mass%)	B content (mass%)	Ti content (mass%)	B content (mass%)	Durability test evaluation	Castingyield evaluation	Percentage of products with internal defects (%)	Percentage of products with misrun defects (%)	Percentage of products with shrinkage cavity defects (%)
Present Ex. 19	11759	207	0.022	0.004	0.07	0.014	Excellent	Good	1.6	0.4	1.2
Present Ex. 20	11460	245	0.034	0.007	0.08	0.017	Excellent	Good	1.2	0.3	2.2
Present Ex. 21	11769	236	0.037	0.007	0.09	0.017	Excellent	Good	1.4	0.4	2.1
Present Ex. 22	13697	164	0.022	0.004	0.07	0.014	Excellent	Good	1.9	0.6	1.6
Present Ex. 23	12648	177	0.019	0.004	0.07	0.014	Good	Good	2.5	0.7	1.0
Present Ex. 24	13975	153	0.015	0.003	0.07	0.013	Good	Good	1.5	1.0	1.6
Present Ex. 25	10856	362	0.032	0.006	0.08	0.016	Good	Good	1.1	0.5	2.3
Present Ex. 26	13036	170	0.045	0.009	0.10	0.019	Good	Good	1.8	0.4	2.1
Present Ex. 27	11416	255	0.014	0.003	0.06	0.013	Good	Good	1.4	1.1	2.0
Present Ex. 28	11316	301	0.013	0.003	0.06	0.013	Good	Good	2.2	0.4	1.8

(continued)

No.	Intermetallic compounds at end section of disc section		Amounts of refining agent components at end section of disc section		Amounts of refining agent components in sections other than end section of disc section		High-temperature characteristics	Productivity			
	Surface density of intermetallic compounds having circle equivalent size of 1 to 6 μm (Number of intermetallic compounds/mm²)	Surface density of intermetallic compounds having circle equivalent size of more than 6 μm (Number of intermetallic compounds/mm²)	Ti content (mass%)	B content (mass%)	Ti content (mass%)	B content (mass%)	Durability test evaluation	Casting yield evaluation	Percentage of products with internal defects (%)	Percentage of products with misrun defects (%)	Percentage of products with shrinkage cavity defects (%)
Com. Ex. 27	7235	642	0.022	0.004	0.07	0.014	Poor	Poor	5.5	0.8	31.8
Com. Ex. 28	12243	205	0.015	0.003	0.07	0.013	Acceptable	Poor	3.1	60.1	1.8
Com. Ex. 29	10490	420	0.006	0.001	0.06	0.011	Acceptable	Poor	2.2	41.4	3.7
Com. Ex. 30	9244	524	0.039	0.008	0.09	0.018	Poor	Acceptable	3.0	1.0	4.8
Com. Ex. 31	10506	494	0.018	0.004	0.07	0.014	Poor	Good	1.3	0.4	1.1
Com. Ex. 32	12598	186	0.029	0.006	0.08	0.016	Poor	Good	1.5	0.8	1.0

[0106] In Present Examples 19 to 28, the surface density of intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section, the surface density of intermetallic compounds having a circle equivalent size of more than 6 μm at the end section of the disc section, and the amounts of the refining agent components in the end section of the disc section and in sections other than the end section fell in the specified ranges, and the high-temperature characteristics, and the casting yield were both desirable.

[0107] On the other hand, in Comparative Example 27, the molten metal temperature was high, and the cooling rate was low. The surface density was therefore low in the intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section, and was high in the intermetallic compounds having a circle equivalent size of more than 6 μm at the end section of the disc section. This caused multiple failures in the appearance of the boss section due to shrinkage cavity, and the casting yield was considerably poor. Further, fracture occurred in the disc section, and the high-temperature characteristics were poor.

[0108] In Comparative Example 28, the molten metal temperature was low, and the casting yield was poor with multiple failures occurring in the appearance of the vane sections due to misruns . Further, cracking occurred in the vane sections, and the high-temperature characteristics were poor.

[0109] In Comparative Example 29, with the low chill temperature, multiple misruns occurred in the disc section, and the casting yield was poor. Further, cracking due to misruns occurred in the disc, and the high-temperature characteristics were poor.

[0110] In Comparative Example 30, the chill temperature was high, and the surface density was low in the intermetallic compounds having a circle equivalent size of 1 to 6 μm at the end section of the disc section, and was high in the intermetallic compounds having a circle equivalent size of more than 6 μm at the end section of the disc section. This caused fractures in the disc section, and the high-temperature characteristics were poor.

[0111] The solution treatment step was not performed in Comparative Example 31, and the aging treatment step was not performed in Comparative Example 32. As a result, the disc section was damaged, and high-temperature characteristics was poor.

Industrial Applicability

[0112] The present invention enables inexpensively providing an Al alloy impeller for compressors that has excellent high-temperature strength, and that can stably withstand an increasing of temperatures due to an increasing of number of rotations over extended time periods. The present invention is also industrially very effective in that the output power of an internal combustion engine can be improved by increasing the supercharge ability of a turbocharger.

Reference Signs List

[0113]

1 Compressor impeller
2 Boss section
3 Disc section
31 End section of disc section
32 Disc section excluding end section
4 Vane section
5 Central axis
6 Chill
7 Plaster mold
8 Molten metal inlet
9 Molten metal pour direction
10 Product-shape space configured from plaster mold and chill

Claims

1. A compressor impeller cast from an Al alloy comprising a boss section, a plurality of vane sections and a disc section, wherein the boss section, the plurality of vane sections, and the disc section excluding an end section comprise an Al alloy comprising Cu: 1.4 to 3.2 mass%, Mg: 1.0 to 2.0 mass%, Ni: 0.5 to 2.0 mass%, Fe: 0.5 to 2.0 mass%, Ti: 0.01 to 0.35 mass%, and B: 0.002 to 0.070 mass% and a balance of Al and unavoidable impurities,
wherein the end section of the disc section comprises an Al alloy comprising Cu: 1.4 to 3.2 mass%, Mg: 1.0 to 2.0 mass%, Ni: 0.5 to 2.0 mass%, Fe: 0.5 to 2.0 mass%, Ti: 0.005 to 0.175 mass%, and B: 0.001 to 0.035 mass% and

a balance of Al and unavoidable impurities, and
wherein at least 10000/mm^2 of intermetallic compounds having a circle-equivalent diameter of 1 to 6 μm, and no greater than 500/mm^2 of intermetallic compounds having a circle-equivalent diameter exceeding 6 μm exist in the end section of the disc section.

2. The compressor impeller cast from the Al alloy according to claim 1,
wherein the compressor impeller is for use in large-scale applications including ships, and
wherein the boss section has a height of 200 to 80 mm, the disc section has a diameter of 300 to 100 mm and the vane sections have a height of 180 to 60 mm with 30 to 10 vanes measuring 4.0 to 0.4 mm in thickness at the vane tip.

3. The compressor impeller cast from the Al alloy according to claim 1,
wherein the compressor impeller is for use in small-scale applications including automobiles, and
wherein the boss section has a height of 100 to 20 mm, the disc section has a diameter of 120 to 25 mm, and the vane sections have a height of 90 to 5 mm with 20 to 4 vanes measuring 3.0 to 0.1 mm in thickness at the vane tip.

4. A method for producing a compressor impeller cast from an Al alloy, comprising:

a step of preparing a 720 to 780°C Al alloy molten metal comprising Cu: 1.4 to 3.2 mass%, Mg: 1.0 to 2.0 mass%, Ni: 0.5 to 2.0 mass%, Fe: 0.5 to 2.0 mass% and a balance of Al and unavoidable impurities, and adding a refining agent to an Al alloy molten metal to incorporate Ti: 0.01 to 0.35 mass% and B: 0.002 to 0.070 mass% in the alloy composition;
a step of casting the Al alloy casting by pressure casting whereby the Al alloy molten metal prepared is injected through a molten metal inlet into a space having a product shape configured from a plaster mold having the molten metal inlet at the bottom of the plaster mold, and a 100 to 250°C chill disposed on a surface that contacts with an impeller disc surface, the space being formed by disposing the plaster mold and the chill so that the chill is at upper position and the plaster mold is at below position, and an inflow rate at the molten metal inlet into the space being 0.12 to 1.00 m/s;
a step of solution treating by subjecting the Al alloy casting to a solution treatment; and
a step of aging treating by subjecting the Al alloy casting to aging after the solution treatment.

5. The method for producing the compressor impeller cast from the Al alloy according to claim 4, wherein the end section of the disc section has a cooling rate of 0.1 to 200°C/s in the casting step.

6. The method for producing the compressor impeller cast from the Al alloy according to claim 4 or 5,
wherein the Al alloy casting is heat treated for 2 hours or more at a temperature 5 to 25°C below the solidus temperature of the Al alloy in the solution treatment step, and
wherein the solution-treated Al alloy casting is subjected to a heat treatment at 180 to 230°C for 3 to 30 hours in the aging treatment step.

Patentansprüche

1. Verdichterrad, das aus einer Aluminiumlegierung gegossen ist, mit einem Nabenabschnitt, einer Vielzahl von Flügelabschnitten und einem Scheibenabschnitt,

wobei der Nabenabschnitt, die Vielzahl von Flügelabschnitte und der Scheibenabschnitt mit Ausnahme eines Endabschnitts eine Aluminiumlegierung aufweisen, die Cu: 1,4 bis 3,2 Massen-%, Mg: 1,0 bis 2,0 Massen-%, Ni: 0,5 bis 2,0 Massen-%, Fe: 0,5 bis 2,0 Massen-%, Ti: 0,01 bis 0,35 Massen-%, und B: 0,002 bis 0,070 Massen-% und einen Rest von Aluminium und unvermeidbaren Fremdstoffen aufweist,
wobei der Endabschnitt des Scheibenabschnitts eine Aluminiumlegierung aufweist, die Cu: 1,4 bis 3,2 Massen-%, Mg: 1,0 bis 2,0 Massen-%, Ni: 0,5 bis 2,0 Massen-%, Fe: 0,5 bis 2,0 Massen-%, Ti: 0,005 bis 0,175 Massen-%, und B: 0,001 bis 0,035 Massen-% und einen Rest von Aluminium und unvermeidbaren Fremdstoffen aufweist, und
wobei mindestens 10000/mm^2 von intermetallischen Verbindungen mit einem Kreis-äquivalenten Durchmesser von 1 bis 6 μm und nicht mehr als 500/mm^2 von intermetallischen Verbindungen mit einem Kreis-äquivalenten Durchmesser, der 6 μm übersteigt, in dem Endabschnitt des Scheibenabschnitts vorkommen.

2. Verdichterrad, das aus der Aluminiumlegierung gegossen ist, gemäß Anspruch 1, wobei das Verdichterrad in großtechnischen Anwendungen, die Schiffe enthalten, eingesetzt wird, und wobei der Nabenabschnitt eine Höhe von 200 bis 80 mm hat, der Scheibenabschnitt einen Durchmesser von 300 bis 100 mm hat und die Flügelabschnitte eine Höhe von 180 bis 60 mm haben, mit 30 bis 10 Flügeln, die an der Flügelspitze 4,0 bis 0,4 mm Dicke messen.

3. Verdichterrad, das aus der Aluminiumlegierung gegossen ist, gemäß Anspruch 1,

wobei das Verdichterrad in Kleinanwendungen, die Automobile enthalten, eingesetzt wird, und wobei der Nabenabschnitt eine Höhe von 100 bis 20 mm hat, der Scheibenabschnitt einen Durchmesser von 120 bis 25 mm hat und die Flügelabschnitte eine Höhe von 90 bis 5 mm haben, mit 20 bis 4 Flügeln, die an der Flügelspitze 3,0 bis 0,1 mm Dicke messen.

4. Verfahren zum Herstellen eines Verdichterrads, das aus einer Aluminiumlegierung gegossen ist, das die folgenden Schritte aufweist:

Vorbereiten einer 720 bis 780°C Metallschmelze aus Aluminiumlegierung, die Cu: 1,4 bis 3,2 Massen-%, Mg: 1,0 bis 2,0 Massen-%, Ni: 0,5 bis 2,0 Massen-%, Fe: 0,5 bis 2,0 Massen-%, und einen Rest von Aluminium und unvermeidbaren Fremdstoffen aufweist, und Beimengen eines Veredlungsmittels zu einer Metallschmelze aus Aluminiumlegierung, um Ti: 0,01 bis 0,35 Massen-%, und B: 0,002 bis 0,070 Massen-% in die Legierungszusammensetzung einzuarbeiten;
Gießen des Aluminiumlegierungsguss durch Druckguss, wodurch die vorbereitete Metallschmelze aus Aluminiumlegierung durch einen Metallschmelzeneinlass in einen Raum eingespritzt wird, der eine Produktform hat, die von einer Gipsform mit dem Metallschmelzeneinlass an dem Boden der Gipsform und einer 100 bis 250°C Kokille gestaltet ist, die an einer Fläche angeordnet ist, die eine Flügelradscheibenfläche kontaktiert, wobei der Raum durch Anordnen der Gipsform und der Kokille ausgebildet wird, sodass die Kokille an einer oberen Position und die Gipsform an einer unteren Position ist und eine Einströmrate an dem Metallschmelzeneinlass in den Raum 0,12 bis 1,00 m/s ist;
Lösungsglühen durch Unterziehen des Aluminiumlegierungsgusses einem Lösungsglühen; und
Auslagern durch Unterziehen des Aluminiumlegierungsgusses einer Auslagerung nach dem Lösungsglühen.

5. Verfahren zum Herstellen des Verdichterrads, das aus der Aluminiumlegierung gegossen ist, gemäß Anspruch 4, wobei der Endabschnitt des Scheibenabschnitts eine Abkühlungsgeschwindigkeit von 0,1 bis 200°C/s in dem Gussschritt hat.

6. Verfahren zum Herstellen des Verdichterrads, das aus der Aluminiumlegierung gegossen ist, gemäß Anspruch 4 oder 5,

wobei der Aluminiumlegierungsguss für zwei Stunden oder mehr auf einer Temperatur 5 bis 25°C unterhalb der Solidustemperatur der Aluminiumlegierung in dem Lösungsglühschritt wärmebehandelt wird, und
wobei der lösungsgeglühte Aluminiumlegierungsguss einer Wärmebehandlung auf 180 bis 230°C für 3 bis 30 Stunden in dem Auslagerungsschritt unterzogen wird.

Revendications

1. Rouet de compresseur moulé à partir d'un alliage d'Al comprenant une section de protubérance, une pluralité de sections d'aubes et une section de disque,
dans lequel la section de protubérance, la pluralité de sections d'aubes et la section de disque excluant la section d'extrémité, comprennent un alliage d'Al comprenant du Cu : 1,4 à 3,2 % en masse, du Mg : 1,0 à 2,0 % en masse, du Ni : 0,5 à 2,0 % en masse, du Fe : 0,5 à 2,0 % en masse, du Ti : 0,01 à 0,35 % en masse et du B : 0,002 à 0,070 % en masse, et le reste d'Al et d'impuretés inévitables,
dans lequel la section d'extrémité de la section de disque comprend un alliage d'Al comprenant du Cu : 1,4 à 3,2 % en masse, du Mg : 1,0 à 2,0 % en masse, du Ni : 0,5 à 2,0 % en masse, du Fe : 0,5 à 2,0 % en masse, du Tri : 0,005 à 0,175 % en masse et du B : 0,001 à 0,035 % en masse, et le reste d'Al et d'impuretés inévitables, et
dans lequel au moins 10 000/m^2 de composés intermétalliques ayant un diamètre de cercle équivalent de 1 à 6 μm, et pas plus de 500/m^2 de composés intermétalliques ayant un diamètre de cercle équivalent supérieur à 6 μm sont présents dans la section d'extrémité de la section de disque.

2. Rouet de compresseur moulé à partir d'un alliage d'Al selon la revendication 1,
dans lequel le rouet de compresseur est destiné à être utilisé dans des applications à grande échelle, notamment les bateaux, et
dans lequel la section de protubérance a une hauteur de 200 à 80 mm, la section de disque a un diamètre de 300 à 100 mm et les sections d'aubes ont une hauteur de 180 à 60 mm avec 30 à 10 aubes ayant une épaisseur de 4,0 à 0,4 mm à la pointe de l'aube.

3. Rouet de compresseur moulé à partir d'un alliage d'Al selon la revendication 1,
dans lequel le rouet de compresseur est destiné à être utilisé dans des applications à petite échelle, notamment les voitures, et
dans lequel la section de protubérance a une hauteur de 100 à 20 mm, la section de disque a un diamètre de 120 à 25 mm et les sections d'aubes ont une hauteur de 90 à 5 mm avec 20 à 4 aubes ayant une épaisseur de 3,0 à 0,1 mm à la pointe de l'aube.

4. Procédé de production d'un rouet de compresseur moulé à partir d'un alliage d'Al, comprenant :

une étape de préparation d'un métal fondu d'alliage d'Al à 720 à 780 °C comprenant du Cu : 1,4 à 3,2 % en masse, du Mg : 1,0 à 2,0 % en masse, du Ni : 0,5 à 2,0 % en masse, du Fe : 0,5 à 2,0 % en masse et le reste d'Al et d'impuretés inévitables, et d'ajout d'un agent de raffinage à un métal fondu d'alliage d'Al pour incorporer du Ti : 0,01 à 0, 35 % en masse et du B : 0,002 à 0,070 % en masse dans la composition d'alliage ;
une étape de moulage de l'alliage d'Al par moulage sous pression, le métal fondu d'alliage d'Al préparé étant injecté à travers une entrée de métal fondu dans un espace ayant une forme de produit configurée à partir d'un moule en plâtre ayant l'entrée de métal fondu au fond du moule en plâtre, et un refroidisseur à 100 à 250 °C disposé sur une surface qui est en contact avec une surface de disque du rouet, l'espace étant formé en disposant le moule en plâtre et le refroidisseur de sorte que le refroidisseur soit en position supérieure et le moule en plâtre soit en position inférieure, et une vitesse d'afflux au niveau de l'entrée de métal fondu dans l'espace étant de 0,12 à 1,00 m/s ;
une étape de traitement en solution en soumettant le moulage de l'alliage d'Al à un traitement en solution ; et
une étape de traitement par vieillissement en soumettant le moulage de l'alliage d'Al à un vieillissement après le traitement en solution.

5. Procédé de production du rouet de compresseur moulé à partir d'un alliage d'Al selon la revendication 4, dans lequel la section d'extrémité de la section de disque a une vitesse de refroidissement de 0,1 à 200 °C/s dans l'étape de moulage.

6. Procédé de production du rouet de compresseur moulé à partir d'un alliage d'Al selon la revendication 4 ou 5,
dans lequel le moulage de l'alliage d'Al est traité thermiquement pendant 2 heures ou plus à une température de 5 à 25 °C en dessous de la température solidus de l'alliage d'Al dans l'étape de traitement en solution, et
dans lequel le moulage de l'alliage d'Al traité en solution est soumis à un traitement thermique à 180 à 230 °C pendant 3 à 30 heures dans l'étape de traitement par vieillissement.

[Fig.1]

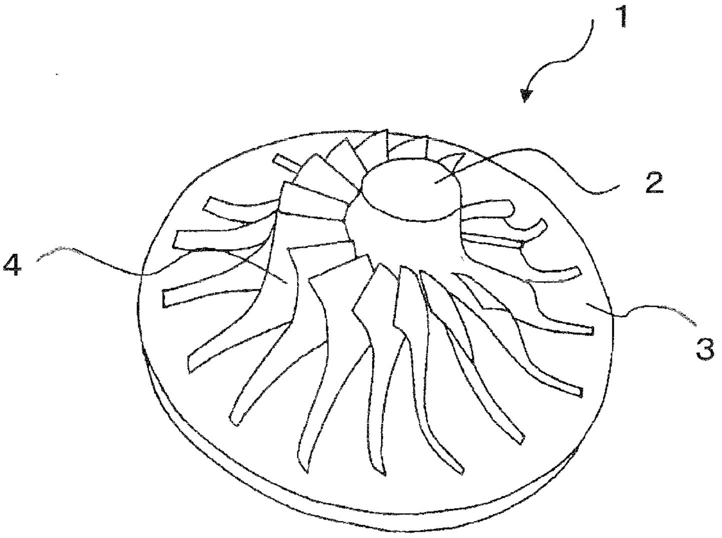

Fig. 1

[Fig.2]

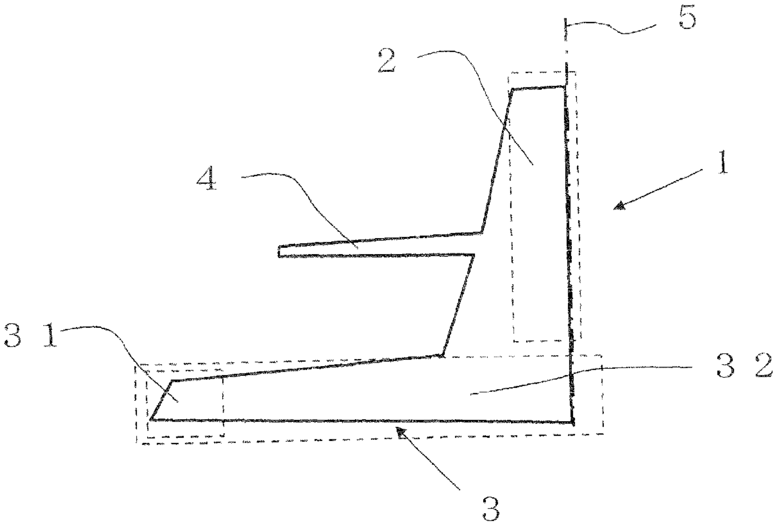

Fig. 2

[Fig.3]

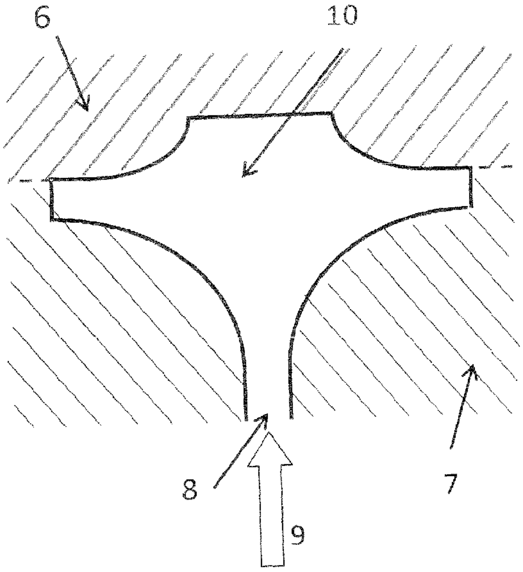

Fig. 3

[Fig.4]

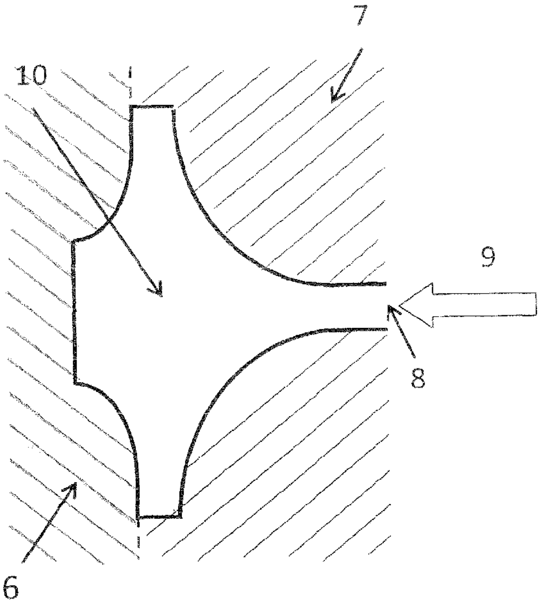

Fig. 4

[Fig.5]

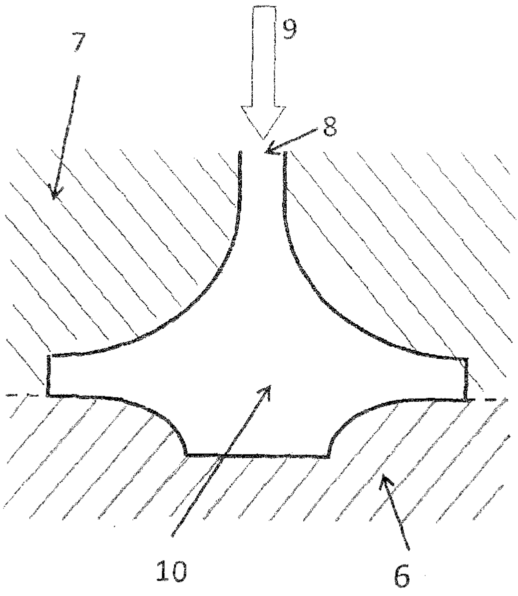

Fig. 5

REFERENCES CITED IN THE DESCRIPTION

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