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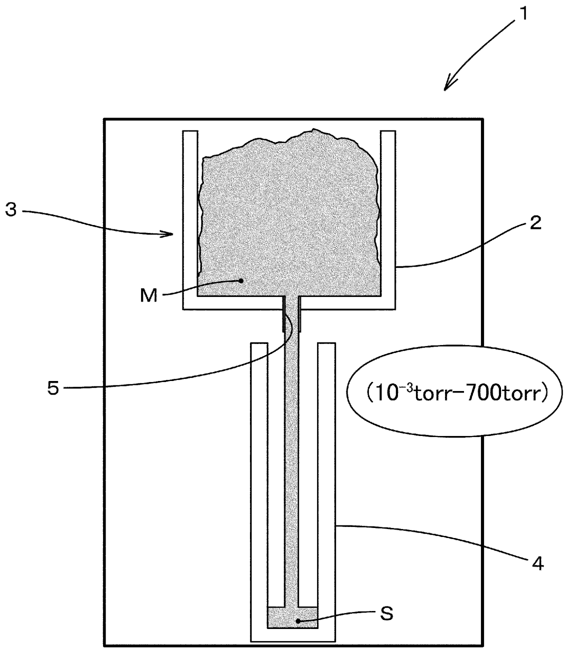
(54) METHOD FOR CASTING TI-AL BASED ALLOY

(57) The objective of the present invention is to improve non-defective product yield by reducing shrinkage cavities inside small-diameter ingots, in a method for casting active metals. In this Ti-Al based alloy casting method for casting an ingot of Ti-Al based alloy by tapping molten metal from a tapping hole (5) provided in a bottom portion of a water-cooled copper crucible (2), in an induction melting furnace (3) employing said crucible (2), into a casting mold (4), the degree of vacuum inside the induction melting furnace (3) when the Ti-Al based alloy is being melted or cast is in a range of 80 to 700 Torr, and the Al concentration in the cast ingot is within ±1.0 mass% of a target value.

FIG.1



EP 3 995 227 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a method for casting a Ti-Al based alloy that can accurately controls a concentration of Al.

BACKGROUND ART

[0002] An induction melting furnace (CCIM: cold crucible induction melting apparatus) using a water-cooled copper crucible is suitable for melting of a Ti-Al based alloy having a high melting point because impurities are hardly mixed into molten metal from a melting atmosphere and a crucible.

[0003] In the induction melting furnace, a raw material can be melted in the furnace regardless of the shape as long as the raw material is smaller than a crucible size, so that a material such as scrap can be effectively used as the raw material.

[0004] Furthermore, since electromagnetic induction that causes heating in the induction melting furnace also generates electromagnetic repulsive force that stirs the molten metal, it is also possible to maintain component homogeneity in the molten metal by stirring by the electromagnetic repulsive force.

[0005] Therefore, casting of a Ti-Al based alloy using an induction melting furnace is an effective method for obtaining a high-quality ingot at a high yield for an ingot of a Ti-Al based alloy which is required to have a high yield due to an expensive raw material cost.

[0006] In general, since a metal has a higher density in a solid state than in a liquid state, a volume of a cast body is reduced during solidification. That is, when shrinkage occurs during solidification, a cavity called a shrinkage cavity is generated as a defect during casting in a portion where a cooling rate is relatively low and solidification is delayed. Such a shrinkage cavity is likely to occur particularly in an axial center portion of an ingot when a small diameter ingot is produced. Therefore, in a case where a metal melted in an induction melting furnace is cast as a small diameter ingot, a technique such as the following Patent Literature 1 has been developed in order to prevent a shrinkage cavity at the time of casting.

[0007] Patent Literature 1 discloses a method for casting an active metal by tapping a molten metal from a tapping hole provided in a bottom portion of a water-cooled copper crucible of an induction melting furnace using the crucible, and casting an ingot of an active metal, in which the ingot has a diameter of 10 mm or more, a ratio (H/D) of a height H of the ingot to a diameter D of the ingot is 1.5 or more, and when casting is performed under casting conditions in which a weight of the molten metal tapped in the casting is 200 kg or less, the casting is performed while setting a temperature of the molten metal during the casting to a temperature higher than a melting point of the active metal and adjusting an opening diameter of the tapping hole to control a casting speed V (mm/sec), which is a speed at which casting proceeds in the mold, to $V \leq 0.1H$ in relation to the height H of the ingot.

[0008] In the technique in Patent Literature 1, it is possible to perform casting close to unidirectional solidification by adjusting the casting speed, and it is possible to realize a yield of up to 86% by preventing the generation of a shrinkage cavity in an active metal such as a Ti-Al based alloy.

CITATION LIST

PATENT LITERATURE

[0009] Patent Literature 1: JP-A-2018-94628

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0010] Incidentally, the technique in Patent Literature 1 focuses on the casting speed as a factor that can be controlled in actual operation, and discloses a very effective method for obtaining a high yield.

[0011] However, in addition to defects in the shape such as a shrinkage cavity, there are also defects in a composition such as a concentration of Al outside a standard range in a criteria for determining the quality of a product in actual manufacturing.

[0012] In this regard, in Patent Literature 1, although the yield is evaluated based on a ratio of the shrinkage cavity in a cast piece, how the concentration of Al in the cast piece changes due to the influence of segregation of Al or the like, in other words, a defect in the composition such as a concentration of Al is not considered at all, and the dissolution condition under which the concentration of Al can be controlled is not found at all.

[0013] That is, the quality of a cast product of a Ti-Al based alloy is required to improve the comprehensive required quality in consideration of not only the shape but also the defect in the composition, and it is important to control the concentration of Al with high accuracy.

[0014] The present invention has been made in view of the above problems, and an object of the present invention is to provide a method for casting a Ti-Al based alloy in which a concentration of Al is controlled with high accuracy, and the comprehensive quality in consideration of not only the shape but also the defect in the composition can be greatly improved.

SOLUTION TO PROBLEM

[0015] In order to solve the above problems, a method for casting a Ti-Al based alloy according to the present invention takes the following technical means.

[0016] That is, the method for casting a Ti-Al based alloy according to the present invention is a method for casting a Ti-Al based alloy including: tapping molten metal from a tapping hole provided in a bottom portion of a water-cooled copper crucible in an induction melting furnace using the crucible; and casting an ingot of Ti-Al based alloy, in which a degree of vacuum in the induction melting furnace at the time of melting or casting the Ti-Al based alloy is set within a range of 80 Torr to 700 Torr, and a concentration of Al of the cast ingot is set within ±1.0 mass% of a target value.

ADVANTAGEOUS EFFECTS OF INVENTION

[0017] According to the method for casting a Ti-Al based alloy of the present invention, it is possible to accurately control the concentration of Al of the cast product, and it is possible to greatly improve the comprehensive quality in consideration of not only a defect in the shape of the cast product but also a defect in the composition.

BRIEF DESCRIPTION OF DRAWINGS

[0018]

[FIG. 1] FIG. 1 is a schematic diagram showing a casting apparatus used in a method for casting a Ti-Al based alloy according to the present embodiment.
[FIG. 2] FIG. 2 is a graph showing a relationship between a degree of vacuum in a furnace and an evaporation rate of Al from a molten metal.
[FIG. 3] FIG. 3 is a graph showing a relationship between the degree of vacuum in the furnace and the number of gas defects.

DESCRIPTION OF EMBODIMENTS

[0019] Hereinafter, embodiments of a method for casting a Ti-Al based alloy according to the present invention will be described in detail with reference to the drawings.

[0020] In the method for casting a Ti-Al based alloy according to the present embodiment, a molten metal M in which a titanium-aluminum based alloy (Ti-Al-based alloy) having an active high melting point is melted is poured into a mold 4 to perform casting, thereby producing a small diameter ingot S (ingot). As the Ti-Al based alloy, various alloys can be considered, and alloys such as a Ti-3Al-2.5V alloy, a Ti-6Al-6V-2Sn-0.5Fe-0.5Cu alloy, a Ti-3Al-10V-2Fe alloy, a Ti-5Al-5V-5Mo-3Cr-0.5Fe alloy, a Ti-3Al-8V-6Cr-4Mo-4Zr alloy, a Ti-3Al-15V-3Cr-3Sn alloy, a Ti-6Al-4V alloy, a Ti-3Al-15Mo-2.7Nb-0.2Si alloy, a Ti-5Al-2Sn-2Zr-4Mo-4Cr alloy, a Ti-6Al-2Sn-4Zr-6Mo alloy, a Ti-6Al-2Sn-4Zr-2Mo alloy, a Ti-6Al-5Zr-0.5Mo-0.25Si alloy, a Ti-5.5Al-3.5Sn-3Zr-1Nb-0.25Mo-0.3Si alloy, and a Ti-5.8Al-4Sn-3.5Zr-0.7Nb-0.5Mo-0.35Si-0.06C alloy are used as alloys used in aircraft parts.

[0021] Hereinafter, a casting apparatus 1 used in the method for casting a Ti-Al based alloy according to the present embodiment will be described.

[0022] As shown in FIG. 1, the casting apparatus 1 used in the casting method of the present embodiment includes an induction melting furnace 3 using a water-cooled copper crucible 2, and a mold 4 into which the molten metal M tapped from a bottom portion of the crucible 2 is injected. The casting apparatus 1 is used for casting the small diameter ingot S of a Ti-Al based alloy by tapping the molten metal M from the bottom portion of the crucible 2 into the mold 4. The induction melting furnace 3, the crucible 2, and the mold 4 disposed below the induction melting furnace 3 and the crucible 2 are housed in a single container (vacuum container), and the small diameter ingot S of a Ti-Al based alloy can be cast while a degree of vacuum in the vacuum container is set to a predetermined degree.

[0023] According to the present invention, gas defects caused by gas involvement or the like inside the ingot can be reduced by controlling the degree of vacuum (atmospheric pressure) in the melting and casting chamber to a predetermined value, and the yield of the cast product can be improved by keeping a concentration of Al of a cast product within a standard range.

[0024] The induction melting furnace 3 used in the casting apparatus 1 of the present embodiment generates an induced current inside a material to be melted to utilize resistive-heating thereof, and is generally called a cold crucible induction melting apparatus. The induction melting furnace 3 melts a Ti-Al based alloy by using the water-cooled copper crucible 2, and is formed of copper without using a refractory that is often used as a material for the crucible 2 in a general melting furnace. Therefore, the casting using the induction melting furnace 3 is less likely to be affected by contamination from the refractory.

[0025] As shown in FIG. 1, the crucible 2 used in the induction melting furnace 3 is formed in a bottomed cylindrical shape opened upward, and can accommodate the melted Ti-Al based alloy therein.

[0026] A wall of the crucible 2 is formed of copper as described above and water-cooled. When the wall of the crucible 2 is formed of such water-cooled copper, the temperature of an inner wall of the crucible 2 does not rise to a predetermined temperature (for example, 250°C) or higher even when the melted Ti-Al based alloy is accommodated in the crucible 2. Specifically, a solidified shell called a scull is formed between an inner peripheral surface of the wall of the crucible 2 and the molten metal when the melted Ti-Al based alloy described above is put into the water-cooled copper crucible 2. Since the scull serves as a crucible, the molten metal is not contaminated from the crucible 2.

[0027] The crucible 2 of the present embodiment is a bottom tapping type, and a tapping hole 5 that can guide the accommodated Ti-Al based alloy downward is formed in the bottom portion of the crucible 2. An opening diameter of the tapping hole 5 can be adjusted, and the amount of the molten metal M guided downward can be adjusted.

The opening diameter of the tapping hole 5 may be adjustable by an electromagnetic method or a mechanical method, or a plurality of valve members having different opening diameters may be prepared in advance, and the opening diameter of the tapping hole 5 may be adjusted by replacing the valve members.

[0028] The mold 4 is formed in a bottomed cylindrical shape opened upward.

[0029] Various inner dimensions of the mold 4 can be considered. Assuming that the diameter of the ingot S is D, the height of the ingot S is H, and the weight of the molten metal M is W, it is preferable that the inner dimension of the mold 4 is set to a size that falls within the following application range.

Diameter D (mm) of ingot: $10 \leq D \leq 150$
Height H (mm) of ingot: $15 \leq H \leq 1600$
Molten metal weight W (kg): $0.2 \leq W \leq 200$

[0030] Next, a procedure for casting an active metal using the induction melting furnace 3 described above, in other words, a method for casting a Ti-Al based alloy will be described.

[0031] In the method for casting a Ti-Al based alloy according to the present embodiment, in the induction melting furnace 3 using the water-cooled copper crucible 2, the molten metal M is tapped from the bottom portion of the crucible 2 to the mold 4 to cast the small diameter ingot S of an active metal. At this time, casting is performed under the casting conditions in which the diameter of the small diameter ingot S to be cast is 10 mm or more, the ratio H/D of the height (H) of the ingot S to the diameter (D) of the ingot S is 1.5 or more, and the weight of the molten metal M tapped by casting is 200 kg or less. In addition, when casting is performed, the tapping hole 5 whose opening diameter can be adjusted is provided in the bottom portion of the crucible 2, the temperature of the molten metal M during casting is made higher than the melting point of the active metal, and the opening diameter of the tapping hole 5 is adjusted, whereby casting is performed while controlling a casting speed V (kg / sec), which is a speed at which casting proceeds in the mold 4, to $V \leq 0.1H$ in relation to the height H of the ingot S, thereby reducing the number of shrinkage cavities inside the ingot S and improving the casting yield. In order to prevent "molten metal clogging" in which the molten metal tapped during casting is clogged and the molten metal does not flow, the temperature of the molten metal M during casting is preferably 20°C or more higher than the melting point of the active metal, and more preferably 40°C or more higher than the melting point of the active metal.

[0032] Incidentally, even when the ingot S of a Ti-Al based alloy is cast at the casting speed V (kg/sec) described above, the concentration of Al is gradually decreased during casting since Al evaporates from the molten metal when the inside of the furnace is in a vacuum state, and finally, there is a possibility that the concentration of Al in a composition of the cast product falls below the standard value of the target concentration of Al. Therefore, in the method for casting a Ti-Al based alloy according to the present embodiment, the degree of vacuum in the induction melting furnace 3 at the time of melting or casting the Ti-Al based alloy is set to be in the range of 80 Torr to 700 Torr and the concentration of Al of the cast product (ingot) is set to be within ±1.0 mass% of a target value when the molten metal M is tapped into the mold 4 from the tapping hole 5 provided in the bottom portion of the water-cooled copper crucible 2 of the induction melting furnace 3 to cast the cast product (ingot) of a Ti-Al based alloy.

[0033] Strictly speaking, the concentration of Al described above differs between a state of being cast into a cast product (solid state) and a state of a molten metal (liquid state). However, in the present embodiment, the concentration of Al is set to be within ±1.0 mass% in both cases of solid and liquid.

[0034] The reason why the degree of vacuum in the induction melting furnace 3 described above is defined within the range of 80 Torr to 700 Torr is as follows.

[0035] That is, in the present embodiment, the weight of the molten metal used for casting is 50 kg. A casting time of 15 minutes is required until all of the molten metal is cast as the ingot S. It is needless to say that the casting time varies depending on a diameter of a nozzle. Even during the casting time of 15 minutes, the concentration of Al of the molten metal is gradually decreased due to evaporation. However, when an amount of decrease in the concentration of Al lost by evaporation is within an allowable variation range of the standard value of the concentration of Al, the cast product (ingot) after casting has an appropriate composition as a Ti-Al based alloy.

[0036] The standard value (target value) of the concentration of Al of the Ti-Al based alloy may be high or low depending on the alloy type of the cast product to be cast. However, the applicant has confirmed that an appropriate composition can be obtained as a Ti-Al based alloy when the concentration of Al is kept within ±1.0 mass% of the standard value of 23.3 mass% to 43.3 mass%. For example, even when the standard value of the concentration of Al of 30 mass% is targeted, the variation range of the concentration of Al allowable for the actual cast product with respect to the standard value is within ± 1.0 mass%.

[0037] Here, in the casting method of the present embodiment, first, a difference between an upper limit and a lower limit of the allowable variation range with respect to the standard value, in other words, the variation range of the concentration of Al is obtained. The variation range of 2.0 mass% thus obtained is divided by the casting time of 15 minutes. It is nothing but determining a rate of change in the concentration of Al such that the amount of decrease does not exceed the variation range of the concentration of Al even when the concentration of Al is decreased in the casting time of 15 minutes. The rate of change in the concentration of Al as a result of the calculation described above is calculated to be: 2.0 mass% ÷ 15 min = 0.13 mass%/min or less.

[0038] After the 0.13 mass%/min described above is calculated, the degree of vacuum at which the rate of change in the concentration of Al is 0.13 mass%/min or less may be obtained by actually performing an experiment. The degree of vacuum of the casting obtained by the experiment in this manner is 80 Torr to 700 Torr described above. The experiment for determining the range of the degree of vacuum will be described in detail in Examples described later.

[0039] When casting is performed under the condition in which the degree of vacuum (pressure in a vacuum container) described above is less than 80 Torr, a large amount of Al in the molten metal evaporates during casting, and thus the composition of the molten metal greatly fluctuates during casting, and the fluctuation in the composition of the cast product cannot be ignored. As a result, the composition (concentration of Al) of the cast product deviates from the standard value, and a cast product having poor composition is likely to be generated, which leads to a decrease in yield.

[0040] In addition, when the casting is performed under the condition in which the degree of vacuum (pressure in the vacuum container) exceeds 700 Torr, the Ti-Al based alloy is cast in an environment in which a large amount of gas is present. Thus, there is a high possibility that the gas existing in the surroundings is involved when the molten metal is solidified in the mold, the gas defects are increased, and the yield is decreased.

[0041] The gas defects are generated due to the involving of the gas existing in the surrounding when the molten metal is solidified in the mold 4, and are often formed on a surface layer of the mold. Therefore, when the degree of vacuum in the furnace at the time of melting and casting is fine, the amount of gas to be involved is also reduced. That is, the gas defects can be reduced by improving the degree of vacuum in the furnace. When the gas defects are reduced, the amount of cutting the cast product in order to remove the gas defects from the cast product is also reduced, so that the yield of the cast product can be improved.

[0042] Although there is no quantitative evaluation result of the number of gas defects in the case of casting at atmospheric pressure, there is a qualitative discussion that the number of gas defects tends to be decreased as the casting environment for casting is changed from atmospheric pressure to vacuum. Therefore, by setting the degree of vacuum at the time of melting or casting to a higher degree of vacuum than 700 Torr described above (lower pressure than 700 Torr), it can be considered that the number of gas defects can be significantly reduced as compared with the case where the degree of vacuum is 760 Torr (atmospheric pressure) or more.

[0043] As described above, by performing casting with the degree of vacuum (air pressure in the vacuum container) set to 80 Torr to 700 Torr, it is possible to appropriately control the composition (concentration of Al) of the cast product to a standard value while preventing the generation of the gas defects, and it is possible to greatly improve the comprehensive quality in consideration of the defect in the composition.

Example

[0044] In Examples, a maximum of 50 kg of a Ti-Al based alloy material (Ti-33.3Al-4.8Nb-2.55Cr (mass%)) was melted, and a molten metal obtained by melting was used for casting.

[0045] Specifically, the materials described above were heated using the water-cooled copper crucible 2 in the cold crucible induction melting furnace 3 shown in FIG. 1, a molten metal melted by heating was held in the furnace in which a degree of vacuum was changed in a range of 0.001 Torr to 700 Torr, a concentration of Al of the molten metal was measured, and a relationship between the degree of vacuum in the furnace and an evaporation rate of Al was investigated. The results are shown in FIG. 2.

[0046] As shown in FIG. 2, it can be seen that there is a relationship between the degree of vacuum in the furnace and the evaporation rate of Al that the higher the degree of vacuum in the furnace is, the lower the evaporation rate of Al is. Further, based on the obtained data, the evaporation rate of Al was 0.13 mass%/min or less even when the degree of vacuum in the furnace was 0.001 Torr, but in order to safely and reliably perform casting, the case of 80 Torr was considered to be the lower limit value of the degree of vacuum at which the evaporation rate of Al was 0.13 mass%/min or less, and the control range of the degree of vacuum was set to 80 Torr or more.

[0047] After the relationship between the degree of vacuum in the furnace and the evaporation rate of Al was obtained in advance by the procedure described above, a cast product (ingot) was cast by actually tapping into the cast mold 4.

[0048] Note that casting was performed by tapping the molten metal from a graphite nozzle (tapping hole 5) installed at a bottom portion of the crucible 2 in which the molten metal was sealed, and solidifying the molten metal with the graphite mold 4 located below the crucible 2. The casting was also performed under an Ar atmosphere with reduced pressure, in other words, under an Ar atmosphere in which the degree of vacuum was controlled in the range of 0.001 Torr to 700 Torr. The cast product (ingot) to be produced can be changed in accordance with the shape of the graphite mold 4. In the present embodiment, an ingot was produced by casting with two types of the graphite mold 4 having a rectangular nozzle opening shape and the graphite mold 4 having a circular nozzle opening shape. Specifically, there are two types of nozzle opening shapes, 65 mm x 65 mm and 55 mm x 55 mm for a rectangular shape, and φ72 mm and φ50 mm for a circular shape. A cylindrical ingot is obtained when the nozzle opening shape is circular, and a prismatic ingot is obtained when the nozzle opening shape is rectangular.

[0049] A height of the ingot is between 620 mm and 1520 mm, and a casting speed of the ingot is in a range of 0.18%/s to 0.4%/s, although they depend on experiments.

[0050] With respect to the obtained ingot product, the applicant has confirmed that the evaporation rate of Al is suppressed in the range of the degree of vacuum of the present embodiment, and an ingot in which the concentration of Al is controlled to be in the range of ± 1.0 mass% of a target value is obtained. When a Ti-Al alloy having a target value of concentration of Al of 33.3 mass% was cast at 80 Torr by the method of the present invention, the concentration of Al was within ± 1 mass% of the target value of 33.3 mass% and was 32.79 mass%.

[0051] Among the obtained ingots, the number of gas defects per unit height of the ingot was measured for the cast product cast at a degree of vacuum of 200 Torr, and was 30/mm or less. This shows a result that the number of gas defects is significantly reduced compared with the number of gas defects being on order of several hundred in the case of casting under atmospheric pressure, and that the generation of gas defects is prevented.

[0052] As shown in the above results, the concentration of Al can be controlled with high accuracy by setting the degree of vacuum in the induction melting furnace 3 at the time of melting or casting the Ti-Al based alloy within the range of 80 Torr to 700 Torr when the molten metal is tapped from the tapping hole 5 provided in the bottom portion of the water-cooled copper crucible 2 of the induction melting furnace 3 to the mold 4 to cast the ingot of the Ti-Al based alloy, and by setting the concentration of Al of the cast ingot within ±1.0 mass% of the target value, and the comprehensive quality of the cast product can be greatly improved considering not only the defect of the shape but also the defect of the composition.

[0053] It should be understood that the embodiments disclosed herein are illustrative and non-restrictive in all respects. In particular, items that are not explicitly disclosed in the embodiments disclosed herein, such as operating conditions, operational conditions, various parameters, and dimensions, weights, volumes, and the like of components do not depart from the scope of normal implementation by those skilled in the art, and values that can be easily assumed by those skilled in the art are adopted.

[0054] The present application is based on Japanese Patent Application No. 2019-143776, filed on August 5, 2019, and the contents thereof are incorporated herein by reference.

REFERENCE SIGNS LIST

[0055]

1 Casting apparatus
2 Crucible
3 Induction melting furnace
4 Mold
5 Tapping hole
M Molten metal
S Cast Product (ingot)

Claims

1. A method for casting a Ti-Al based alloy comprising:

tapping molten metal from a tapping hole provided in a bottom portion of a water-cooled copper crucible in an induction melting furnace; and casting an ingot of Ti-Al based alloy, wherein
a degree of vacuum in the induction melting furnace at the time of melting or casting the Ti-Al based alloy is set within a range of 80 Torr to 700 Torr, and
a concentration of Al of the cast ingot is set within ±1.0 mass% of a target value.

FIG.1

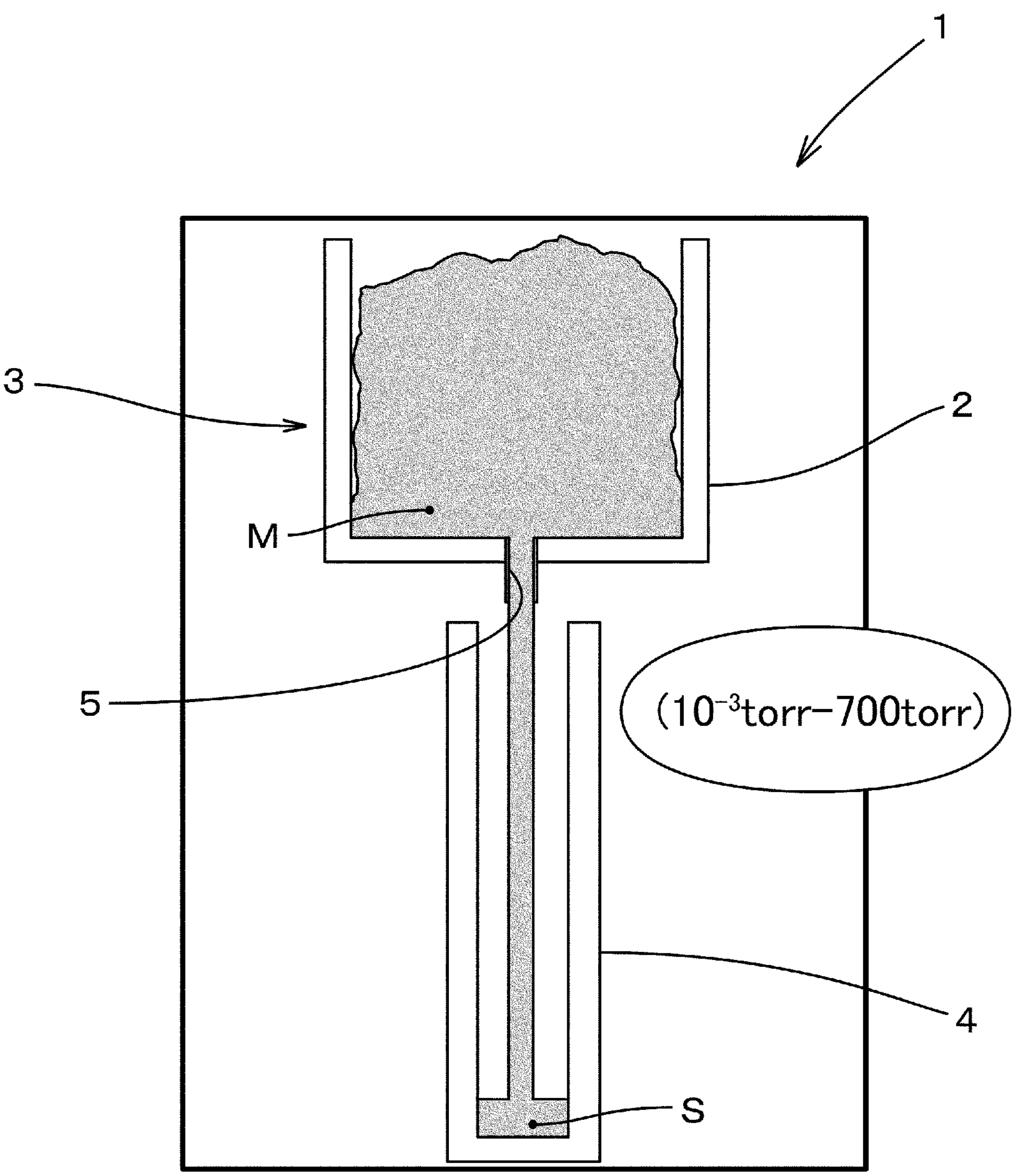


FIG.2

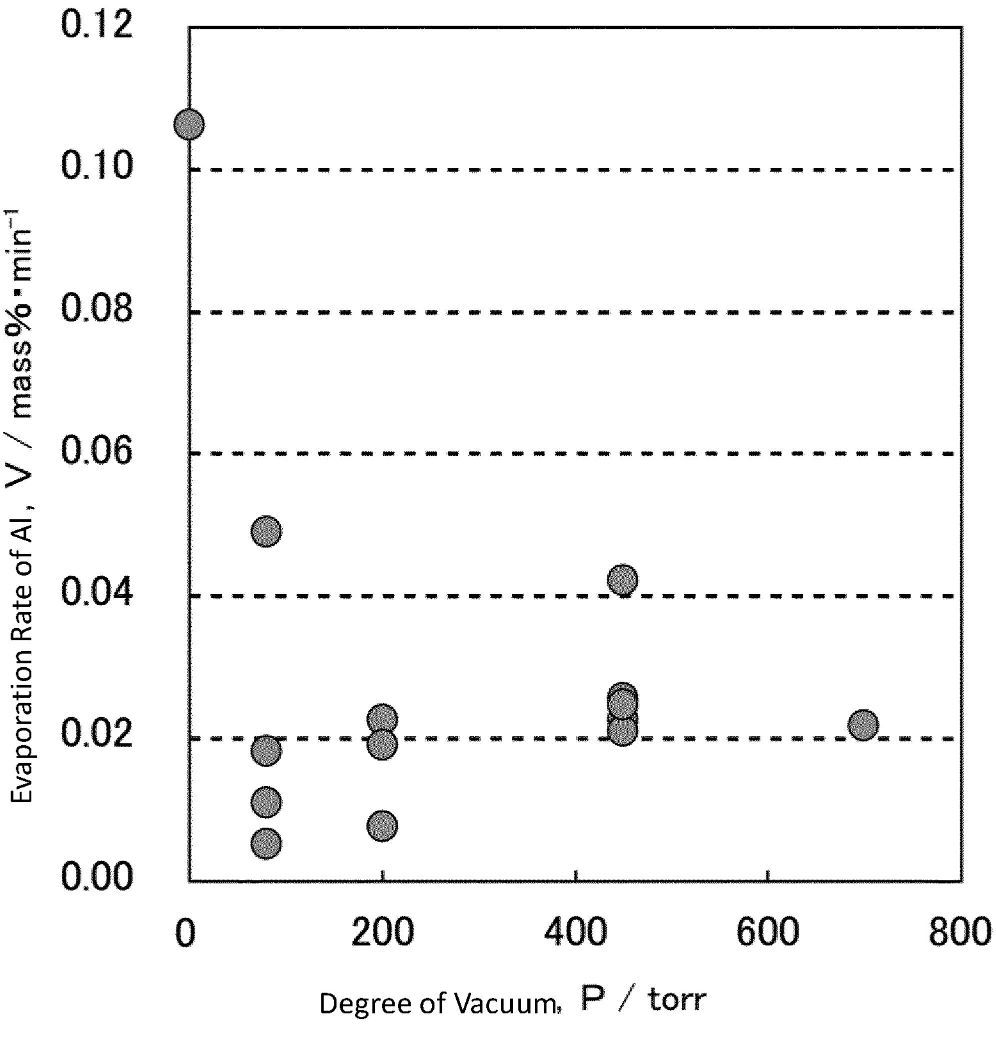
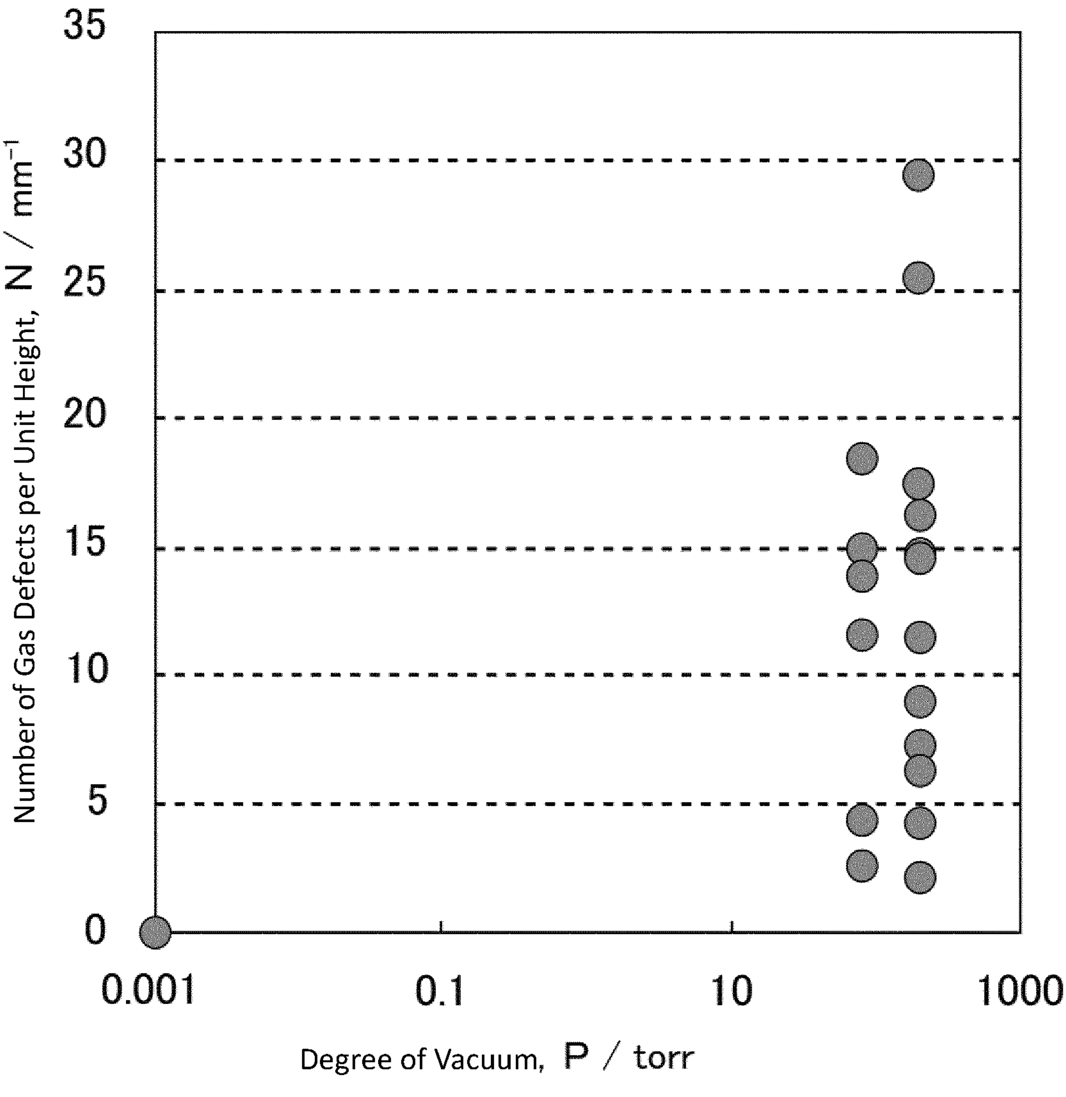

0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
200
400
600
800
Evaporation Rate of Al, V / mass%・min⁻¹
Degree of Vacuum, P / torr

FIG.3


35
30
25
20
15
10
5
0
Number of Gas Defects per Unit Height, N / mm⁻¹
0.001
0.1
10
1000
Degree of Vacuum, P / torr

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/027164

A. CLASSIFICATION OF SUBJECT MATTER
B22D 21/02(2006.01)i; B22D 23/00(2006.01)i
FI: B22D21/02; B22D23/00 B

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B22D21/00-B22D27/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2018/110370 A1 (KOBE STEEL, LTD.) 21.06.2018 (2018-06-21) paragraphs [0015]-[0022], fig. 1	1
Y	JP 8-238553 A (HONDA MOTOR CO., LTD.) 17.09.1996 (1996-09-17) paragraph [0016], fig. 3	1
A	JP 2008-142717 A (DAIDO STEEL CO., LTD.) 26.06.2008 (2008-06-26) entire text, fig. 1-3	1
A	JP 63-273562 A (DAIDO STEEL CO., LTD.) 10.11.1988 (1988-11-10) entire text	1

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 September 2020 (16.09.2020)	29 September 2020 (29.09.2020)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/027164

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