ALUMINUM DIE CAST PRODUCT AND PROCESS FOR MANUFACTURING THE SAME

An object is to provide an aluminum die cast product, e.g., a pressure vessel that requires high air-tightness, in which pressure leak or gas leak ratio can be reduced and the product yield can be increased and also to provide a method for manufacturing the product. An aluminum die cast product in which a cast hole (2A) is formed by a core pin (5) in a thick portion (4) that is made thicker than other portions, wherein a chill layer (2B) with a secondary dendrite arm spacing of at least 5.5 μm or less is provided at the surface of the cast hole (2A).

FIG. 2

2 (2A)
4
3 (3A)
2B
Description

Technical Field

[0001] The present invention relates to an aluminum die cast product that can be advantageously used, e.g., for a pressure container that requires high airtightness, as in a compressor housing, and to a method for manufacturing the aluminum die cast product.

Background Art

[0002] A solidification shrinkage space is known to occur in aluminum die cast products as a result of solidification shrinkage of a melt injected into a die during die cast molding. In the case of aluminum alloys, a volume shrinkage of about 6% occurs during solidification. Shrinkage cavities occur due to inclusion of such shrinkage spaces in the product, and the shrinkage cavities become casting defects. Shrinkage cavities tend to expand to a wide range where the cast portion has a large thickness or a low cooling rate.

In die cast products, the cooling rate of a portion located close to the surface (casting surface) that is in contact with a die is generally high and, therefore, a region with a small number of defects that is called a chill layer is formed at the casting surface. However, because the cooling rate is low inside thick portions, shrinkage cavities occurring due to solidification shrinkage are formed therein. In most cases, the shrinkage cavities are formed via three-dimensional expansion.

[0003] For example, in the case of a compressor housing, which is a pressure container, a port hole for taking in and discharging a cooling gas and a screw hole for attaching a fitting serving to connect a pipe to the port hole are provided in a thick portion that is thicker than other portions of the housing. Cast holes obtained by die casting using core pins usually serve as rough holes for the port hole and screw hole, and because the dimensional accuracy of as-cast products is low, machining is typically performed with a cutting allowance of about 0.5 mm.

In this case, although no defects are present on the casting surface and the appearance is beautiful, the shrinkage cavity defects sometimes appear inside, as described hereinabove. As a result, where the thickness of the region without shrinkage cavity defects is less than the cutting allowance, the shrinkage cavity defects are exposed on the cut surface after the cutting, thereby creating a risk of causing the inside and outside of the housing, or the port hole and screw hole to be linked to each other. This can cause pressure leak or cooling gas leak and becomes an important reason for the decrease in the product yield.

[0004] On the other hand, a local pressurization method and a local cooling method (see, for example, Patent Citation 1) are known as methods for inhibiting the occurrence of shrinkage cavity defects in the thick portions, and it has been empirically established that the occurrence of shrinkage cavity defects can be inhibited by intensifying local cooling.

Further, a core pin for die casting a cast hole has been suggested (see, for example, Patent Citation 2), the pin having a configuration in which a cooling water path is formed by fitting a cooling water pipe into the core pin body and cooling water is forced to flow in the cooling water path. Furthermore, a process of casting a rough hole for a bolt hole provided in a cylinder block has been described as an example.


Disclosure of Invention

[0006] As described above, the effectiveness of local cooling intensification in inhibiting the occurrence of shrinkage cavity defects has been recognized by those skilled in the art.

However, it is presently not clear how to the cooling should be intensified to inhibit the occurrence of shrinkage cavity defects, to what degree a region without shrinkage cavity defects is formed due to intensification of cooling, what correlation exists between the intensification of cooling and the growth of dendrites during solidification shrinkage of the melt, and whether the shrinkage cavity defects causing pressure leak or gas leak do not occur if the growth of dendrites is somehow controlled. There is thus a need for establishing a technology that can reduce a pressure leak or gas leak ratio and increase the product yield in the manufacture, e.g., of pressure containers that require a high degree of airtightness, as in compressor housings.

[0007] The present invention was created in view of the foregoing, and it is an object of the present invention to provide an aluminum die cast product, e.g., a pressure vessel that requires high airtightness, in which pressure leak or gas leak ratio can be reduced and in which the product yield can be increased, and also to provide a method for manufacturing the product.
The aluminum die cast product and method for the manufacturing the same in accordance with the present invention utilize the following means to resolve the above-described problems.

Thus, the aluminum die cast product in accordance with the present invention is an aluminum die cast product in which a cast hole is formed by a core pin in a thick portion that is made thicker than other portions, wherein a chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less is provided at the surface of the cast hole.

The tests conducted by the inventors have demonstrated that the growth of dendrites during solidification shrinkage of a melt is inhibited by the intensification of local cooling, and where the secondary dendrite arm spacing is at least 5.5 μm or less, a chill layer can be formed in which shrinkage cavity defects that cause pressure leak or gas leak do not appear on the casting surface. In accordance with the present invention, a chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less remains at the cast hole surface after cutting has been performed with the cutting allowance, the chill layer in which no shrinkage cavity defects have occurred can be reliably left at the surface thereof and the occurrence of pressure leak or gas leak via the cast holes can be reliably inhibited. Therefore, when a pressure vessel or the like is manufactured, the yield thereof can be greatly increased.

The secondary dendrite arm spacing is a distance between the centers of the adjacent secondary dendrite arms and it is represented by an average value of secondary dendrite arm spacing in a portion where four or more secondary dendrite arms are continuously arranged side by side. More specifically, a portion in which four or more secondary dendrite arms are arranged side by side is selected, a total of n (n is 4 or more) spacings 1 of secondary dendrite arm spacings are measured, and 1/(n - 1) is found. The measurements are performed in three or more locations and an arithmetical average of the results is found.

Further, the aluminum die cast product in accordance with the present invention is the above-described aluminum die cast product in which a thickness of a chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less is made larger than the cutting allowance of the cast hole that is set in advance.

In accordance with the present invention, the thickness of the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less is made larger than a cutting allowance of the cast hole that is set in advance. Therefore, even when the cast hole is machined as a rough hole by cutting, the machining surface thereof can be confined within a range of the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less in which the shrinkage cavity defects have not occurred. Therefore, the shrinkage cavity defects are not exposed on the cutting surface, and the occurrence of pressure leak or gas leak directly from the cast hole portion or via a screw hole, or the like, adjacent to the cast hole portion can be reliably inhibited.

Further, the aluminum die cast product in accordance with the present invention is the above-described aluminum die cast product in which the thickness of the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less remains after cutting has been performed with the aforementioned cutting allowance.

In accordance with the present invention, because the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less remains after cutting has been performed with the cutting allowance, the chill layer in which no shrinkage cavity defects have occurred remains at the cast hole surface in the product after cutting. Therefore, the exposure of shrinkage cavity defects on the cutting surface can be reliably prevented and the occurrence of pressure leak or gas leak directly from the cast hole portion or via a screw hole, or the like, adjacent to the cast hole portion can be reliably inhibited.

Further, the aluminum die cast product in accordance with the present invention is any of the above-described aluminum die cast products in which the thickness of the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less is at least 0.5 mm or more.

In accordance with the present invention, because the thickness of the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less is at least 0.5 mm or more, the thickness of the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less can be made larger than the cutting allowance of aluminum die cast products that is generally set to 0.5 mm or less. As a result, the chill layer in which no shrinkage cavity defects have occurred can be reliably left at the surface of cast hole after cutting. Therefore, the shrinkage cavity defects are not exposed on the cutting surface and the occurrence of pressure leak or gas leak directly from the cast hole portion or via a screw hole, or the like, adjacent to the cast hole portion can be reliably inhibited.

Further, the aluminum die cast product in accordance with the present invention is any of the above-described aluminum die cast products in which the aluminum die cast product is a pressure vessel.

In accordance with the present invention, because the aluminum die cast product is a pressure vessel, a pressure vessel can be obtained in which no internal fluid leak occurs from the cast hole via the shrinkage cavity defects. Therefore, when an aluminum die cast pressure vessel is manufactured, the yield thereof can be greatly increased and a high-quality pressure vessel can be obtained at a low cost.

Further, the aluminum die cast product in accordance with the present invention is the above-described aluminum die cast product in which the pressure vessel is a compressor housing.

In accordance with the present invention, because the pressure vessel is a compressor housing, it is possible
to obtain a compressor housing with high airtightness in which no internal cooling gas leaks from the cast hole via the
shrinkage cavity defects. Therefore, when an aluminum die cast compressor housing is manufactured, the yield thereof
can be greatly increased and a high-quality compressor housing can be obtained at a low cost.

[0020] The method for manufacturing an aluminum die cast product in accordance with the present invention is a
method for manufacturing an aluminum die cast product in which a cast hole is formed by a core pin in a thick portion
that is made thicker than other portions, wherein a chill layer with a secondary dendrite arm spacing of at least 5.5 μm
or less is formed to a thickness equal to, or larger than a predetermined thickness at the cast hole surface by passing
a flow of a cooling medium through the core pin and locally cooling the cast hole.

[0021] In accordance with the present invention, by passing a flow of a cooling medium through the core pin and
increasing the local cooling capacity with the core pin during die casting, the temperature gradient during melt solidification
shrinkage can be increased. Therefore, the growth of dendrites can be inhibited and the chill layer with a secondary
dendrite arm spacing of at least 5.5 μm or less can be formed to a thickness equal to, or larger than a predetermined
thickness at the cast hole surface. As a result, no shrinkage cavity defects are exposed on the surface of the cast hole
even when it is used as a rough hole, the occurrence of pressure leak or gas leak via the cast hole can be reliably
inhibited, and a yield in the manufacture of aluminum die cast products such as pressure vessels can be greatly increased.

[0022] Further, the method for manufacturing an aluminum die cast product in accordance with the present invention
is the above-described method for manufacturing an aluminum die cast product in which a core pin with a double-pipe
structure in which a central pipe is inserted into a hollow core pin body is used as the core pin, the cooling medium is
supplied from the central pipe to a distal end portion of the core pin, the cooling medium is forced to flow into a cooling
medium channel between the central pipe and the pin body, and the cast hole is locally cooled.

[0023] In accordance with the present invention, because a core pin with a double-pipe structure in which a central
pipe is inserted into a hollow core pin body is used as the core pin, the cooling medium is supplied from the central pipe
to a distal end portion of the core pin, and the cooling medium is forced to flow into a cooling medium channel between
the central pipe and the pin body, a uniform cooling medium flow channel is formed along the entire periphery, the flow
rate of the cooling medium can be stabilized, and local cooling of the cast hole can be performed uniformly. As a result,
the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less can be reliably formed to a thickness
equal to, or larger than a predetermined thickness at the cast hole surface with uniformity over the entire periphery.
Therefore, the quality of the aluminum die cast product obtained by casting can be stabilized and the yield thereof can
be increased.

[0024] Further, the method for manufacturing an aluminum die cast product in accordance with the present invention
is the above-described method for manufacturing an aluminum die cast product, wherein the cooling medium is caused
to flow at a flow rate of 12 cc/s or more.

[0025] In accordance with the present invention, because the cooling medium is caused to flow at a flow rate of 12
cc/s or more, the temperature gradient during melt solidification shrinkage is sufficiently increased and the dendrite
growth is inhibited. As a result, the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less can be
reliably formed to a thickness equal to, or larger than a predetermined thickness at the cast hole surface.

[0026] Further, the method for manufacturing an aluminum die cast product in accordance with the present invention
is the above-described method for manufacturing an aluminum die cast product, wherein a core pin of a partition plate
structure in which a partition plate arranged along a pin axial direction is inserted into a hollow core pin body is used as
the core pin, the cooling medium is supplied from one of the cooling medium channels partitioned by the partition plate,
the cooling medium is caused to flow into the other cooling medium channel, and the cast hole is locally cooled.

[0027] In accordance with the present invention, because a core pin of a partition plate structure in which a partition
plate arranged along a pin axial direction is inserted into a hollow core pin body is used as the core pin, the cooling
medium is supplied from one of the cooling medium channels partitioned by the partition plate, and the cooling medium
is caused to flow into the other cooling medium channel, a uniform cooling medium flow channel can be formed, the
flow rate of the cooling medium can be stabilized, and the cooling performance can be improved. As a result, the chill
layer with a secondary dendrite arm spacing of at least 5.5 μm or less can be reliably formed to a thickness equal to,
or larger than a predetermined thickness at the cast hole surface. Therefore, the quality of the aluminum die cast product
obtained by casting can be stabilized and the yield thereof can be increased.

[0028] Further, the method for manufacturing an aluminum die cast product in accordance with the present invention
is any of the above-described methods for manufacturing an aluminum die cast product, wherein the flow of the cooling
medium is initiated simultaneously with, or immediately prior to the completion of melt injection.

[0029] In accordance with the present invention, because the flow of the cooling medium is initiated simultaneously
with, or immediately prior to the completion of melt injection, no adverse effect, such as melt overcooling and melt flow
disruption, is produced on melt injection, and rapid cooling can be performed simultaneously with completion of injection.
As a result, the temperature gradient during melt solidification shrinkage can be sufficiently increased and dendrite
growth can be inhibited. Therefore, the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less can
be reliably formed to a thickness equal to, or larger than a predetermined thickness at the cast hole surface.
With the aluminum die cast product and method for manufacturing the same in accordance with the present invention, the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less can be reliably formed to a thickness equal to, or larger than a predetermined thickness at the cast hole surface. As a result, where the cast hole serves as a rough hole, the shrinkage cavity defects are not exposed on the surface thereof and the occurrence of pressure leak or gas leak via the cast hole can be reliably inhibited. Therefore, when a pressure vessel or the like is manufactured, the yield thereof can be greatly increased and high-quality aluminum die cast products can be manufactured at a low cost.

Brief Description of Drawings

[FIG. 1] FIG. 1 is a perspective view illustrating the external appearance of a compressor housing that is an aluminum die cast product of one embodiment of the present invention.

[FIG. 2] FIG. 2 is a cross-sectional view along arrows Y-Y of the compressor housing shown in FIG. 1.

[FIG. 3] FIG. 3 is a partial simplified cross-sectional view illustrating a die casting state of the compressor housing shown in FIG. 1.

[FIG. 4] FIG. 4 is a cross-sectional view illustrating an example of a core pin employed for die casting of the compressor housing shown in FIG. 1.

[FIG. 5] FIG. 5 is a cross-sectional view illustrating another example of a core pin employed for die casting of the compressor housing shown in FIG. 1.

[FIG. 6] FIG. 6 is a conceptual diagram illustrating solidification shrinkage of the melt in the case of a small temperature gradient during die cooling.

[FIG. 7] FIG. 7 is a conceptual diagram illustrating solidification shrinkage of the melt in the case of a large temperature gradient during die cooling.

[FIG. 8] FIG. 8 illustrates observations performed with an optical microscope for DAS measurements.

[FIG. 9] FIG. 9 is a graph illustrating the relationship between a cooling water flow rate V (cc/s) and a thickness t (mm) of the region free of shrinkage cavity defects.

[FIG. 10] FIG. 10 is a graph illustrating the relationship between a depth d (mm) from the casting surface in which shrinkage cavity is observed and DAS (μm).

Explanation of Reference:

1: compressor housing
2: port hole
2A: cast hole
2B: chill layer
4: thick portion
5, 50: core pin
5A: pin body
5E: central pipe
5F, 50I, 50J: cooling medium channel
50E: partition plate
20: dendrite arm
21: secondary dendrite arm
DAS: secondary dendrite arm spacing

Best Mode for Carrying Out the Invention

An embodiment of the present invention will be described below with reference to the drawings. FIG. 1 is a perspective view of a compressor housing 1 of one embodiment of the present invention. FIG. 2 is a cross-sectional view along arrows Y-Y in FIG. 1. In the present embodiment, the compressor housing 1, which is a pressure vessel requiring airtightness, is explained as an example of an aluminum die cast product, but the aluminum die cast product in accordance with the present invention is not limited thereto.

The compressor housing 1 constitutes the outer shell of the compressor, and a compression mechanism (not shown in the figure) is contained inside thereof. The compression mechanism compresses a low-pressure cooling gas
sucked in via a port hole 2 from the outside of the compression housing 1 and discharges the resultant high-pressure cooling gas to the outside via a port hole (not shown in the figure) provided in the compression housing 1. The compression housing 1 forms a compressor accommodation space that covers and seals the outer periphery of the compression mechanism so as to prevent leak to the outside as the cooling gas is taken in, compressed, and discharged, and the compression housing acts as a pressure vessel.

The aforementioned port hole 2 is provided so as to pass through the compression housing 1, as shown in FIG. 2, and a cooling medium pipe (not shown in the figure) is connected to the port hole 2. A thick portion 4 that is thicker than other portions is provided in the outer peripheral portion of the compression housing 1, and the port hole 2 is provided together with a screw hole 3 for attaching a fitting for connecting the cooling medium pipe in this thick portion 4. However, the screw hole 3 is not necessarily provided and may be omitted.

The compression housing 1 is produced from an aluminum alloy in order to reduce weight and is manufactured by die casting. The rough holes of the port hole 2 and screw hole 3 are formed as cast holes 2A and 3A with core pins during die casting and then finished by machining to predetermined dimensions after die casting.

FIG. 3 is a schematic sectional view illustrating a state in which the cast holes 2A and 3A for the port hole 2 and screw hole 3 are die cast with core pins 5 and 6. A molding space 9 of the thick portion 4 for molding the cast holes 2A and 3A is formed by a fixed die 7 and a movable die 8. The core pins 5 and 6 for molding the cast holes 2A and 3A are introduced from the side of the fixed die 7 into the molding space 9 and disposed therein. During die casting, the molding space 9 is filled with a melt, thereby molding the cast holes 2A and 3A serving as rough holes for the port hole and screw hole 3 with the core pins 5 and 6.

The thick portion 4 where the port hole 2 and screw hole 3 are provided is thicker than other portions, and during die casting, a solidification shrinkage space is produced by solidification shrinkage of the melt and shrinkage cavity defects easily appear therein. As described above, because the cast holes 2A and 3A molded by the core pins 5 and 6 are finished to obtain the port hole 2 and screw hole 3, where a chill layer 2B on the casting surface is cut, the shrinkage cavity defects can be exposed on the cutting surface and the inside and outside of the compressor housing 1 or the port hole 2 and screw hole 3 can be lined together via the shrinkage cavity defects. As mentioned hereinabove, this can result in a leak of pressure or cooling medium gas from inside the compressor housing 1 to the outside.

In order to prevent the leak of pressure or cooling medium gas, the chill layer 2B in which no shrinkage cavity defects have appeared is formed to a thickness above a predetermined thickness at the casting surface, and when the cutting is performed with a predetermined cutting allowance, no shrinkage cavity defects are exposed on the cutting surface. Furthermore, locally cooling the cast holes with the core pins would be also effective for forming the chill layer 2B in which no shrinkage cavity defects have occurred to a thickness exceeding the cutting allowance. From among the core pins 5 and 6, the core pin 6 for the screw hole 3 has a small pin diameter, and providing a cooling medium flow channel inside thereof is difficult. For this reason, a flow channel for the cooling medium (water) is provided inside the core pin 5 with a comparatively large diameter that serves to mold the port hole 2, local cooling capacity with the core pin 5 is enhanced, and a region (chill layer 2B) where no shrinkage cavity defects occur is made thicker.

FIG. 4 shows a configuration of the core pin 5 provided with a flow channel for a cooling medium (water) inside thereof. The core pin 5 is a core pin 5 of a double pipe structure composed of a hollow pin body 5A, a holder 5C connected via a thread 5B to the upper portion of the pin body 5A, a plug 5D screwed into the end portion of the holder 5C, a central pipe 5E having one end thereof held in an up-down partition portion within the holder 5C and another end opened at the distant end portion inside the hollow pin body 5A, a cooling medium flow channel 5F formed between the hollow pin body 5A and the central pipe 5E and serving to pass the cooling medium (water) therethrough, a cooling medium supply pipe 5G connected to a space in the upper portion inside the holder 5C, and a cooling medium discharge pipe 5H connected to a space in the lower portion inside the holder 5C. The cooling medium (water) can flow at a preset flow rate from a water supply device 10 via the cooling medium supply pipe 5G and cooling medium discharge pipe 5H inside the core pin 5.

The core pin 5 can be replaced with a core pin 50 shown in FIG. 5. The core pin 50 has a partition plate structure in which the central pipe 5E of the core pin 5 is replaced with a partition plate 50E, one of the flow channels partitioned by the partition plate 50 is a cooling medium supply channel 50I and the other flow channel is a cooling medium discharge channel 50J. Other components are identical to those of the core pin 5 and assigned with identical symbols. The explanation thereof is omitted.

A method for forming the chill layer 2B with a thickness above a predetermined value in which no shrinkage cavity defects have occurred at the surface of the cast hole 2A serving as a rough hole for the port hole 2 by using the core pin 5 or 50 and a configuration of the compressor housing 1 provided with the chill layer 2B will be described below. First, the relationship between the temperature gradient and growth of dendrite arms during solidification shrinkage of the melt that is shown in FIG. 6 and FIG. 7 will be explained.

As shown in FIG. 6 and FIG. 7, the solidification of melt proceeds while the melt is supplied from a liquid phase side so as to compensate for the volume shrinkage that accompanies solidification between the dendrite arms 20 extending from the solid phase side. In order to prevent the occurrence of solidification shrinkage space (shrinkage cavity), it is
necessary to supply a sufficient amount of melt between the dendrite arms 20. For this purpose, it is important to inhibit the growth of dendrite arms 20. In other words, where the dendrite arms 20 grow, a sufficient amount of melt cannot be supplied therebetween and a solidification shrinkage space X (see FIG. 6) that will become a shrinkage cavity appears between the dendrite arms.

[0042] The growth of dendrite arms 20 can be inhibited by increasing the cooling capacity of the die and increasing the temperature gradient G. The temperature gradient G can be represented by the following formula:

\[ G = \frac{T_L - T_S}{L} \]

In this formula, \( T_L \) stands for a liquidus temperature, \( T_S \) for a solidus temperature, and \( L \) for a length of dendrite arms 20. Where the temperature gradient G is small (the case shown in FIG. 6), the dendrite arms 20 grow and the length \( L \) thereof increases to \( L_1 \). On the other hand, by increasing the temperature gradient G (the case shown in FIG. 7), it is possible to inhibit the growth of dendrite arms 20 and make the length \( L \) thereof as short as \( L_2 \) (\( L_1 > L_2 \)).

[0043] Further, the spacing between the secondary dendrite arms 21 (dendrite arm spacing, referred to hereinbelow as "DAS") can be decreased by increasing the temperature gradient G. As shown in FIG. 8, the DAS can be easily checked by using an optical microscope after completion of solidification. The DAS is a distance between the centers of adjacent secondary dendrite arms and is taken as an average value of secondary dendrite arm spacing in a portion where four or more of secondary dendrite arms are arranged continuously side by side. More specifically, a portion where four or more of secondary dendrite arms are arranged continuously side by side is selected, a total of \( n \) (\( n \) is 4 or more) secondary dendrite arm spacings \( 1 \) are measured, and a value of \( 1/(n - 1) \) is found. The measurements are performed in three or more places and an arithmetical average of the results is found.

[0044] The temperature gradient G can be increased by increasing the cooling capacity of the mold. Therefore, apparently the DAS can be decreased and the thickness of the region (chill layer 2B) where no shrinkage cavities have occurred can be increased by increasing the flow rate of the cooling medium that cools the mold, thereby raising the cooling rate of the mold, and inhibiting the growth of dendrite arms 20 during solidification. Accordingly, the following test was performed.

[0045] In the test, the core pin 5 shown in FIG. 4 was used, the cast holes 2A and 3A for the port hole 2 and screw hole 3 were die cast with the core pins 5 and 6 (see FIG. 3), while varying the flow rate \( V \) (cc/s) of the cooling medium (water), the DAS (\( \mu m \)) in a location at a predetermined depth from the casting surface (surface of cast product) was measured by a linear intercept method, and the thickness \( t \) (mm) of the region (chill layer 2B) without the shrinkage cavity defects was measured. The measurement results are shown in Table 1.

[0046] The casting conditions in the above-described process were as follows: melt temperature 665°C, die temperature 200°C, injection rate 0.2 m/s (low rate) and 2.3 m/s (high rate). These casting conditions are identical to a melt

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Cooling water flow rate (cc/s)</th>
<th>Secondary dendrite arm spacing [DAS] (( \mu m ))</th>
<th>Thickness of region without shrinkage cavities (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Depth from casting surface: 0.25 mm</td>
<td>Depth from casting surface: 1.0 mm</td>
</tr>
<tr>
<td>a-1</td>
<td>0</td>
<td>5.8</td>
<td>9.3</td>
</tr>
<tr>
<td>a-2</td>
<td>0</td>
<td>5.1</td>
<td>8.0</td>
</tr>
<tr>
<td>b-1</td>
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<td>4.7</td>
<td>9.4</td>
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</tr>
<tr>
<td>d-2</td>
<td>20.7</td>
<td>3.3</td>
<td>6.6</td>
</tr>
</tbody>
</table>

[0047]
temperature of 640-690°C and mold temperature of 150-300°C that are typical molding conditions for casting the aluminum die cast housing. As for the conditions relating to the flow of cooling medium (water), the flow of cooling medium (water) was initiated simultaneously with the completion of injection and the flow passage time was 3 sec.

The test results were analyzed and the relationship between the flow rate V (cc/s) of the cooling medium (water) and the thickness t (mm) of the region without shrinkage cavity defects was plotted as shown in FIG. 9. A thick solid line in FIG. 9 connects the minimum values of the thickness t (mm) of the region without shrinkage cavities obtained at each flow rate V (cc/s) of cooling water. These results also demonstrated that the thickness t (mm) of the region without shrinkage cavities can be obtained by increasing the flow rate V (cc/s) of cooling water flowing in the core pin 5, increasing the cooling capacity with the core pin 5, and increasing the temperature gradient G during solidification. In particular, it was confirmed that the thickness t (mm) of the region without shrinkage cavities can be increased to 0.8 mm or more by raising the flow rate V (cc/s) of cooling water to 12.0 cc/s or more.

Further, a graph representing the relationship between the depth d (mm) from the casting surface (surface of cast product) where shrinkage cavities are observed and DAS (μm) is shown in FIG. 10. The region shown by thick solid lines in FIG. 10 indicates a region in which the depth d (mm) from the casting surface (surface of cast product) where shrinkage cavities are observed, that is, the thickness of the region without shrinkage cavities assumes a minimum value (t_{min}) in the molded products obtained at various flow rates V (cc/s) of cooling water shown by broken lines. This region could be considered as a threshold (5.5-6.9 μm) of DAS at which shrinkage cavities were observed, and it was made clear that the condition for DAS at which no shrinkage cavities occur was 5.5 μm or less.

The above-described results demonstrated that by inhibiting the growth of dendrites during melt solidification shrinkage and making the DAS (secondary dendrite arm spacing) at least 5.5 μm or less, it is possible to form the chill layer 2B (see FIG. 2) in which shrinkage cavity defects causing pressure leak or gas leak in the compressor housing do not occur and which has a thickness equal to or larger than a predetermined thickness.

In the present embodiment, the chill layer 2B with a DAS of 5.5 μm or less was formed to a thickness more than a machining allowance in cutting after die casting at the surface of cast hole 2A for the port hole 2 cast with the core pin 5. Thus, in the case where the cutting allowance has a usual value of 0.5 mm, the chill layer 2B with a DAS of 5.5 μm or less was formed to a thickness of 0.5 mm or more, and the chill layer 2B with a DAS of 5.5 μm or less remained on the cut surface after cutting.

As a result, even when the cast hole 2A is used as a rough hole and subjected to cutting with the usual cutting allowance, no shrinkage cavity defects are exposed on the cut surface and the occurrence of pressure leak or gas leak during die casting at the surface of cast hole 2A can be reliably prevented. Therefore, when the compressor housing 1 is manufactured, the production yield thereof can be greatly increased and the high-quality compressor housing 1 can be manufactured at a low cost. In particular, by increasing the flow rate V (cc/s) of the cooling medium (water) flowing in the core pin 5 to 12.0 cc/s or more, it is possible to increase the thickness t (mm) of the region without shrinkage cavities in which DAS is 5.5 μm or less to be 0.8 (mm) or more and to eliminate reliably the occurrence of pressure leak or gas leak.

Further, in the above-described embodiment, the flow of the cooling medium in the core pins 5, 50 is initiated during die casting at the same time as the melt injection is completed, but performing the two actions simultaneously is not necessary. Thus, the cooling medium can be caused to flow immediately before the completion of melt injection, for example, from about 1 s before the completion of injection.

In sum, where the cooling medium is left to flow or the cooling medium is caused to flow too early, the die is overcooled and an adverse effect is produced on the melt injection. Thus, part of the melt starts solidifying during loading or abnormal melt flow is induced. Therefore, the cooling medium may be caused to flow before the completion of injection, provided that no such adverse effect is produced.

Further, in the present embodiment, an example of applying the present invention to the compressor housing 1 is explained, but it goes without saying that the present invention is not limited to this application and can be applied to a wide variety of aluminum die cast products such as other pressure vessels, aluminum cylinder blocks for engines, and transmission cases. In these cases, the leak of fluid sealed inside the product also can be reliably eliminated.

Claims
1. An aluminum die cast product in which a cast hole is formed by a core pin in a thick portion that is made thicker than other portions, wherein a chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less is provided at the surface of the cast hole.

2. The aluminum die cast product according to claim 1, wherein a thickness of the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less is made larger than a cutting allowance of the cast hole that is set in advance.
3. The aluminum die cast product according to claim 2, wherein
the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less remains after cutting has been
performed with the cutting allowance.

4. The aluminum die cast product according to any of claims 1 to 3, wherein
a thickness of the chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less is at least 0.5 mm or more.

5. The aluminum die cast product according to any of claims 1 to 4, wherein
the aluminum die cast product is a pressure vessel.

6. The aluminum die cast product according to claim 5, wherein
the pressure vessel is a compressor housing.

7. A method for manufacturing an aluminum die cast product in which a cast hole is formed by a core pin in a thick
portion that is made thicker than other portions, wherein
a chill layer with a secondary dendrite arm spacing of at least 5.5 μm or less is formed to a thickness equal to, or
larger than a predetermined thickness at a surface of the cast hole by passing a flow of a cooling medium through
the core pin and locally cooling the cast hole.

8. The method for manufacturing an aluminum die cast product according to claim 7, wherein
a core pin with a double-pipe structure in which a central pipe is inserted into a hollow core pin body is used as the
core pin, the cooling medium is supplied from the central pipe to a distal end portion of the core pin, the cooling
medium is forced to flow into a cooling medium channel between the central pipe and the pin body, and the cast
hole is locally cooled.

9. The method for manufacturing an aluminum die cast product according to claim 8, wherein
the cooling medium is caused to flow at a flow rate of 12 cc/s or more.

10. The method for manufacturing an aluminum die cast product according to claim 7, wherein
a core pin of a partition plate structure in which a partition plate arranged along a pin axial direction is inserted into
a hollow core pin body is used as the core pin, the cooling medium is supplied from one of the cooling medium
channels partitioned by the partition plate, the cooling medium is caused to flow into the other cooling medium
channel, and the cast hole is locally cooled.

11. The method for manufacturing an aluminum die cast product according to any of claims 7 to 10, wherein the flow
of the cooling medium is initiated simultaneously with, or immediately prior to the completion of melt injection.
FIG. 4

COOLING WATER FLOWS IN

COOLING WATER FLOWS OUT

10

5

5A

5B

5C

5D

5E

5F

5G
FIG. 9

○ COOLING WATER FLOW RATE: 0 (cc/s) <a-1, a-2>
△ COOLING WATER FLOW RATE: 1.6 (cc/s) <b-1, b-2>
◇ COOLING WATER FLOW RATE: 12.0 (cc/s) <c-1, c-2, c-3>
□ COOLING WATER FLOW RATE: 20.2 (cc/s) <d-1, d-2>
FIG. 10

○ MINIMUM VALUE OF THICKNESS OF REGION WITHOUT SHRINKAGE CAVITIES

△ COOLING WATER FLOW RATE: 0 (cc/s) <AVERAGE OF a-1, a-2>

◇ COOLING WATER FLOW RATE: 1.6 (cc/s) <AVERAGE OF b-1, b-2>

◆ COOLING WATER FLOW RATE: 12.0 (cc/s) <AVERAGE OF c-1, c-2, c-3>

□ COOLING WATER FLOW RATE: 20.2 (cc/s) <AVERAGE OF d-1, d-2>
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

B22D17/00 (2006.01)i, B22C9/10 (2006.01)i, B22D17/22 (2006.01)i, B22D17/32 (2006.01)i

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)

B22D15/00-17/32, B22CS/00-9/30

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

Jitsuyo Shinan Koho 1922-1996

Jitsuyo Shinan Tsuroku Koho 1996-2007

Kokai Jitsuyo Shinan Koho 1971-2007

Tsuroku Jitsuyo Shinan Koho 1994-2007

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

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>JP 9-277014 A (Hitachi Metals, Ltd.), 28 October, 1997 (28.10.97), (Family: none)</td>
<td>1-11</td>
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<tr>
<td>A</td>
<td>JP 2004-330273 A (Sanden Corp.), 25 November, 2004 (25.11.04), (Family: none)</td>
<td>1-11</td>
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</tbody>
</table>

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

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Date of the actual completion of the international search

15 October, 2007 (15.10.07)

Date of mailing of the international search report

23 October, 2007 (23.10.07)

Name and mailing address of the ISA/

Japanese Patent Office

Authorized officer

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REFERENCES CITED IN THE DESCRIPTION

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