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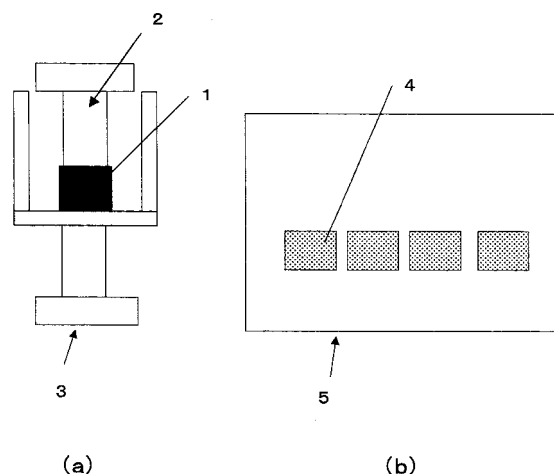
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(54) **PROCESS FOR PRODUCING ALUMINUM COMPOSITE MATERIAL**

(57) The present invention is such that it is an assignment to be solved to provide a process for producing aluminum composite material in which an iron sintered body of much higher adhesion is cast-in inserted with aluminum.

A process according to the present invention for producing aluminum composite material is **characterized in that** it has : a preform molding step of molding a porous iron sintered-material preform by molding an iron powder so that an occupational volumetric fraction becomes from 50% or more to 70% or less, and then by sintering the iron powder, thereby molding a porous iron sintered material preform; and a composite-material forming step of placing said preform in a casting die whose die temperature is from 200 °C or more to 400 °C or less, the preform being preheated at a preheating temperature of from 300 °C or more to 400 °C or less in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas, and then carrying out casting by means of impregnating the preform with molten aluminum or aluminum alloy by pressurizing the molten aluminum or aluminum alloy by a 2-stage pressurizing method, the 2-state pressurizing method comprising a first pressurizing stage and a second pressurizing stage.

Fig.1



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a process for producing aluminum composite material in which an iron sintered body is cast-in inserted with aluminum.

BACKGROUND ART

10 **[0002]** A process for producing composite material has been proposed variously, composite material in which a metal, such as aluminum, is made into a host material and a preform comprising a porous sintered material is composited therewith. As for a production process for producing such a composite material, a process for producing composite material by means of casting has been known, process in which a preform, being made of a porous sintered body, such as iron, for instance, and being molded in advance, is set within a die; and process in which a highly-pressurized metallic molten
15 metal is fed into this die and is pressurized therein to infiltrate the metallic molten metal into the preform, thereby producing a composite material.

[0003] In the aforementioned process for producing composite material by means of casting, a preform, which is formed of an iron porous sintered body, is preheated at a predetermined temperature of 250 °C-350 °C in a preheating furnace, for instance.

20 **[0004]** However, since the closer the temperature of preheating preform is to the fusing temperature of host-material metal the more the infiltratability of host-material metal into preform improves, it has been desired to further make the preheating temperature higher temperature.

[0005] In the case where a preform comprises an iron sintered body, when it is adapted to be 400 °C or more, since the iron sintered body's surface is oxidized so that foreign materials, such as oxides, precipitate in the surface, the
25 preheating temperature is adapted to be the aforementioned predetermined temperature or less so as to avoid it.

DISCLOSURE OF THE INVENTION

[0006] Assignment to be Solved by the Invention

30 **[0007]** Since the aforementioned process for producing composite material is one in which materials of different species are combined to form it, the adhesiveness between the materials is one of the important conditions that determines the characteristic of composite material. In particular, in the case where it is employed in component parts, articles of manufacture, and the like, to which high pressures are applied, there might be a probability of the occurrence of drawbacks, such as pressure leakage, the occurrence or extension of cracks by means of the fact that pressures apply to mal-
35 adhesiveness locations, when the adhesiveness between materials is poor.

[0008] Moreover, when the adhesiveness between materials is poor, there might be a fear that foreign materials or voids, which contain air, are present at the boundary. In the case where the aforementioned material is employed in materials which require thermal conductivity, when there are foreign materials or voids at the boundary, it is believed probable that the thermal conductivity degrades.

40 **[0009]** The present invention is one which has been done in view of such circumstances, and it is an object to provide a process for producing aluminum composite material in which an iron sintered body of much higher adhesion is cast-in inserted with aluminum.

[0010] Means for Solving the Assignment

[0011] Hence, the present inventors studied earnestly in order to solve this assignment, and then, as a result of trial and error over and over again, they discovered that an aluminum composite material of good adhesiveness is obtainable
45 by means of combining the following: adapting the occupational volumetric fraction of iron sintered body to be from 50% or more to 70% or less; enhancing the preheating temperature so that it is adapted to be from 300 °C or more to 400 °C or less by means of preheating iron sintered-body preform in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas; adapting the casting-die temperature to be
50 from 200 °C or more to 400 °C or less; and carrying out the method of pressurizing aluminum or aluminum-alloy molten metal in 2-stage pressurizing at a lower pressure and at a higher pressure, thereby arriving at completing the present invention.

[0012] Specifically, a process according to the present invention for producing aluminum composite material is characterized in that it has:

55 a preform molding step of molding a porous iron sintered-material preform by molding an iron powder so that an occupational volumetric fraction becomes from 50% or more to 70% or less, and then by sintering the iron powder at a sintering temperature of from 1, 100 °C or more to 1,300 °C or less in vacuum, in an inert-gas atmosphere, in

a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas, thereby molding a porous iron sintered material preform; and

a composite-material forming step of placing said preform in a casting die whose die temperature is from 200 °C or more to 400 °C or less, the preform being preheated at a preheating temperature of from 300 °C or more to 400 °C or less in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas, and then carrying out casting by means of impregnating the preform with molten aluminum or aluminum alloy by pressurizing the molten aluminum or aluminum alloy by a 2-stage pressurizing method, the 2-stage pressurizing method comprising a first pressurizing stage in which the molten aluminum or aluminum alloy is pressurized at a lower pressure and a second pressurizing stage which follows the first pressurizing stage and in which the molten aluminum or aluminum alloy is pressurized at a higher pressure than the pressure in the first pressurizing stage.

[0013] Moreover, another process according to the present invention for producing aluminum composite material is characterized in that it has:

a composite-material forming step of placing a porous iron sintered-material preform in a casting die whose die temperature is from 200 °C or more to 400 °C or less, porous iron sintered-material preform which is preheated at a preheating temperature of from 300 °C or more to 400 °C or less in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas, and porous iron sintered-material preform in which an occupational volumetric fraction of iron powder is from 50% or more to 70% or less and then carrying out casting by means of impregnating the porous iron sintered-material preform with molten aluminum or aluminum alloy by pressurizing the molten aluminum or aluminum alloy with a 2-stage pressurizing method, the 2-stage pressurizing method comprising a first pressurizing stage in which the molten aluminum or aluminum alloy is pressurized at a lower pressure and a second pressurizing stage which follows the first pressurizing stage and in which the molten aluminum or aluminum alloy is pressurized at a higher pressure than the pressure in the first pressurizing stage.

[0014] An aluminum composite material, which is produced by the present production process, is such that the adhesiveness at the boundary between aluminum or aluminum alloy and iron sintered body improves.

[0015] It is more preferable that said preheating temperature can be from 350 °C or more to 400 °C or less.

[0016] Moreover, it is more preferable that said die temperature can be from 200 °C or more to 250 °C or less.

[0017] By means of carrying out the preheating of preform in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas, it is possible to make it a high temperature that exceeds 300 °C or more without precipitating any foreign materials, such as iron oxides and the other substances' oxides, which are generated by means of high heat, at the boundary.

[0018] The closer the temperature of preheating preform is to the molten-metal temperature of aluminum or aluminum alloy the more the impregnation of iron sintered body with aluminum or aluminum alloy improves, and thereby the adhesiveness between the two materials improves.

[0019] Moreover, the upper limit of the preform preheating temperature can be 400 °C or less. As aforementioned, although the preheating temperature can be made closer to the molten-metal temperature of aluminum or aluminum alloy as much as possible, the failure adhesiveness between iron sintered body and aluminum or aluminum alloy arises because intermetallic compounds and oxides generate as it becomes a higher temperature.

[0020] Moreover, it is preferable that the die temperature of the casting die can be said preform heating temperature or less. Although the reason for this has not been clear yet, it is believed as follows: since the thermal-expansion coefficient of aluminum is greater than the thermal-expansion coefficient of iron, the impregnation of iron sintered material with aluminum or aluminum alloy becomes better by means of lowering the casting-die temperature than the preform preheating temperature.

[0021] It is preferable that said 2-stage pressurizing method can be a first pressurizing stage in which the molten aluminum or aluminum alloy is pressurized at a lower pressure of from 20 MPa or more to 30 MPa or less for from 5 seconds or more to 15 seconds or less, and a second pressurizing stage which follows the first pressurizing method and in which the molten aluminum or aluminum alloy is pressurized at a higher pressure of from 70 MPa or more to 100 MPa or less for from 3 minutes or more to 5 minutes or less.

[0022] The pores of iron sintered-body preform have been squashed by means of pressurizing it. Accordingly, the pores of iron sintered body are impregnated with the molten metal of aluminum or aluminum alloy firstly at a lower pressure without ever squashing the pores of preform, and then they are impregnated with the molten metal of aluminum or aluminum alloy thereafter at a required pressure. By means of using the aforementioned 2-stage pressurizing method, since it is possible to impregnate the pores of iron sintered body with the molten metal of aluminum or aluminum alloy without ever squashing them, the adhesiveness at the boundary between the two materials improves because of physical

anchor effect.

[0023] It is more preferable that the iron powder's occupational volumetric fraction can be from 55% or more to 65% or less.

[0024] When the iron powder's occupational volumetric fraction falls in said range in a porous preform sintered body, the impregnation of iron sintered body with aluminum or aluminum alloy is good.

[0025] Moreover, it is preferable that said iron powder can be such that the particle diameter can be from 45 μm or more to 200 μm or less.

[0026] By means of the fact that the iron powder's particle diameter falls in the aforementioned range, it is possible to adjust the iron powder's occupational volumetric fraction by means of the iron powder's particle diameter.

[0027] Moreover, by means of the fact that the particle diameter falls in said range, it is possible to secure desirable good cast-in inserting ability, and moreover it is possible to secure desirable strength.

[0028] Effect of the Invention

[0029] The process according to the present invention for producing aluminum composite material, process in which an iron sintered body is cast-in inserted with aluminum can improve the adhesiveness at the boundary between aluminum or aluminum alloy and iron sintered body, because it has the aforementioned production steps. It can inhibit the drawbacks, such as pressure leakage, the occurrence of cracks, the extension of cracks and the degradation of conductivity, for instance, which have been occurring conventionally because of faulty adhesiveness at the boundary.

[0030] In particular, in the case where it is used as a material being employed under high pressure, the effect of adhesiveness improvement becomes more notable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] Fig. 1 illustrates a preform molding step in an embodiment mode according to the present invention: wherein (a) is a schematic diagram of such a state that an iron powder, and the like, are filled into a molding die and are pressurized therein; and wherein (b) is a schematic diagram of such a state that a molded preform is sintered within a sintering furnace.

[0032] Fig. 2 illustrates a composite-material forming step in an embodiment mode according to the present invention: wherein (a) is a schematic diagram of an iron sintered-body preform; wherein (b) is a schematic diagram of such a state that the iron sintered-body preform is placed in a casting die; and wherein (c) is a schematic diagram of an after-casting aluminum composite material.

[0033] Fig. 3 is a cross-sectional schematic diagram of an aluminum composite material in an example according the present invention, aluminum composite material which is subjected to cross-sectional processing.

[0034] Explanation on Reference Numerals

[0035]

- 1: Die 2, 3: Pressing Dies
- 4: Iron Powder 5: Sintering Furnace
- 6: Porous Iron Sintered-material Preform
- 7: Casting Die for Fixing Preform 8: Casting Die
- 9: Aluminum Composite Material
- 10: Porous Iron Sintered-material Preform
- 11: Aluminum Alloy 12: Boundary

BEST MODE FOR CARRYING OUT THE INVENTION

[0036] Hereinafter, a best mode for carrying out a process according to the present invention for producing composite material will be explained.

[0037] A process according to the present invention for producing aluminum composite material comprises: a preform molding step of molding a porous iron sintered-material preform; and a composite-material forming step of impregnating said preform with molten aluminum or aluminum alloy by pressurizing the molten aluminum or aluminum alloy, thereby carrying out casting.

[0038] The preform molding step is a step, which is characterized in that an iron powder is molded so that an occupational volumetric fraction becomes from 50% or more to 70% or less; and in that the iron powder is sintered at a sintering temperature of from 1, 100 °C or more to 1,300 °C or less in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas, thereby molding a porous iron sintered-material perform.

[0039] The porous iron sintered-material preform's shape is such that, as far as it is an aimed shape, there is not any limitation on the shape especially. By means of putting an iron powder in a molding die, which possesses an aimed shape, pressuring it and heating it, it is possible to mold a desirable preform.

[0040] On that occasion, it is desirable that the iron's occupational volumetric fraction can be from 50% or more to 70% or less. Here, the occupational volumetric fraction is expressed as "VF" (the abbreviation of Volume Fraction), and is expressed in %.

[0041] The "VF" can be controlled by means of controlling the particle diameter and amount of the iron powder, and the pressure, upon molding the preform.

[0042] When the "VF" is 70% or less, the porous iron sintered-material preform's porosity fraction becomes 30% or more, and thereby the impregnation of iron sintered material with aluminum or aluminum alloy is good.

[0043] In particular, it is desirable that the iron powder's "VF" can be from 55% or more to 65% or less. By means of employing an iron sintered-material preform, which exhibits the "VF" falling in this range, an aluminum composite material, which is good in terms of the strength and adhesiveness, is obtainable.

[0044] The iron powder is not limited especially as far as being a powder including iron. For example, it is possible to employ powders of pure iron, iron including copper, iron including copper and carbon, iron including copper, carbon and nickel, or iron including chromium and/or molybdenum, and the like.

[0045] It is preferable that the iron powder's particle diameter can be from 45 μm or more to 200 μm or less. By means of using an iron powder whose particle diameter falls in this range, it is possible to secure desirable cast-in inserting ability, and it is possible to secure desirable strength.

[0046] The sintering can be carried out by holding an employed raw material at a high temperature of the employed raw material's fusing point or less in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas.

[0047] For example, the sintering is carried out at a sintering temperature of from 1,100 °C or more to 1,200 °C or less for 45 minutes. It is desirable that an after-sintering cooling rate can be 30 °C -40 °C/min.

[0048] Moreover, after the sintering, it is allowable as well to carry out post treatments, such as carburizing, nitriding, hardening, tempering, normalizing, annealing and steam treatments.

[0049] As the porous iron sintered-material preform raw material, it does not matter to add a lubricant, and the like, in addition to an iron powder.

[0050] The composite-material forming step is a step in which said preform, which is preheated at a preheating temperature of from 300 °C or more to 400 °C or less in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas, is placed in a casting die whose die temperature is from 200 °C or more to 400 °C or less; and then the preform is impregnated with molten aluminum or aluminum alloy by pressurizing the molten aluminum or aluminum alloy by a 2-stage pressurizing method, thereby carrying out casting.

[0051] The inert gas is such that nitrogen, argon, and the like, can be employed.

[0052] As for the reducing gas, hydrogen, carbon monoxide, ammonia, and the like, can be employed.

[0053] The preheating is such that it is allowable as well to put the preform in a heating furnace and then heat it, or it is allowable as well to carry out high-frequency heating. In order to inhibit the superficial oxidation of the preform, it is preferable to carry out the preheating in a short period of time.

[0054] For example, it is possible to employ high-frequency heating under an inert-gas atmosphere.

[0055] It is preferable that the casting die's die temperature can be said preform preheating temperature or less. The preheating is such that it is allowable as well to place the casting die in a heating furnace and then carry out the preheating within the heating furnace, or it is allowable as well to carry out high-frequency heating.

[0056] It is allowable as well to carry out the preheating of the preform and the preheating of the casting die at the same location simultaneously, or it is allowable as well to carry them out at different locations at different times. For example, in the case of high-frequency heating, it is possible to carry out the preheating to the preform and the preheating to the casting die in different temperature settings simultaneously.

[0057] As far as being an alloy including aluminum, the aluminum alloy is not limited especially regarding its type. For example, it is possible to name aluminum alloys, and the like, which include Mg, Cu, Zn, Si, Mn, Fe, Cr or Ti, and so forth.

[0058] The 2-stage pressurizing method comprises: a first pressurizing stage in which the molten aluminum or aluminum alloy is pressurized at a lower pressure; and a second pressurizing stage which follows the first pressurizing stage and in which the molten aluminum or aluminum alloy is pressurized at a higher pressure than the pressure in the first pressurizing step.

[0059] It is allowable as well to carry out the pressurizing using a head pressure, or it is allowable as well to carry it out by the other methods. It is preferable that, especially in view of the removal of gases within casting die and the prevention of casting shrinkage and occurrence of voids that arise being accompanied by cooling and solidification, the pressurizing can be carried out using a head pressure.

[0060] In the case of head pressure, it is allowable that a pressure can be applied thereto to the same extent as die-cast molding (several dozens of MPa-several hundreds of MPa, for instance).

[0061] The aluminum composite material after casting can also be air cooled as it is being kept in the casting die after releasing pressure, or can be taken out of the casting die and then be air cooled.

[0062] Moreover, the other process according to the present invention for producing aluminum composite material

comprises a composite-material forming step of pressurizing a molten aluminum or aluminum alloy and then impregnating a porous iron sintered-material preform with the molten aluminum or aluminum alloy, thereby carrying out casting.

[0063] Except that a porous iron sintered-material preform which is molded by a certain method not being limited especially and in which an occupational volumetric fraction of iron powder is from 50% or more to 70% less is used, this production process is the same as the aforementioned process, the explanations will be omitted.

[0064] Hereinafter, an embodiment mode of the process according to the present invention for producing aluminum composite material will be explained using Fig. 1 and Fig. 2.

[0065] In Fig. 1, an explanatory diagram of a preform molding step is shown. (a) is a schematic diagram of such a state that an iron powder, and the like, are filled into a molding die and are pressurized therein. (b) is a schematic diagram of such a state that a molded preform is sintered within a sintering furnace.

[0066] Using Fig. 1, the preform molding step will be hereinafter explained. A die 1 as the molding die is formed as a cylinder shape, and is configured so that it is disintegrable into a plurality of molding-die constituent pieces. As for the material quality of the die 1, a high-carbon steel (carbon concentration: 0.1%-0.6%), such as S25C, is employed, for instance.

[0067] Within the die 1, a raw material, such as an iron powder, is put in, and is pressurized with the pressing dies 2, 3 so as to make the "VF" of the iron powder within the die 1 from 50% or more to 70% or less. The pressurizing is such that, depending on the iron powder's particle diameter, amount, and the like, an appropriate pressure is used.

[0068] The molded iron powders 4 are put in a sintering furnace 5, and the sintering is carried out in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas. The sintering is carried out by means of holding them at such a high temperature as the melting point or less of the iron powder, and the like.

[0069] Next, the after-sintering preform sintered bodies are cooled by means of cooling the temperature of the sintering furnace.

[0070] Moreover, in addition to the above, in the case where much higher dimensional accuracy is required, it is allowable as well to pressurize the sintered bodies again to carry out dimensional correction. Moreover, for the other purpose, it is allowable as well to carry out treatments, such as high-frequency hardening, carburizing and quenching, steam treatments, or the like.

[0071] Note that, in Fig. 1, the shape of the iron sintered bodies is formed as a cylindrical shape; however, by means of employing the die 1 with a shape which is conformed to the shape of aimed composite material, the iron sintered bodies with a desirable shape are formable.

[0072] Next, using Fig. 2, a composite-material forming step will be hereinafter explained.

[0073] In Fig. 2, an explanatory diagram of a composite-material forming step is shown. (a) is a schematic diagram of an iron sintered-body preform, (b) is a schematic diagram of such a state that the iron sintered-body preform is placed in a casting die, and (c) is a schematic diagram of an after-casting aluminum composite material.

[0074] First of all, a porous iron sintered-body preform 6 is preheated at a preheating temperature of more than 300 °C in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas. The preheating can be carried out either by putting it in a preheating furnace or by performing high-frequency heating. Moreover, it is allowable as well to carry out high-frequency heating in such a state that it is placed onto a casting die 7 for fixing preform.

[0075] The preheated porous iron sintered-body preform 6 is placed onto the casting die 7 for fixing preform. The casting dies 7 and 8 are preheated to such a temperature that is lower than the temperature of preheating the preform 6. Next, aluminum-aluminum-alloy molten metal is poured into the casting die 8 in which the preform 6 is placed.

[0076] Next, it is pressurized in two stages. The 2-stage pressurizing is such that, after carrying it out at a lower pressure for several seconds, it is carried out at a higher pressure for several minutes.

[0077] After releasing pressure, it is air cooled together with the casting dies. A completed aluminum composite material 9 is taken out of the casting dies.

[0078] Examples

[0079] Hereinafter, examples of the process according to the present invention for producing aluminum composite material will be explained.

[0080] An iron powder, from which those with a particle diameter of 45 μm or less were removed by sieving, lithium stearate, i.e., a lubricant, a carbon powder, were mixed using a mixer. The mixing proportion was set as follows: when the entirety is taken as 100% by weight, 98.3%-by-weight iron powder; 0.7%-by-weight carbon powder; and 1%-by-weight lithium stearate.

[0081] Next, a preforming die made of iron was prepared. Said mixed raw material powder was put in the preforming die, and was pressurized so that the "VF" became 60% or 70%. In order to establish 60% "VF," it was pressurized to an extent of about 150 MPa, thereby carrying out molding. The shape of preform was such that a cylindrical shape was used.

[0082] The after-pressurizing iron powder was put in a sintering furnace, and was sintered at 1,150 °C for 45 minutes

in the presence of an AX gas (N_2 -75 % H_2). After the sintering, the cooling of the sintering furnace was carried out at a cooling rate of 30-40 °C /min.

[0083] Thus, a cylinder-shaped porous iron sintered-material preform with 150-mm height, ϕ 120-mm outside diameter and ϕ 100-mm inside diameter was obtained.

[0084] The porous iron sintered-material preform, which was cooled adjacent to room temperature, was put in a heating furnace, and was preheated in the presence of an argon atmosphere.

[0085] The porous iron sintered-material preform, which was preheated, was taken out of the heating furnace, and was placed within a casting die, which had been preheated in advance to 200 °C or 250 °C with the other heating furnace. The preheating temperature was adapted to being 300 °C or 400 °C.

[0086] Through an opening of the casting die, a 750-800 °C molten metal, which comprised an aluminum alloy ADC12, was poured. The molten metal was poured to such an extent that it filled up the inside of the casting die substantially, and then a head pressure was applied to it.

[0087] The head pressure was such that the following were carried out: one in which 80 MPa was applied to the molten metal for 4 minutes from the beginning (Pressurizing Method #1); and one in which 20 MPa was applied to the molten metal for 10 seconds and thereafter 100 MPa was applied to it for 4 minutes (Pressurizing Method #2) .

[0088] Finally, pressure was released, and then the casting die was air cooled.

[0089] Thereafter, a cast product was taken out of the casting die, and the cylindrical inner peripheral surface was subjected to cutting.

[0090] Thus, a cylinder-shaped aluminum composite material with 150-mm height, ϕ 200-mm outside diameter and ϕ 90-100-mm inside diameter was obtained.

[0091] The production conditions of the respective examples are set forth in Table 1.

[0092]

[TABLE 1]

	Preform Production Conditions		Casting Conditions				
	Sintering Atmosphere	VF (%)	Preform Preheating Temp. (°C)	Pressurizing Method	Final Head Pressure	Molten-metal Temp. (°C)	Die Temp. (°C)
Ex. No. 1	AX Gas	60	300	#1	80	750	200
Ex. No. 2	AX Gas	70	400	#2	100	800	250
*Pressurizing Method: #1 is 1-stage pressurizing, and #2 is 2-stage pressurizing.							

[0093] The top end surface of the obtained aluminum composite materials according to Example Nos. 1 and 2 was subjected to milling, thereby subjecting them to cross-sectional processing.

[0094] In Fig. 3, a cross-sectional schematic diagram of an aluminum composite material is displayed, composite material which was subjected to cross-sectional processing.

[0095] An aluminum composite material 9, in which an aluminum alloy 11 was cast-in inserted around a porous iron sintered-material preform 10, is shown therein. The boundary between the preform 10 and the aluminum alloy 11 is designated with a boundary 12.

[0096] Using the processed cross section according to Example Nos. 1 and 2, a solution penetrant test was carried out.

[0097] The solution penetrant test was one in which a red penetrant liquid including a fatty ester, a high-boiling-point hydrocarbon and a red dye was sprayed onto said cross section by a spray; it was washed with a washing liquid 5 minutes later; and thereafter an aerosol developing agent was coated thereon likewise using a spray, thereby observing the cross section visually.

[0098] The red penetrant liquid got into spaces in the boundary between the porous iron sintered material and the aluminum alloy, and thereby the boundary could be observed visually.

[0099] In the results of the cross-section observation in which the aluminum composite materials according to Example Nos. 1 and 2 were used, no red-discolored portions were observed at the boundary between the porous sintered material and the aluminum alloy.

Claims

1. A process for producing aluminum composite material, the process being **characterized in that** it has:

a preform molding step of molding a porous iron sintered-material preform by molding an iron powder so that an occupational volumetric fraction becomes from 50% or more to 70% or less, and then by sintering the iron powder at a sintering temperature of from 1,100 °C or more to 1,300 °C or less in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas, thereby molding a porous iron sintered material preform; and

a composite-material forming step of placing said preform in a casting die whose die temperature is from 200 °C or more to 400 °C or less, the preform being preheated at a preheating temperature of from 300 °C or more to 400 °C or less in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas, and then carrying out casting by means of impregnating the preform with molten aluminum or aluminum alloy by pressurizing the molten aluminum or aluminum alloy by a 2-stage pressurizing method, the 2-stage pressurizing method comprising a first pressurizing stage in which the molten aluminum or aluminum alloy is pressurized at a lower pressure and a second pressurizing stage which follows the first pressurizing stage and in which the molten aluminum or aluminum alloy is pressurized at a higher pressure than the pressure in the first pressurizing stage.

2. The process for producing aluminum composite material set forth in claim 1, wherein said occupational volumetric fraction is from 55% or more to 65% or less.

3. The process for producing aluminum composite material set forth in claim 1 or 2, wherein said preheating temperature is from 350 °C or more to 400 °C or less.

4. The process for producing aluminum composite material set forth in either one of claims 1-3, wherein said die temperature is from 200 °C or more to 250 °C or less.

5. The process for producing aluminum composite material set forth in either one of claims 1-4, wherein said 2-stage pressurizing method comprises: a first pressurizing stage in which the molten aluminum or aluminum alloy is pressurized at a lower pressure of from 20 MPa or more to 30 MPa or less for from 5 seconds or more to 15 seconds or less; and a second pressurizing stage which follows the first pressurizing method and in which the molten aluminum or aluminum alloy is pressurized at a higher pressure of from 70 MPa or more to 100 MPa or less for from 3 minutes or more to 5 minutes or less.

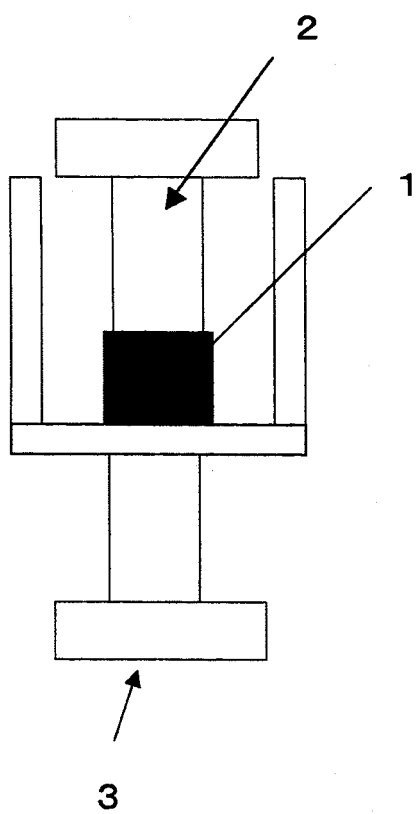
6. The process for producing aluminum composite material set forth in either one of claims 1-5, wherein said iron powder is such that the particle diameter is from 45 μm or more to 200 μm or less.

7. The process for producing aluminum composite material set forth in either one of claims 1-6, wherein said die temperature of the casting die is said preform preheating temperature or less.

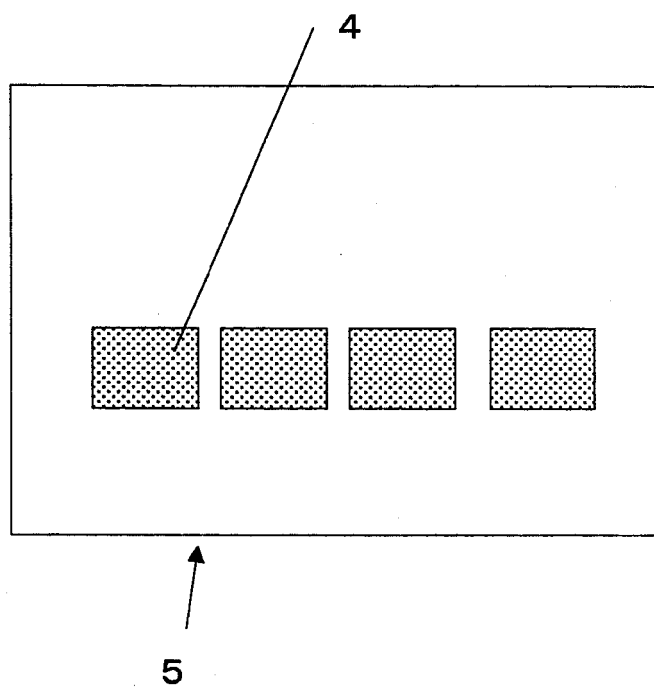
8. A process for producing aluminum composite material, the process being **characterized in that** it has:

a composite-material forming step of placing a porous iron sintered-material preform in a casting die whose die temperature is from 200 °C or more to 400 °C or less, porous iron sintered-material preform which is preheated at a preheating temperature of from 300 °C or more to 400 °C or less in vacuum, in an inert-gas atmosphere, in a reducing-gas atmosphere, or in a mixture-gas atmosphere of inert gas and reducing gas, and porous iron sintered-material preform in which an occupational volumetric fraction of iron powder is from 50% or more to 70% or less and then carrying out casting by means of impregnating the porous iron sintered-material preform with molten aluminum or aluminum alloy by pressurizing the molten aluminum or aluminum alloy with a 2-stage pressurizing method, the 2-stage pressurizing method comprising a first pressurizing stage in which the molten aluminum or aluminum alloy is pressurized at a lower pressure and a second pressurizing stage which follows the first pressurizing stage and in which the molten aluminum or aluminum alloy is pressurized at a higher pressure than the pressure in the first pressurizing stage.

Fig.1



(a)



(b)

Fig.2

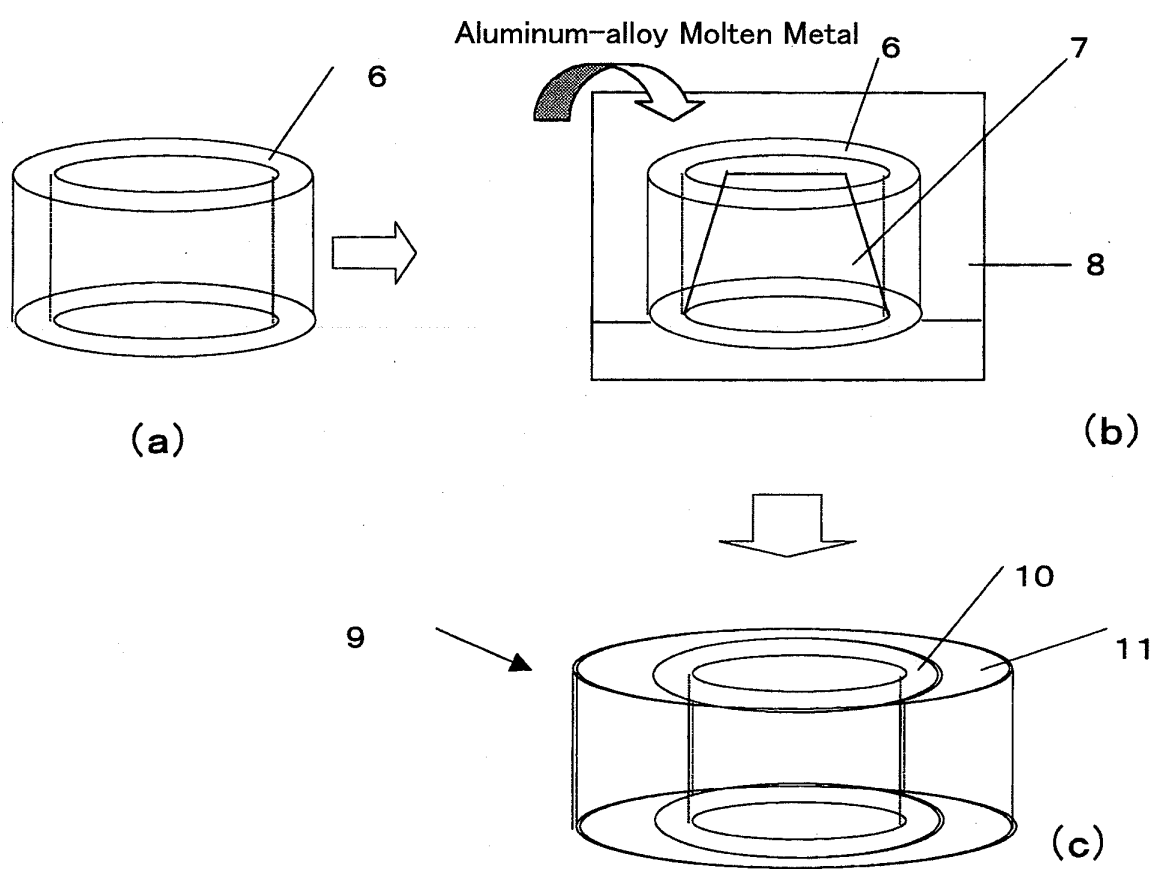
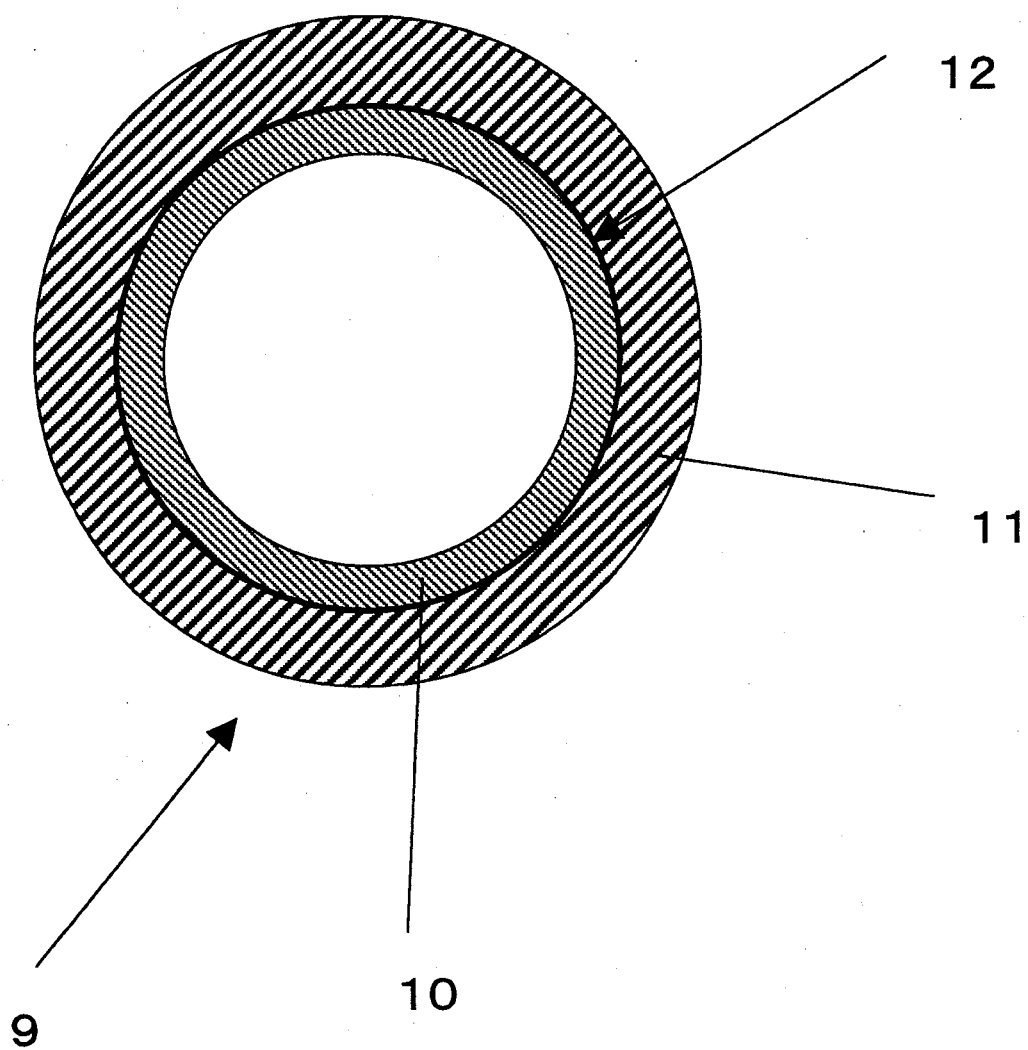


Fig.3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2006/308381

A. CLASSIFICATION OF SUBJECT MATTER

B22D19/00 (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)

B22D19/00

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 Toroku Koho	1996-2006
Kokai Jitsuyo Shinan Koho	1971-2006	Toroku Jitsuyo Shinan Koho	1994-2006

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	JP 2004-050225 A (Hitachi, Ltd.), 19 February, 2004 (19.02.04), Par. No. [0018] (Family: none)	1-8
Y	JP 2002-285205 A (Tocalo Co., Ltd.), 03 October, 2002 (03.10.02), Par. No. [0019] (Family: none)	1-8
Y	JP 05-123856 A (Yoshida Kiyasuto Kogyo Kabushiki Kaisha), 21 May, 1993 (21.05.93), Par. No. [0020] (Family: none)	1-8

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
20 July, 2006 (20.07.06)Date of mailing of the international search report
01 August, 2006 (01.08.06)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2006/308381

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 01-193496 A (Kubota Tekko Kabushiki Kaisha), 03 August, 1989 (03.08.89), Page 2, lower right column, lines 5 to 8 (Family: none)	1-8
Y	JP 2000-336438 A (Kubota Corp.), 05 December, 2000 (05.12.00), Par. No. [0017] (Family: none)	1-8

Form PCT/ISA/210 (continuation of second sheet) (April 2005)