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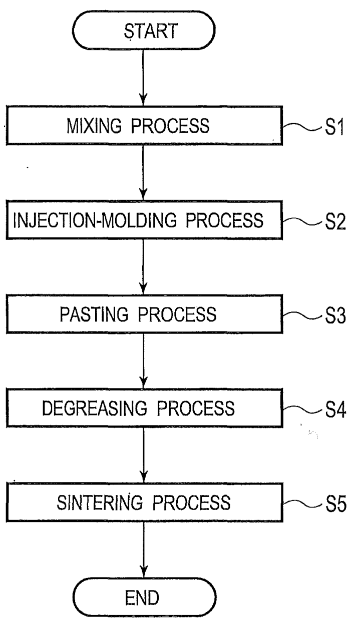
(54) **METHOD FOR BONDING METAL POWDER INJECTION MOLDED BODIES**

(57) In a method for jointing metal injection molded parts, [1] at least two metal injection molded parts each of which is inj ection-molded from mixtures of metal powders and binders are contacted with each other, [2] paste agents containing nitrogen or chlorine are pasted on a jointed portion at which the at least two metal injection molded parts are contacted with each other, and [3] the at least two metal injection molded parts are jointed at the jointed portion by degreasing or sintering, and thereby a metal product is manufactured. According to the jointing method, jointing strength of the jointed portion can be improved.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a method for jointing metal injection molded parts, especially to a method for jointing metal injection molded parts in order to manufacture a metal product by jointing plural metal injection molded parts.

BACKGROUND ART

[0002] Metal injection molding (MIM) is a method for manufacturing a metal product having density more than 95% by degreasing and sintering, in vacuum or under a gas atmosphere, a molded part (a green part) that is injection-molded from mixtures of metal powders and binders, and then injection-molding them to have a predetermined shape. As the binders, mixtures of plural plastics and waxes are used. The shape of the molded part is kept by dispersing plural constituents of the binders sequentially.

[0003] A constituent not to be remained in metal is preferably used for the binders. For example, it is common to use mixtures of waxes such as stearin acid, paraffin wax and carnauba wax that tend to vapor at relatively low temperature not more than 250°C, and plastics such as polyethylene, polypropylene, polystyrene, EVA (ethylene vinyl acetate) and EEA (ethylene-ethyl-acrylate copolymer resin) that tend to decompose and disperse at temperature not more than 500°C.

[0004] And now, stator blades of a turbine compressor are disposed between an annular inner shroud and an annular outer shroud, as disclosed in a Patent Document 1 listed below. In addition, stator blades are formed of alloy containing Ti or Ni as a major ingredient, and constituted by jointing plural stator blade sectors that are divided along a circumferential direction. Generally, the stator blade sector is formed by separately making an outer band that constitutes a portion of the outer shroud, an inner band that constitutes a portion of the inner shroud, and blades, and then brazing the outer band and the inner band with the blades.

[0005] Recently, in view of functional improvement, there are tendencies that a blade is made thinner and that its blade surface has a complicated three-dimensional curved surface, but it is hard to keep shape accuracy of a blade by casting or plastic forming. Therefore, it is proposed to use the above-mentioned metal injection molding as a manufacturing method for a blade(s).

[0006] It may be sometimes difficult to form the above-mentioned stator blade sector provided with the plural blades between the outer band and the inner band by injection molding (one process in the metal injection molding). Therefore, it is proposed to form a stator blade sector by forming divided members of the stator blade sector each has one blade between an outer band and an inner band, and then jointing the plural divided members.

[0007] A Patent Document 2 listed below discloses a method for jointing metal injection molded parts, and its object is to restrict decrease of jointing strength. In this jointing method, used are pastes that are made by diluting, with water, metal powders akin to metal powders that constitute a molded part and gelatinized soluble materials. First, the above-mentioned pastes are pasted on jointed surfaces of the molded parts that are not yet sintered, and then the molded parts are temporarily jointed with each other by the pastes. Subsequently, the temporarily-jointed molded parts are sintered, and thereby molded parts are jointed with each other by the metal powders contained in the pastes. Note that, in the Patent Document 2 listed below, disclosed are a case where the pastes are pasted on the jointed surfaces after degreasing and then sintering is done, and another case where degreasing and sintering are done after the pastes are pasted on the jointed surfaces.

Related Art Document

Patent Document

[0008]

Patent Document 1: Japanese Patent Application Publication No. 2004-197622
Patent Document 2: Japanese Patent Application Publication No. 2010-236042

SUMMARY OF INVENTION

Problems to be solved by the invention

[0009] The gelatinized soluble materials made from farinaceous materials are used in the pastes disclosed in the Patent Document 2. The farinaceous materials are polymer molecules made from carbon (C), Hydrogen (H) and oxygen (O), and are easily decomposed by heats. In addition, since a molded part is made by dispersing the binders from the green part constituted of the metal powders and the binders in the metal injection molding, a size of the molded part is shrunk from a size of the green part. Here, it is difficult to control deformations of the jointed surfaces due to the shrinkage. Therefore, if pastes (adhesive agents) to be easily decomposed by heats are used, the pastes are decomposed and dispersed early in a degreasing process or a sintering process, and thereby it becomes difficult to keep a firmly-contacted state between the shrunk jointed surfaces. Therefore, effects of restricting the decrease of jointing strength are insufficient.

[0010] An object of the present invention is to provide a method for jointing metal injection molded parts that can improve jointing strength.

[0011] An aspect of the present invention provides a method for jointing metal injection molded parts, the method comprising: contacting at least two metal injection molded parts with each other each of which is injection-molded from mixtures of metal powders and binders; pasting paste agents containing nitrogen or chlorine on a jointed portion at which the at least two metal injection molded parts are contacted with each other; and jointing the at least two metal inj ection molded parts at the jointed portion to manufacture a metal product by degreasing or sintering the at least two metal injection molded parts of which the jointed portion is pasted with the paste agents.

[0012] According to the aspect, decomposition rate of the paste agents can be made low by using the paste agents containing nitrogen or chlorine, so that a firmly-contacted state between the metal injection molded parts can be maintained further long during degreasing or sintering to improve jointing strength of the jointed portion.

[0013] Here, it is preferable that the binders contain waxes that vapor at a predetermined temperature range, and plastics that disperse at a higher temperature range than the predetermined temperature range, and part of the paste agents vapor later than the waxes and disperse earlier than the plastics during degreasing or sintering of the at least two metal injection molded parts.

[0014] In addition, it is preferable that the paste agents are pasted on a contact surface or a circumferential side surface of the jointed portion.

[0015] In addition, it is preferable that the at least two metal injection molded parts are degreased or sintered in a state where a gap of the jointed portion is kept not more than 0.1mm.

[0016] In addition, it is preferable that the metal product is a blade sector that includes a plurality of blades and a band portion that supports the plurality of blades, and each of the at least two metal injection molded parts is a divided member of the blade sector, the divided member including a single blade.

[0017] Further, it is preferable that a rib that extends in a direction intersecting with a chord line of the blade is formed on a back surface, located on a back side of a surface on which the blade is raised, of the band portion.

[0018] Here, it is preferable that, when an angle between an extending direction of the band portion and an extending direction of the rib in the band portion is denoted by θ, the angle θ is larger than 0° and not larger than a stagger angle of the blade.

[0019] Alternatively, it is preferable that, when an angle between an extending direction of the band portion and an extending direction of the rib in the band portion is denoted by θ, the angle θ satisfies $0° < \theta \leq 12°$.

BRIEF DESCRIPTION OF DRAWINGS

[0020]

[Fig. 1] It shows a flowchart of a method for jointing metal injection molded parts according to an embodiment.

[Fig. 2] It shows perspective views of a metal product manufactured by the method for jointing metal injection molded parts, and (a) shows a first example, (b) shows a second example and (c) shows a third example.

[Fig. 3] (a) shows a perspective view of metal injection molded parts after injection molding, and (b) shows a perspective view of the metal injection molded parts on which paste agents are pasted.

[Fig. 4] It shows explanatory cross-sectional views of a pasting method of the paste agents, and (a) shows a first example, (b) shows a second example, (c) shows a third example and (d) shows a fourth example.

[Fig. 5] (a) shows a front view of an outer band, and (b) shows a graph showing relations between an extending angle θ of a rib and a stability S.

[Fig. 6] It shows a front view of a modified example of the outer band.

[Fig. 7] It shows explanatory diagrams of a method for testing a gap of a jointed portion, and (a) shows a side view of a gap-adjustment state and (b) shows a side view of a joint-completion state.

DESCRIPTION OF EMBODIMENT

[0021] Hereinafter, a method for jointing metal injection molded parts according to an embodiment will be described with reference to the drawings.

[0022] In the method for jointing metal injection molded parts according to the present embodiment, a metal product 1 is manufactured by jointing metal injection molded parts 2 each of which is inj ection-molded from mixtures of metal powders and binders, and then degreasing (debinding) or sintering (calcining) them. Here, after paste agents 4 containing nitrogen (N) or chlorine (Cl) are pasted on jointed portions 3 of the metal injection molded parts 2, the metal injection molded parts 2 are jointed with each other, and then degreased or sintered.

[0023] Specifically, as shown in Fig. 1, the metal product 1 is manufactured through a mixing process S1 for mixing the metal powders and the binders, an injection-molding process S2 for heating and melting feedstock and then injecting them into dies, a pasting process S3 for coupling the metal injection molded parts 2 took out from the dies with each other and then pasting the paste agents 4 on the jointed portions 3 by a soldering iron or the like, a degreasing process S4 for degreasing the metal injection molded parts 2 on which the paste agents 4 have been pasted in a heating oven, and a sintering process S5 for sintering the metal injection molded parts 2 that have been degreased in a (the) heating oven.

[0024] The metal product 1 is a portion of a stator blade unit of a turbine compressor, for example. The stator blade unit is comprised of an annular inner shroud, an annular outer shroud, and plural stator blades disposed between them. The stator blade unit is manufactured by assembling plural stator blade sectors divided along a circumferential direction. The above metal product 1 is the stator blade sector.

[0025] The metal product 1 (the stator blade sector) shown in Fig. 2 (a) is comprised of an outer band 11 that is a portion of the outer shroud, an inner band 12 that is a portion of the inner shroud, and plural stator blades 13 disposed between the outer band 11 and the inner band 12. Note that dot-and-dash lines in Fig. 2(a) indicate the jointed portions 3.

[0026] The outer band 11 includes a shroud portion 11a that forms a flow path surface on an outer circumferential side of the stator blades 13, and hook portions 11b that are formed along both end edges of the shroud portion 11a, respectively. A stepped portion 11d is formed between the respective hook portions 11b and the shroud portion 11a, and the stepped portion 11d is engaged with a rail formed on a turbine housing. On a back surface, located on a back side of a surface on which the stator blades 13 are raised, of the outer band 11 (an opposite surface to the flow path surface), a depressed portion is formed by the shroud portion 11a and the hook portions 11b. In the depressed portion, ribs 11c each of which joints the pair of hook portions 11b are formed on the shroud portion 11a.

[0027] The inner band 12 includes a shroud portion 12a that forms a flow path surface on an inner circumferential side of the stator blades 13, and slot portions 12b that are formed along both end edges of the shroud portion 12a in an axial direction, respectively. The slot portion (s) 12b is formed by bending back a side edge of the shroud portion 12a. Inner circumferential ends of plural stator blades are jointed by inserting a plate part between the pair of slot portions 12b, and thereby the inner bands 12 formed by the plural shroud portions 12a are held to have an annular shape. The above-mentioned ribs 11c reinforce the outer band 11, and thereby they restrict deformations of the outer band 11 during the degreasing process S4 and the sintering process S5.

[0028] Configuration of the metal product 1 is not limited to the above configuration. As shown in fig. 2(b), the metal product 1 may be a stator blade sector that includes no rib 11c. In addition, as shown in Fig. 2(c), the metal product 1 may be a rotor blade sector that is a portion of the rotor blade unit. The metal product 1 as the rotor blade sector is comprised of an outer band 11 that constitutes a portion of an outer shroud, and plural rotor blades 14 that are integrated with the outer band 11. Note that dot-and-dash lines in Fig. 2(b) and Fig. 2(c) indicate the jointed portions 3.

[0029] In addition, the metal product 1 is not limited to a stator blade sector or a rotor blade sector, and encompasses all parts each of which is manufactured by jointing plural metal injection molded parts 2. In addition, the above-mentioned configuration of the outer band 11 or the inner band 12 is an example, and its shape is not limited to the above-described shape.

[0030] The above-described metal product 1 has a complicated shape, and thereby it may be difficult to manufacture it by one-time inj ection-molding while maintaining its shape accuracy. In addition, if a size of the metal product 1 is made larger, it may deform during degreasing or sintering due to increase of its weight. Therefore, in the present embodiment, the metal product 1 as shown in Fig. 2(a) is manufactured by jointing the plural metal injection molded parts 2 (divided members) as shown in Fig. 3(a). Since each of the metal injection molded parts 2 has a single stator blade 13 between the outer band 11 and the inner band 12, it can be manufactured by one-time injection-molding while maintaining its shape accuracy.

[0031] The metal product 1 manufactured by jointing the plural metal injection molded parts 2 is a blade sector (e.g. the stator blade sector) provided with plural blades (the stator blades 13) and band portions (the outer band 11 and the inner band 12) that support the blades. The metal injection molded part 2 is a part divided from the blade sector to have a single blade. Therefore, even if the metal product 1 has a complicated shape, the metal injection molded part(s) 2 has a shape that can be injection-molded easily, and its shape accuracy can be maintained. Note that, in following descriptions for the metal injection molded part (s) 2, identical reference numerals used for equivalent elements of the metal product 1 will be used (such as the outer band 11, the inner band 12 and the stator blade 13).

[0032] Respective processes of a flowchart shown in Fig. 1 will be described. In the mixing process S1, the metal powders and the binders that become feedstock of the metal injection molded part 2 are mixed, and then pelletized. As the metal powders, powders whose particle diameter is almost 10 to 20 μm made from stainless steel (SUS), titanium, various types of alloys, various types of ceramics and so on are used, for example.

[0033] In addition, the binders contain waxes that vapor at a predetermined temperature range, and plastics that disperse at a higher temperature range than that of the waxes. The waxes are stearin acid, paraffin wax, carnauba wax and so on that tend to vapor at relatively low temperature not more than 250°C, for example. Further, the plastics are polyethylene, polypropylene, polystyrene, EVA (ethylene vinyl acetate), EEA (ethylene-ethylacrylate copolymer resin) and so on that tend to decompose and disperse at temperature not more than 500°C (these can be used by being mixed). Note that lubricants, surfactants and so on are added to the binders as needed in addition to the waxes and the plastics.

[0034] In the injection-molding process S2, the metal injection molded parts 2 shown in Fig. 3(a) are molded. The metal injection molded part 2 is also called as a green part. Since the binders are contained in the metal injection molded part 2 in addition to the metal powders that will constitute the metal product 1, a size of the metal injection molded part 2 is larger than a size of the metal product 1.

[0035] In the pasting process S3, as shown in Fig. 3(b), the plural metal injection molded parts 2 are assembled to have a shape of the metal product 1, and then the paste agents 4 are pasted on the jointed portions 3. The paste agents 4 are waxes or plastics that contain nitrogen (N) or chlorine (Cl), for example. In addition, at least part of the paste agents 4 contains materials that disperse later than the waxes contained in the binders during degreasing or sintering, and materials that disperse earlier than the plastics contained in the binders during degreasing or sintering. Here, the phrase "at least part of the paste agents 4" means that some of constituents contained in the paste agents 4 disperse earlier than the waxes contained in the binders, and disperse later than plastics contained in the binders.

[0036] Specifically, as the paste agents 4, waxes having urethane group (-NHCOO-) or amide group (-CONH$_2$), chlorinated waxes and so on, or hot-melt adhesives having urethane group can be used. As sold products, they are Hi-Bon (registered trademark: Hitachi Kasei Polymer Co., Ltd.), Macromelt (registered trademark: Henkel AG & Co. KGaA), EMPARA (registered trademark: Ajinomoto Fine-Techno Co., Inc.), and so on.

[0037] If the paste agents 4 disperse at early stage during the degreasing process S4 or the sintering process S5 that will be described later, a gap may be generated at the jointed portions 3 of the metal injection molded parts 2, and thereby strength of the metal product 1 after being sintered may degrade. However, since the paste agents 4 in the present embodiment are materials that are not easily decomposed by heats, i.e. waxes or resigns that contain nitrogen (N) and/or chlorine (Cl), they don't disperse at early stage during the degreasing process S4 or the sintering process S5. Note that the paste agents 4 may be mixtures of waxes that contain nitrogen (N) and/or chlorine (Cl) and resigns that contain nitrogen (N) and/or chlorine (Cl).

[0038] By using the above-described paste agents 4, at least part of the paste agents 4 can be made dispersed later than the waxes contained in the binders during degreasing or sintering, and can be made dispersed earlier than the plastics contained in the binders during degreasing or sintering. Since the paste agents 4 contain materials that disperse later than the waxes of the binders that are degreased, the paste agents 4 can be restricted from dispersing in the degreasing process S4, and thereby adhesion (temporary jointing) function of the paste agents 4 can be maintained for a long duration.

[0039] In addition, since the paste agents 4 contain materials that disperse earlier than the plastics contained in the binders during degreasing or sintering (i.e. at least part of the paste agents 4 remains until almost a time when the plastics of the binders disperse), dispersing paths of the plastics of the binders are not blocked in the sintering process S5, and thereby the metal powders can be sintered in a wholly-balanced manner. As a result, deformations of the metal product 1 can be restricted. (Note that the "deformation" used here doesn't include shrinkage from the metal injection molded parts 2 to the metal product 1 due to sintering.) In addition, since the jointed portions 3 of the metal injection molded parts 2 (also called as a brown part (s)) are kept in a firmly-contacted state after the degreasing process S4, strength of the metal product 1 after being sintered is improved.

[0040] The above-described paste agents 4 are pasted, in a heated-and-melted state, on the jointed portions 3 by a soldering iron, a roller, spraying, immersion coating and so on. For example, when using a soldering iron, paste agents 4 having softening temperature not more than 330°C that is an operating temperature of the soldering iron. The paste agents 4 are pasted on contact surfaces 3a or circumferential side surfaces 3b of the jointed portions 3.

[0041] In a first example, shown in Fig. 4(a), the paste agents 4 are pasted on the contact surfaces 3a. In a case of pasting the paste agents 4 on the contact surfaces 3a, adhesive strength (jointed strength) of the jointed portions 3 can be improved. However, it is preferable that a gap g of the jointed portion 3 is kept not more than 0.1mm. If the gap g becomes wide, it may cause strength degradation of the jointed portions 3 in the metal product 1 and deformation of the metal product 1.

[0042] In a second example shown in Fig. 4(b), the paste agents 4 are pasted on the contact surfaces 3a and the circumferential side surfaces 3b. The contact surfaces 3a are opposing surfaces at the jointed portion 3 of the metal injection molded parts 2, and the circumferential side surfaces 3b are side surfaces at the jointed portion 3 of the metal injection molded parts 2. By pasting the paste agents 4 on the circumferential side surfaces 3b in addition to the contact surfaces 3a, a pasted amount on the contact surfaces 3a can be reduced, and thereby the gap g can be easily adjusted to be not more than 0.1mm. In addition, since an adhesive (jointed) area can be increased, adhesive strength (jointed strength) of the jointed portions 3 can be improved.

[0043] In a third example shown in Fig. 4(c), the paste agents 4 are pasted on the circumferential side surfaces 3b. Here, the paste agents 4 are pasted on whole circumferences of the circumferential side surfaces 3b at the jointed portion 3. By pasting the paste agents 4 only on the circumferential side surfaces 3b, the gap g can be easily adjusted to be not more than 0.1mm. In addition, the paste agents 4 pasted on the circumferential side surfaces 3b are heated and then melted in the degreasing process S4 or the sintering process S5, and infiltrate between the contact surfaces 3a voluntarily. Therefore, the gap *g* can be kept to have a desired value, and adhesive strength (jointed strength) of the jointed portions 3 can be improved also by the contact surfaces 3a.

[0044] In a fourth example shown in Fig. 4(d), the paste agents 4 are pasted on a portion of the circumferential side surfaces 3b. In a case where the jointed portion 3 has a complicated shape, the paste agents 4 may be pasted on areas to be easily pasted. In addition, in a case where the contact surfaces 3a extend in a vertical direction as shown in Fig. 4(d), the paste agents 4 pasted on the upper circumferential side surfaces 3b infiltrate between the contact surfaces 3a due to gravity.

[0045] As shown in Fig. 3(b), the metal injection molded parts 2 on which the paste agents 4 are set on a support block 5, and then sent to the degreasing process S4. Here, by making a height level h of the stepped portion 11d of the outer band 11 identical to a height level h of the inner band 12, the stator blades 13 can be set horizontally in a state where the stepped portion 11d is contacted with corner of the support block 5.

[0046] On the other hand, in a case where the above-mentioned height levels h are not made identical to each other, a gap may be generated between an end edge of the inner band 12 and the support block 5 when setting the stator blades 13 horizontally in a state where the stepped portion 11d of the outer band 11 is contacted with the corner of the support block 5. In such a case, a supplemental support block (not shown in the drawings) may be inserted into the gap between the end edge of the inner band 12 and the support block 5. Alternatively, a gap may be generated between the stepped portion 11d of the outer band 11 and the corner of the support block 5 when setting the stator blades 13 horizontally in a state where an end edge of the inner band 12 is contacted with the support block 5. In such a case, a supplemental support block may be inserted into the gap between the stepped portion 11d and (the corner of) the support block 5.

[0047] Since the binders are removed during the degreasing process S4 and the sintering process S5, a size of the metal product 1 after being sintered shrinks wholly from a side of the metal injection molded parts 2. Therefore, the stator blades 13 can be shrunk almost horizontally by setting the stator blades 13 horizontally. As a result, the jointed metal injection molded parts 2 can be shrunk in a wholly-balanced manner, and deformation due to distortion upon shrinking can be restricted.

[0048] In the degreasing process S4, the waxes contained in the binders are removed. Heating temperature for the degreasing process S4 is generally lower than heating temperature for the sintering process S5. Therefore, the metal injection molded parts 2 may be heated in a degreasing apparatus other than a sintering oven used for the sintering process S5. Of course, the metal injection molded parts 2 may be degreased by controlling temperature in a sintering oven used for the sintering process S5.

[0049] In the sintering process S5, the plastics contained in the binders are removed, and thereby the metal powders are sintered. For example, in a case of using IN718 [IN: Inconel (registered trademark: Special Metals Corporation)] that is Ni-base alloy as the metal powders, it is preferable to carry out sintering under a non-oxidizing atmosphere with more than 1200°C. With respect to the metal product 1 after being sintered, as post processes, density measurement may be done in order to confirm progress of sintering, press-working may be done in order to adjust its dimensions precisely, electro-discharge machining may be done in order to treat its surfaces, and grinding or polishing may be done in order to fix its surface roughness.

[0050] The above-mentioned ribs 11c (see Fig. 2(a), Fig. 3(a) and Fig. 3(c)) will be described. As shown in Fig. 5(a), the ribs 11c are extended on a back surface of the outer band 11 (band portion). An extending direction Lr of the rib(s) 11c intersects with a chord line Lc of the stator blade 13. When an angle of the rib 11c to an extending direction of the outer band Le (a vertical direction in a case shown in Fig. 5(a)) is denoted by θ (>0: magnitude of the angle), a lateral width of the outer band 11 of the metal injection molded part 2 is denoted as A, and its height is denoted by B, shape stability S (dB: decibel) of the metal injection molded parts 2 (the metal product 1) can be calculated by $S=10\cdot\log_{10}(B/A)$.

[0051] The metal injection molded parts 2 each of which has the above-mentioned angle θ=0°, 6° or 12° are molded, and then shapes of their outer bands 11 after being sintered are measured three-dimensionally to compare them with ideal shape of the metal injection molded parts 2 (the metal product 1) that are uniformly shrunk. The comparison results are shown in Fig. 5(b). If the stability S is high, shape difference from the uniformly-shrunk metal injection molded parts 2 is small. On the other hand, if the stability S is low, shape difference from the uniformly-shrunk metal injection molded parts 2 is large.

[0052] As shown in Fig. 5(b), the stability S of θ = 6° and 12° is higher than that of θ = 0°. Therefore, it is preferable that the angle θ of the rib 11c is made large (i.e. an intersecting angle with the chord line Lc is made large). However, also in a case of θ = 0°, the stability S can be made high enough to keep shape accuracy of the metal product 1 according to conditions such as size, shape and weight of the metal injection molded part(s) 2. Therefore, the above case of θ = 0° is not excluded.

[0053] In addition, if the angle θ of the rib 11c is too large, it is concerned that deformation during sintering due to its weight is fomented. Therefore, it is preferable to set an upper limit for the angle θ. In view of the above-mentioned matters, it is preferable to set the upper limit of the angle θ to a stagger angle λ (>0: magnitude of the angle) of the stator blade 13. The "stagger angle λ" is an angle of the chord line Lc to a turbine-axis direction La (which is parallel to the extending direction Le in the case shown in Fig. 5(a)), as shown in fig. 5(a). Specifically, it is preferable to determine the upper limit of the angle θ within a range 6° to 12° based on the above-described test results. However, the upper limit of the angle θ is not restricted by these values (range), but can be determined with respect to each metal injection molded part 2 according to weight of the rib 11c.

[0054] Namely, it is preferable that the angle θ between the extending direction Le of the outer band 11 and the extending direction Lr of the rib 11c is set larger than 0° and not larger than the stagger angle λ. Especially, only in view of deformation due to shrinkage, it is further preferable that the angle θ has identical magnitude to that of the stagger angle λ. Here, since the stagger angle λ of the stator blade 13 is determined in some measure, it is specifically preferable that 0°<θ≤12°. Note that a direction of the angle θ from the extending direction Le of the outer band 11 to the extending direction Lr of the rib 11c is opposite to a direction of the stagger angle λ from the turbine-axis direction La to the chord line Lc.

[0055] Fig. 6 shows a modified example in which end surfaces of the metal injection molded part(s) 2 are inclined to the turbine-axis direction La. As shown in Fig. 6, there may be a case where the rib(s) 11 is inclined in this manner according to relation with the stagger angle λ of the stator blade 13. In the present modified example, the extending direction Le of the outer band 11 is not parallel to the turbine-axis direction La. In the case as shown in Fig. 6, difference between overhangs OH1 and OH2 of the outer band(s) 11 to the rib(s) 11c can be made small, so that the deformation of the metal injection molded parts 2 (the metal product 1) due to distortion upon shrinking can be also restricted effectively.

[0056] Next, the above-mentioned gap g of the jointed portion 3 (see Fig. 4(a)) will be described. As shown in Fig. 7(a), two metal injection molded plates 6 are prepared to form a gap between the two metal injection molded plates 6 by inclining one of the two metal injection molded plates 6 on another of the two metal injection molded plates 6 b use of a spacer 7. By changing a horizontal position of the spacer 7, a size of the gap can be adjusted. The paste agents 4 are pasted on this gap and then the metal injection molded plates 6 are degreased and sintered to measure a gap C that can joint the metal injection molded plates 6 with sufficient jointing strength. The cap C realizing sufficient jointing strength is 0.1mm. Therefore, it is preferable that the gap g of the jointed portion 3 is not more than 0.1mm.

[0057] Note that the gap C may vary according to the metal powders, the binders and so on that become feedstock of the metal injection molded plate (s) 6. Namely, the gap *g* of the jointed portion 3 is not necessarily limited to be not more than 0.1mm, but it is preferable, on an empirical basis, that it is not more than 0.1mm-0.5mm.

[0058] According to the jointing method in the present embodiment, since the paste agents 4 contain nitrogen (N) or chlorine (Cl), decomposition rate of the paste agents 4 can be made low. Therefore, a firmly-contacted state between the metal injection molded parts 2 can be maintained further long during degreasing or sintering, and thereby jointing strength of the jointed portion(s) 3 can be improved.

[0059] The present invention is not limited to the present embodiment, and can be modified variedly within a scope that does not extend beyond the subject matter of the present invention. For example, ribs may be formed on the inner band 12. Note that, since the ribs 11c are provided in order to improve the shape accuracy of the metal product 1 (the metal injection molded parts 2) during degreasing or sintering, there may be a case where they are cut away before completion of the stator blade unit (even if the ribs 11c are cut away, the angle θ of the rib (s) 11c are recognizable from their cut-away marks) . In addition, the plural ribs 11c may be provided on a single metal injection molded part 2.

Claims

1. A method for jointing metal injection molded parts, the method comprising:

    contacting at least two metal injection molded parts with each other each of which is injection-molded from mixtures of metal powders and binders;
    pasting paste agents containing nitrogen or chlorine on a jointed portion at which the at least two metal injection molded parts are contacted with each other; and
    jointing the at least two metal injection molded parts at the jointed portion to manufacture a metal product by degreasing or sintering the at least two metal injection molded parts of which the jointed portion is pasted with the paste agents.

2. The method for jointing metal injection molded parts according to claim 1, wherein
the binders contain waxes that vapor at a predetermined temperature range, and plastics that disperse at a higher temperature range than the predetermined temperature range, and
part of the paste agents vapors later than the waxes and disperse earlier than the plastics during degreasing or sintering of the at least two metal injection molded parts.

3. The method for jointing metal injection molded parts according to claim 1 or 2, wherein
the paste agents are pasted on a contact surface or a circumferential side surface of the jointed portion.

4. The method for jointing metal injection molded parts according to any one of claims 1 to 3, wherein
the at least two metal injection molded parts are degreased or sintered in a state where a gap of the jointed portion is kept not more than 0.1mm.

5. The method for jointing metal injection molded parts according to any one of claims 1 to 4, wherein
the metal product is a blade sector that includes a plurality of blades and a band portion that supports the plurality of blades, and
each of the at least two metal injection molded parts is a divided member of the blade sector, the divided member including a single blade.

6. The method for jointing metal injection molded parts according to claim 5, wherein
a rib that extends in a direction intersecting with a

chord line of the blade is formed on a back surface, located on a back side of a surface on which the blade is raised, of the band portion.

7. The method for jointing metal injection molded parts according to claim 6, wherein, when an angle between an extending direction of the band portion and an extending direction of the rib in the band portion is denoted by θ, the angle θ is larger than 0° and not larger than a stagger angle of the blade.

8. The method for jointing metal injection molded parts according to claim 6, wherein, when an angle between an extending direction of the band portion and an extending direction of the rib in the band portion is denoted by θ, the angle θ satisfies $0° < \theta \leq 12°$.

FIG. 1

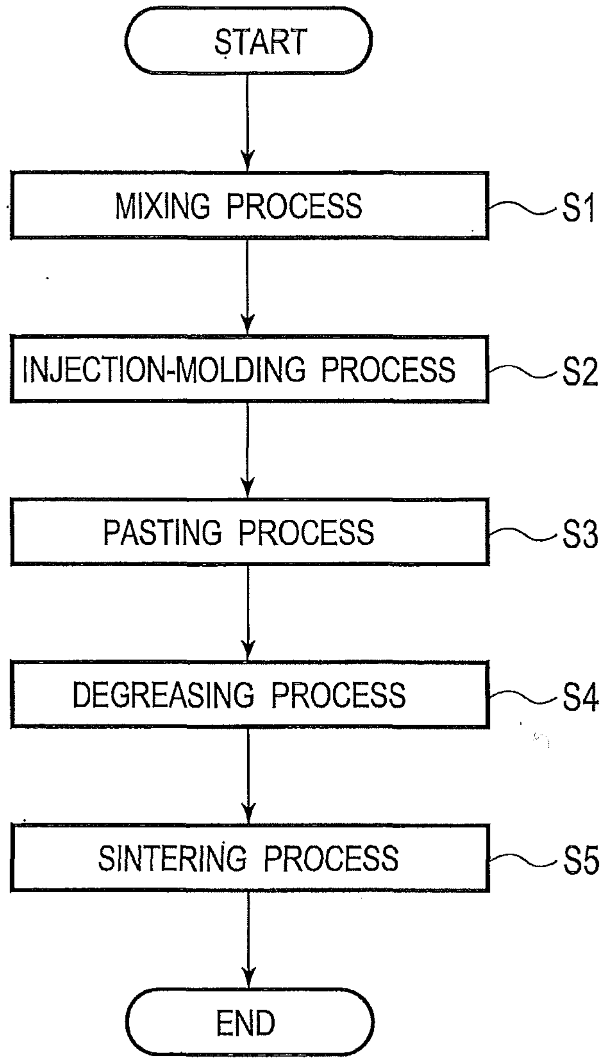
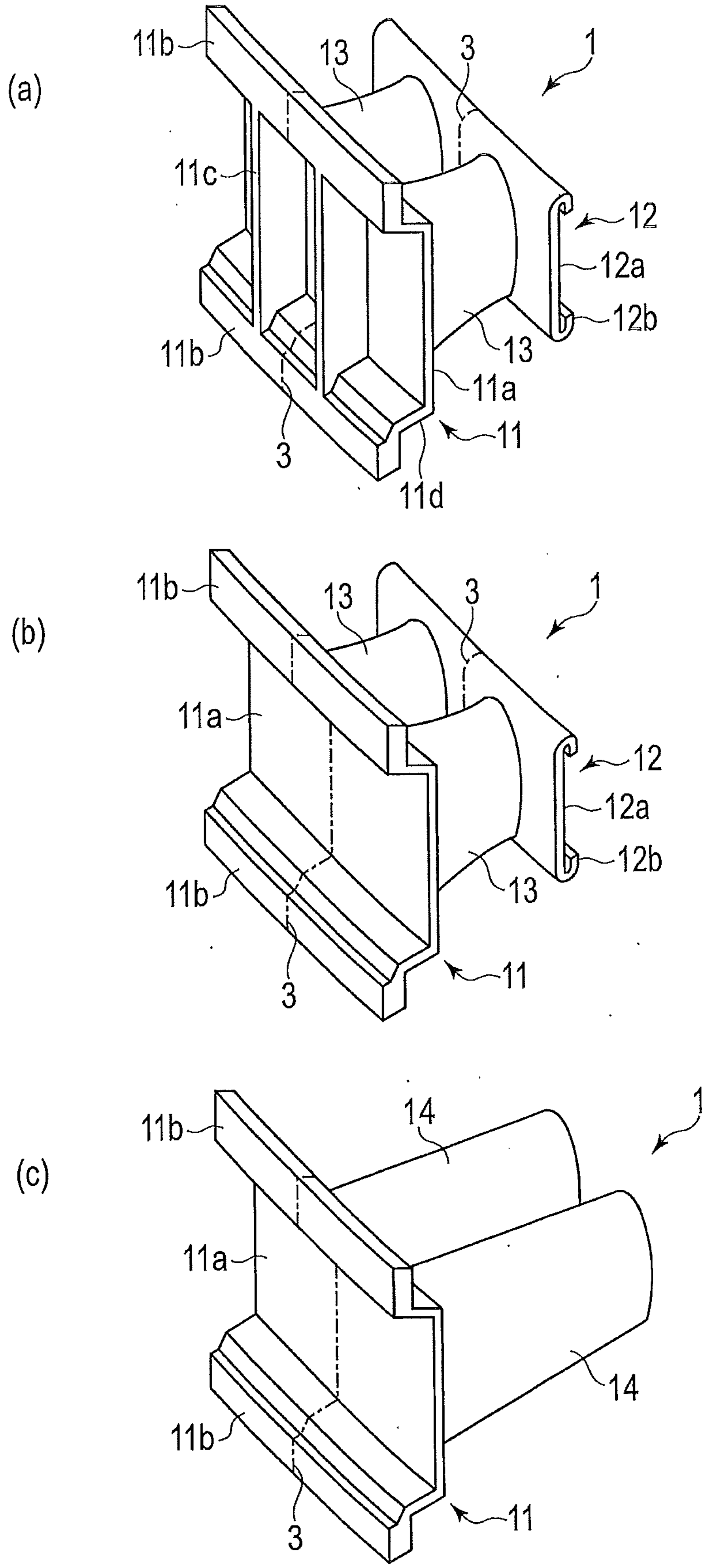

START
MIXING PROCESS
S1
INJECTION-MOLDING PROCESS
S2
PASTING PROCESS
S3
DEGREASING PROCESS
S4
SINTERING PROCESS
S5
END

FIG. 2


(a)
11b
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3
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11c
12
12a
12b
13
11b
11a
11
3
11d
(b)
11b
13
3
1
11a
12
12a
12b
11b
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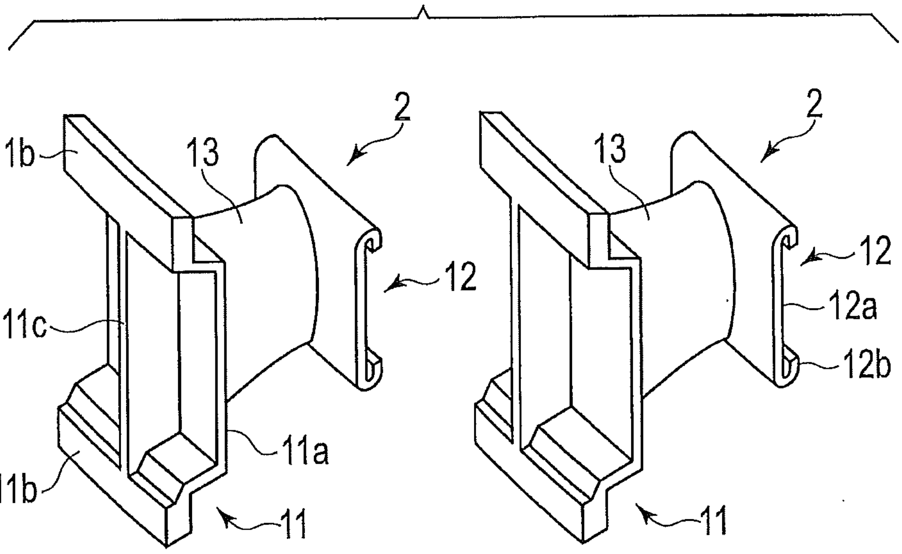
11
3
(c)
11b
14
1
11a
14
11b
11
3

FIG. 3

(a)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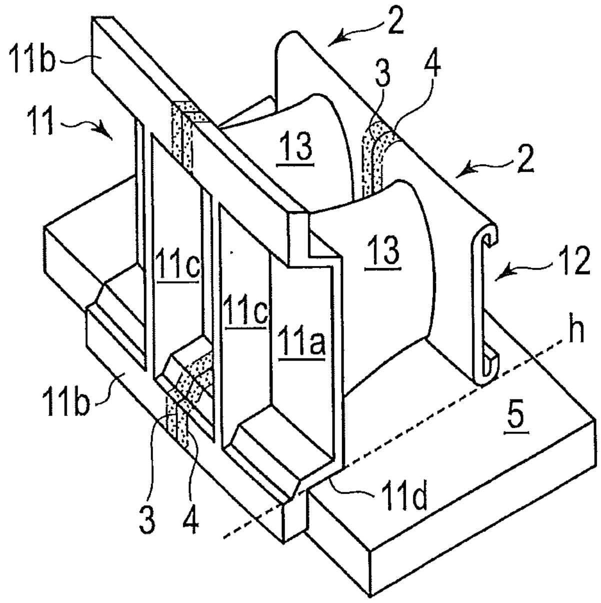
(b)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3
4
13
2
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12
11c
11c
11a
h
11b
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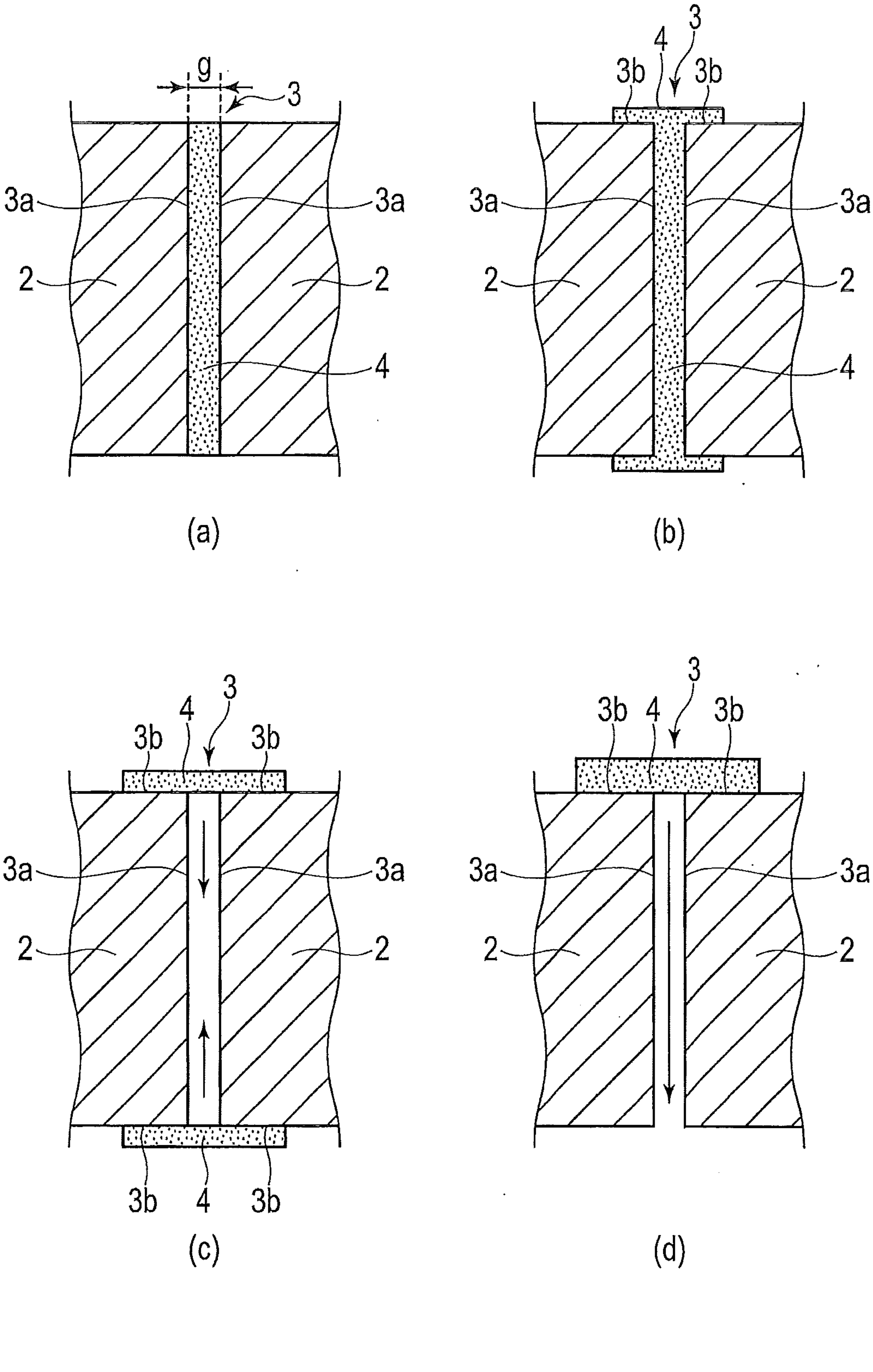
3
4
11d

FIG. 4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4
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3
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3a
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2
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3a
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2
2
(d)

FIG. 5

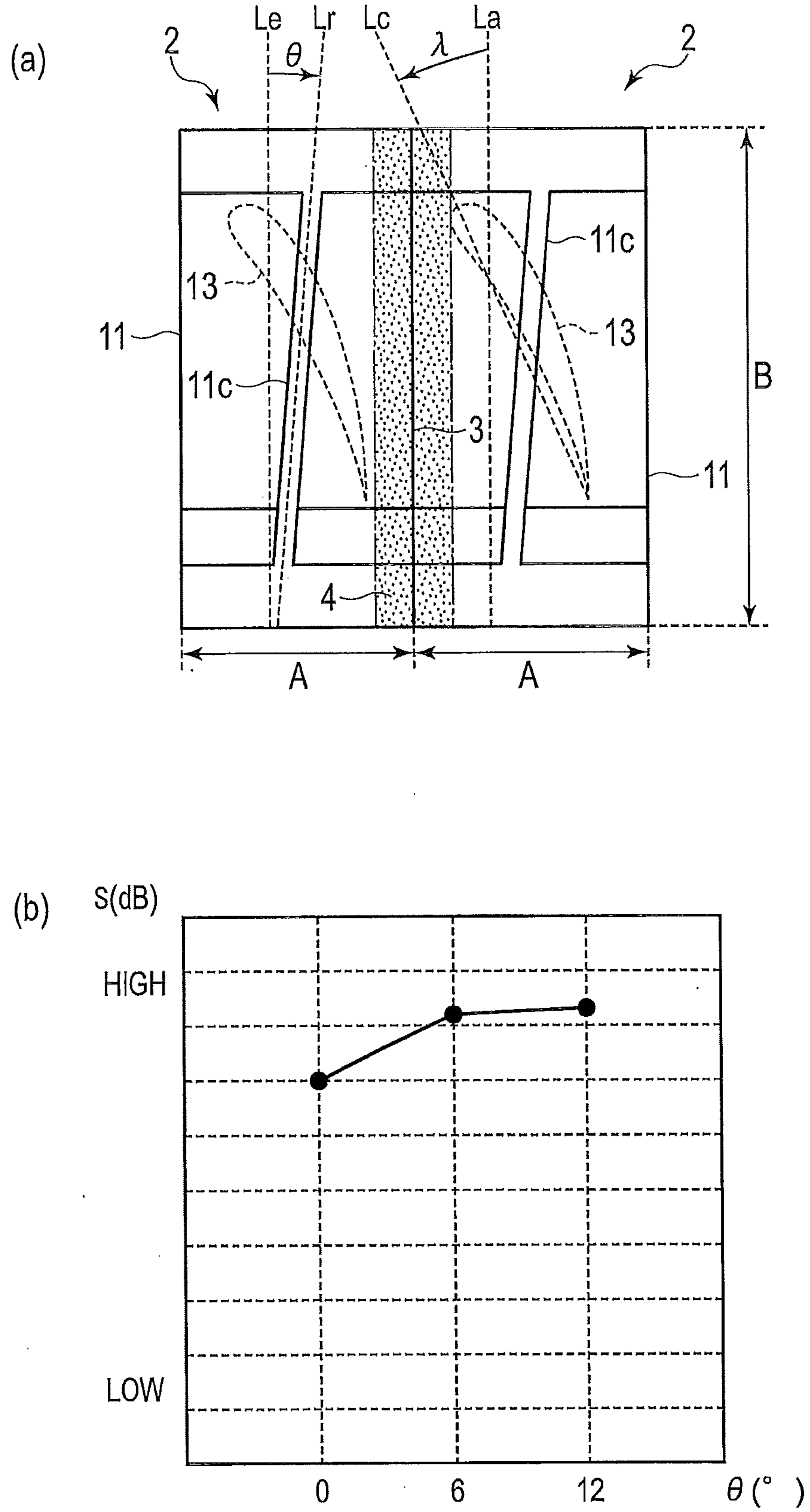
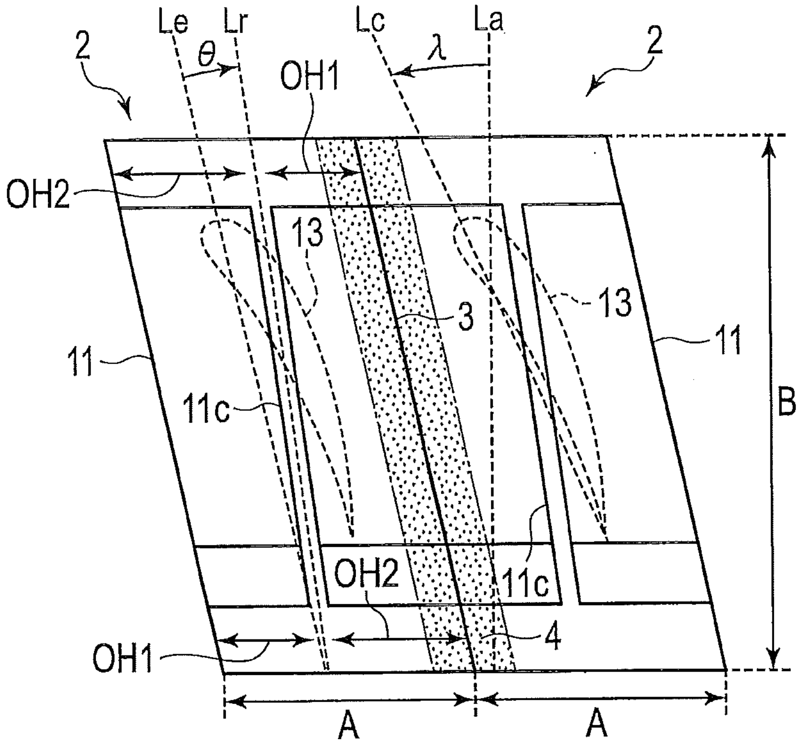


FIG. 6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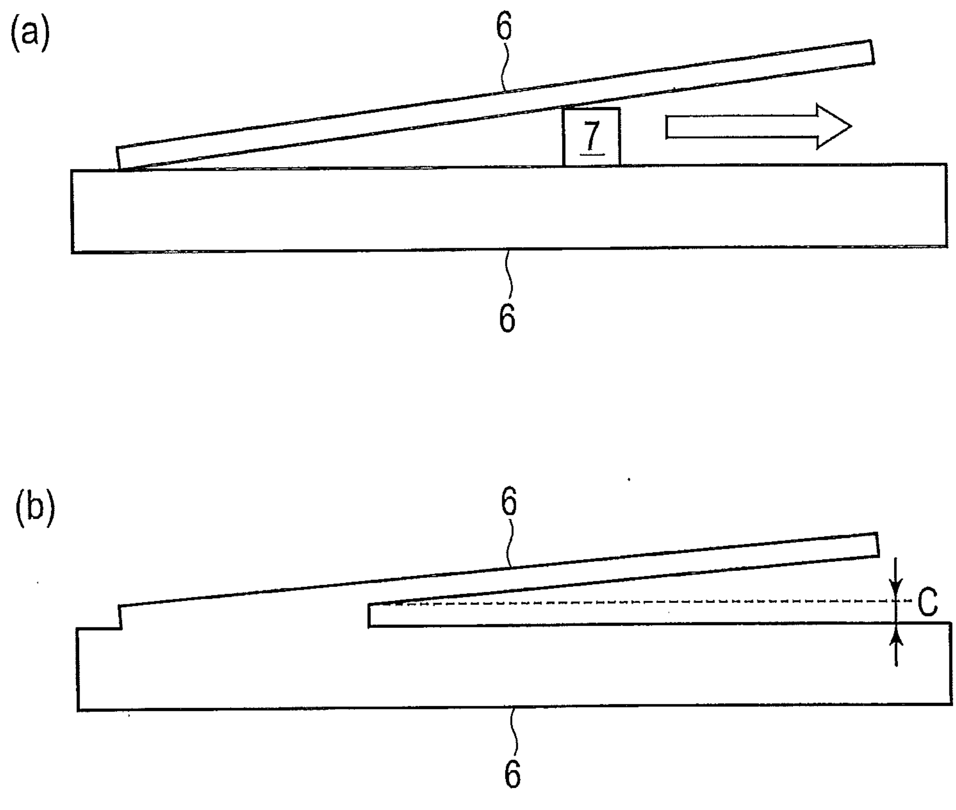
Lr
Lc
La
θ
λ
2
2
OH1
OH2
13
13
3
11
11
11c
11c
B
OH2
4
OH1
A
A

FIG. 7


(a)
6
7
6
(b)
6
C
6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/074514

A. CLASSIFICATION OF SUBJECT MATTER
B22F7/06(2006.01)i, *B22F3/02*(2006.01)i, *F04D29/54*(2006.01)i, *F04D29/64*(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)
B22F7/06, B22F3/02, F04D29/54, F04D29/64

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	1996-2014
Kokai Jitsuyo Shinan Koho	1971-2014	Toroku Jitsuyo Shinan Koho	1994-2014

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
JSTPlus/JMEDPlus/JST7580(JDreamIII)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 8-20808 A (Olympus Optical Co., Ltd.), 23 January 1996 (23.01.1996), claims; paragraphs [0032], [0038] (Family: none)	1-5 6-8
Y	JP 2006-249943 A (Honda Motor Co., Ltd.), 21 September 2006 (21.09.2006), paragraphs [0015], [0018]; fig. 4 (Family: none)	6-8
A	JP 7-11305 A (Seiko Instruments Inc.), 13 January 1995 (13.01.1995), claims (Family: none)	1-8

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

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"&" document member of the same patent family

Date of the actual completion of the international search 28 November, 2014 (28.11.14)	Date of mailing of the international search report 09 December, 2014 (09.12.14)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2014/074514

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2013-18228 A (IHI Corp.), 31 January 2013 (31.01.2013), entire text; all drawings (Family: none)	5-8
A	JP 2009-97370 A (Mitsubishi Heavy Industries, Ltd.), 07 May 2009 (07.05.2009), entire text; all drawings & US 2010/0135782 A1 & EP 2187062 A1 & WO 2009/051089 A1 & CN 101617129 A & KR 10-2009-0104112 A	5-8
A	JP 2009-19629 A (Snecma), 29 January 2009 (29.01.2009), fig. 1 & US 2009/0060745 A1 & EP 2014873 A1 & DE 602008002486 D & FR 2918702 A & CA 2636922 A & RU 2008128378 A & ES 2352583 T & UA 96589 C & CA 2636922 A1	6-8

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Patent documents cited in the description

- JP 2004197622 A **[0008]**
- JP 2010236042 A **[0008]**