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(72) Inventors:
• **YAMADA Hidemi**
Kitakata-shi
Fukushima 966-0845 (JP)
• **ENDO Daisuke**
Kitakata-shi
Fukushima 966-0845 (JP)

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(74) Representative: **Viering, Jentschura & Partner**
Grillparzerstrasse 14
81675 München (DE)

(71) Applicant: **SHOWA DENKO K.K.**
Tokyo 105-8518 (JP)

(54) **METHOD FOR PRODUCING ROTOR**

(57) A rotor is produced efficiently.

The present invention is directed to a rotor producing method. The present invention includes a forging step for obtaining a rotor material 1 having a cylindrical columnar rotor portion 2 in which a plurality of vane grooves 4 extending along an axial direction are formed in an outer peripheral portion at intervals in a circumferential direction and an excess thickness portion 6 integrally formed on one end face of the rotor portion 2 so as to protrude toward one end side of the rotor portion 2 and close the one end side of the vane groove 4, and an excess thickness portion removing step for obtaining a rotor R having the vane groove 4 opened at the one end side by hitting the excess thickness portion 6 with an impact applying member to thereby remove the excess thickness portion 6 from the rotor portion 2.

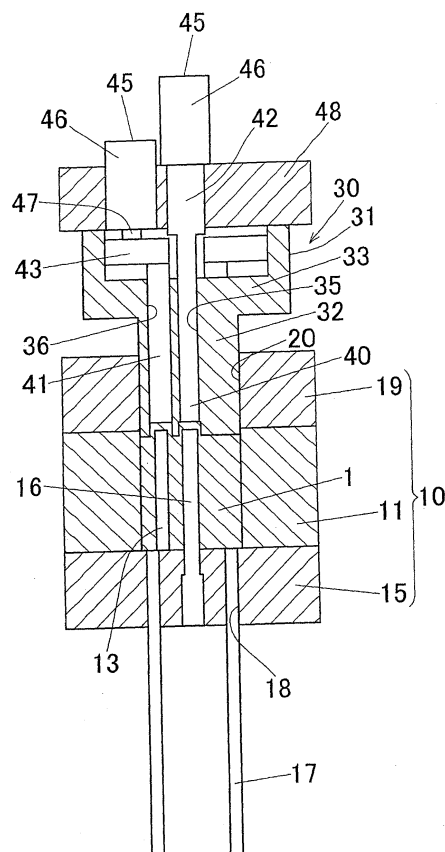


FIG.2C

Description

TECHNICAL FIELD

5 [0001] The present invention relates to a rotor production method for producing a rotor having vane grooves at its outer peripheral portion, and its related technology.

BACKGROUND ART

10 [0002] A rotor for a compressor or a rotor for a rotary type vacuum pump for use in a brake controller is generally provided with a plurality of vane grooves parallel to an axial center formed in an outer peripheral portion at equal intervals in the circumferential direction. Further, most of rotors for an air-conditioning rotary compressor and for a rotary vacuum pump for use in a brake controller, which are to be mounted on a vehicle, are aluminum alloy products for the purpose of attaining the weight saving, and generally produced by forge processing.

15 [0003] For example, according to the rotor production method disclosed by the following Patent Document 1, using a lower die having a forming hole in which vane portions for forming vane grooves are formed, a cylindrical columnar forging raw material set on the forming hole is downwardly pressed with an upper die to thereby fill the forging raw material in the forming hole. With this, a cylindrical columnar rotor material in which each vane groove extends from the lower end face near to the upper end face is formed can be obtained. The upper end portion (excess thickness portion) of the rotor material is removed by cutting along a plane perpendicular to the axial line to open one end side (upper end side) of each vane groove, resulting in vane grooves with both ends thereof opened. Thus, a rotor material is formed.

20 [0004] Further, according to the rotor production method disclosed by the following Patent Document 2, using an upper die provided with groove forming punches for forming vane grooves at the forming surface of the upper die, the upper die with the groove forming punches are driven into a forging raw material set in the forming hole of the lower die, to thereby form vane grooves extending from the upper end face near to the lower end face. Subsequently thereafter, a groove forming punch is driven therein to punch out and remove the excess thickness portion closing the lower end side of the vane groove to open both ends of the vane groove.

PRIOR ART DOCUMENTS

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PATENT DOCUMENT

[0005]

35 Patent Document 1: Japanese Unexamined Laid-open Patent Publication No. H11-230068 (JP H11-230068, A)
Patent Document 2 : Japanese Unexamined Laid-open Patent Publication No. 2000-220588 (JP 2000-220588, A)

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

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[0006] In the conventional rotor producing method disclosed by the aforementioned Patent Document 1, the excess thickness portions of the rotor material obtained by forge processing are removed. The machining process such as cutting work is, however, poor in production efficiency. Therefore, as long as such machining process low in production efficiency is used, it is difficult to perform to improve the overall production efficiency.

45 [0007] Further, in the conventional rotor production method disclosed by the aforementioned Patent Document 2, the excess thickness portion blocking the lower end portion of the vane groove is punched out and removed with a groove forming punch. It is, however, difficult to accurately control the breaking position in the punching operation, and therefore there is a high probability of causing unexpected breaks or lacks. Accordingly, there is a problem that the excess thickness portion cannot be removed accurately.

50 [0008] The preferred embodiments of the present invention have been developed in view of the above-mentioned and/or other problems in the related art. The preferred embodiments of the present invention can significantly improve upon existing methods and/or apparatuses.

55 [0009] The present invention was made in view of the aforementioned problems, and aims to provide a rotor production method capable of accurately removing an excess thickness portion while securing high production efficiency and its related technology.

[0010] Other objects and advantages of the present invention will be apparent from the following preferred embodiments.

MEANS FOR SOLVING THE PROBLEMS

[0011] In order to attain the aforementioned objects, the present invention is provided with the following structures.

[0012] [1] A production method of a rotor, the method comprising:

a forging step for obtaining a rotor material having a cylindrical columnar rotor portion in which a plurality of vane grooves extending along an axial direction are formed in an outer peripheral portion at intervals in a circumferential direction and an excess thickness portion integrally formed on one end face of the rotor portion so as to protrude toward one end side of the rotor portion and close one end side of the vane groove; and
 an excess thickness portion removing step for obtaining a rotor having the vane grooves opened at the one end side by hitting the excess thickness portion with an impact applying member to thereby remove the excess thickness portion from the rotor portion.

[0013] [2] The production method of a rotor as recited in the aforementioned Item 1, wherein, in the rotor material, the excess thickness portion is formed so as to protrude toward the one end side of the rotor portion beyond the one end face and the vane groove is formed so as to reach an inside of the excess thickness portion.

[0014] [3] The production method of a rotor as recited in the aforementioned Item 2, wherein the excess thickness portion has a peripheral wall portion closing a peripheral side surface of the vane groove, and wherein, at the excess thickness portion removing step, the excess thickness portion is broken at the peripheral wall portion and removed.

[0015] [4] The production method of a rotor as recited in the aforementioned Item 2 or 3, wherein, when a dimension from a tip end of the excess thickness portion to one end face of the vane groove is defined as a thickness of a closing portion, the thickness of the closing portion is set to 3 to 10 mm.

[0016] [5] The production method of a rotor as recited in any one of the aforementioned Items 1 to 4, wherein, at the forging step, a crack is formed between the excess thickness portion and the rotor portion, and wherein, at the excess thickness portion removing step, the rotor material is broken along the crack.

[0017] [6] The production method of a rotor as recited in any one of the aforementioned Items 1 to 5, wherein, at the excess thickness portion removing step, a blanking punch as an impactor is driven into the vane groove of the rotor material from the other end side opening to thereby punch out and remove the excess thickness portion toward the one end side.

[0018] [7] The production method of a rotor as recited in any one of the aforementioned Items 1 to 6, wherein, at the forging step, a vane groove forming die is relatively driven into a cylindrical columnar forging raw material from the other end face thereof to thereby form the vane groove extending from the other end face to the one end face, and wherein, when the vane groove forming die is driven into the forging raw material, a back-pressure is applied to an area corresponding to the vane groove forming scheduled portion on the one end face of the forging raw material.

[0019] [8] The production method of a rotor as recited in any one of the aforementioned Items 1 to 7, wherein, when the excess thickness portion is defined as a vane groove side excess thickness portion and the impact applying member is defined as a vane groove side impact applying member, wherein, at the forging processing, a shaft hole is formed in the rotor portion of the rotor material so as to extend in the axial direction, and a shaft hole side excess thickness portion closing the one end side of the shaft hole is integrally formed on the one end face of the rotor portion so as to protrude toward the one end side, and wherein, at the excess thickness portion removing step, the shaft hole side impact applying member is hit against the shaft hole side excess thickness portion to remove the excess thickness portion from the rotor portion so that the shaft hole is opened at the one end side.

[0020] [9] The production method of a rotor as recited in the aforementioned Item 8, wherein a blanking punch as the impact applying member is driven into the shaft hole of the rotor material from the other end side opening to punch out and remove the shaft hole side excess thickness portion toward the one end side.

[0021] [10] The production method of a rotor as recited in the aforementioned Item 8 or 9, wherein, at the forging step, a shaft hole forming die is relatively driven into a cylindrical columnar forging raw material from the other end face thereof to thereby form the shaft hole extending from the other end face to the one end face, and wherein, when the shaft hole forming die is driven into the forging raw material, a back-pressure is applied to an area corresponding to the shaft hole forming scheduled portion on the one end face of the forging raw material.

[0022] [11] The production method of a rotor as recited in the aforementioned Item 1, wherein, in the rotor material, the excess thickness portion is integrally formed on the one end face of the rotor portion so as to protrude toward the one end side, and wherein one end face of the vane groove does not reach the excess thickness portion and is positioned inner than the one end face of the rotor portion.

[0023] [12] The production method of a rotor as recited in the aforementioned Item 11, wherein, when a distance between the one end face of the rotor portion and the one end face of the vane groove in the rotor material is defined

as an end face difference, the end face difference at the vane groove side is set to 0 to 2 mm.

[0024] [13] The production method of a rotor as recited in the aforementioned Item 11 or 12, wherein, when a distance between the inner peripheral surface of the vane groove and an outer peripheral surface of the excess thickness portion of the rotor material is defined as a vane groove side radius difference, the vane groove side radius difference is set to 0.01 to 0.1 mm.

[0025] [14] The production method of a rotor as recited in any one of the aforementioned Items 11 to 13, wherein the vane groove side radius difference partially differs.

[0026] [15] The production method of a rotor as recited in the aforementioned Item 13 or 14, wherein among the vane groove side radius differences, at least one of the radius difference at an inner peripheral side end portion of the vane groove and the radius difference at the outer peripheral side end portion of the vane groove is set to be larger than a radius difference at an intermediate portion of the vane groove.

[0027] [16] The production method of a rotor as recited in any one of the aforementioned Items 11 to 15, wherein, when the excess thickness portion is defined as a vane groove side excess thickness portion and the impact applying member is defined as a vane groove side impact applying member,

wherein, at the forging processing, a shaft hole is formed in the rotor portion of the rotor material so as to extend in the axial direction, and a shaft hole side excess thickness portion closing the one end side of the shaft hole is integrally formed on the one end face of the rotor portion so as to protrude toward the one end side,

wherein, at the excess thickness portion removing step, the shaft hole side impact applying member is hit against the shaft hole side excess thickness portion to remove the excess thickness portion from the rotor portion so that the shaft hole is opened at the one end side, and

wherein, in the rotor material produced by the forging processing, one end face of the shaft hole does not reach the shaft hole side excess thickness portion and is positioned inner than the one end face of the rotor portion.

[0028] [17] The production method of a rotor as recited in the aforementioned Item 16, wherein, when a distance between the one end face of the rotor portion and the one end face of the shaft hole in the rotor material is defined as a shaft hole side end face difference, the shaft hole side end face difference is set to 0 to 2 mm.

[0029] [18] The production method of a rotor as recited in the aforementioned Item 16 or 17, wherein, when a distance between the inner peripheral surface of the shaft hole and an outer peripheral surface of the shaft hole side excess thickness portion of the rotor material is defined as a shaft hole side radius difference, the shaft hole side radius difference is set to 0.01 to 0.1 mm.

[0030] [19] The production method of a rotor as recited in any one of the aforementioned Items 16 to 18, wherein the shaft hole side radius difference partially differs.

[0031] [20] A method of removing an excess thickness portion of a rotor material having a cylindrical columnar rotor portion in which a plurality of vane grooves extending along an axial direction are formed in an outer peripheral portion at intervals in a circumferential direction and the excess thickness portion integrally formed on one end face of the rotor portion so as to protrude toward one end side of the rotor portion and close one end side of the vane groove, wherein an impact applying member is hit against the excess thickness portion to remove the excess thickness portion from the rotor portion to thereby open the vane groove at the one end side.

[0032] [21] A device for removing an excess thickness portion of a rotor material having a cylindrical columnar rotor portion in which a plurality of vane grooves extending along an axial direction are formed in an outer peripheral portion at intervals in a circumferential direction and the excess thickness portion integrally formed on one end face of the rotor portion so as to protrude toward one end side of the rotor portion and close one end side of the vane groove, wherein the device is provided with a blanking punch configured to drive into the vane groove of the rotor material from the other end side opening of the vane groove and hit against the excess thickness portion to punch out and remove the excess thickness portion from the rotor portion to thereby open the vane groove at the one end side.

[0033] In the present invention, it is possible to replace the structures corresponding to the vane groove in the aforementioned items [2] - [7] with those corresponding to the shaft hole to limit to the structures of the aforementioned items [8], [20] and [21].

[0034] Further, it is possible to limit the structures of aforementioned items [20] and [21] with the structures of the aforementioned items [11] - [19].

EFFECTS OF THE INVENTION

[0035] According to the rotor production method of the invention [1], since the excess thickness portions are removed by hitting them with an impact applying member, high production efficiency can be secured. Further, since the excess thickness portion is protruded, hitting by the impact applying member enables assured removal of the excess thickness portions.

[0036] According to the rotor production method of the invention [2] to [6], the aforementioned effects can be obtained more assuredly.

[0037] According to the rotor production method of the invention [7], the excess thickness portions structured as mentioned above can be formed assuredly.

[0038] According to the rotor production method of the invention [9], the shaft side excess thickness portion can be removed more assuredly.

[0039] According to the rotor production method of the invention [10], in the same manner as mentioned above, the excess thickness portions can be removed accurately while maintaining the high production efficiency.

[0040] According to the rotor production method of the invention [11], since the radius difference between the vane groove inner peripheral surface and the excess thickness portion outer peripheral surface can be reduced, the vane groove side excess thickness portions can be removed simply and accurately, which can improve the production efficiency.

[0041] According to the rotor production method of the invention [12] and [13], the aforementioned effects can be obtained assuredly.

[0042] According to the rotor production method of the invention [14] to [15], it is possible to prevent improper dropping of the excess thickness portions.

[0043] According to the rotor production method of the invention [16], since the radius difference between the shaft hole inner peripheral surface and the excess thickness portion outer peripheral surface can be reduced, the shaft hole side excess thickness portion can be removed simply and accurately, which can further improve the production efficiency.

[0044] According to the rotor production method of the invention [17] and [18], the shaft side excess thickness portion can be removed more assuredly.

[0045] According to the rotor production method of the invention [19], it is possible to prevent improper dropping of the shaft side excess thickness portion.

[0046] According to the rotor material excess thickness portion removing method of the invention [20], the shaft hole side excess thickness portion can be removed accurately and efficiently.

[0047] According to the rotor material excess thickness portion removing device of the invention [21], in the same manner as mentioned above, the excess thickness portions can be removed accurately while maintaining the high production efficiency.

BRIEF DESCRIPTION OF DRAWINGS

[0048]

[Fig. 1] Fig. 1 is an exploded perspective view showing a rotor material forging die assembly used in forge processing of a rotor producing method according to a first embodiment of the present invention.

[Fig. 2A] Fig. 2A is a schematic cross-sectional view showing the forge processing at the stage of preparing the forge processing using the forging die assembly according to the first embodiment.

[Fig. 2B] Fig. 2B is a schematic cross-sectional view showing the forge processing at the stage of descending the upper die using the forging die assembly according to the first embodiment.

[Fig. 2C] Fig. 2C is a schematic cross-sectional view showing the forge processing at the processing completion stage using the forging die assembly according to the first embodiment.

[Fig. 2D] Fig. 2D is a schematic cross-sectional view showing the forge processing at the stage of taking out the processed member using the forging die assembly according to the first embodiment.

[Fig. 3] Fig. 3 is a perspective view showing a rotor material obtained by the forge processing according to the first embodiment.

[Fig. 4] Fig. 4 is a perspective view showing a rotor to be produced by the production method of the first embodiment.

[Fig. 5] Fig. 5 is a plan view showing the offset amount of the vane groove of the rotor material shown in Fig. 4.

[Fig. 6] Fig. 6 is a perspective view showing the assembled state of the upper die of the forging die assembly of the first embodiment.

[Fig. 7A] Fig. 7A is a partially cut-out perspective view showing the load applying state to the lower die of the forging die assembly.

[Fig. 7B] Fig. 7B is an explanatory view for explaining the metal flow in the forming die assembly during the forge processing.

[Fig. 8] Fig. 8 is a plan view of the rotor material according to the first embodiment.

[Fig. 9] Fig. 9 is a flowchart showing the step sequence of the production method in the first embodiment.

[Fig. 10] Fig. 10 is a cross-sectional view showing the rotor material cut along the center hole according to the first embodiment.

[Fig. 11] Fig. 11 is a cross-sectional view showing the rotor material cut along the vane groove according to the first embodiment.

[Fig. 12] Fig. 12 is an enlarged cross-sectional view showing the portion surrounded by the alternate long and two

short dashes line shown in Fig. 10.

[Fig. 13] Fig. 13 is an enlarged cross-sectional view showing the portion surrounded by the alternate long and two short dashes line shown in Fig. 11.

[Fig. 14] Fig. 14 is a schematic cross-sectional view of a punching device used at the excess thickness portion removing step in the production method according to the first embodiment.

[Fig. 15] Fig. 15 is an enlarged cross-sectional view showing the vicinity of the center hole portion of the rotor material according to the first embodiment in which the excess thickness portion was removed.

[Fig. 16] Fig. 16 is an enlarged cross-sectional view showing the vicinity of the vane groove portion of the rotor material according to the first embodiment in which the excess thickness portion was removed.

[Fig. 17] Fig. 17 is a cross-sectional view showing the rotor material cut along the center hole according to a first modification of this invention.

[Fig. 18] Fig. 18 is a cross-sectional view showing the rotor material cut along the vane groove according to the first modification of this invention.

[Fig. 19] Fig. 19 is a cross-sectional view showing a rotor material cut along the center hole according to a second modification of this invention.

[Fig. 20] Fig. 20 is a cross-sectional view showing the rotor material cut along the vane groove according to the second modification of this invention.

[Fig. 21] Fig. 21 is a perspective view showing a rotor material obtained by the forge processing according to a second embodiment.

[Fig. 22A] Fig. 22A is a plane view of the rotor material according to the second embodiment.

[Fig. 22B] Fig. 22B is an enlarged cross-sectional view showing the vane groove portion of the rotor material according to the second embodiment.

[Fig. 23] Fig. 23 is a cross-sectional view showing the rotor material cut along the center hole according to the second embodiment.

[Fig. 24] Fig. 24 is a cross-sectional view showing the rotor material cut along the vane groove portion according to the second embodiment.

[Fig. 25] Fig. 25 is an enlarged cross-sectional view showing the vicinity of the center hole side excess thickness portion shown in Fig. 23.

[Fig. 26] Fig. 26 is an enlarged cross-sectional view showing the vicinity of the vane groove side excess thickness portion shown in Fig. 24.

[Fig. 27A] Fig. 27A is a schematic cross-sectional view showing the upper die descending step in the forge processing using the forging die assembly according to the second embodiment.

[Fig. 27B] Fig. 27B is a schematic cross-sectional view showing the process completion step in the forge processing using the forging die assembly according to the second embodiment.

EMBODIMENTS FOR CARRYING OUT THE INVENTION

<ROTOR>

[0049] Initially, the structure of a rotor R to be produced according to a first embodiment of the present invention will be explained. As shown in Fig. 4, the rotor R is a generally cylindrical columnar member in which a center hole 3 as a shaft hole for inserting a shaft therein is formed at the center thereof and five vane grooves 4 with a groove bottom enlarged into a round in cross-section are formed in the outer peripheral surface. These vane grooves 4 are arranged in parallel with the axial line of the cylindrical columnar member and communicated with both end surfaces thereof, and also formed so as to inwardly cut into the columnar member eccentrically with respect to the center hole 3. Furthermore, as shown in Fig. 5, the offset amount U of the vane groove 4 is represented by the distance between the center line L1 extending in the groove width direction and the linear line L2 extending in parallel with the center line L1 and passing through the axial line of the rotor R.

[0050] As the material of the rotor R, aluminum or aluminum alloy is generally used. As one example, aluminum alloy consisting of Si: 14 to 16 mass%, Cu: 4 to 5 mass%, Mg: 0.45 to 0.65 mass%, Fe: 0.5 mass% or less, Mn: 0.1 mass% or less, Ti: 0.2 mass% or less, and the balance being Al and inevitable impurities can be exemplified.

<PRODUCTION STEPS>

[0051] As shown in Fig. 9, the production steps of the rotor in this embodiment mainly include a cutting step, a mass selection step, a forging step, a punching step, a heat treatment step, and an inspection step. Through these steps, a rotor product is shipped.

[0052] The cutting step and the mass selection step are steps for obtaining a forging raw material. In the cutting step,

a continuously cast member is cut into a given length. After obtaining continuously cast members each having a predetermined length, each cast member is selected in accordance with the mass (weight) to obtain a desired forging raw material.

[0053] In the subsequent forging step, the forging raw material is subjected to forge processing to obtain a rotor material. Thereafter, in the punching step, the excess thickness portions are removed from the rotor material to obtain a rotor.

[0054] Thereafter, in the heat treatment step, the rotor is subjected to a heat treatment and a quenching treatment to improve the hardness and the abrasion resistance to thereby obtain a rotor product. Then, in the inspection step, the rotor product is subjected to a final inspection and then shipped when no defect is found.

[0055] Hereinafter, the features of the rotor production method according to the embodiment will be explained in detail.

<FORGING STEP>

[0056] Fig. 1 and Figs. 2A to 2D are views showing a forging die assembly as a forging device for use in forge processing of the first embodiment, and Fig. 3 is a view showing a rotor material 1 to be forged by the forging die assembly.

[0057] As shown in these figures, the forging die assembly includes a lower die 10 and an upper die 30 for giving forming loads. As the materials for these dies, any well-known die steels can be used.

[0058] The lower die 10 is divided into a lower die body 11 having a forming hole 12, a base 15 to be disposed at the lower side of the lower die body 11, and a bush 19 to be disposed at the upper side of the lower die body 11.

[0059] Within the forming hole 12 of the lower die body 11, a total of five vane portions 13 for forming vane grooves 4 are protruded from the hole peripheral wall surface. The vane portion 13 is a thin plate-shaped member having one end circular in cross-section and has a cross-sectional shape corresponding to that of the vane groove 4. The base 15 is formed into a plate-shape, and has a center pin 16 for forming the center hole 3 of the rotor R fixed at the center of the base and through-holes 18 for knockout pins 17 surrounding the center pin 16. The bush 19 is an annular plate member provided with a loading hole 20 penetrated in the up-and-down direction and having the same diameter as that of the forming hole 12 of the lower die body 11.

[0060] By assembling the base 15, the lower die body 11, and the bush 19, the center pin 16 is inserted into the forming hole 12 of the lower die body 11, forming the inner portion of the forming hole 12 into an inversion cross-sectional shape of the rotor R. Further, in this state, the loading hole 20 of the bush 19 communicates with the forming hole 12. Further, in the forging preparation step shown in Fig. 2A, the knockout pins 17 are inserted into the through-holes 18 of the base 15, and the tip end faces thereof are being held at the same height as the upper surface of the base 15.

[0061] The upper die body 31 is divided into an upper die body 31 for applying a main load F to the forging raw material W, a cylindrical pin 40 for applying sub-loads F1 and F2, and flat plates 41.

[0062] In the upper die body 31, the lower-half punch portion 32 is formed into a generally cylindrical columnar member having an outer diameter corresponding to the through-hole 20 of the bush 19, and the larger-diameter upper half portion 33 is provided with a concave portion 34 at the upper surface thereof. Formed in this concave portion 34 are a single circular hole 35 having a cross-section corresponding to the cross-section of the cylindrical pin 40 and configured to insert the cylindrical pin 40 in an advanceable and retractable manner and five flat holes 36 each having a cross-section corresponding to the cross-section of the flat plate 41 and configured to insert the flat plate 41 in an advanceable and retractable manner. The circular hole 35 and the flat holes 36 are penetrated up to the tip end face of the punch portion 32, respectively, and the flat holes 36 are opened to the outer peripheral surface of the punch portion 32. The position of the circular hole 35 and the positions of the flat holes 36 correspond to the position of the center pin 16 and the positions of the vane portions 13 of the lower die body 11, respectively.

[0063] The cylindrical pin 40 is a cylindrical pin having a diameter larger than that of the center pin 16 in the lower die body 11, and is integrally provided with, at its upper end, a retaining portion 42 having a diameter larger than that of the circular hole 35. The flat plate 41 is a thin-plate member having a round portion at its tip end in the same manner as in the vane portion 13 of the lower die body 11, but the flat plate 41 is one size larger than the vane portion 13 and integrally provided with, at its upper end, a retaining portion 43 enlarged in cross-sectional area than the flat hole 36.

[0064] As shown in Figs. 2A and 6, in a state in which the cylindrical pin 40 is fitted into the circular hole 35 from the concave portion 34 of the upper die body 31, and the flat plates 41 are fitted into the respective flat holes 36, the upper die body 31, the cylindrical pin 40, and the flat plates 41 form a single cylindrical columnar member having a continuous tip end face and a continuous peripheral surface.

[0065] Above each of the cylindrical pin 40 and flat plates 41, a gas cushion 45 for applying a load thereto is arranged. In the gas cushion 45, a piston rod 47 is inserted into the cylinder 46 in an advanceable and retractable manner. When a force in the retracting direction is applied to the piston rod 47, the sealed compressed gas causes a force in the advancing direction equal to the force in the retracting direction. As the retraction distance increases, the force in the advancing direction increases. In each gas cushion 45, the cylinder 46 is fixed to the mounting board 48. The upper die body 31 and the mounting board 48 are assembled in a state in which the tip end of the piston rod 47 is in contact with

the corresponding retaining portion 42 and 43 of the cylinder pin 40 and the flat plate 41 and an initial load by the advancing force of each piston rod 47 is applied to the corresponding cylindrical pin 40 and the flat plate 41. When the cylindrical pin 40 and the flat plates 41 are moved upward to cause retraction movements of the piston rods thereof, a load corresponding to the retracted distance is applied to each of the cylindrical pin 40 and the flat plates 41. Therefore, the mounting board 48 is configured to move up and down together with the upper die 30, but the sub-loads F1 and F2 applied to the cylindrical pin 40 and the flat plate 41, respectively, are controlled by the gas cushions 45 independent from the main load F.

[0066] The value of the first sub-load F1 and that of the second sub-load F2 can be adjusted by setting the operating load of the gas cushion 45. Furthermore, the cylindrical pin 40 and the flat plates 41 are each provided with the gas cushion 45, and therefore can be controlled in load independently. In other words, the main load F applied to the upper die body 32, the first sub-load F1 applied to the cylindrical pin 40 and the five second sub-loads F2 applied to the five flat plates 41 can be set independently.

[0067] The lower die body 10 and the upper die body 30 are arranged such that the cylindrical pin 40 and the flat plates 41 are arranged at the respective positions corresponding to the center pin 16 and the vane portions 13. Therefore, as shown in Figs. 7A and 7B, the first sub-load F1 is applied to directly above the center pin 16, and the second sub-load F2 is applied to directly above the vane portion 13. The main load F is applied to the portions other than the center pin 16 and the vane portions 13. Furthermore, in this invention, each of the first sub-load F1 and the second sub-load F2 is set to a value smaller than the main load F.

[0068] Next, a method of forging a forging raw material W for producing a rotor material 1 shown in Fig. 4 using the forging die assembly will be explained with reference to Figs. 2A-2D, Figs. 7A and 7B, and Fig. 8.

[0069] As shown in Fig. 2A, lubricant agent is applied to required portions of the lower die 20 and the upper die 30, and a cylindrical forging raw material 49 is loaded in the loading hole 20 of the bush 19. The forging raw material W is a material produced by a method, such as, e.g., a method in which a continuous cast material is cut into a predetermined length, and heated to a predetermined temperature as needed. As the aforementioned lubricant agent, aqueous graphite lubricant agent and oil-graphite lubricant agent can be exemplified. In order to prevent occurring of galling between the forging raw material W and the dies 10 and 30, it is preferable to use both the aqueous graphite lubricant agent and the oil-graphite lubricant agent. The application quantity thereof is about 2 to 10 g, respectively. Further, in cases where the forging raw material W is made of aluminum alloy, the pre-heating temperature is preferably set to 400 to 450°C.

[0070] From this state, as shown in Fig. 2B, when the upper die 30 is moved downward with a main load F to forge the forging raw material W loaded in the lower die 10, the cylindrical pin 40 to which a first sub-load F1 smaller than the main load F is applied and the flat plates 41 to which a second sub-load F2 smaller than the main load F is applied are pushed up during the process during which the forging raw material W is being filled in the forming hole 12 to cause material inflow into the circular hole 35 and the flat holes 36. As the cylindrical pin 40 and flat plates 41 move upward in accordance with the downward movement of the upper die 30 and therefore the retreat distance of the piston rod 47 increases, the first sub-load F1 applied to the cylindrical pin 40 and the second sub-load F2 applied to the flat plate 41 increase. Thus, the main load F is applied to the portions of the forging raw material W not corresponding to the cylindrical pin 40 and the flat plates 41, while the first sub-load F1 and the second sub-load F2 independent from the main load F are applied to the portions of the forging raw material W corresponding to the cylindrical pin 40 and the flat plates 41.

[0071] As shown in Fig. 2B, applying the first sub-load F1 and the second sub-load F2, which are smaller than the main load F, to the cylindrical pin 40 and the flat plates 41 causes upward movements of the cylindrical pin 40 and the flat plates 41, resulting in material inflow into the circular hole 35 and the flat holes 36. The material inflow into the circular hole 35 and flat holes 36 reduces the forces applied to the center pin 16 and the vane portions 13. As a result, as shown in Fig. 7B, the metal flow $\alpha 1$ between the wall surface of the forming hole 12 and the vane portion 13 and the force $\alpha 2$ which causes an inward deformation of the vane portion 13 by the metal flow $\alpha 1$ are reduced, and further the metal flow $\alpha 3$ directed to the outer periphery at the time of forming the center hole 3 acts on in the direction opposite to the force $\alpha 2$ which causes an inward deformation of the vane portion 13. Therefore, by keeping these forces $\alpha 2$ and $\alpha 3$ balanced, the flexural deformation and torsional deformation of the center pin 16 and the vane portions 13 can be restrained.

[0072] The optimum value of the first sub-load F1 and that of the second sub-load F2 are appropriately set depending on the volume of the center pin 16 and that of the vane portion 13. As these volumes increase, the escape amount of material increases. Therefore, provided that the volume of the vane portion 13 is constant, the balance can be maintained by increasing the inflow amount into the circular hole 35 by decreasing the first sub-load F1 as the volume of the center pin 16 increases.

[0073] Through the aforementioned steps, as shown in Fig. 2C, when the upper die 30 goes down to the bottom dead point, the forming of the rotor material 1 is completed.

[0074] Thereafter, as shown in Fig. 2D, the upper die 30 is raised and the knockout pins 17 are raised to push up the forged rotor material 1. When the cylindrical pin 40 and the flat plates 41 are detached from the rotor 1 and the forces from below are removed, the piston rods 47 of the gas cushions 45 return to the respective original positions.

[0075] In the aforementioned steps, the flexural deformation and torsional deformation of the center pin 16 and vane

portions 13 of the lower die 10 are reduced, and therefore the rotor material 1 shown in Fig. 3 becomes high in dimensional accuracy of the center hole 3 and that of the vane groove 4 and the die life will be extended due to the reduced deformation. Furthermore, it is not required to enlarge the outer diameter of the rotor material to prevent deformation of the vane portion 13, and therefore no portion is required to be removed by post-processing, which incurs no waste.

[0076] Furthermore, since the first sub-load F1 and the second sub-load F2 are set to be smaller than the main load F, the materials pushed back by the cylindrical pin 16 and the vane portions 13 easily flow. This enables the upper die 30 to move downward to the height where the cylindrical pin 16 and the vane portions 13 break into the circular hole 35 and the flat holes 36, respectively. Thus, by the movements of the materials of the center hole 3 and the vane grooves 4, in the rotor material 1 to be produced, excess thickness portions 5 and 6 corresponding to the portions of the center hole 3 and the vane grooves 4 are formed on the upper end face (one end face 2a) of the rotor portion 2.

[0077] Furthermore, the first sub-load F1 and the second sub-load F2 are applied separately. Therefore, the excess thickness portion 5 above the center hole 3 and the excess thickness portion 6 above the vane groove 4 are formed separately. The respective planner shapes of the excess thickness portions 5 and 6 become corresponding cross-sectional shapes of the cylindrical pin 40 and the flat plates 41.

[0078] In this embodiment, the rotor material 1 is constituted by the rotor portion 2 and the excess thickness portions 5 and 6, and the rotor portion 2 does not include the excess thickness portions 5 and 6.

[0079] The formed excess thickness portions 5 and 6 are, as shown in Figs. 10 and 11, formed so that they protrude from one end face 2a of the rotor portion 2 toward the one end side and that the center hole 3 and the vane grooves 4 are formed up to the inside of each excess thickness portion 5 and 6.

[0080] Furthermore, as shown in Fig. 12, the center hole side excess thickness portion 5 includes a closing portion 5a closing one end face 3a of the center hole 3, and a peripheral wall portion 5b closing the peripheral side surface of the center hole 3, and is finished to have a generally reversed U-shape in cross-section. In the same manner, as shown in Fig. 13, the vane groove side excess thickness portion 6 includes a closing portion 6a closing one end face 4a of the vane groove 4, and a peripheral wall portion 6b closing the peripheral side surface of the vane groove 4, and is finished to have a generally reversed U-shape in cross-section. The peripheral wall portions 5b and 6b of the excess thickness portion 5 are portions to be positioned within the range from one end face 2a of the rotor portion 2 to one end faces 3a and 4a of the center hole 3 and the vane groove 4. The closing portions 5a and 6a are portions to be positioned at the one end side outer than one end faces 3a and 4a of the center hole 3 and the vane groove 4.

[0081] Furthermore, in this embodiment, during the forge processing, the main load F, the first and second sub-load F1 and F2 are adjusted so as to cause cracks 7 and 7 in the peripheral wall portions 5b and 6b of the excess thickness portions 5 and 6. These cracks 7 and 7 are formed to facilitate the removals of the excess thickness portions 5 and 6 during the punching step mentioned below. In this embodiment, the excess thickness portions 5 and 6 are formed to have a specific structure to easily and accurately remove the excess thickness portions 5 and 6. The detail structures of the excess thickness portions 5 and 6 will be explained later.

[0082] Further, in this embodiment, back-pressures by the first and second sub-loads F1 and F2 are applied at the time of the forge processing. This assuredly prevents such drawbacks that the excess thickness portions 5 and 6 are torn apart or torn off from the rotor portion 2. As a result, the excess thickness portions 5 and 6 having the below-mentioned desired structures can be integrally formed with the rotor material 1.

[0083] Needless to say, at the other end face (lower end face 2b) of the rotor portion 2 of the rotor material 1, both the center hole 3 and the vane grooves 4 are opened.

[0084] In the forge processing of this embodiment, the main load F, the first sub-load F1, and the second sub-load F2 are appropriately set depending on the shape, the dimension of each portion, the material composition, the processing temperature, etc., of the rotor material 1. For example, as the set values in producing an aluminum or aluminum alloy rotor R having a diameter of 40 to 70 mm and a height of 30 to 60 mm, a main load F: 270 to 325 MPa, a first sub-load F1 and second sub-load F2: 29 to 89 MPa can be exemplified.

[0085] Further, if the first sub-load F1 and the second sub-load F2 are set too small, there is a possibility that the excess thickness portion 5 and 6 will be torn off. To the contrary, if they are set too large, the effects of reducing the force to be applied to the center pin 16 and the force to be applied to the vane portion 13 decrease. As mentioned above, in the case of forging the aluminum alloy rotor R, it is preferable to set the first sub-load F1 and the second sub-load F2 so as to fall within the range of 29 to 89 MPa, more preferably 39 to 49 MPa, respectively. In the case of using a spring-type sub-load applying means such as a gas cushion 45, the first sub-load F1 and the second sub-load F2 increase as the upper die 30 goes downward. The load within the aforementioned preferable range is an initial load.

[0086] Further, the sub-load applying means for applying the first sub-load F1 and the second sub-load F2 are not specifically limited, but it is preferable to use a means which can apply a load in accordance with the raising and lowering operation of the upper die 30. From this aspect, a spring-type means such as a gas cushion is preferably used. As other sub-load applying means, a mechanical type spring, a hydraulic mechanism, and a shock absorber can be exemplified.

[0087] Further, as shown in Fig. 8, the planner shape of each of the excess thickness portions 5 and 6 of the rotor 1 is preferably set to a shape in which an enlarged portion having a width "t": 0.1 to 3 mm is added to the periphery of

each of the center pin 16 and the vane portion 13. In other words, it is preferable to set the circular hole 35 and the flat hole 36 so that the gap "t" between the center hole 35 of the upper die body 31 and the center pin 16 and the gap "t" between the flat hole 36 and the vane portion 13 fall within the range of 0.1 to 3 mm. If the width "t" is less than 1 mm, the material flow during the forge processing deteriorates, causing breakages of the excess thickness portions 5 and 6, which in turn may cause deteriorated deformation preventing effects by breakages. If it exceeds 3 mm, there is a possibility that the circular hole 35 and the flat hole 36 in the upper die 30 interfere with each other. The most preferable gap "t" is 1 to 2 mm.

<PUNCHING STEP>

[0088] Fig. 14 is a cross-sectional view schematically showing a punching device (die set) as an excess thickness portion removing device used in the punching step (excess thickness portion removing step). As shown in this figure, this punching device is equipped with a lower die 8 and an upper die 9, and configured to punch out the excess thickness portions 5 and 6 from the rotor material 1 by punching processing, as will be detailed below.

[0089] The lower die 8 is equipped with a lower plate 81 and a lower die body 85 disposed on the upper surface of the lower plate 81.

[0090] The lower plate 81 has, at its center portion, an excess thickness portion discharging hole 82 penetrated in the up-and-down direction. Further, at both side portions of the lower plate 81, guide bars 83 are formed so as to extend in the vertical direction.

[0091] The lower die body 85 is fixed to the upper surface of the lower plate 81 so as to close the excess thickness discharging hole 82.

[0092] The lower die body 85 is provided with a work mounting portion 86 corresponding to the excess thickness discharging hole 82 of the lower plate 81. The work mounting portion 86 is configured such that the rotor material 1 can be mounted with its one end face 2a facing downward. In detail, in this work mounting portion 86, a center hole side punch-out hole 87 is formed corresponding to the center hole side excess thickness portion 5 and a vane groove side punch-out hole 88 is formed corresponding to the vane groove side excess thickness portion 6. This center hole side punch-out hole 87 is formed to have an inner peripheral shape corresponding to the outer peripheral shape of the center hole side excess thickness portion 5, so that the center hole side excess thickness portion 5 can be fitted therein in a closely fitted manner. Further, the vane groove side punch-out holes 88 are formed to have an inner peripheral shape corresponding to the outer peripheral shape of the vane groove side excess thickness portion 6, so that the vane groove excess thickness portion 6 can be fitted therein in a closely fitted manner. Further, each punch-out hole 87 and 88 is penetrated in the up-and-down direction, and the lower end side thereof is communicated with the excess thickness discharging hole 82 of the lower plate 81.

[0093] It is configured such that the rotor material 1 can be set on the work mounting portion 86 in a positioned state by fitting the excess thickness portions 5 and 6 of the rotor material 1 in the punch-out holes 87 and 88 in a closely fitted manner, respectively, and disposing one end face 2a of the rotor portion 2 on the work mounting portion 86.

[0094] The upper die 9 is equipped with an upper plate 91 and an upper die body 95 disposed on the lower surface of the upper plate 91.

[0095] The upper plate 91 is configured to move upward and downward in the vertical direction by being driven upward and downward by a lifting and lowering driving means such as a hydraulic cylinder (not illustrated).

[0096] Further, at both side ends of the upper plate 91, guide holes 93 are formed corresponding to the guide bars 83 of the lower plate 81. As will be described later, when the upper plate 91 is moved downward, the guide bars 83 are inserted in the guide holes 93 to guide the descending movement of the upper plate 91.

[0097] The upper die body 95 is fixed to the lower surface of the upper plate 91 so as to face the lower die body 85.

[0098] A center hole side blanking punch 97 and vane groove side blanking punches 98 are attached to the upper die body 95 in a downwardly protruded manner, corresponding to the center hole side punch-out hole 87 and the vane groove side punch-out holes 88, respectively, i.e., corresponding to the center hole 3 and vane grooves 4 of the rotor material 1 set to the lower die 85.

[0099] In this embodiment, the blanking punches 97 and 98 are structured as an impactor.

[0100] Next, a method of removing the excess thickness portions 5 and 6 of the rotor material 1 using the punching device structured mentioned above will be explained.

[0101] Initially, the rotor material 1 is mounted on the work mounting portion 86 of the lower die 8 of the punching device with the one end face 2a facing downward in a state in which each excess thickness portion 5 and 6 is fitted in the corresponding punch-out hole 87 and 88. In this mounted state, the center hole side blanking punch 97 and vane groove side blanking punch 98 of the upper die body 85 are arranged so as to face the other end side openings of the center hole 3 and vane grooves 4 of the rotor material 1.

[0102] In a state in which the rotor material 1 is set, when the upper die 85 is moved downward, the punches 97 and 98 of the upper die body 85 are inserted into the center hole 3 and vane grooves 4 from the upper end face (the other

end face 2b) side of the rotor material 1 and each punch 97 and 98 hits against the excess thickness portion 5 and 6 in a pressed state. Thus, the excess thickness portions 5 and 6 are punched out. With this, the excess thickness portions 5 and 6 are removed from the rotor portion 2, and the removed excess thickness portions 5 and 6 are discharged below via the excess thickness portion discharging hole 82. Thus, as shown in Figs. 15 and 16, one end side of the center hole 3 and that of the vane groove 4 of the rotor material 1 are opened, so that a rotor R in which both ends of the center hole 3 and the vane groove 4 are opened can be obtained.

[0103] Here, in this embodiment, the excess thickness portions 5 and 6 are formed on one end face 2a of the rotor portion 2 so as to protrude from one end side. Therefore, when the excess thickness portions 5 and 6 are punched out, the excess thickness portions 5 and 6 can be accurately broken at the positions of the peripheral wall portions 5a and 6a, thereby enabling accurate removals of the excess thickness portions 5 and 6 with high dimensional accuracy.

[0104] Especially, in this embodiment, as shown in Figs. 12 and 13, since cracks 7 and 7 are formed in the peripheral wall portion 5b and 6b of the excess thickness portion 5 and 6, easy breakage of the excess thickness portion can be performed assuredly at the portion of the crack 7. This enables removal of the excess thickness portion 5 and 6 from the rotor R with higher dimensional accuracy.

[0105] Furthermore, the crack 7 and 7 is formed at the breakage scheduled portion, and therefore the punching load of the punch 97 can be concentrated at the position of the crack 7, resulting in assured breakage at the position. Thus, even if the load of the punch 97 and 98 is decreased, the excess thickness portion 5 and 6 can be punched out assuredly. As mentioned above, since the press working can be performed at a low load, it is possible to effectively prevent occurrence of harmful cracks and/or breakage in the rotor R, which in turn can produce a high quality rotor product. In a concrete example, in the case in which cracks 7 and 7 are formed, the punch load can be reduced into about 1/2 as compared with the case in which no crack is formed.

[0106] Furthermore, since press working can be performed with a low load, the abrasion of the punch itself can be reduced, resulting in extended durability of the punch 97 and 98. This in turn can further improve the durability of the punching device. In addition, since the load is low, the strength of the punch 97 and 98 can be reduced. Therefore, for example, even a thin-plate like punch 97 and 98 having a thickness of about 2.5 mm can be employed without problems.

[0107] Furthermore, in this embodiment, the excess thickness portions 5 and 6 are partially formed at the vicinities of the center hole 3 and the vane groove 4 in the end face of the rotor material 1 by the forge processing, and it is configured to remove only the partial excess thickness portions 5 and 6. Therefore, the capacity of the excess thickness portions 5 and 6, or the excessive material, can be reduced, enabling improvement of the material yield ratio, which in turn can reduce the cost.

[0108] In this embodiment, the punching processing is performed as cold working since it is not especially required to heat the rotor material 1. In the present invention, however, the punching processing can be performed as hot processing by heating the rotor material 1 immediately before performing the punching processing.

[0109] In the meantime, in cases where the excess thickness portions 5 and 6 are removed at the peripheral wall portions 5b and 6b by breaking, as shown in Figs. 15 and 16, although burrs 5c 6c are occurred at the broken portion, the burrs 5c and 6c are removed as the need arises. For example, it can be configured to provide a burr removing step between the punching step and the heat treatment step to remove the burrs 5c and 6c or to provide a burr removing step between the heat treatment step and the inspection step.

[0110] Further, in cases where the end faces are subjected to finish cutting work at the shipped place, burrs 5c and 6c can be removed by the finish cutting work. Therefore, it is not required to dare to remove the burrs 5c and 6c during the production step of the rotor R.

[0111] Furthermore, as will be mentioned later, the breaking section at the time of removing the excess thickness portion 5 and 6 can be positioned at the same position as one end 2a of the rotor portion 2 or at the position inner than the one end 2a to prevent occurring the burrs 5c and 6c.

[0112] Next, one example of a rotor R according to this embodiment is exemplified, and the most preferable structure for assuredly removing the excess thickness portions 5 and 6 in the exemplified rotor with high dimensional accuracy will be explained below.

[0113] The exemplified rotor R to be manufactured is set to 30 to 60 mm in axial direction length; 45 to 65 mm in outer diameter (diameter); 10 to 15 mm in diameter of the center hole 3; 2 to 4 mm in the width of the vane groove 4; and 15 to 20 mm in the depth of the vane groove 4 from the outer peripheral surface.

[0114] In the rotor material 1 used in producing the exemplified rotor R, as shown in Fig. 12, when the thickness of the center hole side closing portion 5a, i.e., the dimension from the tip end of the excess thickness portion 5 to one end face 3a of the center hole 3, is defined as "T5," and the height of the peripheral wall portion 5b, i.e., the dimension from one end face 5a of the center hole 5 to one end face 2a the rotor portion 2 is defined as "Z5," the protruded amount H5 of the excess thickness portion 5 becomes equal to "T5+Z5."

[0115] As the most preferable structure of the center hole side excess thickness portion 5 at this time, it is preferably set to: 3.5 to 12 mm in the protruded amount H5 of the excess thickness portion 5; 3 to 10 mm in the thickness T5 of the closing portion 5a; and 0.5 to 2 mm in the height T5 of the peripheral wall portion 5b. Especially, if the closing portion

thickness T5 is too small, the breaking position at the time of removing the excess thickness portion 5 becomes unstable, resulting in short die life and deteriorated dimensional accuracy. To the contrary, if the closing portion thickness T5 is too large, the material yielding rate deteriorates.

[0116] It is preferable that the draft angle $\theta 5$ of the excess thickness portion 5 is set to 0 to 10° and that the curvature radius r5 of the raising portion (basal portion) in the outer peripheral surface of the excess thickness portion 5 is set to 0.5 to 3 mm.

[0117] Further, as shown in Fig. 13, also in the vane groove side excess thickness portion 6, in the same manner as in the aforementioned case, the protruded amount H6 of the excess thickness portion 6 becomes equal to the value obtained by adding the height Z5 of the peripheral wall portion 6b to the thickness T6 of the closing portion 6a.

[0118] The most preferable structure of the vane groove side excess thickness portion 6 is the same as mentioned above. That is, for the same reasons as mentioned above, it is preferable that the protruded amount H6 of the excess thickness portion 6 is set to 3.5 to 12 mm, the thickness T6 of the closing portion 6a is set to 3 to 10 mm, and the height Z6 of the peripheral wall portion 6b is set to 0.5 to 2 mm. Furthermore, in the same manner as mentioned above, it is preferable that the draft angle $\theta 6$ of the excess thickness portion 6 is set to 0 to 10° and that the curvature radius r6 of the raising portion (basal portion) in the outer peripheral surface of the excess thickness portion 6 is set to 0.5 to 3 mm.

[0119] In cases where the excess thickness portions 5 and 6 are structured as mentioned above, the excess thickness portions 5 and 6 can be accurately punched out with punches 97 and 98. Among other things, the adjustments of the curvature radii r5 and r6 are important. That is, if the curvature radius r5 and r6 is decreased, cracks will be generated easily, which can enlarge the cracks. To the contrary, if the curvature radii r5 and r6 are increased, cracks 7 will be hardly generated, resulting in small cracks 7. Accordingly, by adjusting the curvature radius r5 and r6, the size, shape, position, etc., of the crack can be controlled appropriately, which enables assured removals of the excess thickness portions 5 and 6 with higher dimensional accuracy.

[0120] As discussed above, in this embodiment, since the excess thickness portions 5 and 6 are removed by punching operation, as compared with the case in which the excess thickness portions are removed by machining process, such as, cutting work, which is poor in efficiency, the excess thickness portions 5 and 6 can be removed more efficiently, which in turn can improve the product efficiency.

[0121] In addition, since the excess thickness portions 5 and 6 are formed so as to protrude from one end face 2a of the rotor material 1, the excess thickness portions 5 and 6 can be easily removed with high dimensional accuracy by punching operation.

[0122] On the other hand, the rotor R in which the excess thickness portions 5 and 6 have been removed at the punching step will be shipped through the heat treatment step and the inspection step after removal of the burrs 5c and 6c as need arises as mentioned above (see Fig. 9).

<MODIFIED EMBODIMENT>

[0123] In the aforementioned embodiment, the explanation was directed to an example in which each of the excess thickness portions 5 and 6 was structured by a protruded portion protruded from one end face 2a of the rotor portion 2 and each of the center hole 3 and the vane groove 4 was formed up to the position located at the outside of the one end face 2a in each of the excess thickness portions 5 and 6. In the present invention, however, it is not always required to form each end face 3a and 4a of the center hole 3 and the vane groove 4 so as to be located at the outside of the rotor portion 2.

[0124] For example, as shown in Figs. 17 and 18, it can be configured such that each one end face 3a and 4a of the center hole 3 and the vane groove 4 is formed so as to be located at approximately the same position as one end face 2a of the rotor portion 2.

[0125] In this case, corresponding to the position of one end face 2a of the rotor portion 2, cracks 7 and 7 are formed in the excess thickness portions 5 and 6, and broken and removed at the positions. Accordingly, it becomes possible to reduce the size of burrs remained after the removals of the excess thickness portions 5 and 6 as compared with the burrs 5c and 6c of the aforementioned embodiment.

[0126] Further, as shown in Figs. 19 and 20, the center hole 3 and the vane groove 4 can be formed such that each of one end faces 3a and 4a is positioned inner than one end face 2a of the rotor portion 2.

[0127] In this case, cracks 7 and 7 are formed from the raising position of the outer peripheral surface of each of the excess thickness portion 5 and 6 to the end corner position of each of the center hole 3 and the vane groove 4, and each of the excess thickness portions 5 and 6 is broken at the position and removed. Therefore, at the removed positions of the excess thickness portions 5 and 6, chamfered cutout portions are formed at the center hole peripheral edge portion and the vane groove peripheral edge portion of one end face 2a of the rotor material 1. This assuredly prevents forming of burrs.

[0128] Further, in the aforementioned embodiment, although cracks are formed in the excess thickness portions 5 and 6, as will be detailed in the following second embodiment, in the present invention, it is not always required to form

cracks 7 and 7.

[0129] On the other hand, in the aforementioned embodiment, the excess thickness portions 5 and 6 are punched out by the punches 97 and 98 inserted from the other end side of the center hole 3 and vane grooves 4. In the present invention, however, the removal processing of the excess thickness portions is not limited to the blanking processing by a punch.

[0130] That is, it can be configured such that an impact member such as a hammer is hit against the excess thickness portions from the outside of the rotor material 1, for example, in a direction perpendicular to the axis direction to remove the excess thickness portion by the impacts, or the basal ends (base end portions) of the excess thickness portions 5 and 6 are cut (sheared) along the plane perpendicular to the axial direction using an impact member such as a cutting tool.

[0131] Furthermore, in the aforementioned embodiment, it is configured such that the center pin 16 and vane groove forming vane portions 13 are formed in the lower die 10 and that the center hole 3 is formed simultaneously with the forming of the vane grooves 4. However, the forming method of the center hole is not limited to the above. For example, it can be configured such that the center hole is formed in the forming raw material in advance before performing the forge processing, or that only vane grooves are formed by forge processing using a die assembly with no center pin and then the center hole is formed in the rotor material with vane grooves at the post-processing.

[0132] Furthermore, in the aforementioned embodiment, the forge processing and the excess thickness portion blanking processing are performed using separate devices. In the present invention, however, it is not limited to the above, and the forge processing and the excess thickness portion blanking processing can be performed with the same device.

[0133] For example, in the forging device shown in Figs. 1 and 2, as the vane portions 13 and the center pin 16 of the lower die 10, longer ones are used. At the time of forge processing, the upper die 30 is moved downward at approximately the same stroke amount as in the aforementioned embodiment to thereby perform the same forge processing. In the subsequent excess thickness portion blanking processing, the upper die 30 is subsequently moved downward at the stroke amount larger than in the forge processing to thereby punch out the excess thickness portions 5 and 6 by the vane portions 13 and the center pin 16.

[0134] Furthermore, in the aforementioned embodiment, as a forging device, a forging device of the type in which the vane groove forming vane portions 13 and the center hole forming pin 16 are arranged in the fixed side die such as the lower die 10 is used. The present invention, however, is not limited to it, and allows the use of a forging device of the type in which the vane groove forming vane portions (punches) and the center hole forming pin (punch) are arranged in the movable side die such as the upper die 30. Also in this case, by using longer vane groove forming punches and longer center hole forming punch, in the same manner as in the above case, both the forging processing and the excess thickness portion blanking processing can be performed with a single device (forging device).

<SECOND EMBODIMENT>

[0135] Figs. 21 to 26 show a rotor material 1 to be obtained by forge processing according to a second embodiment of the present invention. As shown in these figures, in this second embodiment, the rotor material 1 is constituted by a rotor portion 2 and excess thickness portions 5 and 6. The rotor portion 2 does not include the excess thickness portions 5 and 6.

[0136] The excess thickness portions 5 and 6 are formed so as to protrude toward one end side from one end face 2a to the rotor portion 2.

[0137] Furthermore, in the rotor material 1 of this embodiment, one end face 3a of the center hole 3 does not reach the inside of the excess thickness portion 5, and the one end face 3a is disposed inner than the one end face 2a of the rotor 2.

[0138] Furthermore, one end face 4a of the vane groove 4 also does not reach the inside of the excess thickness portion 6, and the one end face 4a is disposed inner than the one end face 2a of the rotor 2.

[0139] At the other end face (lower end face 2b) of the rotor portion 2 of the rotor material 1, both the center hole 3 and the vane grooves 4 are opened.

[0140] Here, as shown in Figs. 25 and 26, the end face difference (breaking length D3) between one end face 2a of the rotor portion 2 and one end face 3a of the center hole 3 is set to 0 to 2 mm, and the end face difference (breaking length D4) between one end face 2a of the rotor portion 2 and one end face 4a of the vane groove 4 is also set to 0 to 2 mm.

[0141] The radius difference D5 between the outer peripheral surface of the excess thickness portion 5 and the inner peripheral surface of the center hole 3 is set to 0.01 to 0.1 mm, preferably 0.05 to 0.1 mm. Further, the radius difference D6 between the outer peripheral surface of the excess thickness portion 6 and the inner peripheral surface of the vane groove 4 is also set to 0.01 to 0.1 mm, preferably 0.05 to 0.1 mm.

[0142] On the other hand, as shown in Fig. 22B, in this embodiment, among the radius differences between the excess thickness portion 6 and the vane groove 4, the radius difference D61 at the rotor portion outer peripheral side end portion and the radius difference D62 at the rotor portion inner peripheral side end portion are formed to be thicker than the radius difference D60 at the intermediate main portion.

[0143] Further, as shown in Figs. 25 and 26, in this embodiment, the curvature radius r_3 between the inner periphery of the center hole 3 of the rotor material 1 and one end face 3a of the center hole 3 is set to 0.2 to 1 mm. Further, it is preferable that the curvature radius r_4 between the inner periphery of the vane groove 4 and one end face 4a thereof is also set to 0.2 to 1 mm. By setting them within the aforementioned ranges, as shown in Fig. 26, at the time of removing the excess thickness portion 5 and 6 by punching, it is possible to adjust the average value of the height B1 of the inner burr remained at the inner side of the center hole 3 and the vane groove 4 from the inner periphery of the center hole 3 and the vane groove 4 to a preferred value. Concretely, the height B1 of the inner burr can be set to 1 mm or less. In cases where the height B1 of the inner burr exceeds 1 mm, the breaking position becomes unstable, resulting in difficult accuracy control of the inner side dimension of the center hole 3 and that of the vane groove 4.

[0144] Furthermore, in this embodiment, it is preferable that the curvature radius r_{3a} (r_{4a}) between the excess thickness portion 5 (6) of the rotor material 1 and one end face 2a of the rotor material 1 is set to be equal to or less than the inner periphery side curvature radius r_3 (r_4) of the excess thickness portion 5 (6). Concretely, it is preferable to satisfy the relation of " $r_{3a} \leq r_3$ " and " $r_{4a} \leq r_4$." By setting them within the aforementioned ranges, at the time of removing the excess thickness portions 5 and 6 by punching as shown in Fig. 26, it is possible to adjust the average value of the protruded burr height B2 remained at one end face 2a to a preferred value. Concretely, the protruded burr height B2 can be set to 1 mm or less. Further, the breaking position can also be stabilized, resulting in smaller variation of the protruded burr height B2, which makes it easy to control the cut portion control at the post-processing and therefore makes it easy to control the dimensional accuracy of the center hole 3 and the vane groove 4. In cases where the height B2 of the inner burr exceeds 1 mm, the breaking position becomes unstable, which makes it difficult to control the accuracy of the inner size of the center hole 3 and the vane groove 4.

[0145] The die used in the present invention is a die for forming a rotor material having the aforementioned shape in which the curvature radius r_{3a} is formed at the circular hole 35 of the upper die, an inversion shape of the curvature radius r_{4a} is formed at the flat hole 36, an inversion shape of the curvature radius r_3 is formed at the center pin 16 of the lower die, and an inversion shape of the curvature radius r_4 is formed at the vane portion 13.

[0146] In this embodiment, the rotor material 1 having the aforementioned structure is produced using the same forging device as in the first embodiment.

[0147] That is, a forging raw material 49 is mounted in the mounting hole 20 of the lower die 20 (see Fig. 2A showing the first embodiment). From this state, as shown in Fig. 27A, the upper die 30 is moved downward. Thus, when the upper die 30 has moved down to the bottom dead point, it is formed into a shape of the rotor material 1 as shown in Fig. 27B.

[0148] Thereafter, after the upward movement of the upper die 30, in the same manner as mentioned above, the rotor material 1 as a forged article is taken out.

[0149] In this embodiment, in a state in which the upper die 30 has reached the bottom dead point (in the die mated state), it is configured such that the level of the tip end face (upper end face) of the center pin 16 coincides with or distances from the level of the opening face (lower end face) of the circular hole 35. With this, as mentioned above, the one end face 3a of the center hole 3 in the rotor material 1 does not reach the inside of the excess thickness portion 5 and is positioned inner than the one end face 2a of the rotor portion 2, and that the one end face 4a of the vane groove 4 does not reach the inside of the excess thickness portion 6 and is positioned inner than the one end face 2a of the rotor portion 2.

[0150] Here, in the die mated state, the distance (end face difference D3) between the tip end face of the center pin 16 and the opening face of the circular hole 35 is equal to the aforementioned center hole side breaking length D3 and set to 0 to 2 mm, and the distance (end face difference D4) between the tip end face of the vane portion 13 and the opening face of the flat hole 36 is equal to the aforementioned vane groove side breaking length and set to 0 to 2 mm (see Figs. 25 and 26).

[0151] Furthermore, the clearance (diameter difference D5) between the outer periphery of the center pin 16 and the inner periphery of the circular hole 35 is equal to the radius difference D5 between the inner peripheral surface of the center hole 3 and the inner peripheral surface of the excess thickness portion 5 in the aforementioned rotor material 1, and set to 0.01 to 0.1 mm, preferably 0.05 to 0.1 mm, and the clearance (diameter difference D6) between the outer peripheral surface of the vane portion 13 and the outer peripheral surface of the flat hole 36 is equal to the diameter difference D6 between the inner periphery of the flat hole 36 and the inner periphery of the excess thickness portion 5 of the rotor material 1 and set to 0.01 to 0.1 mm, preferably 0.05 to 0.1 mm (see Figs. 25 and 26).

[0152] If the radius differences D5 and D6 and/or the broken lengths D3 and D4 of the outer peripheries of the excess thickness portions are too large, in the punching processing, the excess thickness portions 5 and 6 cannot be removed with a high degree of accuracy, which may cause adverse affects by the broken remains. To the contrary, if the radius differences D5 and D6 are too small, before the punching processing, the excess thickness portions 5 and 6 may drop improperly.

[0153] From the obtained rotor material 1 according to the second embodiment, for example, in the same manner as mentioned above, the excess thickness portions 5 and 6 are removed using the punching device shown in Fig. 14 to produce a rotor R.

[0154] In the rotor production method according to the second embodiment, in addition to the effects of the first embodiment, the following effects can be obtained.

[0155] In the rotor material 1 as a forged article in the second embodiment, since the radius difference D5 between the excess thickness portion 5 and the center hole 3 and the radius difference D6 between the excess thickness portion 6 and the vane groove 4 are set to be small, respectively, the excess thickness portions 5 and 6 can be correctly removed at predetermined positions with high dimensional accuracy.

[0156] Especially, in this embodiment, since the breaking length D3 and D4 of the excess thickness portions 5 and 6 are set to be small, the breaking area at the time of removing the excess thickness portions can be reduced and the removal operation can be performed easily with a low load, which can improve the production efficiency.

[0157] Furthermore, at the time of removing the excess thickness portions 5 and 6, the excess thickness portions 5 and 6 can be punched out by punches 97 and 98 with a low load. This effectively prevents occurring of harmful cracks and/or breakages in the rotor R due to a high load, and therefore a high quality rotor product can be produced.

[0158] In addition, the processing can be performed with a low load, and therefore the abrasion of the punches 97 and 98 themselves can also be reduced, which can improve the durability of the punches 97 and 98. This in turn can further improve the durability of the punching device.

[0159] Furthermore, since the breakage area at the time of removing the excess thickness portion is small, the fracture remain (broken section) also becomes small. Thus, the adverse effects by the fracture remain can be avoided. Therefore, for example, it is not required to perform finish processing for finishing the fracture remain at the post-step, resulting in reduced steps, which can further improve the productivity and reduce the production cost.

[0160] Further, in this embodiment, one ends 3a and 4a of the center hole 3 and the vane grooves 4 are positioned inner than one end face 2a of the rotor portion 2, and therefore the fracture remains after the removals of the excess thickness portions are positioned at the inner peripheries of the center hole 3 and vane groove 4 or at the inside of the rotor R. Also in this regard, adverse effects by the fracture remains can be prevented, assuredly making the post-finishing processing for the fracture remains unnecessary, which can further improve the productivity.

[0161] Furthermore, in this embodiment, among the radius differences D6 between the excess thickness portion 6 and the vane groove 4, the radius difference D61 at the rotor portion outer peripheral side end portion and the radius difference D62 at the rotor portion inner peripheral side end portion are formed to be thicker than the radius difference D60 at the intermediate main portion. Therefore, after the forge processing but before the punching processing, improper dropping of the excess thickness portion 6 can be prevented. For example, such a problem that the excess thickness portion 6 remains in the forge processing die can be prevented assuredly, which can maintain the high productivity.

[0162] In addition, in this embodiment, since both endportions of the excess thickness portion 6 are formed to have large radius differences D61 and D62, improper breakage of these portions can be prevented assuredly, which can more assuredly prevent improper dropping of the excess thickness portion 6. In other words, both end portions of the excess thickness portion 6 often become breakage starting points at the time of dropping. Therefore, by forming both end portions to be thick, it becomes hard to cause the breakage, which prevents improper dropping more assuredly.

[0163] Furthermore, in this embodiment, the radius difference (D6) of the outer periphery of the excess thickness portion 6 at the side of the vane groove 4 is partially increased. The present invention, however, is not limited to the above, and allows partially increasing the radius difference D5 of the outer periphery of the excess thickness portion 5 at the side of the center hole 3.

EXAMPLES

[EXAMPLE 1]

[0164] A rotor material 1 shown in Fig. 3 was forged using a forging dies 10 and 30 shown in Figs. 1 and 2. The rotor material 1 was a material for producing an aluminum alloy rotor R shown in Fig. 4.

[0165] The rotor R had an outer diameter: 52 mm, a height: 50 mm, a diameter of the center hole 3: 10 mm, the number of vane grooves 4: 5, a groove width: 3 mm, a groove depth: 15 mm, an offset dimension U: 10 mm. The material alloy was A390 aluminum alloy.

[0166] As shown in the following Table 1, in the forging die, the clearance D5 between the center pin 16 of the lower die 10 and the circular hole 35 of the upper die 30 was set to 0.1 mm, and the clearance D6 between the vane portion 13 of the lower die 10 and the flat hole 36 of the upper die 30 was also set to 0.1 mm in the same manner as mentioned above.

[0167] Furthermore, the distance (breaking length D3) between the center pin 16 of the lower die 10 and the opening face of the circular hole 35 of the upper die 30 was set to 1.5 mm, and the distance (breaking length D4) between the vane portion 13 of the lower die 10 and the opening face of the flat hole 36 of the upper die 30 was also set to 1.5 mm in the same manner as mentioned above.

[0168] Then, a forging raw material W heated to 400 °C was mounted in the lower die 10 and formed into a rotor

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material 1 by applying the following forming loads. During this forging, the first sub-load F1 and the second sub-load F2 increased. Each of the final loads was 1.5 times of each initial load.

Main load F=325 MPa

[0169]

Initial load of the first sub-load F1: 32.9 MPa (4.0 kg/mm²)

Initial load of the second sub-load F2: 44.1 MPa (4.5 kg/mm²)

[0170] The excess thickness portions 5 and 6 were removed from the obtained rotor material 1 using the punching device shown in Fig. 14 to thereby obtain a rotor R.

[0171] The material yielding percentage of the rotor R with respect to the forging raw material W (weight of the rotor R / weight of the forging material W x 100) was 82.9 %.

[0172]

[TABLE 1]

	D3, D4	D5, D6	Fracture during forging	Fracture position	Fracture area
Example 1	1.5 mm	0.1 mm	Nil	Inner periphery	Small
Example 2	0	0.1 mm	Nil	Inner periphery	Small
Comparative Example 1	-2 mm	0.1 mm	Yes	Outer periphery	Small
Comparative Example 2	-2 mm	2 mm	Nil	Outer periphery	Large

[EXAMPLE 2]

[0173] As shown in Fig. 1, a rotor R was produced in the same manner as in the aforementioned Example 1 except that the breaking lengths D3 and D4 of the excess thickness portions 5 and 6 were set to "0 (zero)," respectively.

[COMPARATIVE EXAMPLE 1]

[0174] As shown in Table 1, a rotor R was produced in the same manner as in the aforementioned Example except that the breaking lengths D3 and D4 of the excess thickness portions 5 and 6 were set to "-2 mm," respectively.

[COMPARATIVE EXAMPLE 2]

[0175] As shown in Table 1, a rotor R was produced in the same manner as in the aforementioned Example except that the breaking lengths D3 and D4 of the excess thickness portions 5 and 6 were set to "-2 mm," respectively, and that the clearances D5 and D6 of the outer periphery of the excess thickness portions 5 and 6 were set to "2 mm," respectively.

[EVALUATION]

[0176] As shown in Table 1, in the production methods of Examples 1 and 2, no breakage and/or dropping of the excess thickness portions 5 and 6 was occurred during the forge processing, and therefore the processing could be completed without any delay.

[0177] Furthermore, in the production methods of Examples 1 and 2, the fracture section after the punching processing (after removal of the excess thickness portions) was small, and the fracture remain (fracture section) was formed in the center hole 3 and the vane groove 4, respectively. Therefore, it is considered that there is no problem even if no finishing processing of the fracture remain is performed.

[0178] On the other hand, in the production method of Comparative Example 1, the excess thickness portions 5 and 6 were broken improperly during the forge processing. Thus, the processing could not be performed smoothly.

[0179] Furthermore, in the production method of Comparative Example 2, the fracture cross-section after the punching processing was large, and the fracture remain (fracture cross-section) was positioned so as to protrude outward. Therefore, in the case of the practical usage, it is considered to remove the fracture remains by finish processing.

[TEST EXAMPLES 1-7]

[0180] Rotors R were produced in the same conditions as in the aforementioned Example 1 except that the curvature radiuses r3 and r3a of the center hole 3 were adjusted to the values as shown in Table 2. Then, the inner burrs and protruded burrs (see Fig. 26) were evaluated. The results are also shown in Table 2.

[0181]

[TABLE 2]

	r3 [mm]	r3a [mm]	Average height of protruded burrs [mm]	Variation of protruded burrs	Average height of inner burrs [mm]
Test Example 1	1	0.1	0.1	Small	0.5
Test Example 2	1	0.5	0.5	Small	0.5
Test Example 3	1	1	1	Small	0.5
Test Example 4	0.5	0.1	0.1	Small	0.3
Test Example 5	0.2	0.1	0.1	Small	0.1
Test Example 6	0.2	0.5	0.5	Medium	0.1
Test Example 7	2	1	1	Small	Fracture position was unstable

[0182] As will be apparent from the above Table, in the products in which the curvature radiuses r3 and r3a were adjusted to a specific value, the status of inner burrs and protruded burrs was stable.

[0183] As to the products having vane groove 4 side curvature radiuses r4 and r4a, the same tests as mentioned above were performed, resulting in the same evaluation.

[0184] This application claims priorities to Japanese Patent Application No. 2008-164327 filed on June 24, 2008, and Japanese Patent Application No. 2009-47963 filed on March 2, 2009, the entire disclosure of each of which is incorporated herein by reference in its entirety.

[0185] It should be understood that the terms and expressions used herein are used for explanation and have no intention to be used to construe in a limited manner, do not eliminate any equivalents of features shown and mentioned herein, and allow various modifications falling within the claimed scope of the present invention.

[0186] While the present invention may be embodied in many different forms, a number of illustrative embodiments are described herein with the understanding that the present disclosure is to be considered as providing examples of the principles of the invention and such examples are not intended to limit the invention to preferred embodiments described herein and/or illustrated herein.

[0187] While illustrative embodiments of the invention have been described herein, the present invention is not limited to the various preferred embodiments described herein, but includes any and all embodiments having equivalent elements, modifications, omissions, combinations (e.g., of aspects across various embodiments), adaptations and/or alterations as would be appreciated by those in the art based on the present disclosure. The limitations in the claims are to be interpreted broadly based on the language employed in the claims and not limited to examples described in the present specification or during the prosecution of the application, which examples are to be construed as non-exclusive.

INDUSTRIAL APPLICABILITY

[0188] The rotor production method according to the present invention can be applied in producing a rotor for use in, e.g., a compressor.

BRIEF DESCRIPTION OF THE REFERENCE NUMERALS

[0189]

- 1: rotor material
- 2: rotor portion
- 2a: one end face
- 3: center hole (shaft hole)
- 3a: one end faces

	4:	vane groove
	4a:	one end face
	5, 6	excess thickness portion
	5a:	closing portion
5	5b:	peripheral wall portion
	7:	cracks
	13:	vane portion (vane groove forming die)
	97, 98:	driving punch
	D3, D4:	end face difference
10	D5, D6:	radius difference
	R:	rotor
	T5:	closing portion thickness
	W:	forging raw material

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Claims

1. A production method of a rotor, the method comprising:

20 a forging step for obtaining a rotor material having a cylindrical columnar rotor portion in which a plurality of vane grooves extending along an axial direction are formed in an outer peripheral portion at intervals in a circumferential direction and an excess thickness portion integrally formed on one end face of the rotor portion so as to protrude toward one end side of the rotor portion and close one end side of the vane groove; and
25 an excess thickness portion removing step for obtaining a rotor having the vane grooves opened at the one end side by hitting the excess thickness portion with an impact applying member to thereby remove the excess thickness portion from the rotor portion.

30 2. The production method of a rotor as recited in claim 1, wherein, in the rotor material, the excess thickness portion is formed so as to protrude toward the one end side of the rotor portion beyond the one end face and the vane groove is formed so as to reach an inside of the excess thickness portion.

35 3. The production method of a rotor as recited in claim 2, wherein the excess thickness portion has a peripheral wall portion closing a peripheral side surface of the vane groove, and wherein, at the excess thickness portion removing step, the excess thickness portion is broken at the peripheral wall portion and removed.

40 4. The production method of a rotor as recited in claim 2 or 3, wherein, when a dimension from a tip end of the excess thickness portion to one end face of the vane groove is defined as a thickness of a closing portion, the thickness of the closing portion is set to 3 to 10 mm.

45 5. The production method of a rotor as recited in any one of claims 1 to 4, wherein, at the forging step, a crack is formed between the excess thickness portion and the rotor portion, and wherein, at the excess thickness portion removing step, the rotor material is broken along the crack.

50 6. The production method of a rotor as recited in any one of claims 1 to 5, wherein, at the excess thickness portion removing step, a blanking punch as an impactor is driven into the vane groove of the rotor material from the other end side opening to thereby punch out and remove the excess thickness portion toward the one end side.

55 7. The production method of a rotor as recited in any one of claims 1 to 6, wherein, at the forging step, a vane groove forming die is relatively driven into a cylindrical columnar forging raw material from the other end face thereof to thereby form the vane groove extending from the other end face to the one end face, and wherein, when the vane groove forming die is driven into the forging raw material, a back-pressure is applied to an area corresponding to the vane groove forming scheduled portion on the one end face of the forging raw material.

8. The production method of a rotor as recited in any one of claims 1 to 7, wherein, when the excess thickness portion is defined as a vane groove side excess thickness portion and the impact applying member is defined as a vane groove side impact applying member, wherein, at the forging processing, a shaft hole is formed in the rotor portion of the rotor material so as to extend in

the axial direction, and a shaft hole side excess thickness portion closing the one end side of the shaft hole is integrally formed on the one end face of the rotor portion so as to protrude toward the one end side, and wherein, at the excess thickness portion removing step, the shaft hole side impact applying member is hit against the shaft hole side excess thickness portion to remove the excess thickness portion from the rotor portion so that the shaft hole is opened at the one end side.

9. The production method of a rotor as recited in claim 8, wherein a blanking punch as the impact applying member is driven into the shaft hole of the rotor material from the other end side opening to punch out and remove the shaft hole side excess thickness portion toward the one end side.

10. The production method of a rotor as recited in claim 8 or 9, wherein, at the forging step, a shaft hole forming die is relatively driven into a cylindrical columnar forging raw material from the other end face thereof to thereby form the shaft hole extending from the other end face to the one end face, and wherein, when the shaft hole forming die is driven into the forging raw material, a back-pressure is applied to an area corresponding to the shaft hole forming scheduled portion on the one end face of the forging raw material.

11. The production method of a rotor as recited in claim 1, wherein, in the rotor material, the excess thickness portion is integrally formed on the one end face of the rotor portion so as to protrude toward the one end side, and wherein one end face of the vane groove does not reach the excess thickness portion and is positioned inner than the one end face of the rotor portion.

12. The production method of a rotor as recited in claim 11, wherein, when a distance between the one end face of the rotor portion and the one end face of the vane groove in the rotor material is defined as an end face difference, the end face difference at the vane groove side is set to 0 to 2 mm.

13. The production method of a rotor as recited in claim 11 or 12, wherein, when a distance between the inner peripheral surface of the vane groove and an outer peripheral surface of the excess thickness portion of the rotor material is defined as a vane groove side radius difference, the vane groove side radius difference is set to 0.01 to 0.1 mm.

14. The production method of a rotor as recited in any one of claims 11 to 13, wherein the vane groove side radius difference partially differs.

15. The production method of a rotor as recited in claim 13 or 14, wherein among the vane groove side radius differences, at least one of the radius difference at an inner peripheral side end portion of the vane groove and the radius difference at the outer peripheral side end portion of the vane groove is set to be larger than a radius difference at an intermediate portion of the vane groove.

16. The production method of a rotor as recited in any one of claims 11 to 15, wherein, when the excess thickness portion is defined as a vane groove side excess thickness portion and the impact applying member is defined as a vane groove side impact applying member, wherein, at the forging processing, a shaft hole is formed in the rotor portion of the rotor material so as to extend in the axial direction, and a shaft hole side excess thickness portion closing the one end side of the shaft hole is integrally formed on the one end face of the rotor portion so as to protrude toward the one end side, wherein, at the excess thickness portion removing step, the shaft hole side impact applying member is hit against the shaft hole side excess thickness portion to remove the excess thickness portion from the rotor portion so that the shaft hole is opened at the one end side, and wherein, in the rotor material produced by the forging processing, one end face of the shaft hole does not reach the shaft hole side excess thickness portion and is positioned inner than the one end face of the rotor portion.

17. The production method of a rotor as recited in claim 16, wherein, when a distance between the one end face of the rotor portion and the one end face of the shaft hole in the rotor material is defined as a shaft hole side end face difference, the shaft hole side end face difference is set to 0 to 2 mm.

18. The production method of a rotor as recited in claim 16 or 17, wherein, when a distance between the inner peripheral surface of the shaft hole and an outer peripheral surface of the shaft hole side excess thickness portion of the rotor material is defined as a shaft hole side radius difference, the shaft hole side radius difference is set to 0.01 to 0.1 mm.

19. The production method of a rotor as recited in any one of claims 16 to 18, wherein the shaft hole side radius difference partially differs.

5 20. A method of removing an excess thickness portion of a rotor material having a cylindrical columnar rotor portion in which a plurality of vane grooves extending along an axial direction are formed in an outer peripheral portion at intervals in a circumferential direction and the excess thickness portion integrally formed on one end face of the rotor portion so as to protrude toward one end side of the rotor portion and close one end side of the vane groove, wherein an impact applying member is hit against the excess thickness portion to remove the excess thickness portion from the rotor portion to thereby open the vane groove at the one end side.

10 21. A device for removing an excess thickness portion of a rotor material having a cylindrical columnar rotor portion in which a plurality of vane grooves extending along an axial direction are formed in an outer peripheral portion at intervals in a circumferential direction and the excess thickness portion integrally formed on one end face of the rotor portion so as to protrude toward one end side of the rotor portion and close one end side of the vane groove, wherein the device is provided with a blanking punch configured to drive into the vane groove of the rotor material from the other end side opening of the vane groove and hit against the excess thickness portion to punch out and remove the excess thickness portion from the rotor portion to thereby open the vane groove at the one end side.

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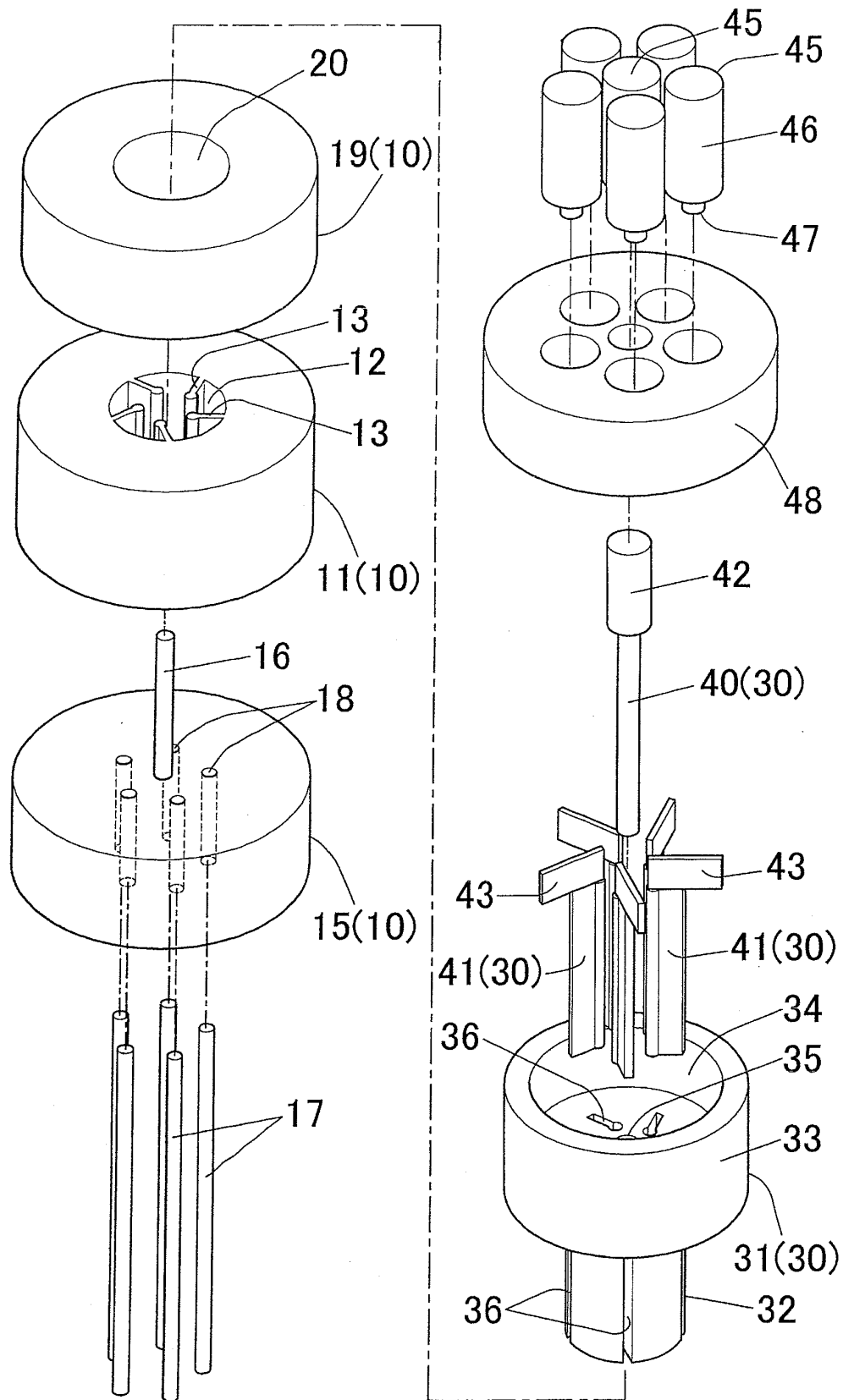
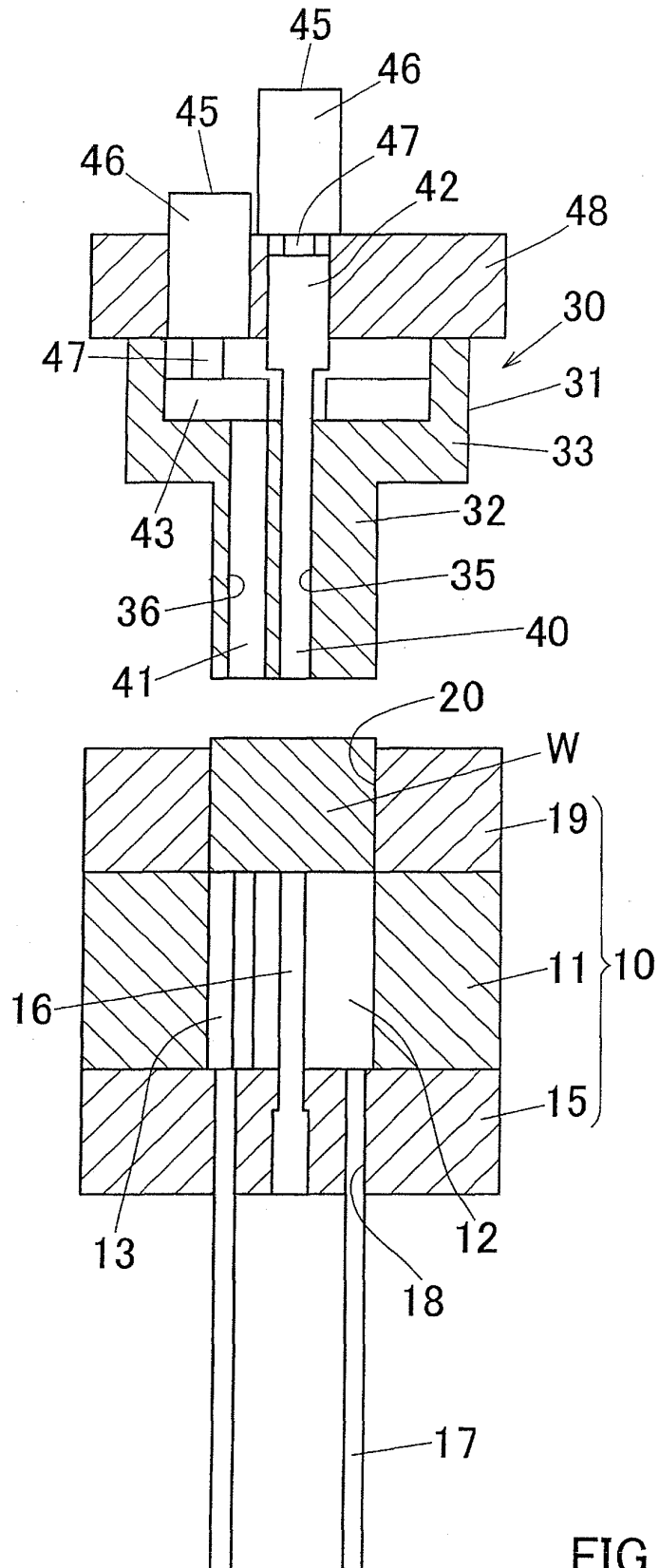


FIG.1



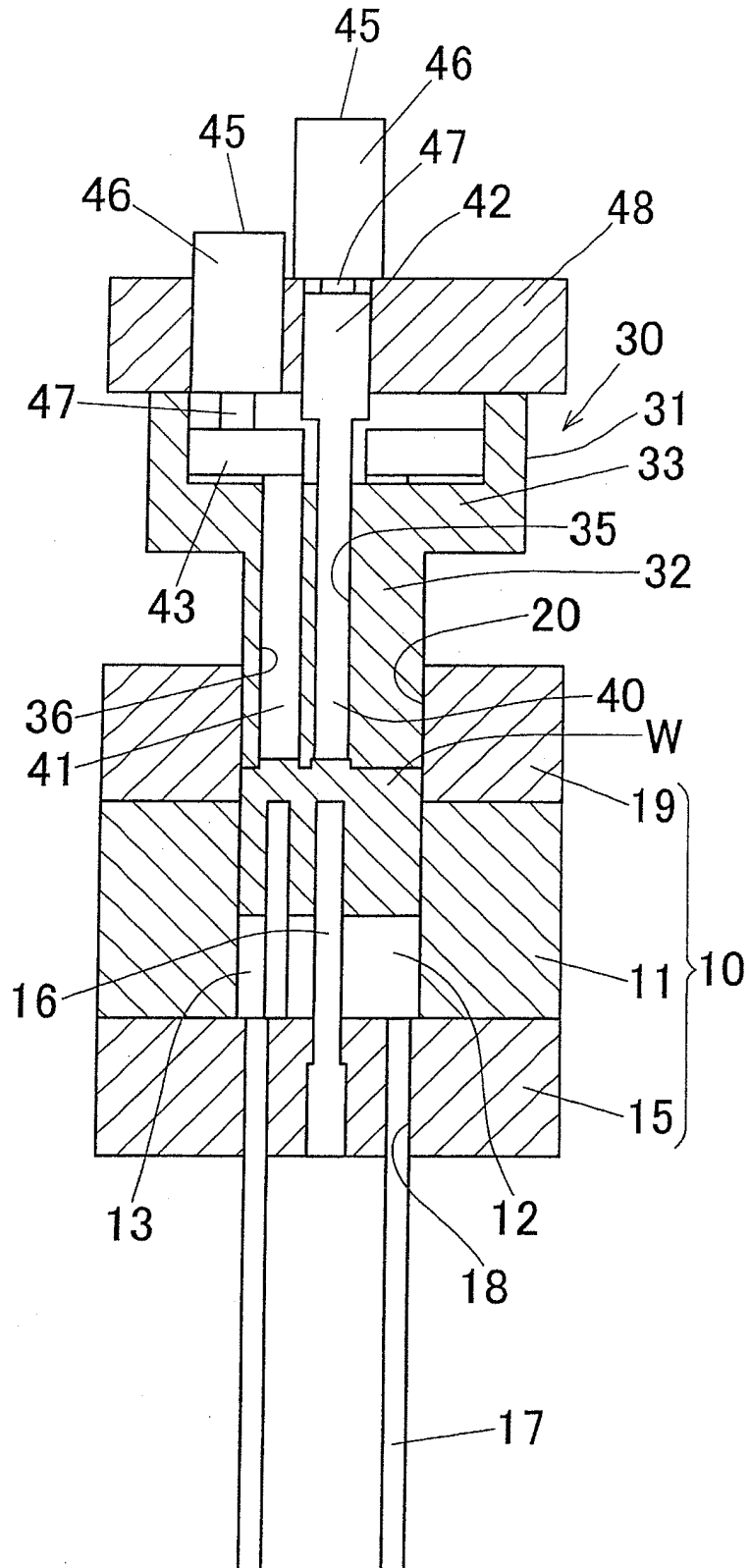


FIG.2B

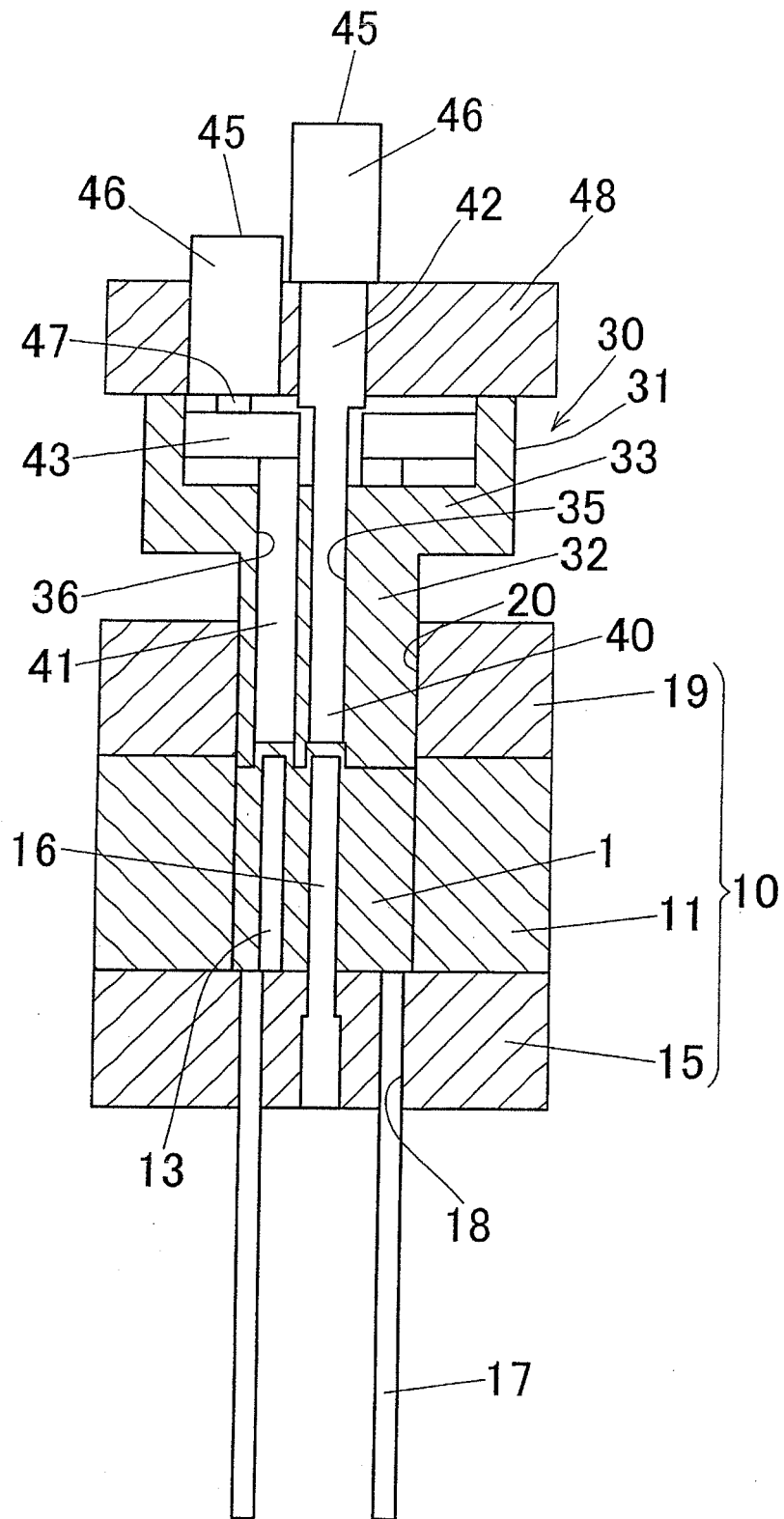
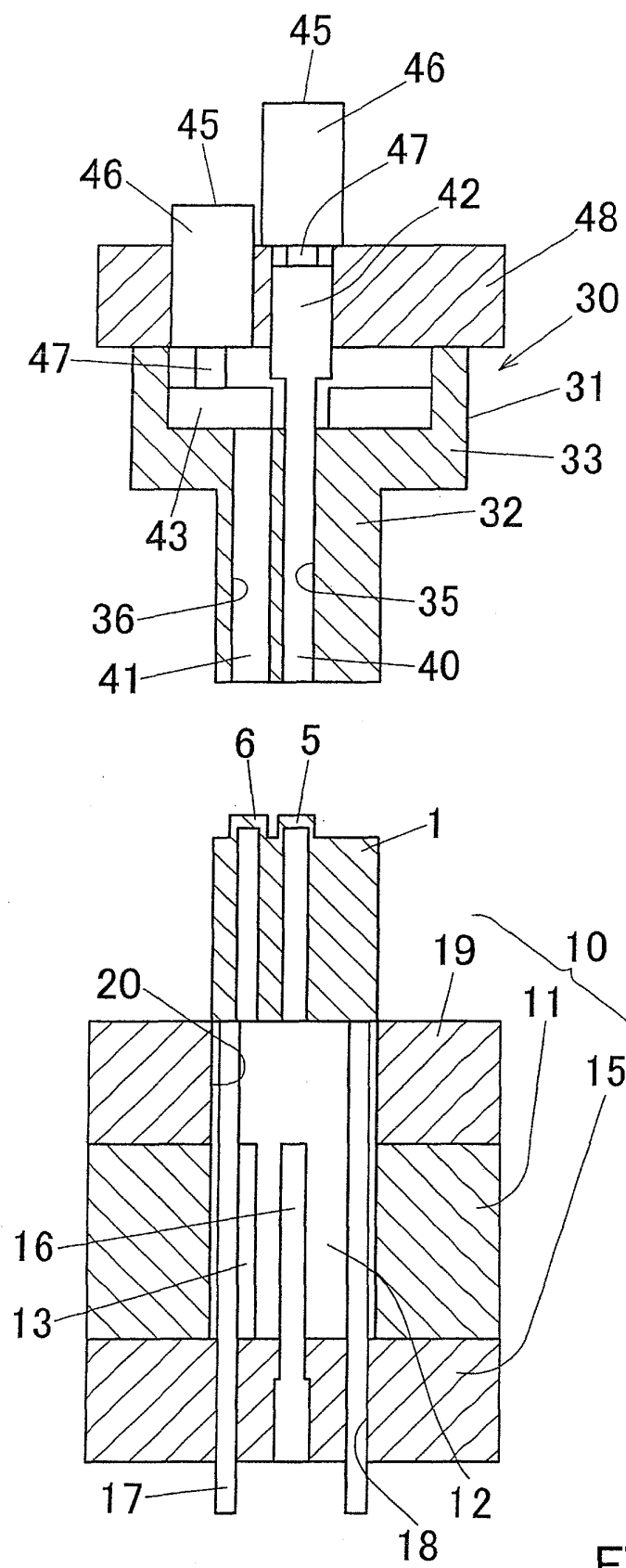


FIG.2C



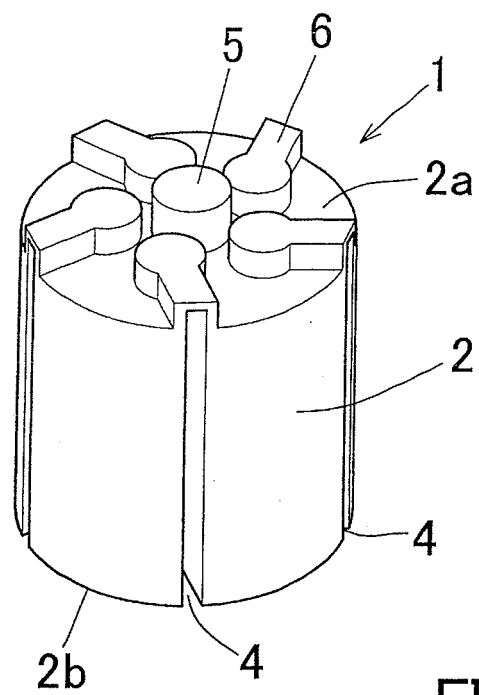


FIG. 3

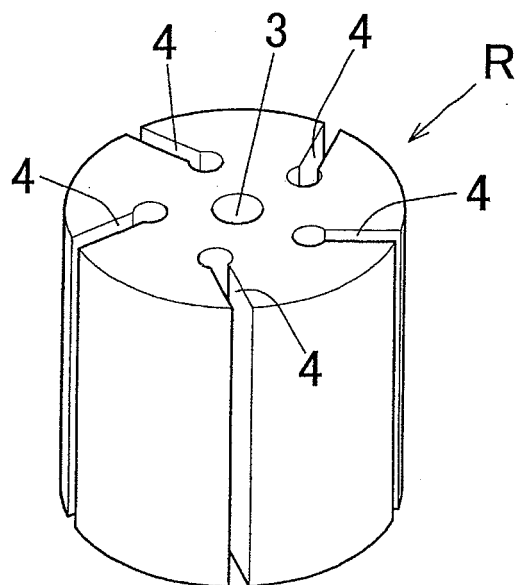


FIG. 4

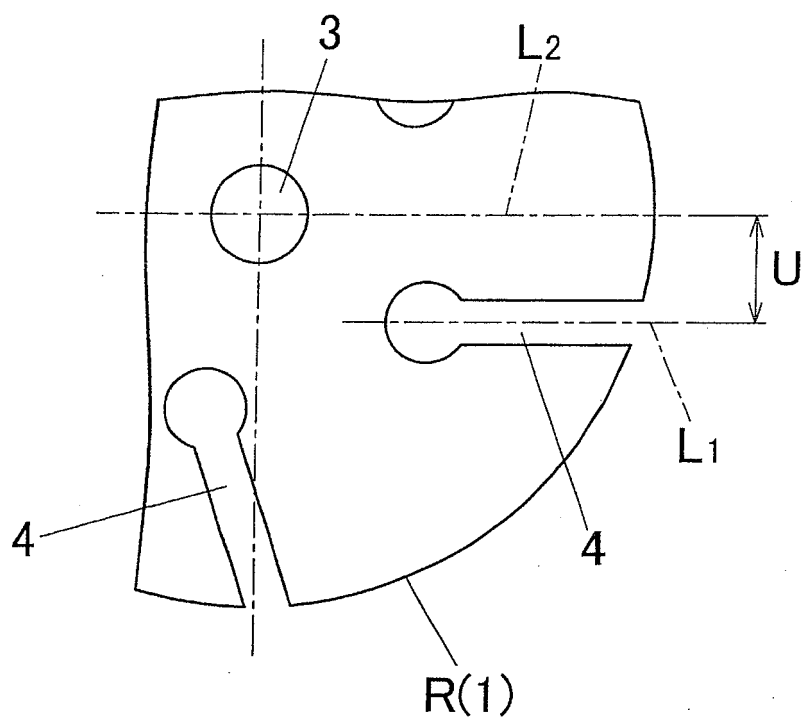


FIG.5

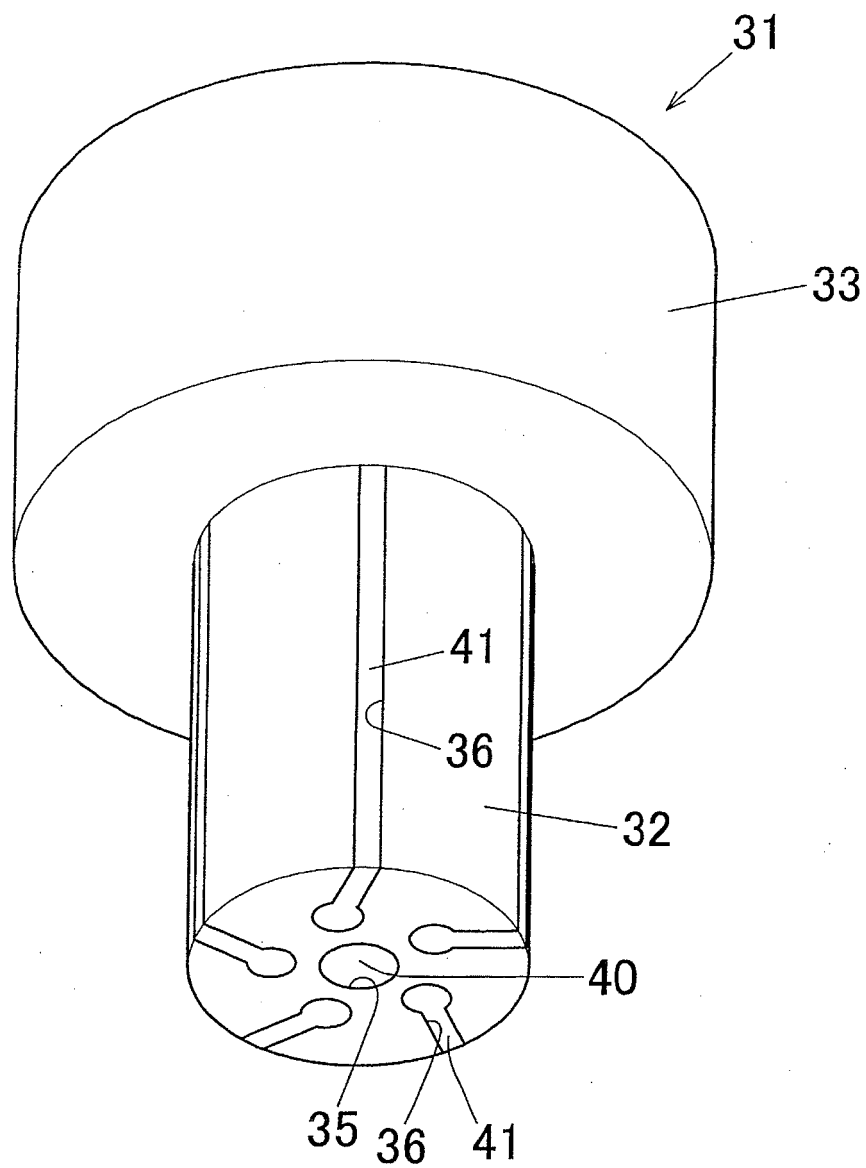


FIG. 6

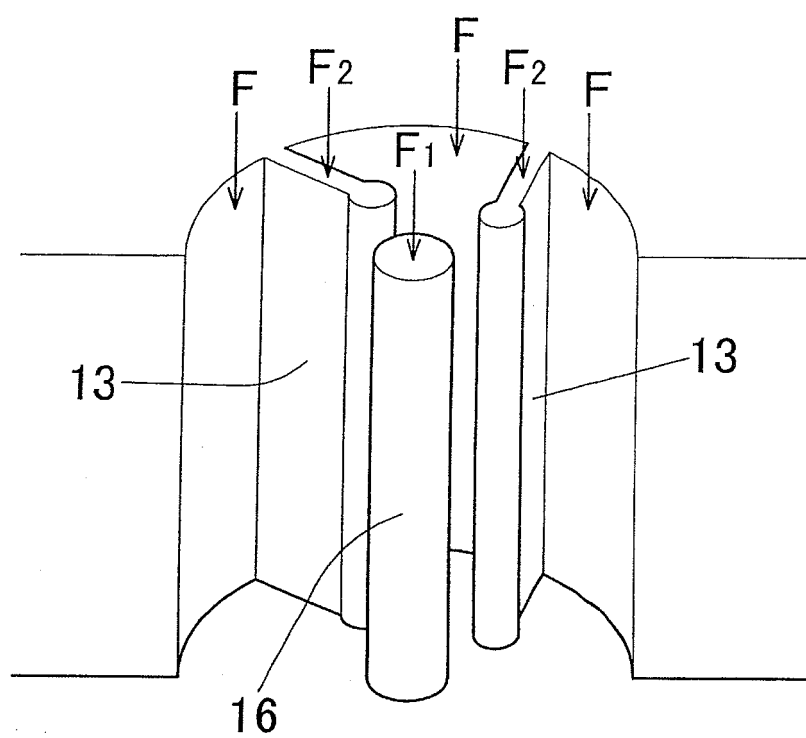


FIG. 7A

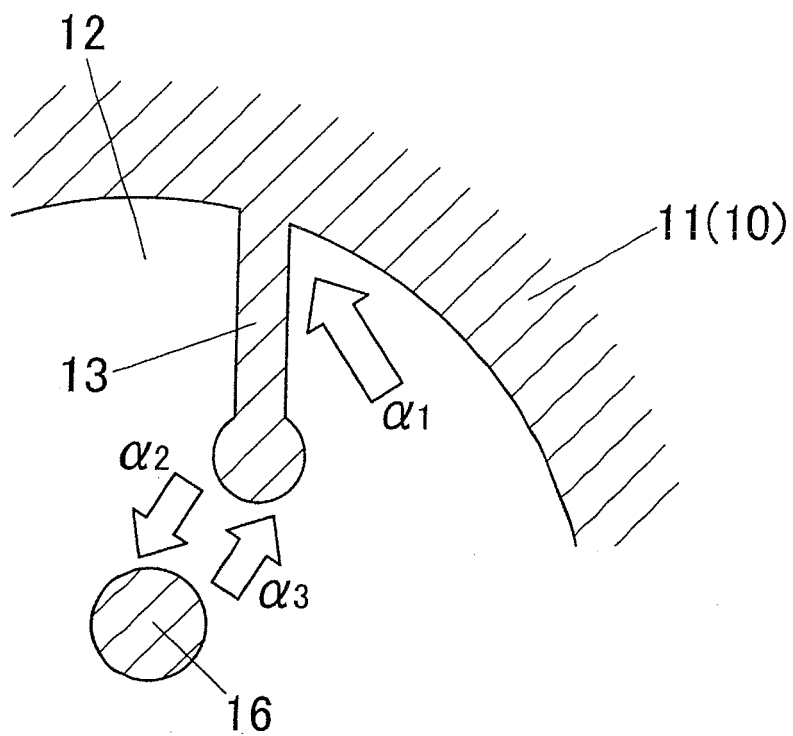


FIG. 7B

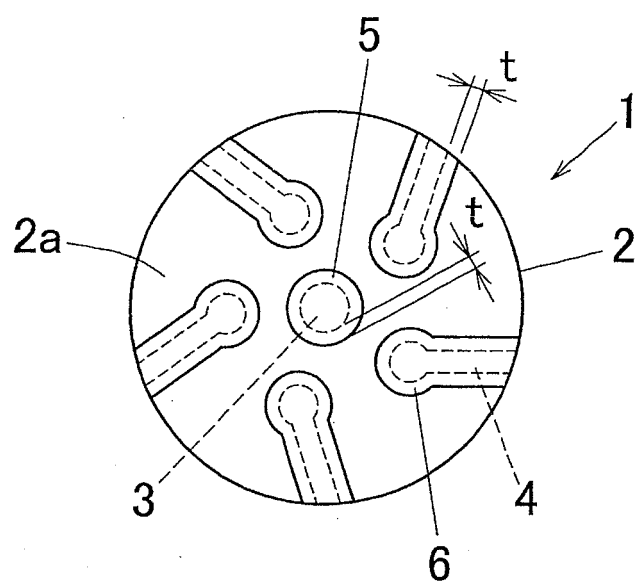


FIG. 8

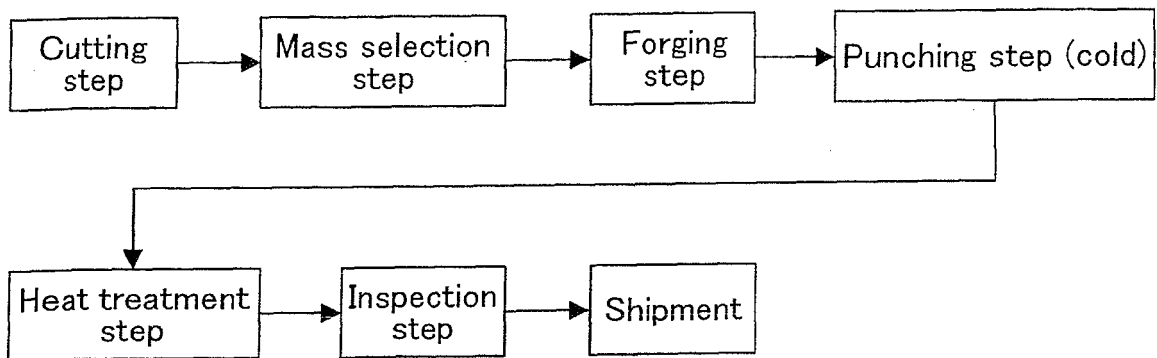


FIG.9

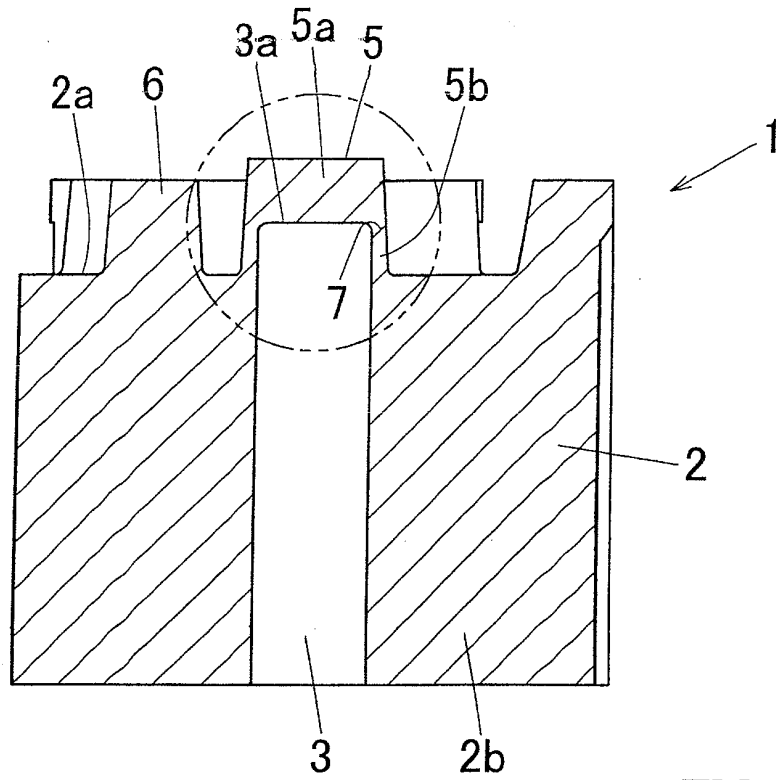


FIG. 10

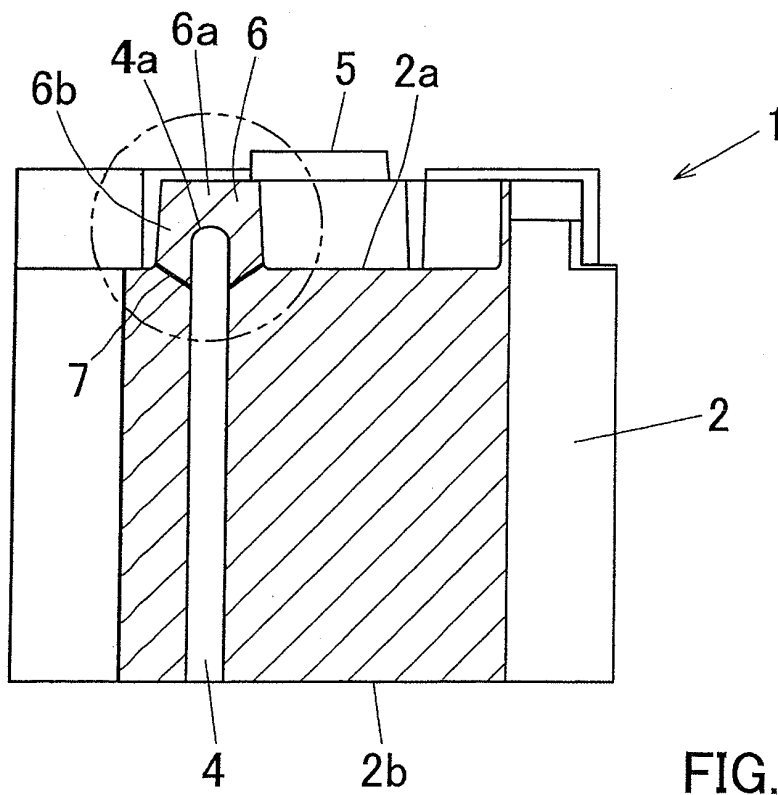


FIG. 11

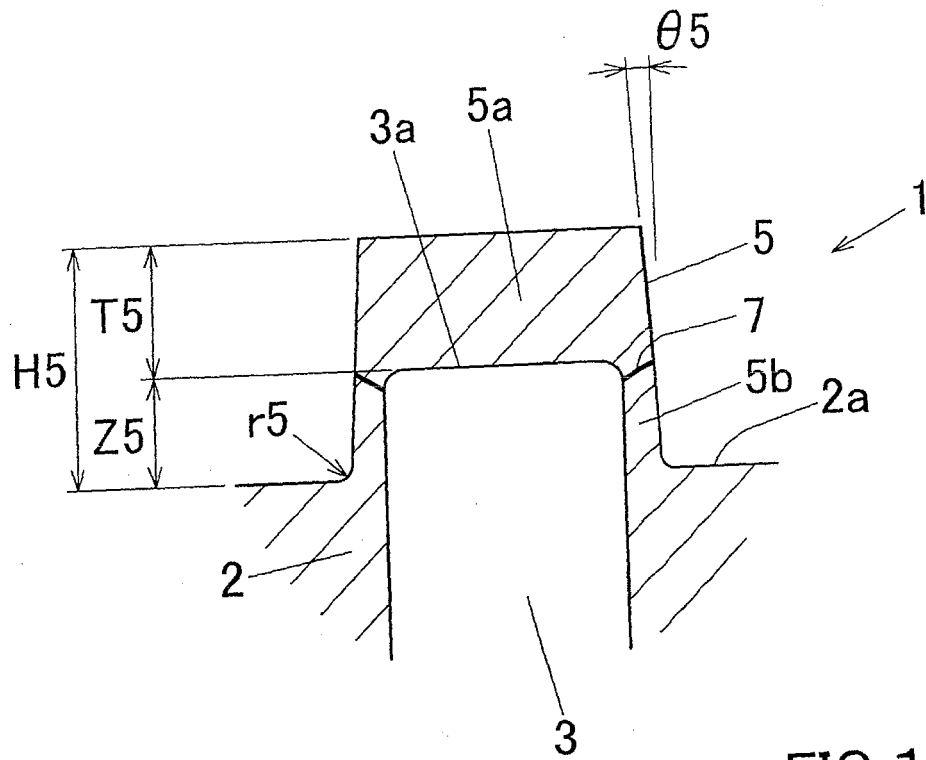


FIG. 12

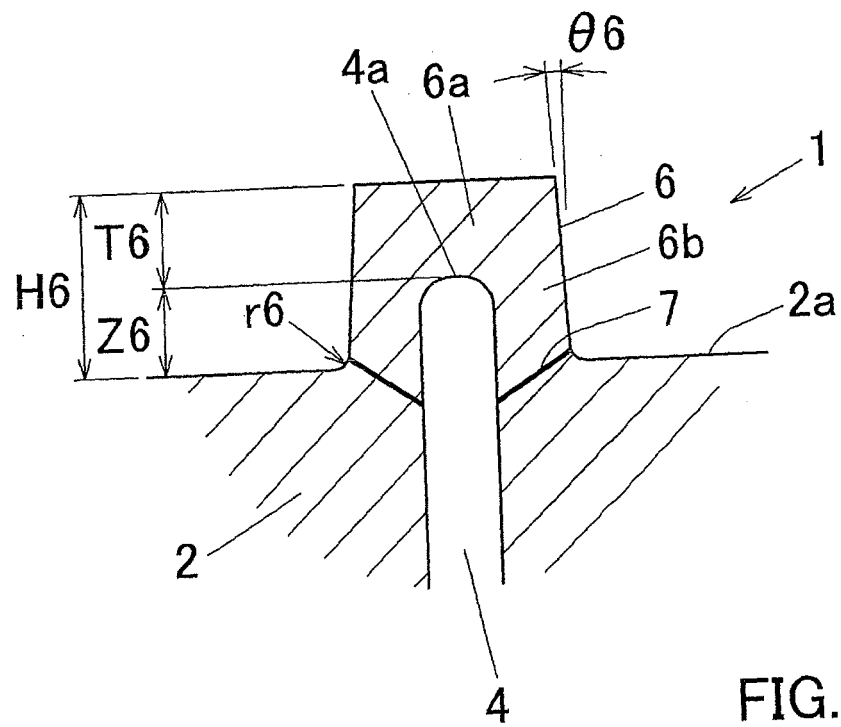


FIG. 13

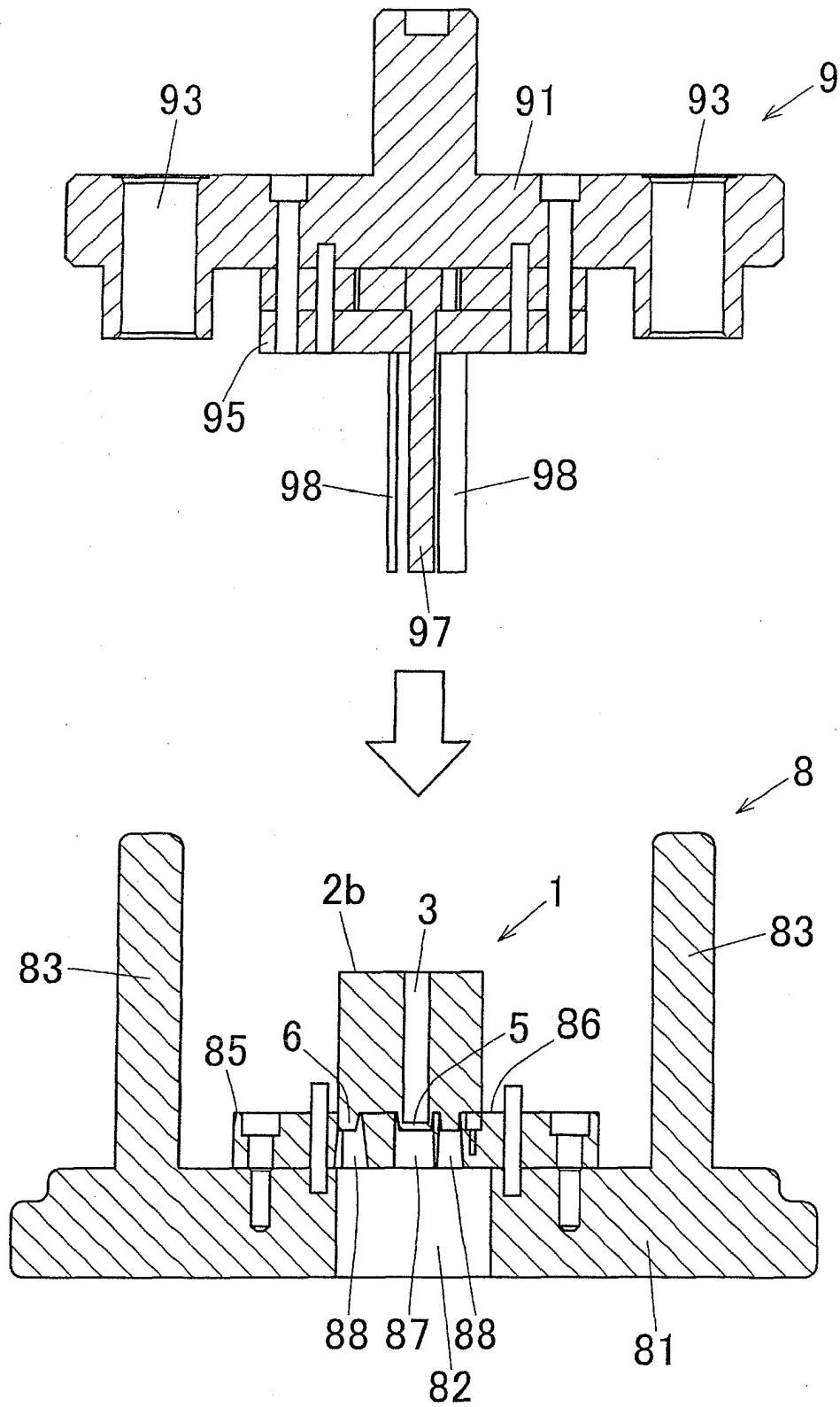


FIG. 14

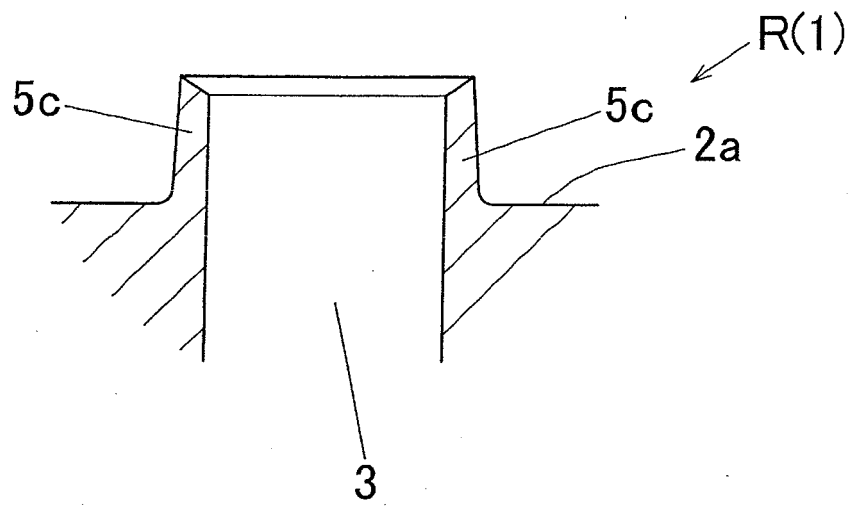


FIG. 15

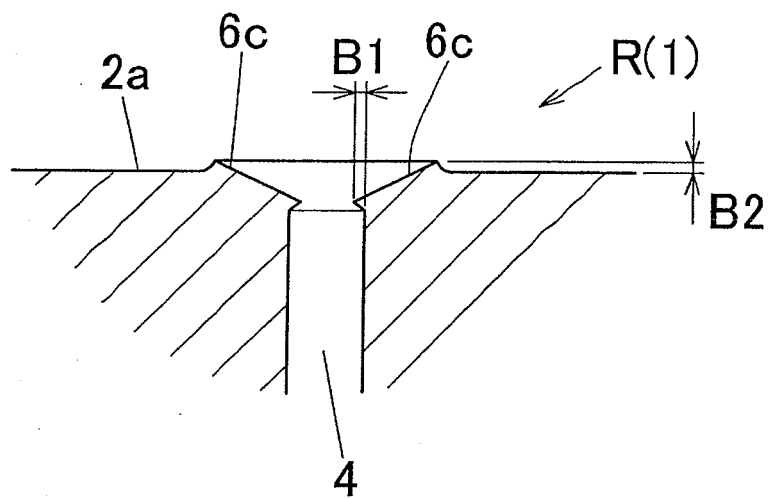


FIG. 16

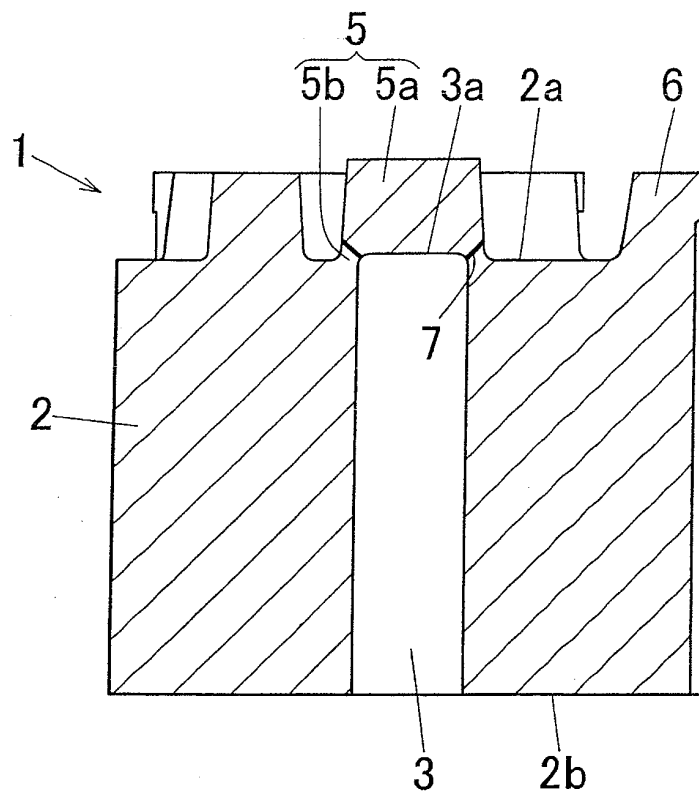


FIG.17

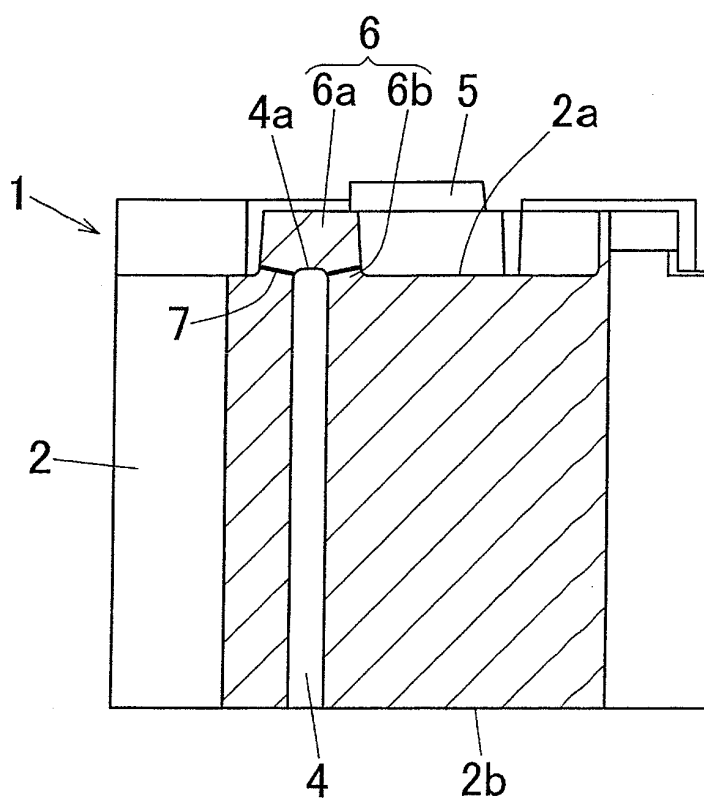


FIG.18

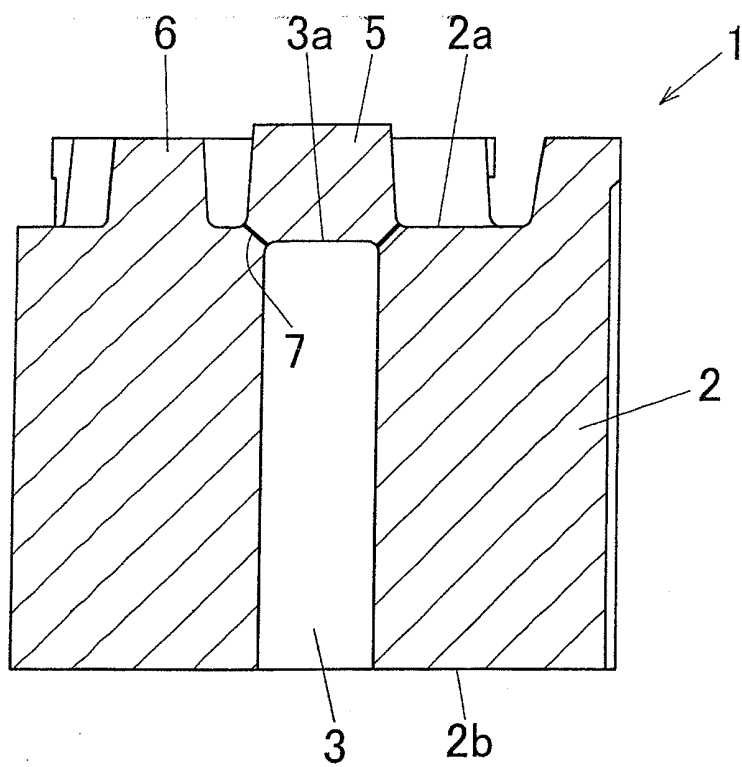


FIG.19

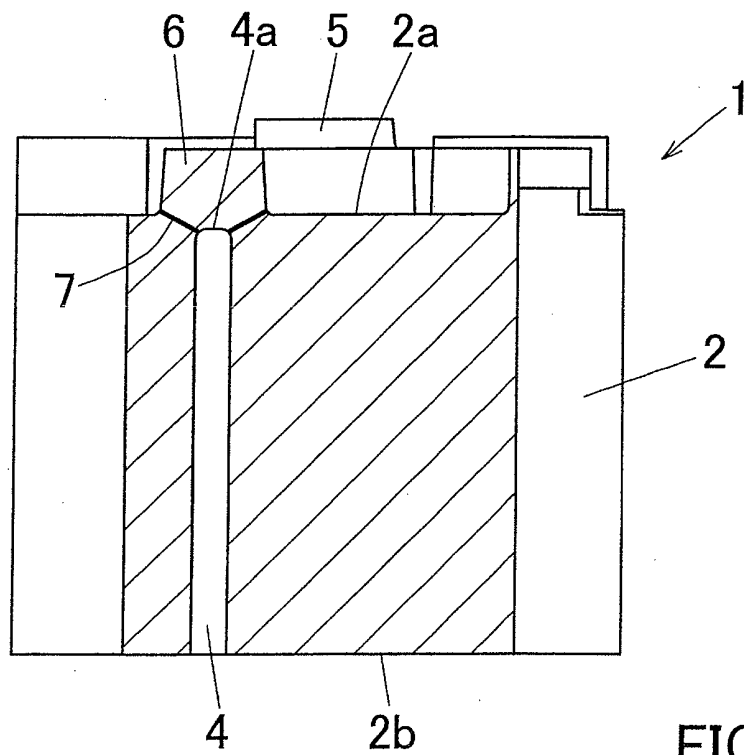


FIG.20

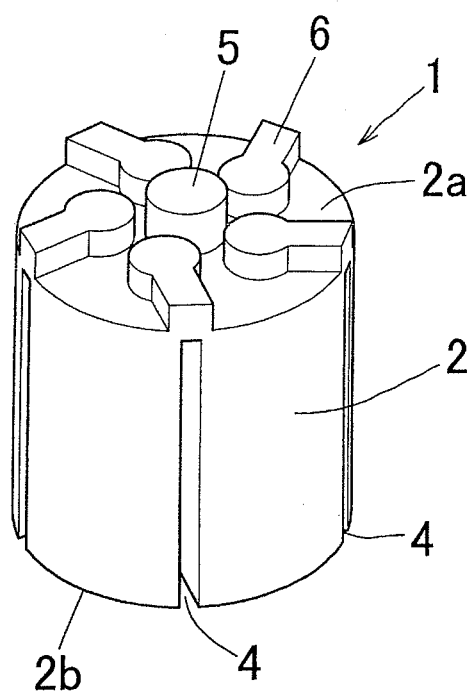


FIG.21

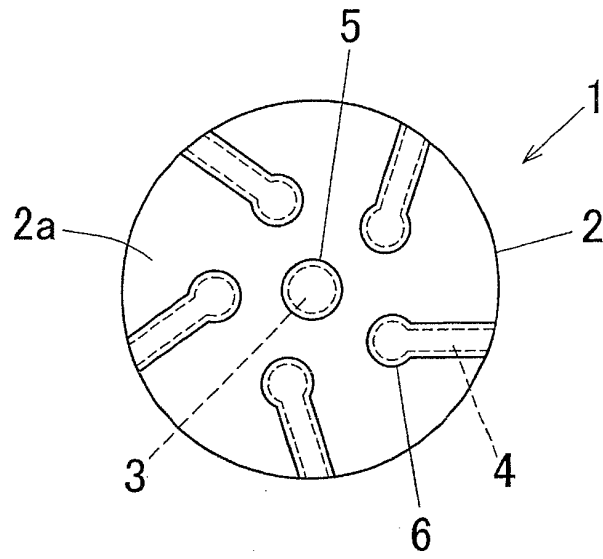


FIG. 22A

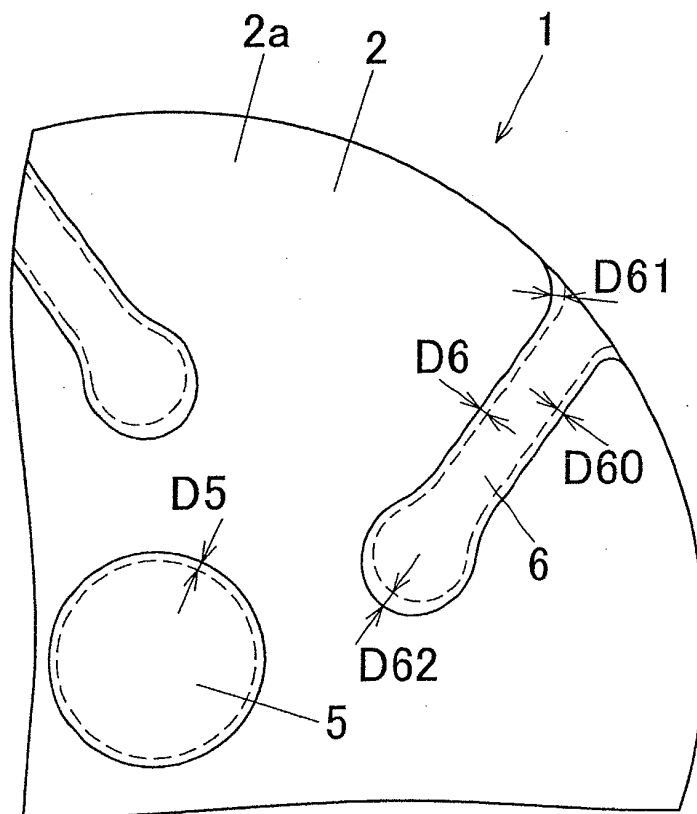


FIG. 22B

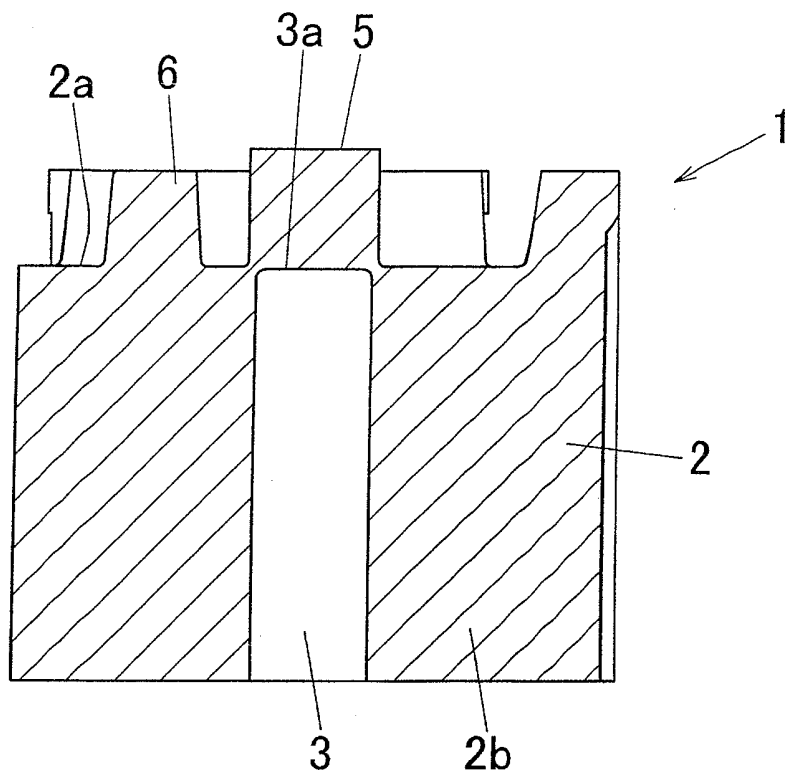


FIG. 23

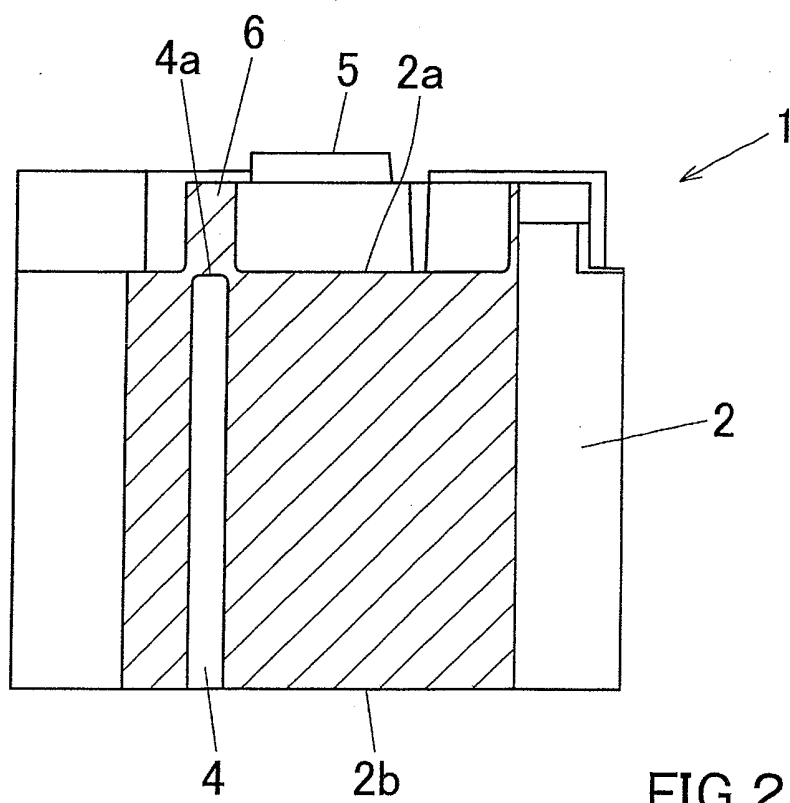


FIG. 24

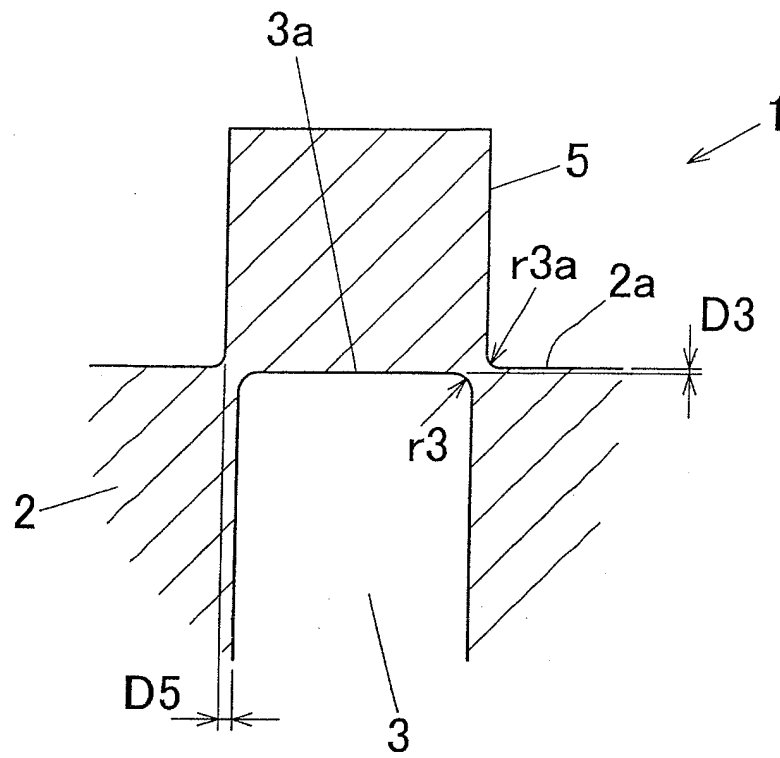


FIG.25

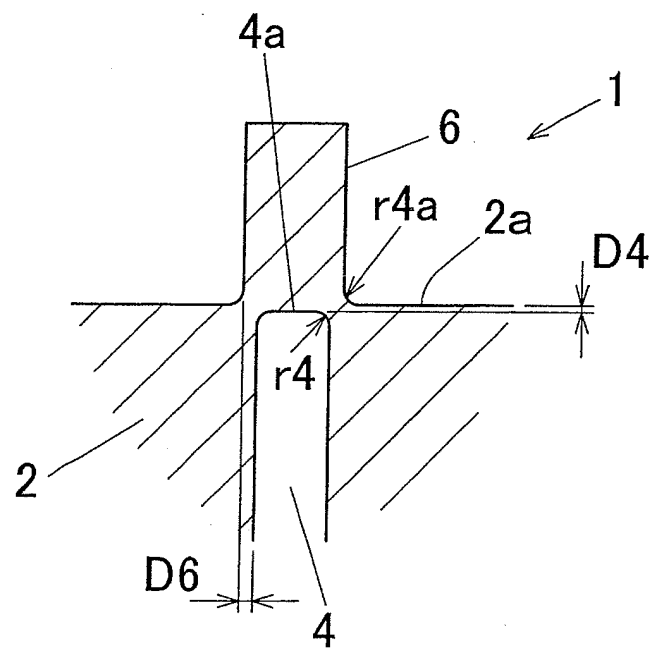


FIG.26

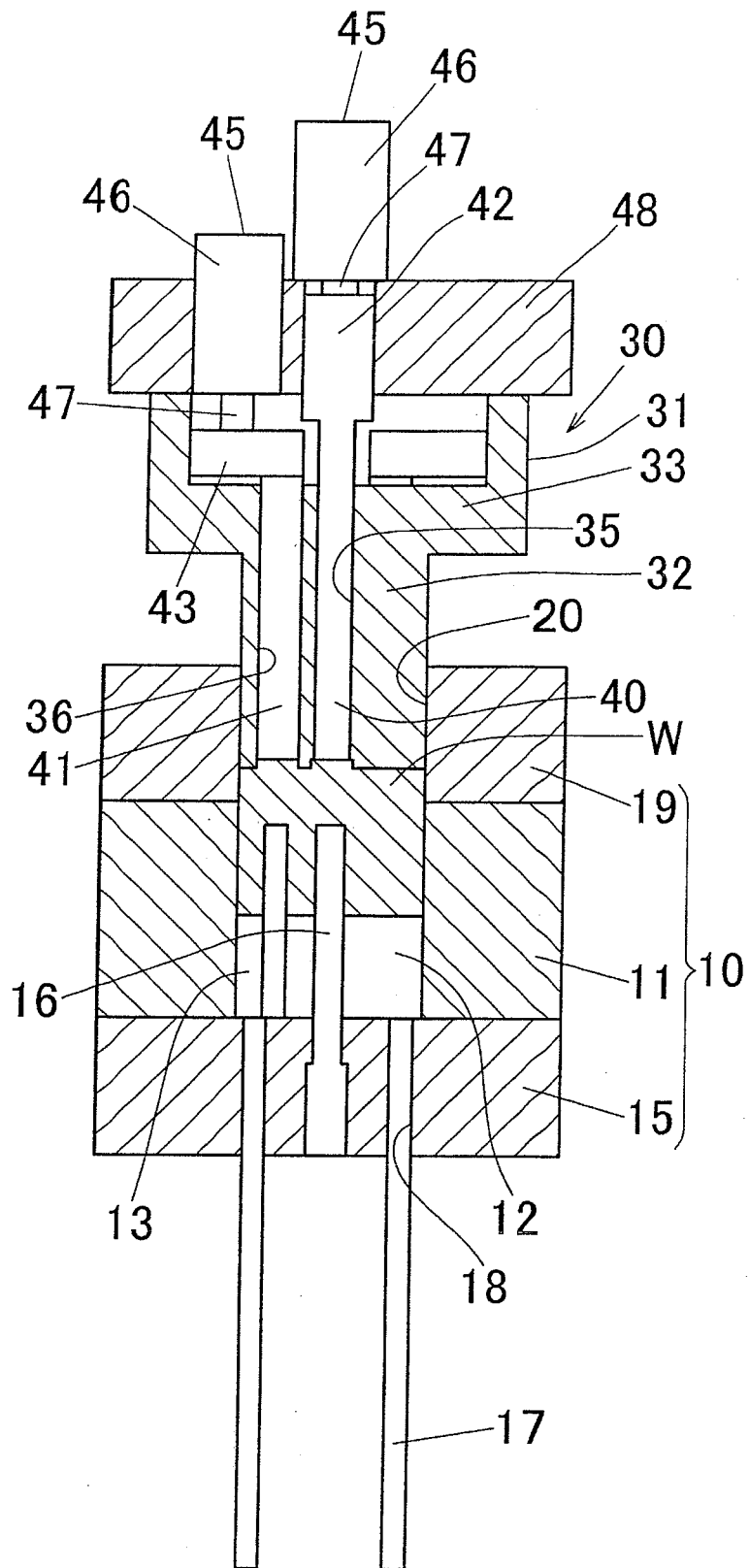


FIG.27A

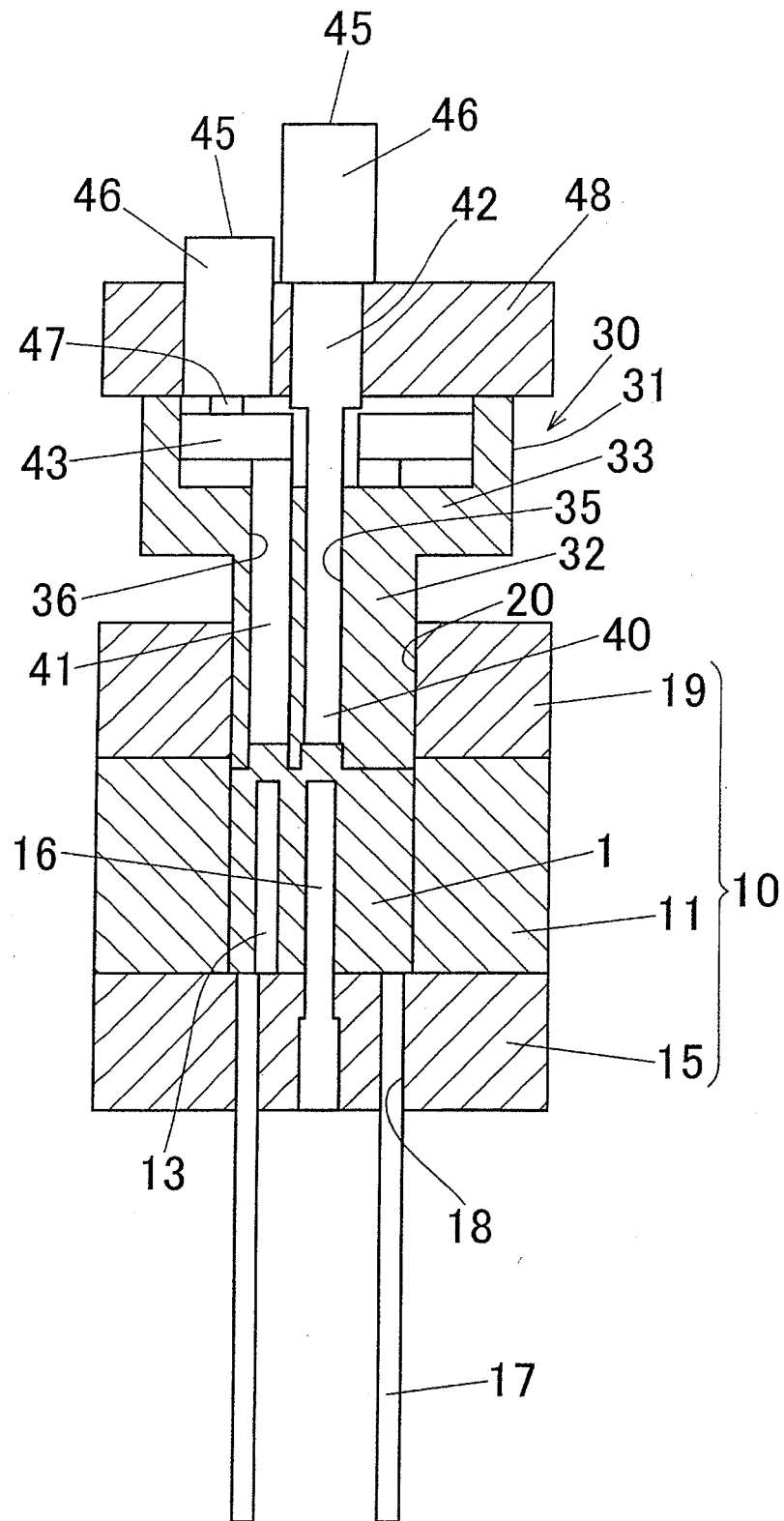


FIG.27B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/061468

A. CLASSIFICATION OF SUBJECT MATTER <i>F04C18/344</i> (2006.01) i, <i>F04C29/00</i> (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) <i>F04C18/344</i> , <i>F04C29/00</i>		
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 1996-2009 Kokai Jitsuyo Shinan Koho 1971-2009 Toroku Jitsuyo Shinan Koho 1994-2009		
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 A	JP 4003147 B2 (Valeo Thermal Systems Japan Corp.), 07 November, 2007 (07.11.07), Claim 1; Figs. 1 to 2, 5 & US 6094815 A Column 2, lines 40 to 67; column 3, lines 1 to 29; Figs. 1 to 2, 5	1-4, 6-21 5
Y A	JP 2000-220588 A (Nissei Corp.), 08 August, 2000 (08.08.00), Claims 1 to 2; Figs. 1, 7 to 8 (Family: none)	1-4, 6-21 5
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "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) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "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 "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 "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 "&" document member of the same patent family		
Date of the actual completion of the international search 10 July, 2009 (10.07.09)		Date of mailing of the international search report 21 July, 2009 (21.07.09)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

REFERENCES CITED IN THE DESCRIPTION

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