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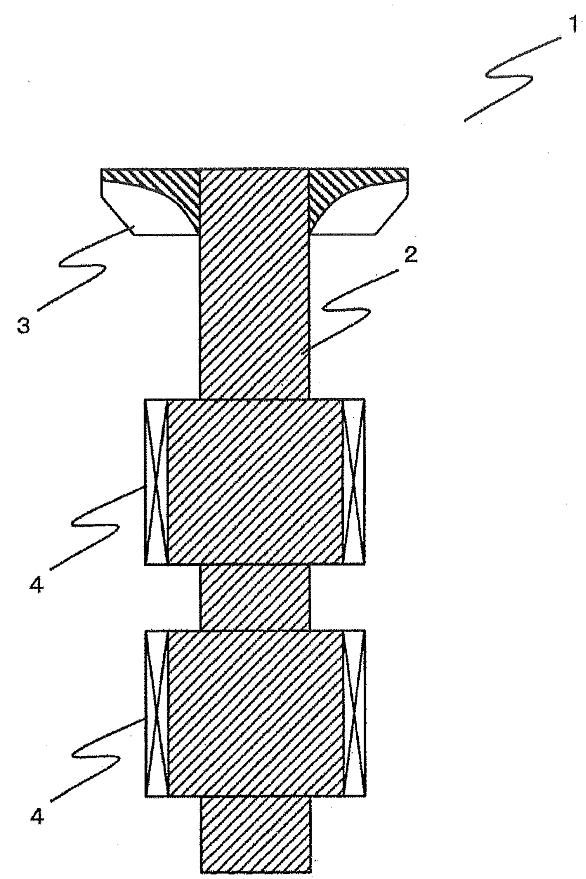
(54) DOWNHOLE COMPRESSOR

(57) A downhole compressor 1 includes: a casing disposed inside a gas well; a rotor 2 built inside the casing; and an impeller 3 disposed at the rotor 2, and an electromagnetic control unit that electromagnetically controls a relative position of the rotor 2 inside the casing is provided.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a downhole compressor, and particularly relates to a downhole compressor suitable for securing reliability at the time of high-speed rotation.

2. Description of the Related Art

[0002] Since a downhole compressor installed inside a natural gas well and adapted to assist production of natural gas is installed inside a borehole having a diameter of approximately several centimeters, size reduction of the device is needed. When the size of the compressor is reduced, a gas production amount may be reduced because a flow passage cross-sectional area is reduced. Further, in the case of adopting a centrifugal compressor as a form of the compressor, centrifugal force used for gas compression is reduced due to reduction of an outer diameter size of an impeller due to size reduction of the compressor. Therefore, there may be possibility that a pressure ratio is reduced and sufficient pressure cannot be obtained for gas production.

[0003] A rotational speed of a rotor is required to be accelerated in the downhole compressor in order to compensate such a reduced flow rate and reduced pressure ratio caused by size reduction. In other words, a gas flow rate is increased because a flow speed is increased by accelerating rotation of the rotor. Further, the pressure ratio is increased because the centrifugal force is increased by acceleration. For instance, a downhole compressor disclosed in US Patent No. 7,338,262, is operated at a high rotational speed of 20,000 rpm to 50,000 rpm.

[0004] In a general industrial turbo machine, an oil lubrication sliding bearing and a rolling bearing are widely used. However, in a high-speed rotary machine such as a downhole compressor, these general bearings are hardly applied because an amount of heat generation at the bearings is excessively large. As a countermeasure to such a phenomenon, the above-described known art adopts, for example, a static pressure gas bearing in which natural gas is pressurized and then used. In the gas bearing, heat generation of the lubricant can be kept low because viscosity of the gas that is the lubricant is extremely low compared to viscosity of liquid such as oil, and it can be considered that reliability of the bearing can be secured.

SUMMARY OF THE INVENTION

[0005] In natural gas inside a borehole, foreign matters such as liquid like water and oil and solids like earth and sand may be mixed some times. In the case of using the natural gas as lubricant, such mixture of the foreign matters causes increase of heat generation and physical damages, and reliability of the bearing may be degraded. Such foreign matters may be reduced by a structure using a separator or the like, but there may be possibility that the foreign matters cannot be completely removed and reliability of the bearing may not be sufficiently secured.

[0006] On the other hand, when the foreign matters are mixed inside the natural gas used as working fluid of the compressor, properties such as density and viscosity of the fluid are changed. Therefore, when the compressor is operated without considering such mixture of the foreign matters, there is concern that deterioration of operation efficiency, generation of excessive fluid force, occurrence of unstable phenomena in the fluid, and the like may be caused by change of operating characteristics of an impeller. In the downhole compressor using the gas bearing, such change of the gas properties can be hardly detected, and there may be possibility that sufficient reliability of a device cannot be secured.

[0007] Further, a thrust load acting on the impeller may be increased due to mixture of the foreign matters inside the natural gas. In a high-speed bearing such as the gas bearing, load capacity is generally small compared to an oil bearing and the like. Therefore, it is difficult to design a bearing that can handle a large thrust load caused by mixture of the foreign matters.

[0008] In view of the above-described situations, the present invention is directed to providing a downhole compressor in which reliability can be secured at the time of high-speed rotation even when natural gas properties are changed due to mixture of foreign matters and the like.

[0009] To achieve the above-described object, the present invention provides a downhole compressor, including: a casing disposed inside a well; a rotor built inside the casing; and an impeller disposed at the rotor, wherein an electromagnetic control unit configured to electromagnetically control a relative position of the rotor inside the casing is provided.

[0010] Further, the present invention is the downhole compressor characterized in including a bearingless motor as an electromagnetic control unit.

[0011] Furthermore, the present invention is the downhole compressor characterized in that the electromagnetic control unit includes a magnetic bearing.

[0012] Furthermore, the present invention is the downhole compressor characterized in that a pressure regulating chamber is provided at a back surface portion of the impeller, a shaft sealing device is provided between an outlet portion of the impeller and the pressure regulating chamber, and a communication unit is provided between the pressure regulating chamber and an inlet portion of the impeller.

[0013] Furthermore, the present invention is the downhole compressor characterized in that a displacement meter to measure axial displacement of the rotor is provided, and the displacement meter is disposed at the back surface portion of the impeller.

[0014] Furthermore, the present invention is the downhole compressor characterized in that a leakage amount at the shaft sealing device is reduced when the rotor is displaced to an axial upstream side.

[0015] Furthermore, the present invention is the downhole compressor characterized in that the shaft sealing device includes axial clearance, and the axial clearance is reduced when the rotor is displaced to the axial upstream side.

[0016] Furthermore, the present invention is the downhole compressor characterized in that a control device for the electromagnetic control unit is disposed on the ground.

[0017] Furthermore, the present invention is the downhole compressor characterized in that an operating condition is determined by using a control signal of the electromagnetic control unit.

[0018] According to the present invention, the rotor can be supported by electromagnetically controlling a position of the rotor without using lubricant such as natural gas. Therefore, deterioration of reliability of the bearing caused by heat generation of the lubricant can be prevented. Further, reliability of the device can be stably secured because there is no effect on supporting characteristics from change of the natural gas properties.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

Fig. 1 is a cross-sectional view illustrating a main portion of a downhole compressor according to a first embodiment of the present invention;
Fig. 2 is a cross-sectional view illustrating an installation state of the downhole compressor according to the first embodiment of the present invention;
Fig. 3 is a cross-sectional view illustrating a main portion of a downhole compressor according to a second embodiment of the present invention;
Fig. 4 is a cross-sectional view illustrating a main portion of a downhole compressor according to a third embodiment of the present invention; and
Fig. 5 is a cross-sectional view illustrating a main portion of a downhole compressor according to a fourth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] Embodiments to implement the present invention will be described below using the drawings.

First embodiment

[0021] Fig. 1 is a cross-sectional view illustrating a main portion of a downhole compressor according to a first embodiment of the present invention.

[0022] An impeller 3 is disposed at an end portion of a rotor 2, and natural gas is pressurized by rotation of the rotor 2. A thrust load generated at the impeller 3 is supported by a thrust bearing not illustrated. A bearingless motor 4 disposed at center of the rotor 2 generates drive torque at the rotor 2 and simultaneously supports the rotor 2 by generating electromagnetic force such that relative positions between the rotor 2 and a casing not illustrated is kept substantially constant. Since the position of the rotor 2 is electromagnetically controlled, supporting characteristics of the rotor 2 do not change even when the natural gas properties are changed, and the rotor 2 can be stably supported.

[0023] Fig. 2 is a cross-sectional view illustrating an installation state of the downhole compressor 1 according to the present embodiment. The downhole compressor 1 is installed inside a natural gas well 5. A controller 6 of the bearingless motor 4 is disposed on the ground 15, and the downhole compressor 1 and the controller 6 are connected via a cable 7. Since the controller 6 is disposed on the ground 15, a control signal of the bearingless motor 4 can be easily extracted and used for setting an operating condition of the downhole compressor 1.

[0024] Electromagnetic control force to control the position of the rotor 2 inside the casing of the downhole compressor 1 is proportional to the square of control current. Therefore, dynamic fluid force that acts on the rotor 2 can be grasped by monitoring the control current. The natural gas properties and unsteadiness thereof can be estimated by collating the fluid force, operating characteristics of the impeller 3, drive torque, rotational speed, and so on. An operating condition such as the rotational speed can be appropriately set by collating the estimated gas properties and operating characteristics of the impeller 3, and excessive fluid force that may act on the impeller 3 and unstable phenomena of the fluid can be prevented. For example, in the case where the fluid force is increased by increased liquid content inside the gas, the fluid force can be decreased by reducing the rotational speed of the rotor 2, and reliability of the device can be secured.

Second embodiment

[0025] A second embodiment of the present invention will be described using Fig. 3. Fig. 3 is a cross-sectional view illustrating a main portion of a downhole compressor 1 according to the present embodiment. In a structure of the present embodiment, a component denoted by a reference sign same as a first embodiment has the same structure and effects. Therefore, a description therefor will be omitted and only a different point from the above-described first embodiment will be described.

[0026] In the present embodiment, a motor 8 is disposed as a unit to generate drive torque at a rotor 2 instead of a bearingless motor 4. Further, as an electromagnetic control unit for a position of the rotor 2, a magnetic bearing 9 disposed at a casing not illustrated is used instead of the bearingless motor 4. On both sides of the motor 8, radial magnetic bearings 9a to support a load in an axial orthogonal direction are disposed. Further, a thrust collar 10 to transmit a thrust load is disposed between the motor 8 and the impeller 3, and thrust magnetic bearings 9b are disposed on both sides of the thrust collar 10. A displacement sensor and an electromagnetic actuator are built inside the magnetic bearing 9, and electromagnetic force is controlled such the position of the rotor 2 inside the casing is kept substantially constant. Load capacity can be increased by using the magnetic bearing 9 independent from the motor 8, and reliability can be improved.

Third embodiment

[0027] Next, a third embodiment of the present invention will be described using Fig. 4.

[0028] Fig. 4 is a cross-sectional view illustrating a main portion of a downhole compressor 1 according to the present embodiment. In a structure of the present embodiment, a component denoted by a reference sign same as above-described embodiments has the same structure and effects. Therefore, a description therefor will be omitted and only a different point from the above-described embodiments will be described. According to the second embodiment illustrated in Fig. 3, pressure in a flow passage portion of an impeller 3 is increased from an inlet portion 3b to an outlet portion 3a, but pressure on a back surface of the impeller 3 is substantially equal to the pressure at the outlet portion 3a of the impeller 3. Therefore, a thrust load is generated at the impeller 3 in a direction from the back surface side to a flow passage side. Load capacity of a magnetic bearing 9 is small compared with a general oil lubrication bearing. Therefore, in the case of applying the magnetic bearing 9 in the downhole compressor 1, the thrust load is preferably reduced as much as possible.

[0029] According to the third embodiment, a shaft sealing device 12 is disposed at a back surface portion of the impeller 3 and forms a pressure regulating chamber 11. Further, a communication unit 13 is provided between the pressure regulating chamber 11 and the inlet portion 3b of the impeller 3 and decreases pressure at the pressure regulating chamber 11. As a result, the thrust load can be reduced by decreasing the pressure at the back surface of the impeller 3, and reliability of a thrust magnetic bearing 9b can be improved.

[0030] Further, in order to stabilize the thrust load in the present embodiment, axial clearance of the shaft sealing device 12 is preferably kept constant. Therefore, a position sensor 14 for an axial rotor 2 used to control the thrust magnetic bearing 9b is provided at the back surface portion of the impeller 3, and the thrust magnetic bearing 9b is controlled so as to keep the clearance of shaft sealing device 12 constant.

[0031] Additionally, according to the present embodiment, an axial groove is provided as the communication unit 13 at a fixing portion of the impeller 3 of the rotor 2. The axial groove may also be provided on the impeller 3 side and a communication hole may be provided at the rotor 2 and the impeller 3.

Fourth embodiment

[0032] Next, a fourth embodiment of the present invention will be described using Fig. 5.

[0033] Fig. 5 is a cross-sectional view illustrating a main portion of a downhole compressor 1 according to the present embodiment. In a structure of the present embodiment, a component denoted by a reference sign same as above-described embodiments has the same structure and effects. Therefore, a description therefor will be omitted and only a different point from the above-described embodiments will be described.

[0034] According to the present embodiment, a shaft sealing device 12 is disposed at an outer diameter portion of an impeller 3. The shaft sealing device 12 includes a so-called labyrinth seal 12a opposing to an outer periphery of the impeller 3 and an axial clearance 12b projecting to a flow passage side of the impeller 3. When a leakage amount at the shaft sealing device 12 is increased, back pressure of the impeller 3 is increased and a thrust load is increased, thereby moving a rotor 2 to an axial upstream side. At this point, the axial clearance 12b at the shaft sealing device 12 becomes small, and the leakage amount is reduced at the shaft sealing device 12. Therefore, the thrust load is reduced and the rotor 2 is pushed back to an axial downstream side. Since the thrust load is thus automatically adjusted in accordance with movement of the rotor 2, the thrust load that acts on a thrust magnetic bearing 9b can be properly adjusted and reliability of the device can be improved.

[0035] Meanwhile, in the fourth embodiment also, the thrust magnetic bearing 9b can be controlled so as to keep the clearance at the shaft sealing device 12 constant by providing a position sensor 14 at an axial rotor 2 illustrated in the third embodiment.

[0036] Features, components and specific details of the structures of the above-described embodiments may be exchanged or combined to form further embodiments optimized for the respective application. As far as those modifications are readily apparent for an expert skilled in the art they shall be disclosed implicitly by the above description without specifying explicitly every possible combination, for the sake of conciseness of the present description.

Claims

1. A downhole compressor (1), comprising:

a casing disposed inside a well;
a rotor (2) built inside the casing; and
an impeller (3) disposed at the rotor (2),

wherein an electromagnetic control unit configured to electromagnetically control a relative position of the rotor (2) inside the casing is provided.

2. The downhole compressor (1) according to claim 1, wherein a bearingless motor (4) is provided as the electromagnetic control unit.

3. The downhole compressor (1) according to claim 1, wherein a magnetic bearing is provided as the electromagnetic control unit.

4. The downhole compressor (1) according to claim 1, wherein
a pressure regulating chamber is provided at a back surface portion of the impeller (3),
a shaft sealing device is provided between an outlet portion of the impeller (3) and the pressure regulating chamber, and
a communication unit is provided between the pressure regulating chamber and an inlet portion of the impeller (3).

5. The downhole compressor (1) according to claim 1 or 4, wherein
a displacement meter configured to measure axial displacement is provided, and
the displacement meter is disposed at a back surface portion of the impeller (3).

6. The downhole compressor (1) according to claim 4, wherein a leakage amount at the shaft sealing device is reduced when the rotor (2) is displaced to an axial upstream side.

7. The downhole compressor (1) according to claim 6, wherein the shaft sealing device includes axial clearance, and the axial clearance is reduced when the rotor (2) is displaced to the axial upstream side.

8. The downhole compressor (1) according to claim 1, wherein a control device for the electromagnetic control unit is disposed on the ground.

9. The downhole compressor (1) according to claim 1 or 8, wherein an operating condition is determined by using a control signal of the electromagnetic control unit.

FIG. 1

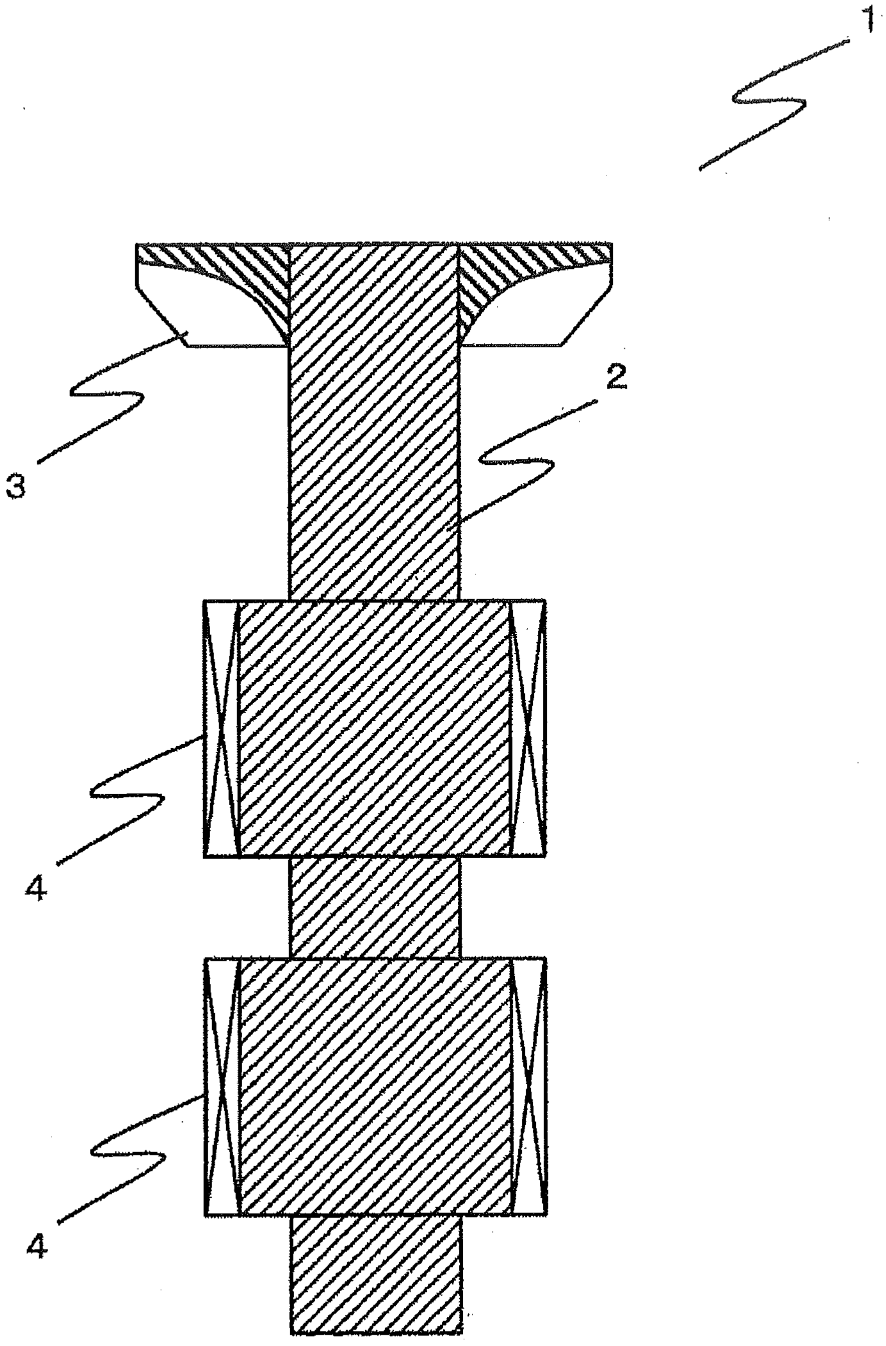


FIG. 2

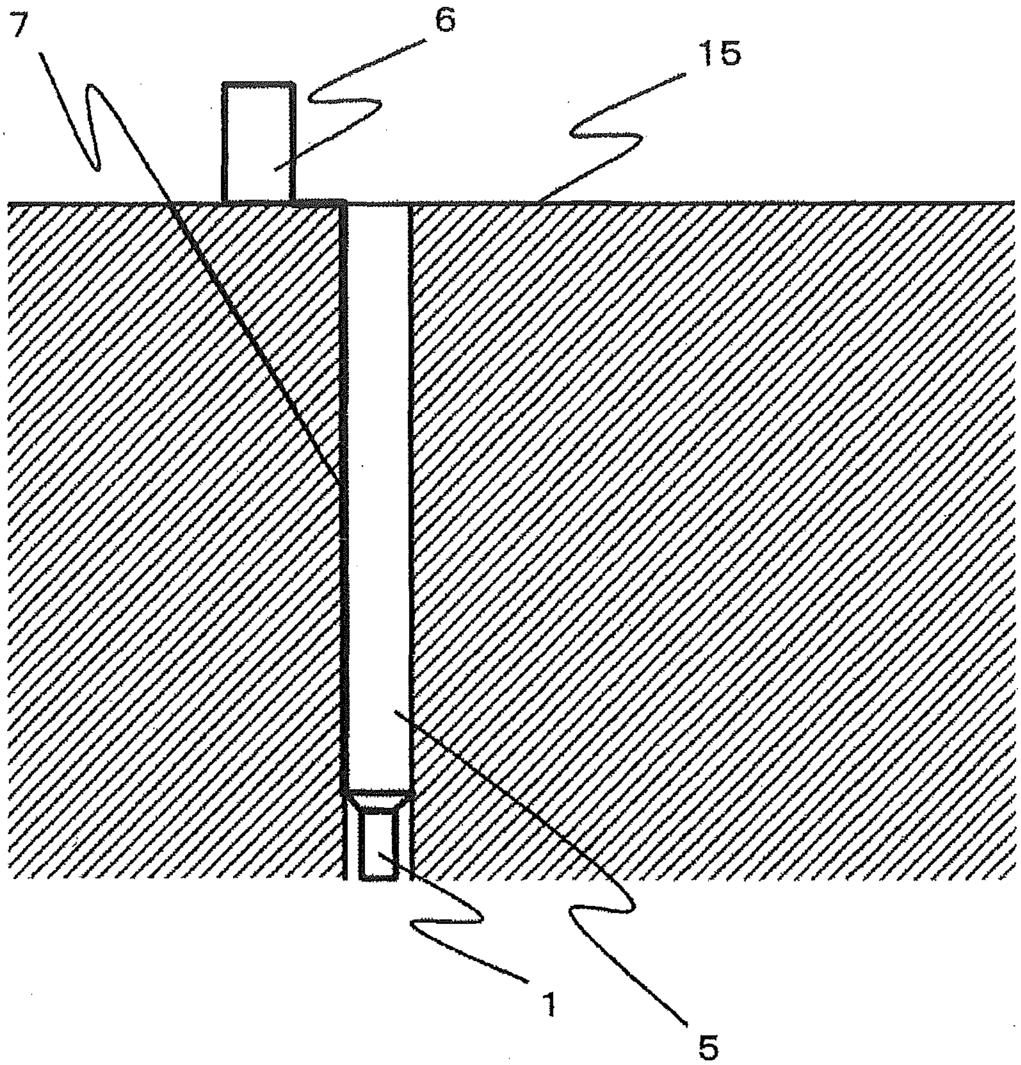


FIG. 3

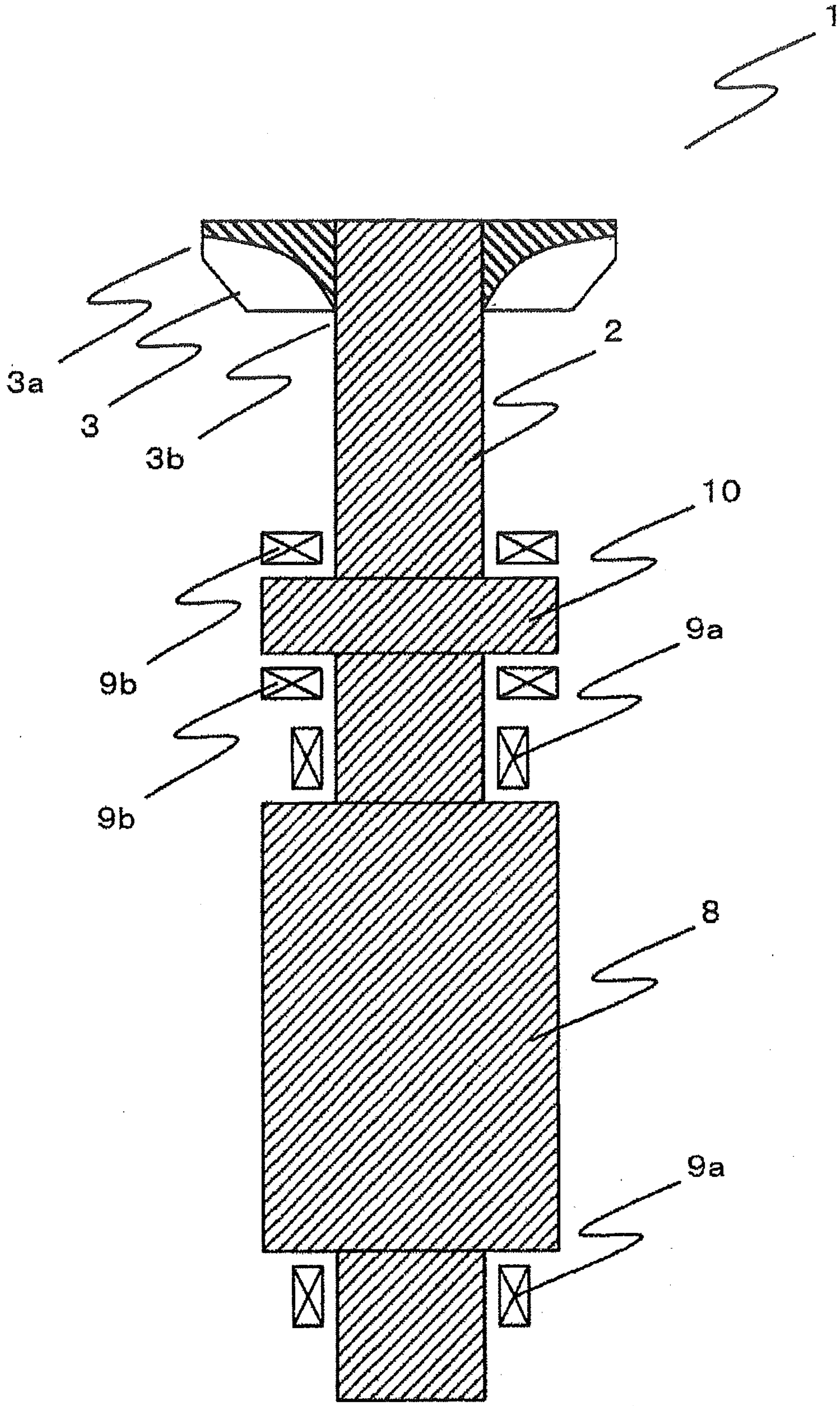


FIG. 4

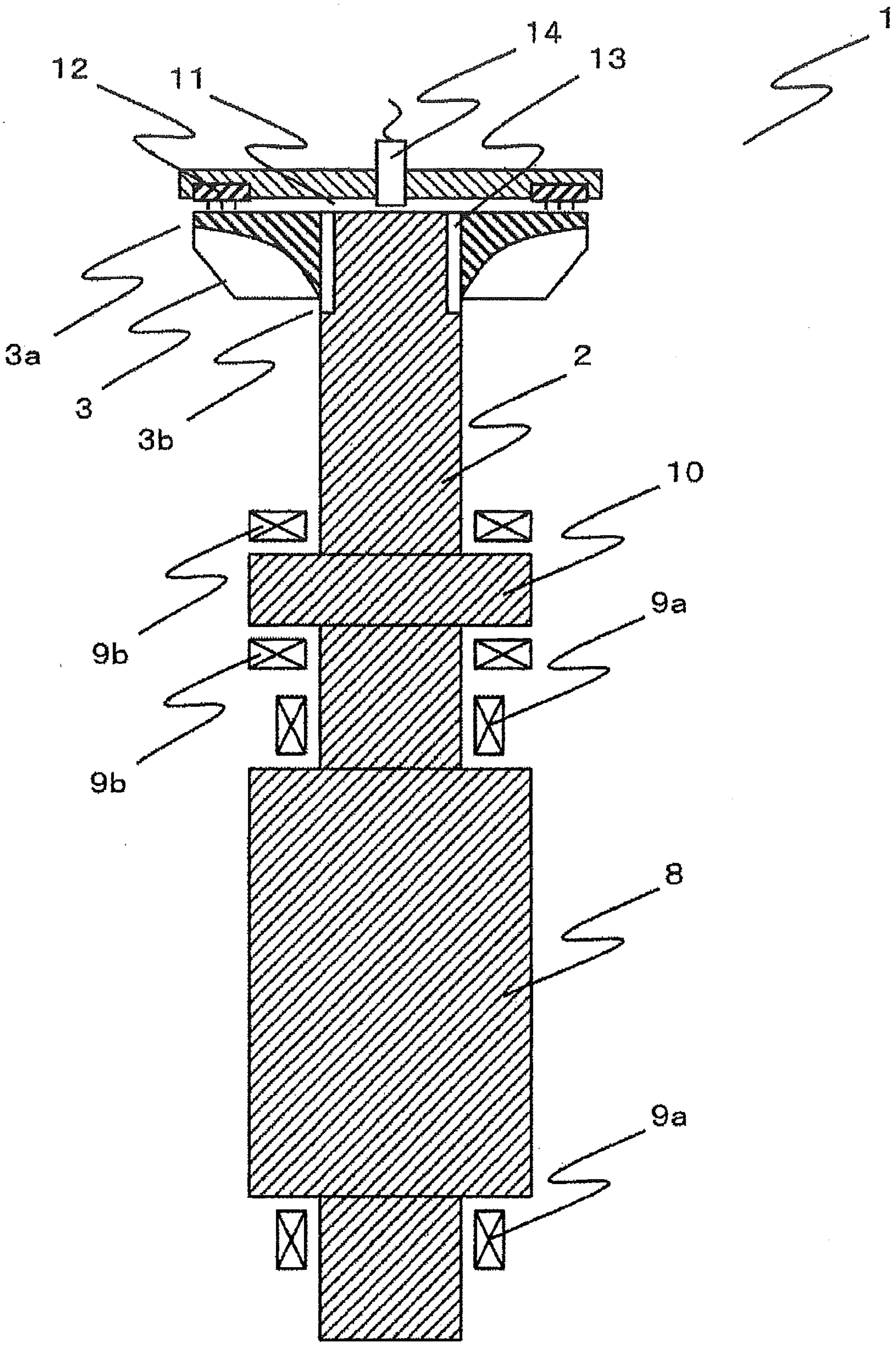
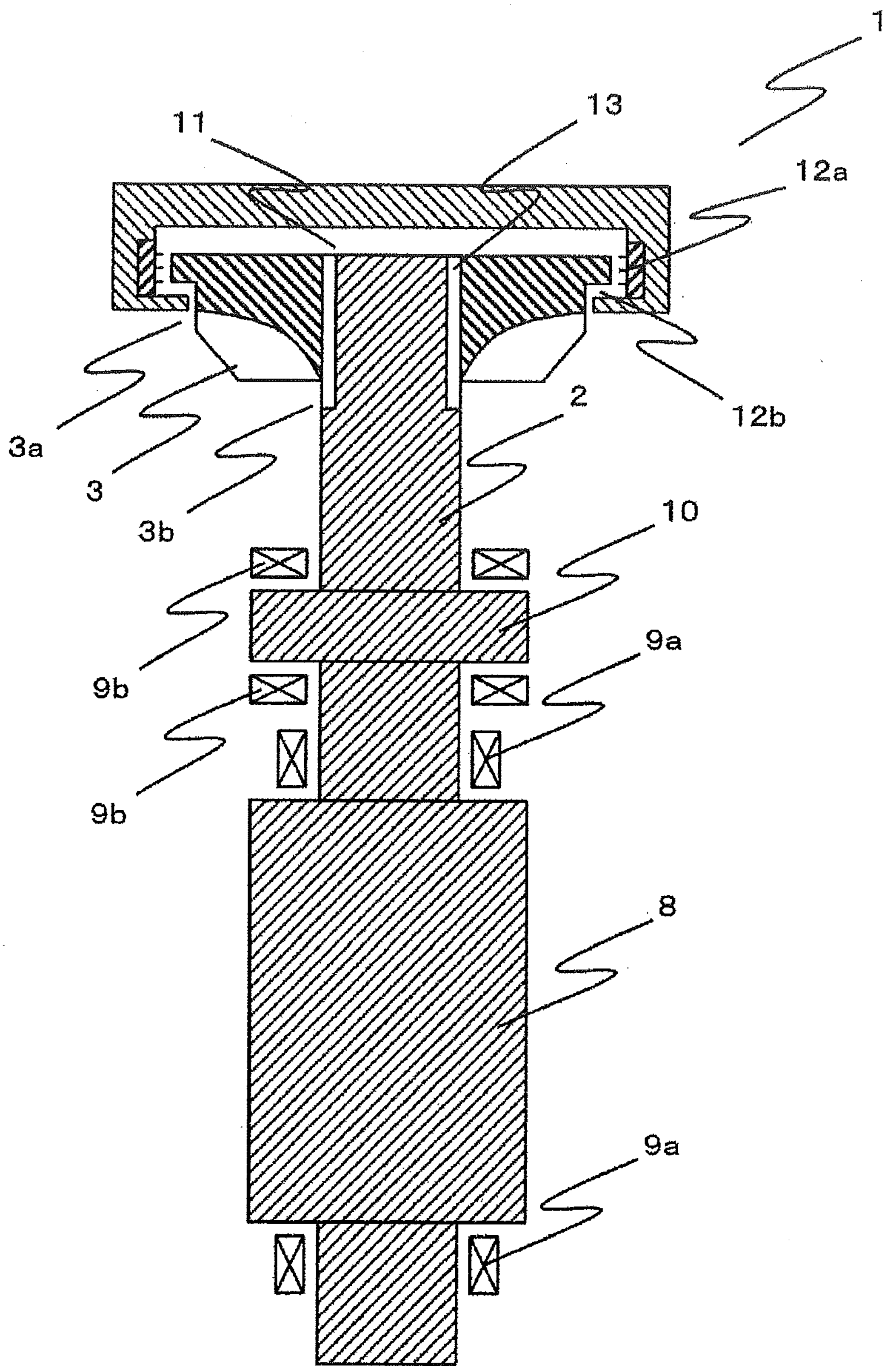


FIG. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 16 15 9927

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	GB 2 384 274 A (CORAC GROUP PLC [GB]) 23 July 2003 (2003-07-23) * abstract; figures 1-3,6 * * page 2, paragraph 3 * * page 6, paragraph 2 * -----	1-9	INV. E21B43/12 F04D25/06 F04D29/058
A	US 5 355 042 A (LEWIS DAVID W [US] ET AL) 11 October 1994 (1994-10-11) * abstract; figures 1,2 * * column 5, paragraphs 2,3 * * column 2, paragraphs 2,3 * -----	1-9	
A	US 2014/271270 A1 (PIERCE MICHAEL [US] ET AL) 18 September 2014 (2014-09-18) * abstract; figures 2a,c * * paragraphs [0006], [0020], [0026], [0029] * -----	1-9	
A	EP 1 895 180 A2 (EBARA CORP [JP]) 5 March 2008 (2008-03-05) * abstract * * paragraphs [0010] - [0012], [0095], [0096], [0152]; figure 1 * -----	1-9	TECHNICAL FIELDS SEARCHED (IPC) E21B F04D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	12 July 2016	Wehland, Florian

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 16 15 9927

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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