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(54) ULTRASONIC MACHINING APPARATUS

(57) Provided is an ultrasonic machining apparatus enabling improvement of precision of micromachining of a workpiece. An ultrasonic machining apparatus 10 includes a base 12, a stage 14 arranged with the base 12 as a base, and a support column 16. The ultrasonic machining apparatus 10 further includes an ultrasonic unit 18 configured to generate micro-vibration in directions along the support column 16, and a holder 20 that supports the ultrasonic unit 18 along the support column 16. The holder 20 includes guide rollers 22 configured to guide the ultrasonic unit 18 such that the ultrasonic unit 18 vibrates along an upright axis of the support column 16. At least one guide roller (e.g., a guide roller 22c) of the guide rollers 22 is provided with a biasing device 36 that generates a biasing force toward an axial center of the ultrasonic unit 18.

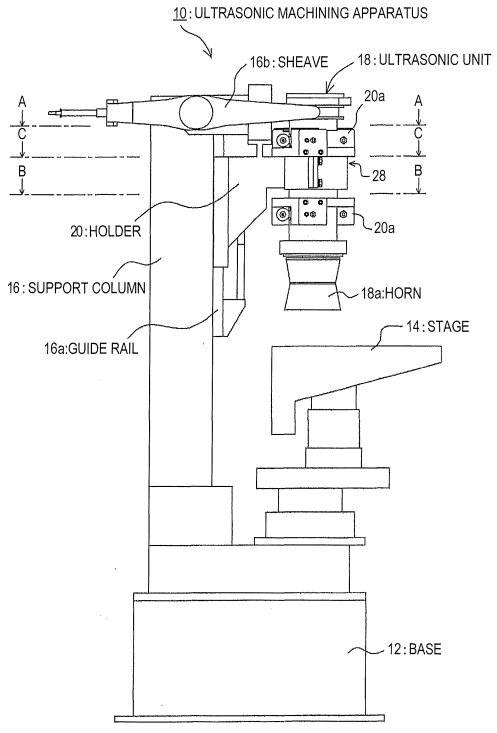

FIG. 1

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Description

TECHNICAL FIELD

[0001] The present invention relates to an ultrasonic machining apparatus, and particularly relates to an ultrasonic machining apparatus suitable for performing high-precision micromachining of a showerhead used for plasma treatment.

BACKGROUND ART

[0002] Known ultrasonic machining apparatuses for use in micromachining of showerheads used for plasma treatment are, for example, those having configurations as disclosed in Patent Document 1 and Patent Document 2.

[0003] The ultrasonic machining apparatuses disclosed in these documents each comprise a base for placement of a workpiece, a support column provided to stand with the base as a base, and an ultrasonic unit arranged and supported along the support column. Further, a machining tool called a horn is attached to a portion of the ultrasonic unit that faces the workpiece.

[0004] In the ultrasonic machining apparatus configured as above, the horn is pressed against the workpiece, and micro-vibration caused by ultrasonic waves is applied to the horn. Abrasive particles are supplied between the workpiece and a horn contact portion during application of micro-vibration to the horn, to thereby grind a portion of the workpiece where the horn is in contact, thus performing micromachining.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0005]

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2012-35374
Patent Document 2: Japanese Unexamined Patent Application Publication No. 2014-14826

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0006] In the ultrasonic machining apparatuses having the configurations as disclosed in the above-described patent documents, the ultrasonic unit is supported so as to be movable along an upright axis of the support column and, when the horn micro-vibrates due to the ultrasonic waves, the ultrasonic unit itself also vibrates by receiving the reaction force therefrom. In the ultrasonic machining apparatuses as disclosed in the above-described patent documents, when the abrasive particles used for machining, or the like, intervene between the ultrasonic unit and a support portion, micro-vibration for machining is hindered. For this reason, a gap is arranged between the ultrasonic unit and the support portion to such an extent as not to cause biting of the abrasive particles therebetween. Misalignment of the ultrasonic unit in directions intersecting with vibration directions caused by this gap has been a factor of decreasing precision of micromachining of the workpiece.

[0007] Therefore, an object of the present invention is to provide an ultrasonic machining apparatus that resolves the above-described problem and that enables improvement of precision of micromachining of a workpiece.

MEANS FOR SOLVING THE PROBLEMS

[0008] An ultrasonic machining apparatus according to the present invention for achieving the above-described object is an ultrasonic machining apparatus comprising a base, a support column arranged with the base as a base, an ultrasonic unit configured to generate micro-vibration in directions along the support column, and a holder that supports the ultrasonic unit along the support column. The holder comprises first guide rollers configured to guide the ultrasonic unit such that the ultrasonic unit vibrates along an upright axis of the support column. The first guide rollers are radially arranged about an axial center of the ultrasonic unit. The first guide rollers comprises guide rollers rigidly fixed to a holding portion of the holder; and at least one guide roller provided with a biasing device that generates a biasing force toward the axial center of the ultrasonic unit to press the ultrasonic unit toward the guide rollers rigidly fixed.

[0009] In the ultrasonic machining apparatus having the above-described features, when the number of the first guide rollers arranged is an even number, the first guide rollers may be evenly arranged radially about the axial center of the ultrasonic unit, and one of the first guide rollers arranged opposed to each other may be provided with the biasing device. Such features result in a configuration in which the first guide roller opposed to the first guide roller provided with the biasing device is a rigidly fixed guide roller. Thus, a pressed state of the ultrasonic unit can be stabilized, and improvement of machining precision can be sought.

[0010] The holder in the ultrasonic machining apparatus having the above-described features may comprise an anti-rotation device configured to suppress rotation of the ultrasonic unit about an axis thereof caused during micro-vibration thereof. Such a feature enables suppression of rotation of the ultrasonic unit and improvement of precision of machining on a workpiece.

[0011] Further, the anti-rotation device in the ultrasonic machining apparatus having the above-described features may comprise a guide fixed to the holder or to the support column; and second guide rollers fixed to the ultrasonic unit and biased toward the guide. Such a feature enables the anti-rotation device to be supported

elastically. As a result, even if fine dust particles are bitten between the guide and the second guide rollers, guiding can be performed getting over the fine dust particles.

EFFECTS OF THE INVENTION

[0012] The ultrasonic machining apparatus having the above-described features enables improvement of precision of micromachining of the workpiece.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

FIG. 1 is a side view showing a configuration of an ultrasonic machining apparatus according to an embodiment.

FIG. 2 is a diagram showing a cross-section of an ultrasonic unit taken along A-A and B-B in FIG. 1.

FIG. 3 is a block diagram explaining a configuration in FIG. 2.

FIG. 4 is a diagram showing a cross-section of the ultrasonic unit taken along C-C in FIG. 1.

FIG. 5 is a diagram showing a cross-section taken along D-D in FIG. 4.

FIG. 6 is a diagram showing a configuration of a misalignment suppression structure of an ultrasonic machining apparatus according to a second embodiment.

MODE FOR CARRYING OUT THE INVENTION

[0014] Embodiments of an ultrasonic machining apparatus according to the present invention will be described below in detail with reference to the drawings. In the drawings, FIG. 1 is a side view showing a configuration of an ultrasonic machining apparatus according to an embodiment. FIG. 2 is a diagram showing a cross-section of an ultrasonic unit taken along A-A and B-B in FIG. 1. FIG. 3 is a block diagram explaining a configuration in FIG. 2. FIG. 4 is a diagram showing a cross-section of the ultrasonic unit taken along C-C in FIG. 1. FIG. 5 is a diagram showing a cross-section taken along D-D in FIG. 4.

[Basic Configuration of Ultrasonic Machining Apparatus]

[0015] An ultrasonic machining apparatus 10 according to an embodiment comprises a base 12, a stage 14 arranged with the base 12 as a base, and a support column 16, and further comprises an ultrasonic unit 18 supported by the support column 16. The base 12 is a base for arrangement of the stage 14 and the support column 16. The stage 14 has a function as a surface plate for placement of a workpiece, and may have a configuration including movement axes (e.g., X-axis and Y-axis) in planar directions where appropriate.

[0016] The support column 16 is a support structure provided to stand with the base 12 as a base, and is provided to extend to a position at least higher than the stage 14. The support column 16 according to the embodiment comprises a guide rail 16a and a holder 20 slidable along the guide rail 16a. The guide rail 16a is arranged along a longitudinal axis of the support column 16. The holder 20 is an element to hold the ultrasonic unit 18, the details of which will be described below. The holder 20 slides along the guide rail 16a to thereby enable adjustment of the height where the ultrasonic unit 18 is arranged, and also thereby absorb a reaction force (micro-vibration) from the micro-vibration generated by ultrasonic waves. Further, the support column 16 according to the embodiment comprises a sheave 16b, thus providing a configuration enabling substantial cancellation of the weight of the ultrasonic unit 18 by a not-shown counterweight.

[0017] The ultrasonic unit 18 is a unit comprising an ultrasonic generator, the details of which are not shown. The ultrasonic unit 18 is supported by the above-described holder 20 and suspended by the counterweight via the sheave 16b. The stage 14 is positioned at a position facing a lower end of the ultrasonic unit 18. The ultrasonic unit 18 has, at a lower end thereof, a machining tool called a horn 18a attached thereto, and is configured such that ultrasonic vibration generated by the ultrasonic generator is transmitted to the horn 18a.

[Misalignment Suppression Structure: First Embodiment]

[0018] In the ultrasonic machining apparatus 10 according to the embodiment having such a basic configuration, as seen from FIG. 2 showing the A-A cross-section and the B-B cross-section (only the ultrasonic unit part) taken in FIG. 1, the ultrasonic unit 18 is supported by guide rollers (first guide rollers) 22 (22a to 22c) provided to a holding portion 20a of the holder 20. By supporting the ultrasonic unit 18 with the guide rollers 22, when the ultrasonic unit 18 micro-vibrates along an axis thereof, support can be performed following this micro-vibration.

[0019] In the case of the embodiment, a plurality of the guide rollers (three in number in the example shown in FIG.2) 22a to 22c are arranged on an outer periphery of the ultrasonic unit 18 formed in a cylindrical shape, to thereby perform support with these guide rollers 22a to 22c. The guide rollers 22a to 22c are arranged about an axial center O of the ultrasonic unit 18 so as to be spaced at equal intervals around the ultrasonic unit 18. The guide rollers 22 are basically fixed rigidly to the holding portion 20a. However, at least one guide roller (the guide roller 22c in the example shown in FIG. 2) among the guide rollers 22 is elastically fixed so as to generate a biasing force toward the ultrasonic unit 18.

[0020] Specifically, a roller holder 24 that holds the guide roller 22c is arranged so as to be slidable with respect to the holding portion 20a. Here, as shown in the block diagram of FIG. 3, a sliding direction of the roller

holder 24 is designed to be a direction (direction indicated by arrow E) orthogonal to a tangential line passing through a point of tangency of the guide roller 22c with respect to the ultrasonic unit 18. Then, a configuration may be adopted in which a biasing device 26, such as a spring, is interposed between the holding portion 20a and the roller holder 24 to press the guide roller 22c toward the ultrasonic unit 18.

[0021] Such a configuration allows the ultrasonic unit 18 to maintain a state of being pressed against the rigidly fixed guide rollers 22a and 22b, thus enabling suppression of misalignment caused by micro-vibration. Further, since the guide roller 22c is elastically pressed against the ultrasonic unit 18, even if fine dust particles (e.g., abrasive particles) are bitten between the guide rollers 22a to 22c and the ultrasonic unit 18, guiding can be performed getting over the fine dust particles.

[Torsion Suppression Structure]

[0022] The ultrasonic machining apparatus 10 according to the embodiment further comprises an anti-rotation device 28 for suppressing rotation (torsion) about the axial center O of the ultrasonic unit 18 caused by micro-vibration. As seen from FIG. 4 showing the C-C cross-section (only the ultrasonic unit part) taken in FIG. 1, the anti-rotation device 28 comprises a roller base 30 and a guide 32. The roller base 30, which is a base fixed to the ultrasonic unit 18, comprises guide rollers (second guide rollers) 34 (34a, 34b). The guide rollers 34 are arranged such that rolling directions thereof are along an axis of the ultrasonic unit 18. The guide rollers 34 are arranged so as to form a pair with their roller surfaces facing each other so that the guide 32, the details of which will be described below, can be held therebetween.

[0023] The paired guide rollers 34 are configured such that one guide roller 34a is fixed to the roller base 30 and the other guide roller 34b is slidable in a direction indicated by arrow F along a mounting surface of the roller base 30. Arranged between the one guide roller 34a and the other guide roller 34b is a biasing device 36 configured with a spring or the like, thus providing a configuration in which the other guide roller 34b is attracted toward the one guide roller 34a.

[0024] The guide 32, which is an element to roll the guide rollers 34, comprises a guide base 32a fixed to the holder 20 or the support column 16 described above; and a guide rail 32b coupled to the guide base 32a and arranged along the axis of the ultrasonic unit 18. Specific configurations of the guide base 32a and the guide rail 32b are not limited in particular; however, the guide rail 32b shall comprise, at at least both sides thereof, rolling surfaces for the guide rollers 34.

[0025] Such a configuration allows the guide rail 32b fixed to the holder 20 or the like to be held between the guide rollers 34a and 34b that micro-vibrate together with the ultrasonic unit 18. This generates a reaction force against a rotational force of the ultrasonic unit 18 about the axial center O, thus enabling suppression of rotation of the ultrasonic unit 18. Further, since the paired guide rollers 34a and 34b are biased toward the guide rail 32b by the biasing device 36, even if dust particles, such as abrasive particles, adheres to the rolling surfaces, the paired guide rollers 34a and 34b can operate getting over the dust particles.

[Action and Effect]

[0026] The ultrasonic machining apparatus 10 configured as above enables suppression of misalignment and rotation of the ultrasonic unit 18 caused by micro-vibration generated by the ultrasonic waves. Thus, precision of micromachining of the workpiece can be improved.

[Second Embodiment]

[0027] In the above-described embodiment, the structure to support the ultrasonic unit 18 has been described as having a configuration in which the number of the guide rollers 22 provided to the holding portion 20a of the holder 20 is three and in which the biasing device 26 toward the ultrasonic unit 18 is provided to one (the guide roller 22c) of the guide rollers 22.

[0028] However, the number of the guide rollers 22 supporting the ultrasonic unit 18 is not limited to three. For example, as shown in FIG. 6, the number of the guide rollers 22 may be four (the guide rollers 22a to 22d). In the case, a configuration may be adopted in which the four guide rollers 22 are evenly arranged about the axial center O of the ultrasonic unit 18 and in which the adjacent two guide rollers 22 (the guide rollers 22c and 22d in the example shown in FIG. 6) each comprise the biasing device 26.

[0029] Such a configuration results in the biasing device 26 being provided to each of the guide rollers 22 (the guide rollers 22c and 22d in the example shown in FIG. 6) corresponding to the guide rollers 22 (the guide rollers 22a and 22b, respectively, in the example shown in FIG. 6) rigidly fixed to the holding portion 20a. This allows the ultrasonic unit 18 to be pressed stably, thus enabling more effective suppression of misalignment caused by micro-vibration.

[0030] Also in the case where the misalignment suppression structure is configured like this, effects similar to those of the above-described embodiment can be exerted.

EXPLANATION OF REFERENCE NUMERALS

[0031] 10...ultrasonic machining apparatus, 12...base, 14...stage, 16...support column, 16a...guide rail, 16b...sheave, 18...ultrasonic unit, 18a...horn, 20...holder, 20a...holding portion, 22 (22a to 22d)...guide rollers, 24...roller holder, 26...biasing device, 28...anti-rotation device, 30...roller base, 32...guide, 32a...guide base, 32b...guide rail, 34 (34a, 34b)...guide rollers, 36...biasing

device.

Claims

1. An ultrasonic machining apparatus comprising:

   a base;
   a support column arranged with the base as a base;
   an ultrasonic unit configured to generate micro-vibration in directions along the support column; and
   a holder that supports the ultrasonic unit along the support column,
   the holder comprising first guide rollers configured to guide the ultrasonic unit such that the ultrasonic unit vibrates along an upright axis of the support column, and
   the first guide rollers being radially arranged about an axial center of the ultrasonic unit, the first guide rollers comprising guide rollers rigidly fixed to a holding portion of the holder; and at least one guide roller provided with a biasing device that generates a biasing force toward the axial center of the ultrasonic unit to press the ultrasonic unit toward the guide rollers rigidly fixed.

2. The ultrasonic machining apparatus according to claim 1,
   wherein, when the number of the first guide rollers arranged is an even number, the first guide rollers are evenly arranged radially about the axial center of the ultrasonic unit, and
   wherein one of the first guide rollers arranged opposed to each other is provided with the biasing device.

3. The ultrasonic machining apparatus according to claim 1 or 2,
   wherein the holder comprises an anti-rotation device configured to suppress rotation of the ultrasonic unit about an axis thereof caused during micro-vibration thereof.

4. The ultrasonic machining apparatus according to claim 3,
   wherein the anti-rotation device comprises:

   a guide fixed to the holder or to the support column; and
   second guide rollers fixed to the ultrasonic unit and biased toward the guide.

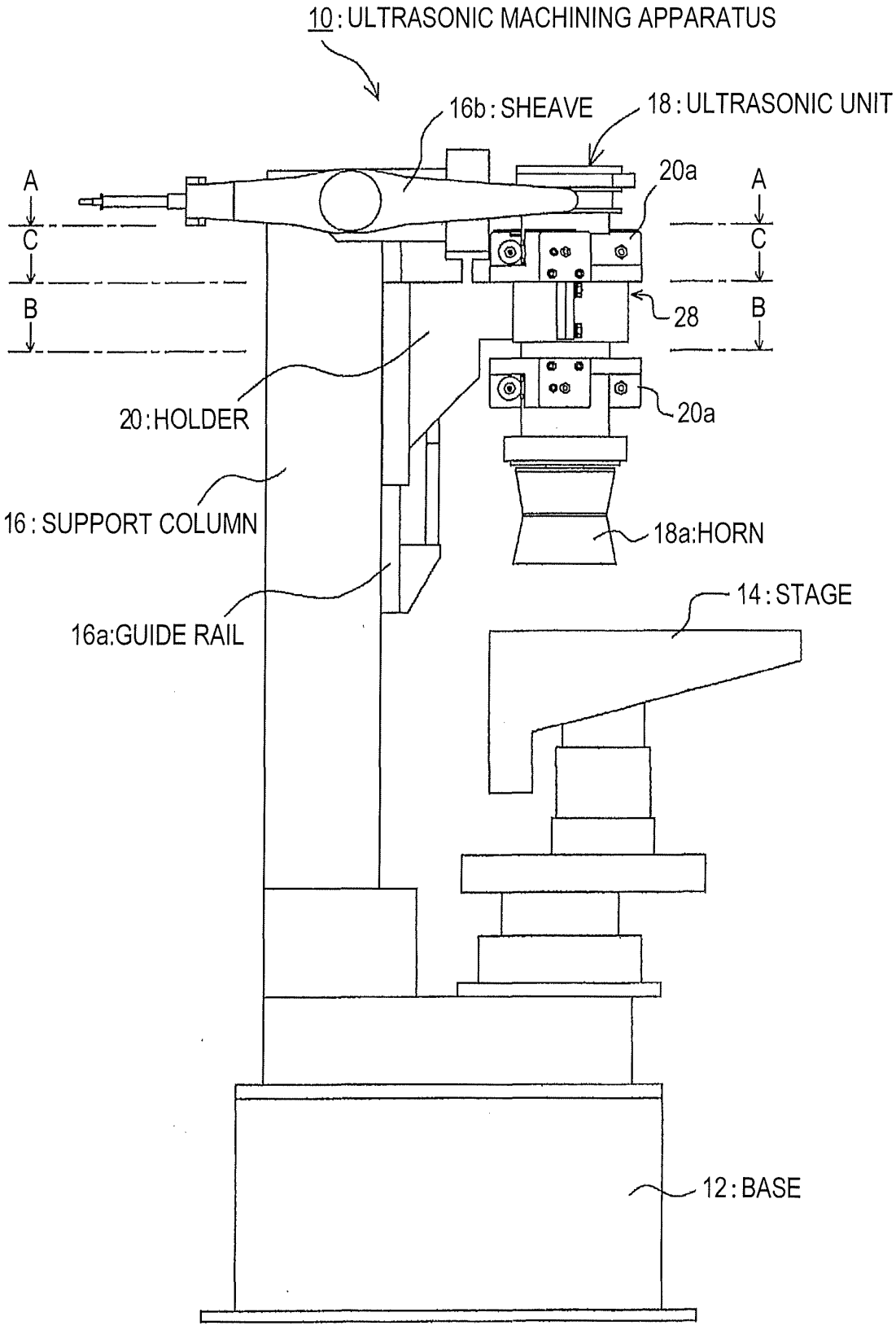
10 : ULTRASONIC MACHINING APPARATUS
16b : SHEAVE
18 : ULTRASONIC UNIT
A
C
B
20a
28
20 : HOLDER
16 : SUPPORT COLUMN
16a:GUIDE RAIL
18a:HORN
14 : STAGE
12 : BASE

FIG. 1

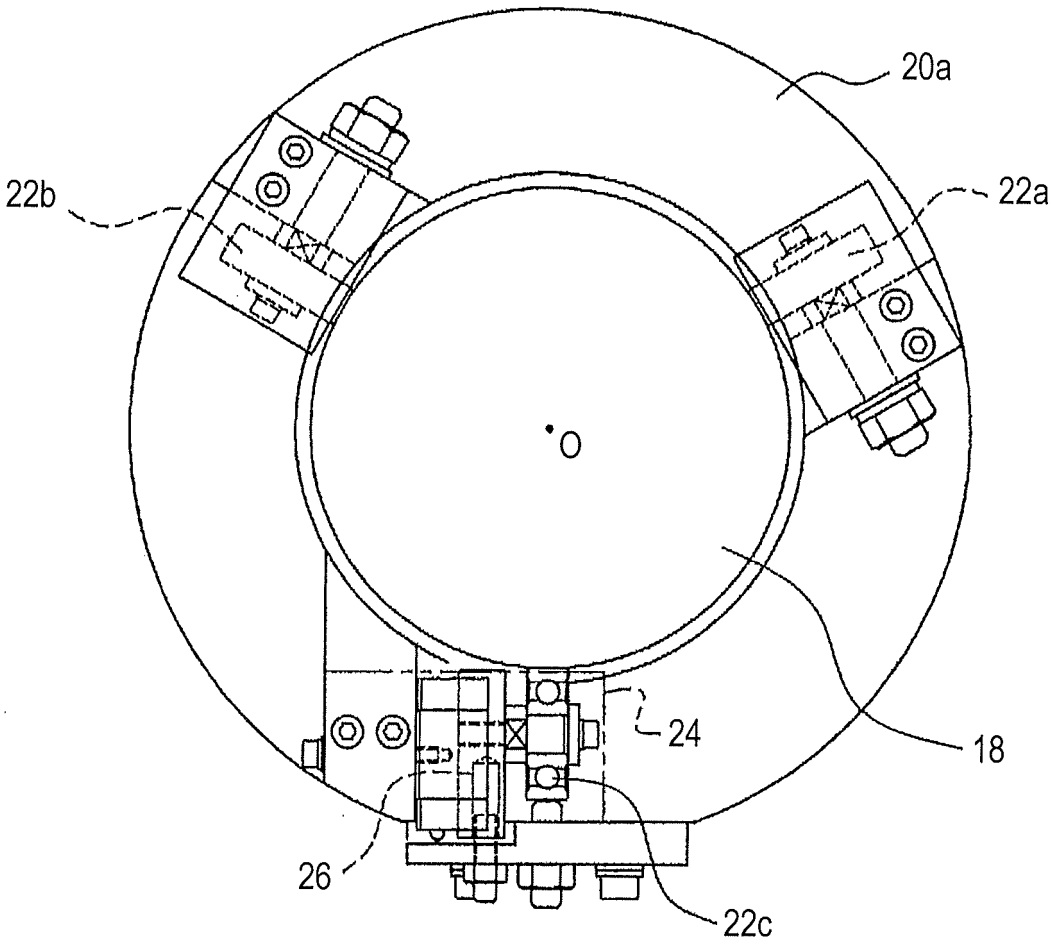

FIG. 2

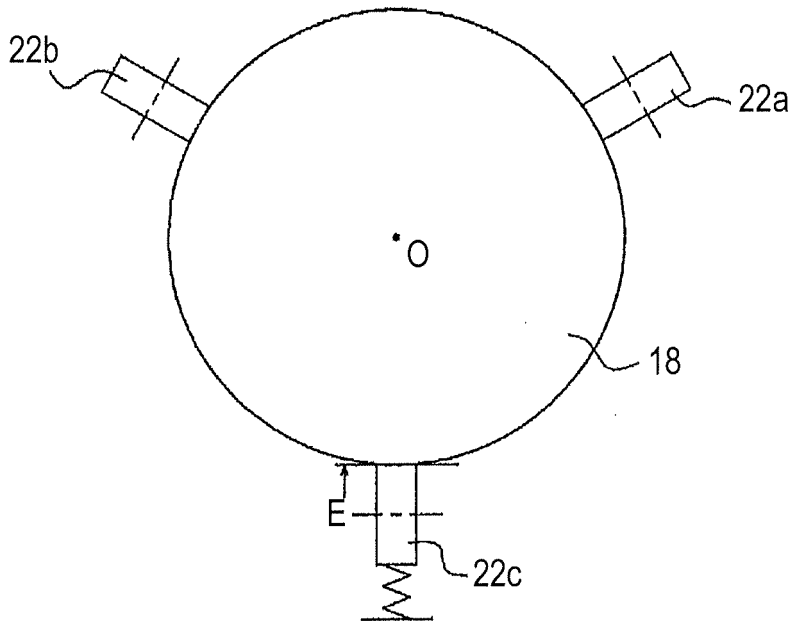

FIG. 3

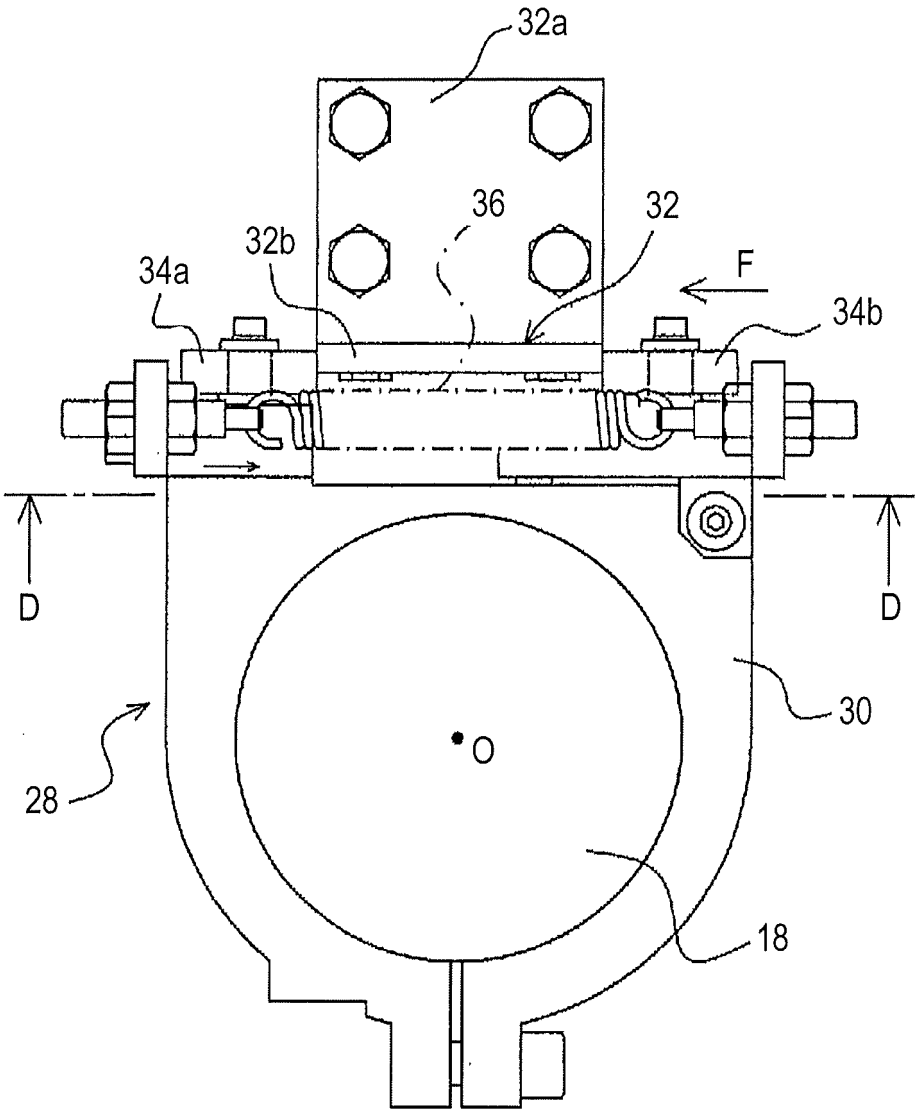

FIG. 4

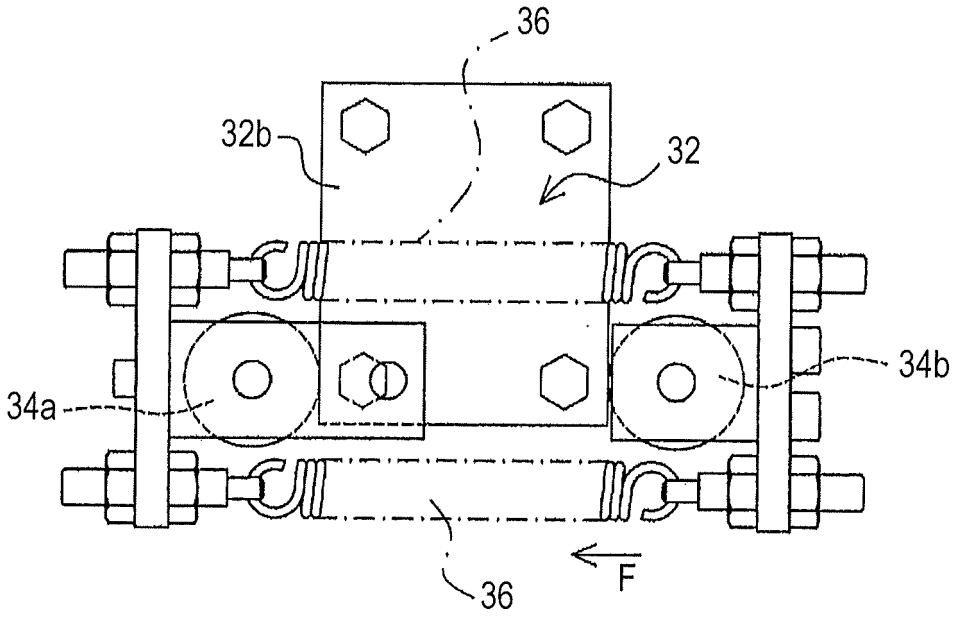

FIG. 5

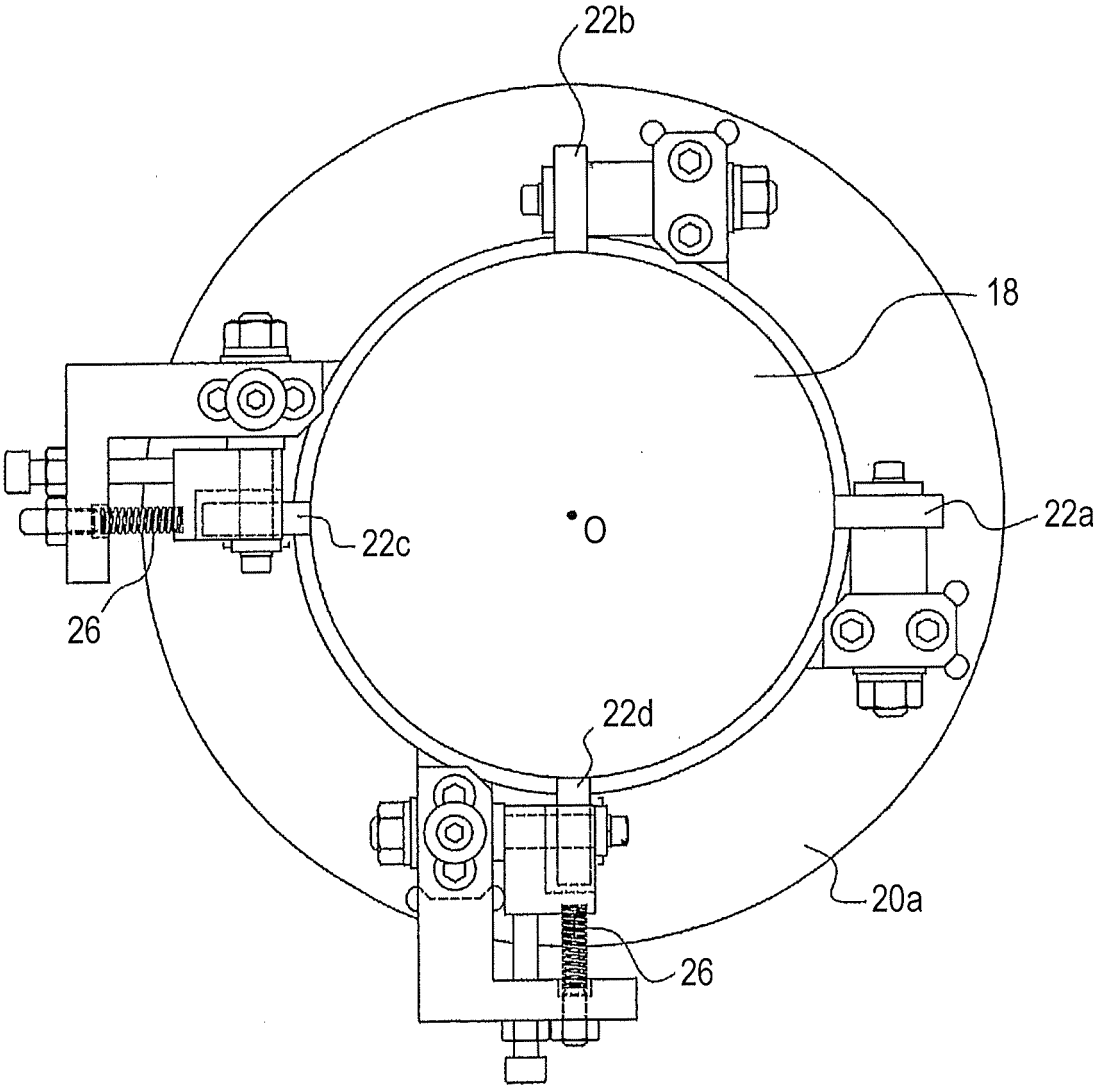

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/019802

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. B24B37/00(2012.01)i, B24B1/04(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)
Int.Cl. B24B37/00, B24B1/04

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2018
Registered utility model specifications of Japan	1996-2018
Published registered utility model applications of Japan	1994-2018

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 62-225280 A (MITSUBISHI ELECTRIC CORP.) 03 October 1987, page 3, lower left column, line 2 to page 4, lower left column, line 3, fig. 2-3 (Family: none)	1-4
A	JP 02-026388 A (MITSUBISHI ELECTRIC CORP.) 29 January 1990, page 2, upper left column, line 13 to page 2, upper right column, line 9, fig. 1-3 (Family: none)	1-4

☒ 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
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"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	Date of mailing of the international search report
30 August 2018 (30.08.2018)	11 September 2018 (11.09.2018)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/019802

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 64-058464 A (ULTRASONIC ENGINEERING CO., LTD.) 06 March 1989, page 3, lower right column, line 1, fig. 1 (Family: none)	3-4
A	JP 04-053610 A (TOSHIBA CERAMICS CO., LTD.) 21 February 1992, page 2, upper right column, line 5 to page 2, lower right column, line 3, fig. 1 (Family: none)	1-4
A	JP 59-094591 A (BROTHER INDUSTRIES, LTD.) 31 May 1984, page 2, upper right column, line 1 to page 4, lower left column, line 17, fig. 1 (Family: none)	1-4
A	CN 202062262 U (BEIJING INST OF ELECTRO MACHINING) 07 December 2011, paragraphs [0053]-[0062], fig. 1-2 (Family: none)	1-4

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2012035374 A **[0005]**
- JP 2014014826 A **[0005]**