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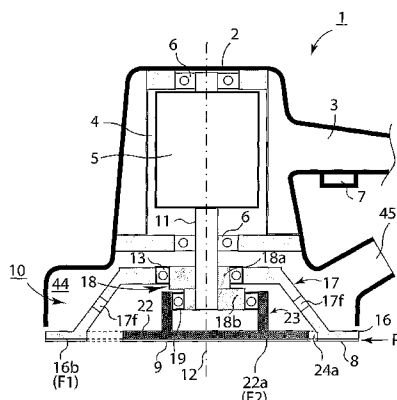
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(54) Title: ANTI-VIBRATION DEVICE FOR AN ABRASIVE MACHINE, A MACHINE HAVING SUCH DEVICE AND A
METHOD FOR CLEANING THE SURFACE OF A WORK PIECE



(57) Abstract: A power sander (1) comprises a housing (2), a motor (4) arranged in the housing (2), a motor shaft (11), a first outer or ring-shaped pad (16) for attaching thereto a first sanding paper (8), and a second inner or circular pad (22) for attaching thereto a second sanding paper (9). The anti-vibration device (10) serves to transfer energy from the motor (4) to the pads (16, 22) with movements in opposition of phase, so that inertial and friction forces are dynamically compensated. Simultaneously vibrations that are usually transmitted to the motor shaft (11) and from there to the operator of the machine (1) are drastically reduced. This is even true when the operator increases the operation force to the sander (1) in order to increase the sanding depth or to speed up the sanding operation. For this purpose, cams (18a, 18b) are fixed on the motor shaft (11). The cams (18a, 18b) rotate the central axes (15, 21) of the pads (16, 22) about the motor shaft axis (12) with a phase shift, preferably of 180°.

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Anti-Vibration Device for an Abrasive Machine, a Machine having such Device and a Method for Cleaning the Surface of a Work Piece

Background of the Invention

The present invention relates to the field of portable power tools for working plane surfaces. It specifically refers to an anti-vibration device for power abrasive tools, preferably for orbit sanders and polishers. It also relates to a power machine incorporating such anti-vibration device, and to a method for abrasively cleaning the surface of a work piece.

Description of the Prior Art

It is well known that orbit tools of the above-mentioned type generally include a plate or pad that is normally suited to support an abrasive object, such as a sanding paper. The pad is coupled, by means of proper means of transmission, to a motor arranged in a housing, which is a case provided with one or more handles. The transmission means can incorporate a cam rotationally driven by the motor shaft. The cam is housed in a circular hole that is placed in the center of the pad. The rotation of the cam drives every point of the pad in a circular orbit whose radius equals the eccentricity of the cam, that is the distance between the rotation axis of the motor shaft and the center of the circular hole which is substantially coincident with the center of the pad that supports the object. By means of allowing the pad to rotate around the center of the circular orbit, it describes a rotation-orbit compound motion also called, "random orbit".

Instant by instant, said orbit motion can be seen as a linear motion (stroke) in which the pad mass is accelerated in a certain direction. The acceleration produces a reaction force directed in the opposite direction. This reaction force is an unwanted vibration which is transmitted to the machine body and ultimately to the operator's hand and arm. The amplitude of this unwanted vibration depends on the size of the orbit diameter, and on the ratio between the mass of the pad and the mass of the machine. Operators of these machines are used to apply a certain pressure or load to the machine in order to speed up their job and increase their productivity, with the result of enlarging the amplitude of these vibrations.

In order to keep the vibrations within an acceptable level, machines, equipment and power tools available in the market are designed in such a way that the working surface (size of the pad) and the orbit diameter are relatively small. However, these limitations reduce the efficiency of the machine.

In order to compensate these efficiency limitations, the operator tends to apply a certain load to the machine, thereby increasing the friction on the work piece. But this procedure causes an increase of the vibrations. In order to counteract the resulting increase of vibrations, the operator tends to grasp and apply the machine with even more force to the work piece. By doing this, the mass of the machine is virtually increased, and the vibrations are absorbed by the operator's hand and arm, with severe consequences for the operator's health.

Even those people, who occasionally use orbit tools, experience a quick insurgence of numbness and tingling in their fingers, hand and arm. The insurgence of these symptoms can be as quick as in a few minutes of operation, and is accompanied by an unpleasant loss of feeling and control in the fingers that can last for hours after ceasing the operation of the tool. If the use is prolonged for hours, the full recover process can take several days. The consequence of vibrations for professional workers can be even much more severe.

Disorders caused by exposure of workers to vibrations of a power tool and equipment causes a high percentage workers to retire from work, and thus causes high social costs. On the other hand, an adoption of guidelines relating to vibration threshold values would have a heavy impact on productivity and production costs.

In view of these reasons, it is evident that manufacturers and users of orbiting or vibrating power tools have interest in canceling or reducing the vibration that is transmitted to the operator, so that they can achieve an improvement to the safety of workers and productivity, and cut related social costs.

A first type of solution for overcoming the above-mentioned problems is that of adopting one or more eccentric masses or counter-balance weights that move in a direction that is opposed to that of the pad, so that they virtually counterbalance the vibrations. Examples of this kind of solution are illustrated in US 4,660,329, US 4,729,194, US 5,888,128, US 6,244,943, US 6,206,771, US 2001/0003087, DE 3922522, EP 0303955, EP 0455618, WO 98/01733, WO 02/068151. In general, this solution works fine when the pad is not touching the work piece, but displays major limitations in normal working operation. As soon as the pad including the abrasive or sanding object is put on the work piece, the load virtually modifies the mass of the pad itself, therefore varying the ratio between the mass of the pad and the counter-balance mass. As a result, the counter-balance mass cannot cancel the vibrations induced by the virtual increase of the mass of the pad. The higher the load, the more the system is unbalanced and the higher are the unwanted vibrations. With a load tending to become infinite, the sanding pad will be standing and the machine body will vibrate with an amplitude equal to the radius of the sanding pad orbit.

It has to be noted that operators of this kind of power tools tend to apply a certain load to the tool so that the speed of the work is increased. Remarkably, the increase of the working efficiency that is achieved by the increase of the load is exclusively due to the increase of the friction between the working pad and the work piece. On the other hand, the increase of the load unbalances the machine and therefore increases the unwanted vibrations. The diameter of the unwanted vibrations is subtracted from the orbit diameter of the pad. So it must be assumed that the effective working orbit diameter is the result of the theoretical orbit diameter minus that of the unwanted vibrations.

A second type of solution for overcoming the above-mentioned problems is that of using elastic materials as an interface between the machine and the operator's hands for dampening the vibrations by transforming the kinetic energy of the vibrations into thermal energy. Examples for solutions of this type are illustrated in US 4,905,772, US 5,453,577, US 5,347,764, US 2001/0011856 A1, WO 03/049902. However, this second solution does not provide any real advantage. By interposing an elastic element between the machine body and the operator's hand, the power tool is free for vibrating with greater amplitude than if it was firmly held by the operator. In the real world, the operator instinctively feels the decreased efficiency of the machine and tends to grasp it with increased force in an attempt to restore an acceptable efficiency. By doing this, the efficiency of the elastic element is minimized, so that vibrations are transmitted to the operator's hand and arm. Moreover, the increased muscular force reduces the human body's natural capability of dampening vibrations, therefore making the consequences even worse.

Summary of the Invention

Objects

It is a general object of the present invention to overcome the above-described problems and drawbacks by providing an anti-vibration device for a power tool with high efficiency and flexibility in every working condition.

It is a particular object of the present invention to provide an anti-vibration device that significantly reduces the amplitude of the vibrations that are transmitted from the tool to the operator, so that risks for the operator's health are reduced.

It is another specific object of the present invention to provide an anti-vibration device for a tool at relatively low costs, providing easy use and convenient maintenance.

It is also a specific object of the present invention to provide a method for performing sanding work on a work piece without causing an excessive amount of vibrations to the operator.

It is still another object of the invention to provide a portable power tool, specifically a sander or a polisher, comprising an anti-vibration device, which allows the user to accomplish coarse and/or fine surface sanding work on whichever material with high efficiency and productivity and with a substantial reduction of vibrations affecting the operator, no matter how much the load is that is applied to the power tool by the user.

Solution

According to the present invention, these object are achieved by an anti-vibration device for an abrasive machine, such as for a polishing machine, preferably for a sander machine, which machine is driveable by means of a motor shaft having a rotation axis, characterized in

- a) a first pad having a first surface and a first predetermined orientation,
- b) a second pad having a second surface and a second predetermined orientation, wherein said first and second surfaces are determined for attaching an abrasive object thereto, such as a polishing tool or a sanding paper, and wherein said surfaces are arranged substantially in the same plane, and
- c) means for moving said pads such that they perform orbital rotations preferably about said rotation axis, wherein said orbital rotations are shifted in phase.

In a finishing sander said pads essentially maintain their predetermined orientations.

It must be noted that this anti-vibration device dynamically compensates the inertial and friction forces and reduces vibrations that are transmitted to the motor shaft. These vibrations will be kept low or even completely compensated.

Thanks to this design, the functionality of this device does not depend on the rotation speed, the weight of the machine, the type of the abrasive surfaces, the radius of rotation of the pads, and the load conditions.

Furthermore, thanks to the absence of a conventional counter-balance weight it has been possible to increase the useful energy, that is the energy available for the abrasive work.

Even in the case, where the load is not equally shared among the abrasive surfaces, the residual vibrations transmitted by the power tool to the operator are lower than in a conventional machine provided with a counter-balance mechanism.

Preferably, the active surfaces of the pads are substantially planar and lying in the same plane. Moreover, one of these surfaces may be substantially central, while the other is peripheral to the first one.

In a preferred embodiment, the central pad is substantially circular, while the peripheral pad is substantially a ring. But the pads may also have a square form, and there may be four or even more of them.

It is of specific advantage if the means for moving the pads comprise an eccentric piece assembly that includes at least one pair of cams which are substantially identical to each other, which are longitudinally shifted and which are angularly shifted by 180°.

Each one of the cams must be coupled, directly or indirectly, with the motor shaft. Each of them may have a substantially cylindrical shape with an eccentricity relative to the axis of the motor shaft that equals the diameter of the desired orbit trajectory.

The external diameter of the inner circular pad may be slightly smaller than the internal diameter of the external ring pad, so that a predetermined minimum gap is left between the pads during operation. As a result, the gap between the two pads can be connected to suction means such as a fan for removing debris and dust from the work piece. This would replace the holes that are normally included in conventional machines.

Additional embodiments of the anti-vibration device are claimed in the sub-claims.

According to the present invention, there is also provided a method for working on a work piece using a first pad having a first predetermined orientation and a second pad having a second predetermined orientation, wherein said pads are driven by means of a motor shaft having a rotation axis. The method is characterized in that said first pad circles about a first axis and said second pad circles about a second axis, wherein said first axis and said second axis preferably coincide.

In a finishing sander both pads maintain their predetermined orientations.

In a preferred embodiment the method may be additionally characterized in

- a) using a ring-shaped first pad and a circular shaped second pad, wherein said second pad is arranged within the inner or central space of said first pad,
- b) circulating the center axis of said second pad about said rotation axis,
and
- c) circulating the center axis of said first pad also about said rotation axis
in the same direction of circulation, but angularly shifted or offset by approximately 180° with respect to said center axis of said second pad.

And according of the present invention, a portable abrasive power machine, in particular a sander or polisher, comprises

- a) a housing provided with a handle for an operator,
- b) an inner space within said housing,
- c) a motor arranged in said inner space and having a motor shaft with a longitudinal rotation axis,
- d) at least a first pad for attaching a first abrasive object thereto, and a second pad for attaching a second abrasive object thereto, and
- e) transmission means and an anti-vibration device for transmitting energy from said motor shaft to said pads, wherein the anti-vibration device is designed as described here-before and in the appended claims.

This abrasive power machine or tool may be designed as a “rotary sander”.

In order to compensate or cancel torque, the power machine may be provided with a weight which is associated with or even directly connected to the motor shaft or which is arranged on a cooling fan, and which has a center of gravity which is located outside the rotation axis of the motor shaft.

According to another embodiment, this abrasive power machine may also be designed as a “finishing sander”, when holding devices, such as connection pieces made of a resilient material, are used.

For avoiding high rotational speeds especially when no load is applied to the pads, brakes may be used.

Brief Description of the Drawings

Additional characteristics and advantages of the invention will become more evident according to the following description of preferred embodiments of an anti-vibration device for a portable power tool, incorporating the drawings. In the drawings:

Fig. 1 is a partially sectioned side view of a portable hand-held power tool, specifically of a “rotary sander”, incorporating an anti-vibration device,

Fig. 2 is an exploded perspective view of the anti-vibration device of Fig. 1,

Fig. 3 is an exploded cross-sectional view of the anti-vibration device of Fig. 1,

Fig. 4 is a view from below at the device of Figs. 1 – 3 in a reduced scale,

Fig. 5 is a cross-sectional view of the device of Figs. 1 – 3 after assembling,

Fig. 6 is a perspective view of a double-cam assembly used in the device of Figs. 1–3,

Fig. 7 is a cross-sectional view as in Fig. 5, where there is provided a weight on the motor shaft,

Fig. 8 a view of eight small sanding particles travelling during operation,

Figs. 9 – 12 a view of the travelling of another four small sanding particles during operation,

Fig. 13 is a bottom view of the arrangement of four pads according to a second basic embodiment of an anti-vibration device,

Fig. 14 is a cross-sectional view as in Fig. 5 with the provision of a weight on a cooling fan,

Fig. 15 is a side view as in Fig. 1, but incorporating connection pieces, in order to illustrate a “finishing sander”, and

Fig. 16 is a side view as in Fig. 1 where brakes are provided.

Detailed Description of the Drawings

Referring now to the drawing of Fig. 1, an abrasive power tool 1, e.g. a sander or polisher, incorporating a preferred embodiment of an anti-vibration device according to the present invention, is illustrated.

The power tool 1 essentially includes a housing 2 that has a handle or grip 3 and an inner space 4 for housing a motor 5, for example an electric motor, having a motor shaft 11 with a longitudinal axis 12, which shaft 11 is supported by ball, cylinder or oil bearings 6. The motor 5 can be of a type other than electric, for example pneumatic. Subsequently the axis 12 will be termed motor shaft axis or rotation axis. The motor 5 may work with any speed, even with very high speeds. In an exemplary design an electric motor 5 was used which had a variable speed from 2.000 to 12.000 rpm.

A power switch 7 is placed on the hand grip 3 so that it can be conveniently operated by the operator by connecting the motor 5 with a mains power, or a rechargeable battery, or a compressed air tank, which is not represented in the drawing.

The shaft 11 is coupled, by means of mechanical transmission means including an anti-vibration device 10 which are described below, to pads 16, 22 which support substantially plane abrasive objects 8, 9, for instance abrasive layers or sanding papers. The transmission means and the anti-vibration device 10 are suitable to support the abrasive objects 8, 9 and to reduce the amplitude of the vibrations that are conventionally generated by the reaction of the work piece surface on the tool pads 16, 22 and therefore on the motor shaft 11 and consequently on the machine housing 2 and the operator.

In order to achieve this goal, the transmission means including the anti-vibration device 10 are made so that the pads 16, 22 are distinctive and separated from each other. They have

substantially identical mass, and preferably their active surfaces 16b, 22a have substantially identical surface areas F_1 , F_2 . These outside surfaces 16b, 22a are located in the very same plane P.

Furthermore, the transmission means, which are driven by the motor shaft 11, are designed so that they provide not only rotational motions, but also orbital motions with phase opposition for the pads 16, 22. By the orbital motions they dynamically compensate the inertial forces and the friction forces, and thus reduce the vibrations transmitted back to the motor shaft 11. The orbital motions will be considered first.

Specifically, the transmission and anti-vibration means incorporate a double eccentric piece assembly 18 having cams 18a, 18b that drive the pads 16, 22 with respective orbit motions. This will subsequently be described.

The housing 2 includes a collection room 44 above the assembly 18. To this room 44 is connected an air and dust emitting tube 45 which is arranged under the handle 3. A sucking fan (not shown) may be connected to the tube 45 for health protection of the operator.

According to Figs. 2 – 6, the anti-vibration device 10 for the abrasive machine 1 comprises the first or outer pad 16 which is here in the form of a ring, and which has a central inner space 16a and a first outer surface 16b for attachment of a ring-shaped sanding paper 8. The size of the outer surface area of the outer pad 16 is designated as F_1 . The outer pad 16 is joined with a bell-shaped first support 17. The device 10 also comprises a second or inner pad 22 which is shaped as a round or circular disc. The inner pad 22 is accommodated in the central inner space 16a of the outer pad 16. It has a second outer surface 22a for attachment of a circular sanding paper 9. The size of the outer surface area of the inner pad 22 is designated as F_2 . Preferably the surface areas F_1 , F_2 are equal to each other, i.e. $F_1 = F_2$. The surfaces 16b, 22a are located substantially in the same plane P (see Figs. 1 and 5). A second support 23 is provided as a central cylindrical holder on the inner surface of the inner pad 22. The support 23 forms a cylindrical central space 23a.

It will be noted from Figs. 2 and 3 that the bell-shaped support 17 of the outer pad 16 has a conical portion 17a and a planar ring portion 17b joined thereto, thereby forming a central lower space 17c. There may be a central cylindrical holder 17d (not shown) which is joined to the ring portion 17b and which forms a central upper space 17e. Here the space 17e is formed by the portion 17b. As can be seen in Figs. 2, 3 and 5, at least one air and dust sucking hole 17f may be provided in the support 17, notably in the conical portion 17a. When a fan (not shown) is connected to the tube 45, it will suck dust and debris coming from a work piece during the sanding or polishing operation.

There are also provided a first bearing 13 and a second bearing 19, which both may be ball bearings or cylinder bearings. The outer surface of the first bearing 13 is firmly received in the central upper space 17e of the planar ring portion 17b. And the outer surface of the second bearing 19 is firmly received in the space 23a of the cylindrical holder 23 of the inner pad 22. The center of the first bearing 13 is denoted as 13a, its central hole as 14, and its central axis as 15. The center of the second bearing 19 is denoted as 19a, its central hole as 20, and its central axis as 21.

Both central axes 15, 21 are arranged parallel to the rotation axis 12, but on opposite sides of the rotation axis 12. The central axis 15 coincides with the central axis of the outer pad 16 including its support 17, and the central axis 21 coincides with the central axis of the inner pad 22 including its support 23. The design is such that the center 25 of gravity of the outer pad 16 including its support 17 and the center 26 of gravity of the inner pad 22 including its support 23 are aligned along a straight line 27 passing vertically through the rotation axis 12 (see Fig. 5). During operation the central axis 15 circulates or orbits about the rotation axis 12. (According to the embodiment of Fig. 15, this occurs while the outer pad 16 maintains its orientation 16z (see Fig. 4).) And during operation the central axis 21 also circulates or orbits about the rotation axis 12, but shifted in phase by 180° with respect to the circulation of the central axis 15. (According to the embodiment of Fig. 15, this occurs while the inner pad 22 maintains its orientation 22z (see Fig. 4).)

The essential element of the anti-vibration device 10 depicted in Figs. 1 – 7 is the eccentric piece assembly 18. It is here a double piece assembly 18 having a first cam 18a and a second cam 18b which is attached to the first cam 18a. The cams 18a, 18b are substantially identical to each other, they are longitudinally shifted, and they are angularly shifted or offset by about 180° with respect to each other. The eccentric piece assembly 18 is provided with a central hole 18c which goes all the way through and which serves for a firm connection to the motor shaft 11. Thus, the central hole axis coincides with the rotation axis 12.

As can be seen in Fig. 6, the cams 18a, 18b have a substantially a cylindrical shape. They may also have another shape, e.g. an elliptical shape. Their cylinder axes or central axes are denoted 15 and 21, respectively. The cams 18a, 18b both constitute a monolithic, e.g. made of a block of metal. Alternatively the cams 18a, 18b may originally be single pieces which are later-on firmly connected to each other. The eccentricities e_1 , e_2 of the cams 18a, 18b, respectively, with respect to the central hole axis 12, that is the distances of the axes 15, 12 and 21, 12, respectively, are equal to each other ($e_1 = e_2$) and to the orbit of the diameter of the desired orbit trajectory.

The outer surface of the first or upper cam 18a is received in the central hole 14 of the first bearing 13 (and fixed therein), and the second or lower cam 18b is received in the central hole 20 of the second bearing 19 (and fixed therein). The rotation of the motor shaft 11 is transferred to the cams 18a, 18b and from there slidingly via the bearings 13 and 19, respectively, to the supports 17 and 23, respectively, and to the associated pads 16 and 22, respectively. (In the embodiment of Fig. 15, the orientations 16z, 22z will be maintained during the entire rotation.) Consequently, both pads 16, 22 will describe eccentric orbits which are shifted in phase by 180° relative to each other.

As can be seen in Figs. 4 and 5, the outer diameter of the inner circular pad 22 may be slightly smaller than the inner diameter of the ring-shaped outer pad 16, so that a predetermined minimum gap 24a may be maintained between the pads 16, 22 during the entire rotational operation. The whole gap 24 between pad 22 and pad 16 defines a passage for suction of debris and dust coming from the work piece during operation. The suction may be caused by a fan (not shown) associated with the tube 45.

During operation, a force K1, K2 is generated and associated with each pad 16, 22, respectively (see Fig. 4). These forces K1, K2 point in directions opposite to each other (due to the phase shift of 180°), and therefore there are cancelled vibrations otherwise transferred back to the housing 2 of the tool 1 and subsequently to the operator, at least to a large degree. They are cancelled also when the load exercised by the operator on the tool 1 is increased.

As illustrated in Fig. 7, during operation of the machine 1 there may be caused a small torque by forces f1, f2 generated around a point 30, which is the center of gravity of the system: pads 22, 16, supports 17, 23, bearings 13, 19, and cam assembly 18. These forces f1, f2 may be generated by centrifugal effects, and they may lead to vibrations. In order to cancel such torque, a weight 28 is provided which is associated with the motor shaft 11. It may be firmly connected either directly to the motor shaft 11, or to the assembly 18, or it may be arranged on a cooling fan 43 (shown in Fig. 14) driven by the motor 4 for cooling the motor 4. The center 29 of gravity of the weight 28 is located outside the motor rotation axis 12. The eccentricity is designed as j in Fig 7. The weight 28 may basically have any shape. Here a cylindrical shape was chosen. Yet, it should be observed that the mass of the outer pad 16 including its support 17 equals the mass of the inner pad 22 including its support 23 plus the mass of the weight 28, since for balancing purposes, not only the mass of the weight 28 is essential, but also its distance q from point 31. The total center of gravity is then positioned in point 31.

In Fig. 8 a view from below of the outer pad 16 and of the inner pad 22 is illustrated. This view illustrates the function of the device 10. The surfaces 16b, 22a of both pads 16, 22 are located in the very same plane P. And it is assumed that their surface areas F1, F2 are equal. There may be instances where this requirement should not be fulfilled. During operation the center axis 15 of the outer ring pad 16 describes a small circle around the rotation axis 12 of the motor shaft 11, and the center axis 21 of the inner circular pad 22, with a phase shift of 180°, describes also a small circle around the rotation axis 12. These circulations are indicated by two small curved arrows 40, 41, respectively.

A connection line 42 is shown to connect the axes 15, 12, 21. Preferably the distance between the axes 12, 15 equals the distance between the axes 12, 21. This is the preferred design, since it makes the construction simple, but there may be occasions and conditions where a deviation from this condition should be chosen.

An arrow 16z is assumed to be fixed on the surface 16b of the outer pad 16. It indicates a predetermined direction or orientation of this outer pad 16 with regard to the machine 1. It is e.g. directed from the front side of the machine 1 to its back side. And an arrow 22z is assumed to be fixed on the surface 22a of the inner pad 22. It similarly indicates a predetermined direction or orientation of this inner pad 22 with regard to the machine 1. For instance, it may also be directed from the front side of the machine 1 to its back side. (It is important to realize that in the embodiment of Fig. 15 these orientations 16z, 22z are maintained during the entire operation of the machine 1. In other words, in all working positions, (five of which are indicated in Fig. 8 by reference signs (1) through (5)) the arrows 16z, 22z are each parallel to a predetermined line which is oriented perpendicularly to the rotation axis 12.)

It is also assumed that eight small sanding particles a, b, ... h are associated in the shown rotation and circulation position (1) with the outer rims of pads 16, 22. The particles a, b, c, d of pad 16 are assumed to be angularly separated from each other by 90°, and similarly the particles e, f, g, h of pad 22 are also assumed to be angularly separated from each other by 90°. The particles a – h travel along small circles t of the same diameter when they reach consecutive positions (1) - (5), thereby having an erasive effect on the work piece to be worked on.

This is again shown in Figs. 9 – 12, where the travelling of three particles k, l, m is shown when the pads 16, 22 take four consecutive positions (1), (2), (3) and (4), respectively. In this case, the particles k, l, m are situated in the interior portions of the pads 22 and 16. Again, the particles k, l, m travel along small circles t having all the same diameter.

It must be stressed with regard to Figs. 8 to 12 that – in addition to the orbiting motion around circles t – there is a rotation of the pads 16 and 22 due to the internal friction of the bearings 13 and 19, respectively. The rotation speed of these rotations is dependent on the load applied to the sanding papers 16b and 22a, respectively. These rotations are characterized by curved rotation arrows 33 and 34, respectively, in Figs 8 – 12. The ring pad 16 rotates repeatedly around its central axis 15, and the circular pad 22 rotates repeatedly around its central axis 21. These rotations will subsequently be termed as “pad rotations”. They cause coarse sanding of the work piece, while the orbiting rotations cause fine sanding of the work piece.

It will be noted from Figs. 1 – 7 (as opposed to Fig. 14) that the only connection between the two pads 16, 22 and the housing 2 are the two ball bearings 13 and 19, respectively. The motor shaft 11 is strongly fixed to the double cam 18 so that the cams 18a, 18b rotate at the same speed as the motor shaft 11. The cams 18a, 18b drive the two pads 16, 22 in orbital motions, as explained above.

The relatively small frictions of the metal-balls of the ball bearings 13, 19 create a certain rotation force that drives the pads 16 and 22, respectively, to rotate around their central axes 15 and 21, respectively. If the tool 1 is started to work with no load, e.g. if it is held into the air by the operator, each pad 16, 22 starts to rotate in the same direction as the motor shaft 11, and each pad 16, 22 is accelerated (see arrows 33 and 34) until it finally reaches the same speed as the motor shaft 11. This is because there is no friction between the sanding paper 16b, 22a and the working piece (e.g. the surface of a table made of wood), under this condition. Yet, if now a load is applied to the tool 1, i.e. if the sanding papers 16b, 22a are now applied to the surface of the wooden table, the rotation speed of each pad 16, 22 will be considerably reduced. The pad rotations (see arrows 33, 34) will now be almost stopped, and just a very low rotation speed may remain for coarse sanding. Of course, the orbital rotations will remain, and they will now primarily perform the sanding work.

After this explanation, it will be obvious that the rotation speed of the pad rotations and thus the coarse sanding is dependent on the load applied. In contrast thereto, the rotation speed of the orbital rotations (leading to cancellation of vibrations) is strongly related to the motor speed, and fine or finishing sanding is not dependent on the load applied.

During the working, the frictions between pad 16 and load (e.g. table surface) on the one hand and pad 22 and load (e.g. table surface) on the other hand are not always the same so that the final pad rotations of pad 16 and pad 22 are not the same. This is not important for the anti-vibration performance, because the low pad rotations do not create vibrations.

A sander with this kind of operation may be called “rotary sander” or “random sander”.

In Fig. 13 a four-pad embodiment is illustrated. It works on the principles disclosed in Figs. 1 – 12.

There are four pads A1, A2, A3, A4 arranged in a symmetrical square configuration. They are all arranged in the same plane around the rotation axis 12 of a motor shaft 11. All pads A1 – A4 may have any shape, here they have a rectangular, specifically a square shape. All are planar, and all have the same size of surface area B1 – B4 for attachment of equal-size sanding or polishing papers. It is assumed that small sanding particles a, b, c, d are present at the outer corners. During operation, these sanding particles a – d assume the consecutive positions (1), (2), (3), (4) etc., of which only positions (1) and (3) are illustrated. Position (3) results from a shift in the direction of the corner arrows by 45° with respect to position (1). The pads A1 – A4 and circular areas C1 – C4 in their centers S1 – S4 are shown in solid lines in position (1), whereas pads A1 – A4 and areas C1 – C4 are shown in broken lines in position (3). The centers including center axes of pads A1 – A4 are denoted as S1 – S4.

It is important to understand that there are provided four axes R1 – R4 about which the centers S1 – S4 of the pads A1 – A4 including their center areas C1 – C4 orbit from one position (1) to consecutive positions (2), (3), (4) etc. on relatively small circles (not shown). These orbit axes R1 – R4 have all the same distance $d1 = d2 = d3 = d4$ from the rotation axis 12 which is positioned in the middle of the pad arrangement. These distances d1 – d4 remain unchanged during operation.

T1, T2, T3, T4 indicate the orbital rotation directions. It is also important to realize that all neighboring pads A1 – A4 orbit in opposite direction with respect to each other, whereby the individual orientation O1, O2, O3, O4 of the pads A1, A2, A3, A4 remains unchanged. Thus, vibrations are cancelled.

This function is performed by a cam assembly (not shown) and a gear assembly (not shown). The cam assembly may be similar to that of Fig. 6, i.e. including two (preferably circular or cylindrical) cams for neighboring pads A1, A3 and A2, A4, wherein each of the two cams assemblies is connected to the motor shaft 11. By such cam assemblies and by a gear assembly the rotation of the motor rotation axis 12 may be transferred to the four axes S1, S2, S3, S4, so that the pads A1 – A4 rotate in the directions of the arrows T1 – T4. In such a design, it can be assumed that the circles C1 – C4 shown in solid line in each pad A1 – A4 indicate the location of the associated cylindrical cam in the first position (1), whereas the circles shown in broken lines in each pad A1 – A4 indicate the location of the associated cylindrical cam in the third position (3).

Also in this embodiment, a significant reduction of vibrations is obtained.

In addition to orbiting, the entire configuration will rotate around the rotation axis 12, thereby performing “pad rotations” for coarse sanding.

This embodiment can also be designed as a finishing sander.

According to Fig. 14, a cooling fan 43 for cooling the motor 4 is connected to the motor shaft 11. A weight 28 is arranged on the lower outer side of the cooling fan 43. The combined center of gravity 29A of the weight 28 and of the cooling fan 43 is located outside the rotation axis 12. In this way unbalances are compensated.

In Fig. 15 an embodiment is shown which is used as a “finishing sander”. It is basically identical to the embodiment shown in Fig. 1, but additionally it contains at least one first resilient holder or connection piece 46 and at least one second resilient holder or connection piece 47. Both connection pieces 46, 47 are elongated and made of an elastic material, such as rubber. The first connection piece 46 is arranged between the outer ring pad 16 and the housing 2, and the second connection piece 47 is arranged between the inner circular pad 22 and the support 17, i.e. indirectly also between pad 22 and housing 2. Both connection pieces 46, 47 make sure that the associated pads 16 and 22, respectively, cannot rotate about their center axes 15 and 21, respectively. Since such rotations are prevented, the sanding papers 16b and 22a, respectively, can basically carry out only small circles t, as illustrated in Figs. 8 to 12, which represent orbiting sanding motions. In other words: The flexible connection pieces 46, 47 prevent the afore-mentioned “pad rotations”, while they allow for the “orbital rotations”.

In Fig. 16 there is illustrated that two brakes 50, 51 may be used in the rotary sander of Fig. 1 in order to slow down the rotation of the pads 16 and 22, specifically when there is no load applied to the tool 1. The rotation speed is now kept low because the brakes 50, 51 simulate a load. The brakes 50, 51 are here schematically illustrated as rubber rings of different diameter.

LIST OF REFERENCE NUMERALS

- 1 abrasive power tool, specifically sander
- 2 housing
- 3 handle
- 4 inner space
- 5 electric motor
- 6 ball bearing
- 7 power switch
- 8 ring shaped sanding paper
- 9 circular sanding paper
- 10 anti-vibration device for the abrasive tool 1
- 11 motor shaft
- 12 motor shaft axis, rotation axis

- 13 first bearing
 - 13a center of first bearing 13
- 14 central hole of first bearing 13
- 15 central axis of first bearing 13
- 16 first or outer pad
 - 16a inner space
 - 16b outer surface
 - 16z orientation of first pad 16
- 17 first support
 - 17a conical portion
 - 17b ring portion
 - 17c central lower space
 - 17d central cylindrical holder
 - 17e central upper space
 - 17f dust sucking hole
- 18 double eccentric piece assembly
 - 18a first cam
 - 18b second cam
 - 18c central hole
 - 18d center
- 19 second bearing
 - 19a center of second bearing 19
- 20 central hole of second ball bearing 19
- 21 central axis of second ball bearing 19
- 22 second or inner pad
 - 22a outer surface
 - 22z orientation of second pad 22
- 23 second support or holder
 - 23a central space
- 24 small gap
 - 24a minimum gap
- 25 center of gravity of elements 16, 17
- 26 center of gravity of elements 22, 23
- 27 straight connection line (vertical on rotation axis 12)
- 28 weight
- 29 center of gravity of weight 28
 - 29A center of gravity of weight 28 and fan 43
- 30 center of gravity system 16, 22, 17, 23, 13, 19, 18 center of gravity system
- 31 point; total center of gravity
- 33 rotation arrow of outer pad 16
- 34 rotation arrow of inner pad 22
- 40 arrow indicating orbiting of center 15 of ring pad 16
- 41 arrow indicating orbiting of center 21 of circular pad 22
- 42 connection line
- 43 cooling fan
- 44 collection room
- 45 air and dust emitting tube
- 46 first resilient connection piece
- 47 second resilient connection piece
- 50 first brake
- 51 second brake

a, b, c, d	sanding particles
e1, e2	eccentricities
f1, f2	forces
j	eccentricity
k, l, m	sanding particles
q	distance
t	circle
F1, F2	outer, inner surface area
K1, K2	forces
P	plane
(1) ; (3)	positions (consecutive) of sanding particles a, b, c, d
A1, A2, A3, A4	pads
B1, B2, B3, B4	surfaces of pads A1, A2, A3, A4
S1, S2, S3, S4	centers, center axes of pads A1, A2, A3, A4
C1, C2, C3, C4	center circular area of pads A1, A2, A3, A4
R1, R2, R3, R4	axes about which pads A1, A2, A3, A4 and areas C1, C2, C3, C4 orbit
T1, T2, T3, T4	arrows indicating orbital rotation direction
d1 = d2 = d3 = d4	distances between rotation axis M and orbit axes R1, R2, R3, R4
C1(3), C2(3), C3(3), C4(3)	circular areas in position (3)
O1, O2, O3, O4	orientation of pads A1, A2, A3, A4

Claims

1. An anti-vibration device (10) for an abrasive machine (1), such as for a polishing machine, preferably for a sander machine, which machine (1) is driveable by means of a motor shaft (11) having a rotation axis (12), characterized in
 - d) a first pad (16; A1) having a first surface (16b; B1) and a first predetermined orientation (16z; O1),
 - e) a second pad (22; A2) having a second surface (22a; B2) and a second predetermined orientation (22z; O2),
 wherein said first and second surfaces (16b, 22a; B1, B2) are determined for attaching an abrasive object (8, 9) thereto, such as a polishing tool or a sanding paper, and
 wherein said surfaces (16b, 22a; B1, B2) are arranged substantially in the same plane (P), and
 - f) means for moving said pads (16, 22; A1, A2) such that they perform orbital rotations about an axis (12; R1, R2), preferably about said rotation axis (12), wherein said orbital rotations are shifted in phase.
2. The device (10) according to claim 1, wherein said first pad (16) has attached thereto a first support (17), and wherein said second pad (22) has attached thereto a second support (23).
3. The device (10) according to claim 2, wherein said first pad (16) including said first support (17) has essentially the same mass as said second pad (22) including said second support (23).
4. The device (10) according to claim 1, 2 or 3, wherein the outer surface (16b; B1) of said first pad (16; A1) has essentially the same surface area (R1, R2) as the outer surface (22a; B2) of said second pad (22; A2).
5. The device (10) according to any of the claims 1 – 4, wherein the outer surfaces (16b, 22a; B1, B2) of said pads (16, 22; A1, A2) are substantially plane and coplanar.
6. The device (10) according to any of the claims 2 – 5, wherein including said first support (17) and said second pad (22) including said second support (23) have respective centers (25, 26) of gravity which are essentially aligned along a straight line (27) passing through said rotation axis (12).
7. The device (10) according to any of the claims 1 – 6, wherein the outer surface (16b) of said first pad (16) is arranged substantially centrally with regard to said rotation axis (12), and wherein the outer surface (22a) of said second pad (22) is arranged substantially

- peripherally and eccentrically with regard to said outer surface (16b) of said first pad (16).
8. The device (10) according to claim 7, wherein said outer surface (22a) of said second pad (22) has substantially a round shape.
 9. The device (10) according to claim 7 or 8, wherein said outer surface (16b) of said first pad (16) substantially has a ring shape.
 10. The device (10) according to any of the claims 3 – 9, wherein said first support (17) is bell-shaped and comprises a conical portion (17a) joined to said first pad (16), and a ring portion (17b).
 11. The device (10) according to any of the claims 3 – 10, wherein said first support (17) is provided with at least one dust sucking hole (17f) for suction of debris and dust coming from a work piece during operation, when a fan is associated with said device (10).
 12. The device (10) according to any of the claims 1 – 11, wherein said means for moving said pads (16, 22; A1, A2) comprise an eccentric piece assembly (18).
 13. The device (10) according to claim 12, wherein said eccentric piece assembly (18; A1, A2) comprises at least a first cam (18a) and a second cam (18b), which are longitudinally shifted, which are substantially identical to each other, which are angularly offset with respect to each other, and which are provided with a central hole (18c) for connection to said motor shaft (2).
 14. The device (10) according to claim 13, wherein said cams (18a, 18b) are angularly shifted by approximately 180°.
 15. The device (10) according to claim 13 or 14, wherein said cams (18a, 18b) are a monolithic block.
 16. The device (10) according to claim 13, 14 or 15, wherein said cams (18a, 18b) have a substantially cylindrical shape, and wherein their eccentricities (e1, e2) with respect to the central axis (12) of said central hole (18c) equal the orbit of the diameter of the desired orbit trajectory.
 17. The device (10) according to any of the claims 9 – 16, wherein the outer diameter of said circular inner pad (22) is slightly smaller than the inner diameter of said ring-shaped outer pad (16) so that a predetermined gap (24) having a minimum gap (24a) is left between said pads (16, 22) during operation.
 18. The device (10) according to claim 17, wherein said gap (24) defines a passage for suction of debris and dust coming from a work piece during operation, when a fan is associated with said device (10).
 19. The device (10) according to any of the claims 2 – 18, wherein a first bearing (13) is

provided on said first support (17), and wherein a second bearing (19) is provided on said second support (23).

20. The device (10) according to any of the claims 13 – 18 and claim to 19, wherein each of said cams (18a, 18b) is placed inside of the respective bearing (13, 19).
21. The device (10) according to any of the claims 1 – 6 and of claims 10 – 20, wherein said first and said second pad (16, 22; A1, A2) have a substantially rectangular or square shape.
22. The device (10) according to any of the claims 1 – 6 and of claims 10- 21, wherein four pads (A1, A2, A3, A4) having individual orbiting axes (R1, R2, R3, R4) are provided, and wherein neighboring pads (A1, A2, A3, A4) are designed to orbit in opposite directions (T1, T2, T3, T4).
23. The device (10) according to any of the claims 1 – 22, wherein said means for moving said pads (16, 22; A1, A2) are designed in such a way that, during orbital rotation, said pads (16, 22; A1, A2) essentially maintain their predetermined orientations (16z, 22z; O1, O2).
24. Method for working on a work piece using a first pad (16; A1) having a first predetermined orientation (16z; O1) and a second pad (22; A2) having a second predetermined orientation (22z; O2), wherein said pads (16, 22; A1, A2) are driven by means of a motor shaft (11) having a rotation axis (12), characterized in that
said first pad (16; A1) orbits about a first axis (12; R1) and said second pad (22; A2) orbits about a second axis (12; R2) in a phase shifted manner, whereby vibrations are compensated, and wherein said first axis (12) and said second axis (12) may coincide.
25. Method in accordance with claim 24, characterized in that both pads (16, 22; A1, A2) maintain their predetermined orientations (16z, 22z; O1, O2) during orbiting.
26. Method in accordance with claim 24 or 25, characterized in
 - a) using a ring-shaped first pad (16) and a circular shaped second pad (22), wherein said second pad (22) is arranged within the inner space of said first pad (16),
 - b) circulating the center axis (21) of said second pad (22) about said rotation axis (12), and
 - c) circulating the center axis (15) of said first pad (16) also about said rotation axis (12) in the same direction of circulation, but angularly offset by approximately 180° with respect to circulating said center axis (21) of said second pad (22).

27. A portable abrasive power machine (1), in particular a sander or polisher, comprising
- a) a housing (2) provided with a handle (3) for an operator,
 - b) an inner space (4) within said housing (2),
 - c) a motor (4) arranged in said inner space (4) and having a motor shaft (11) with a longitudinal rotation axis (12),
 - d) at least a first pad (16; A1) for attaching a first abrasive object (8) thereto, and a second pad (22; A2) for attaching a second abrasive object (9) thereto, and
 - e) transmission means and an anti-vibration device (10) for transmitting energy from said motor shaft (11) to said pads (16, 22; A1, A2), said anti-vibration device (10) being designed in accordance with any of the claims 1 – 23.
28. The power machine (1) in accordance with claim 27, wherein a weight (28) is associated with said motor shaft (11), and wherein the center of gravity (29) of said weight (28) is located outside said rotation axis (12).
29. The power machine (1) in accordance with claim 27, wherein a cooling fan (43) is connected to said motor shaft (12), wherein a weight (28) is arranged on said cooling fan (43), and wherein the center of gravity (29A) of said weight (28) along with that of said cooling fan (43) is located outside said rotation axis (12).
30. The power machine (1) in accordance with any of the claims 27, 28, or 29, wherein an air and dust emitting tube (45) is connected to said housing (2) for connection of a fan thereto.
31. The power machine (1) in accordance with any of the claims 27 to 30,
- wherein a first resilient connection piece (46), preferably made of rubber, is arranged between said first pad (16) and said housing (2) and
 - wherein a second resilient connection piece (47), preferably made of rubber, is arranged between said second pad (22) and said housing (2).
32. The power machine (1) in accordance with claim 31, wherein a support (17, 23), is arranged between at least one of said pads (16, 22), one of said connection pieces (46, 47) and said housing (2).
33. The power machine (1) in accordance with any of the claims 27 to 32, wherein at least one brake (50, 51) is provided for reducing the rotational speed of at least one of said pads (16, 22), at least when no load is applied to at least one of said pads (16, 22).
34. A ring shaped sanding paper (8) and a circular sanding paper (9) for attaching to said pads (16, 22) in accordance with any of the claims 9 to 20 or with claim 23.

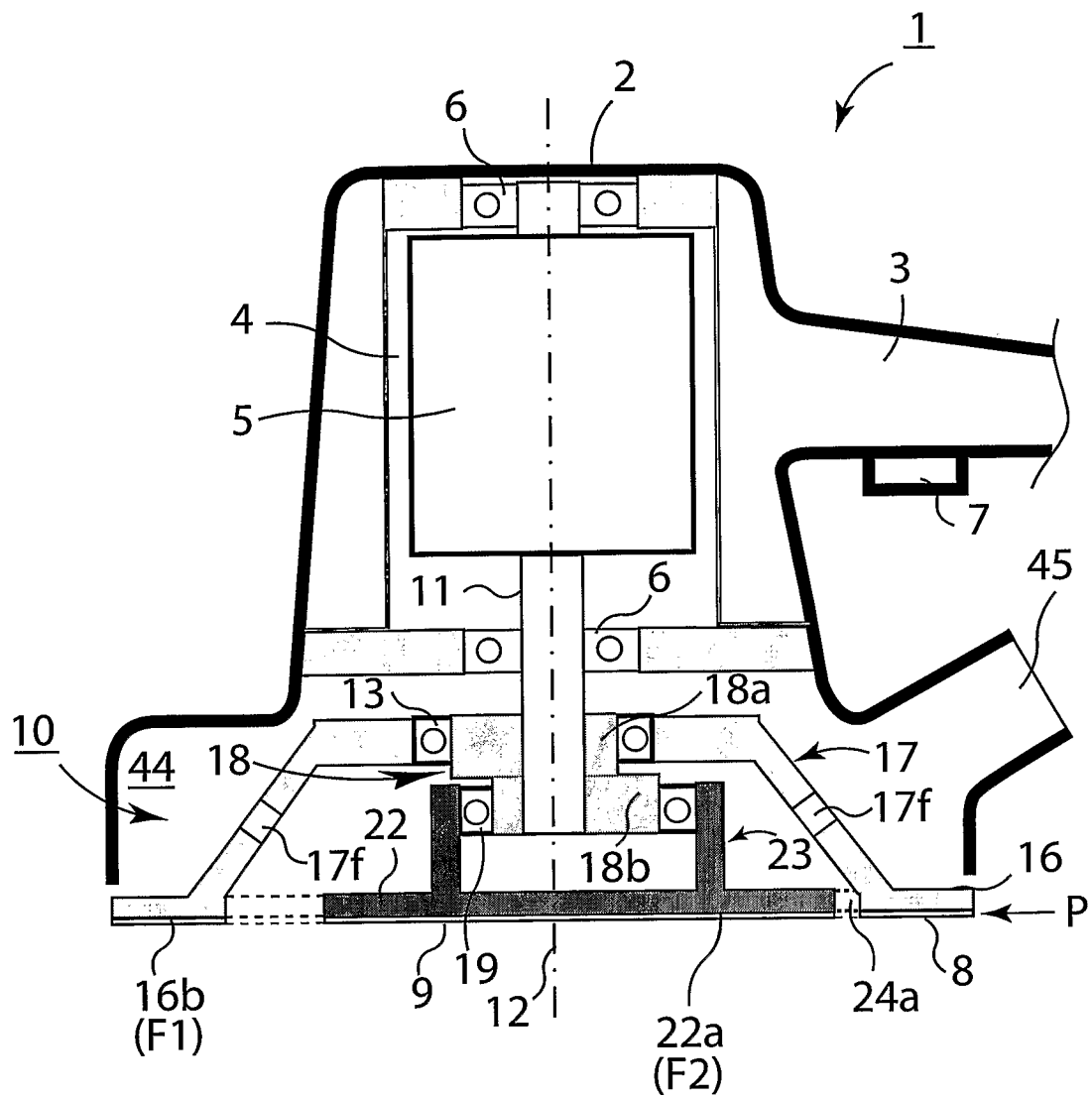


Fig.1

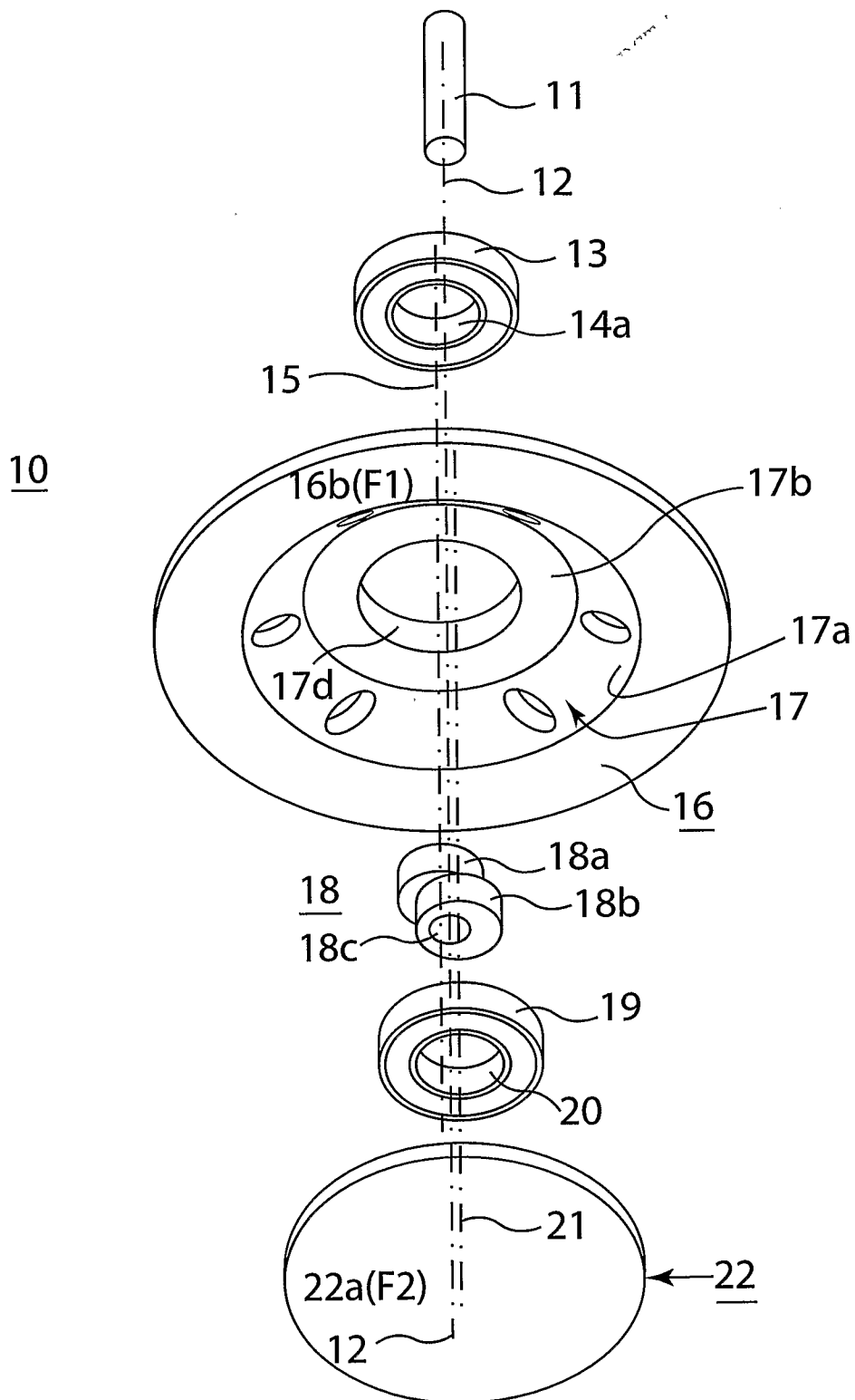


Fig.2

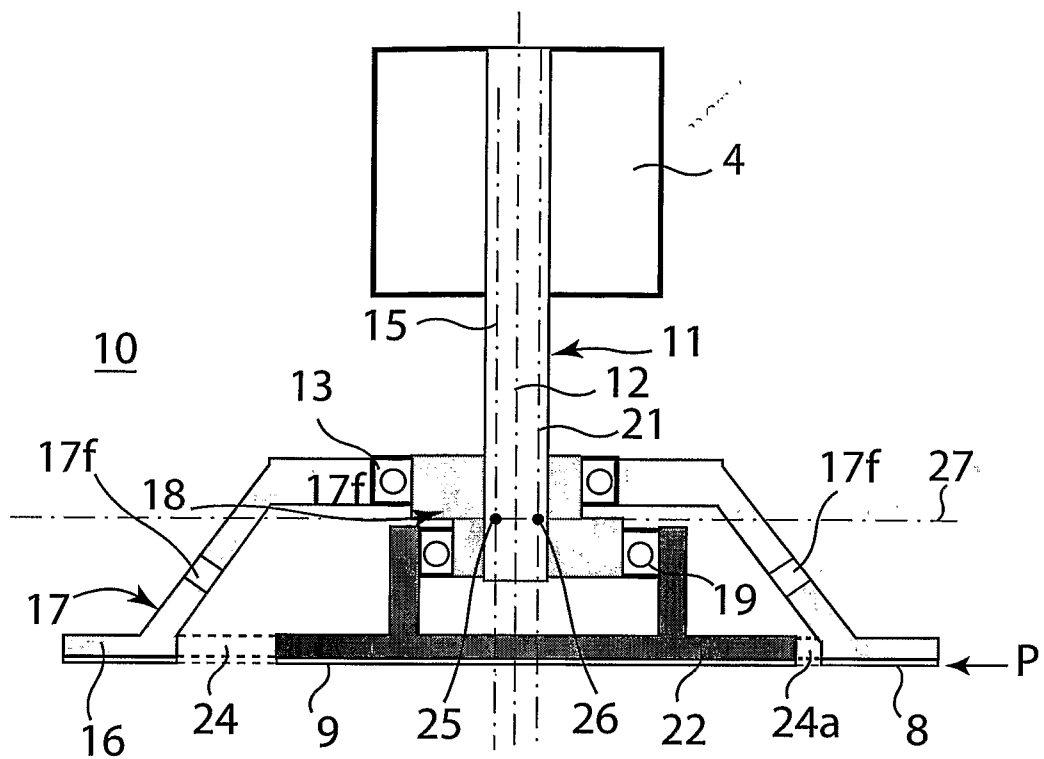


Fig.5

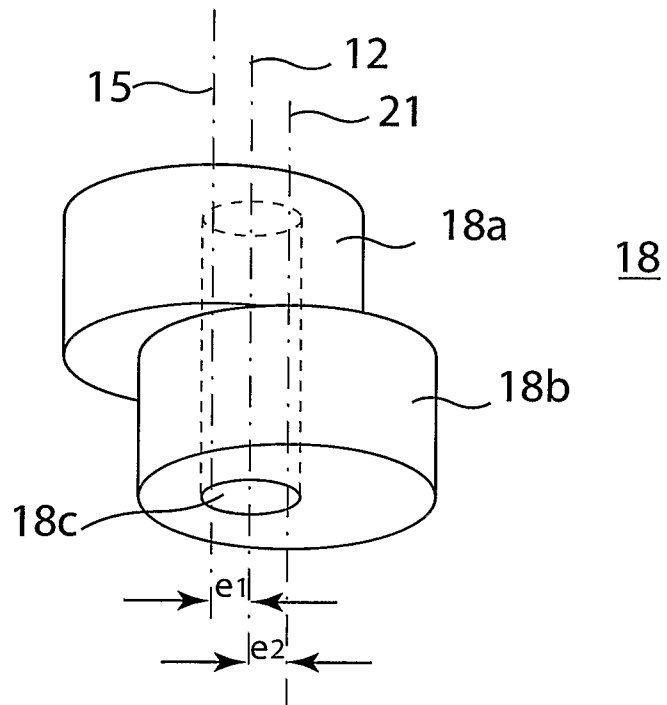


Fig.6

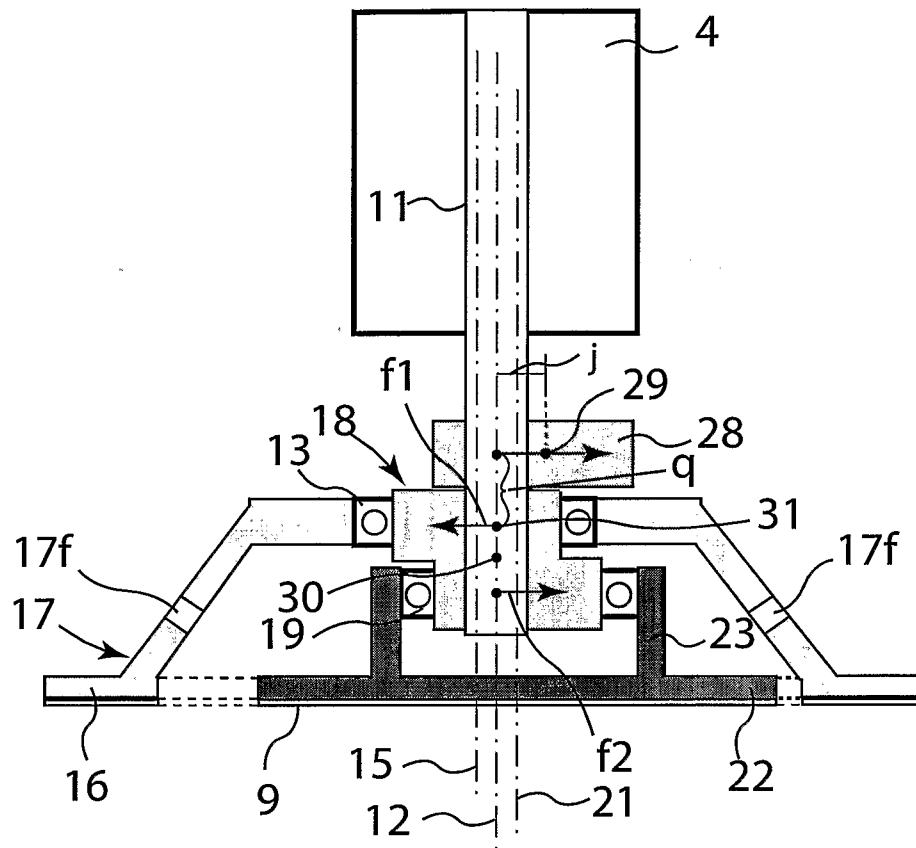


Fig.7

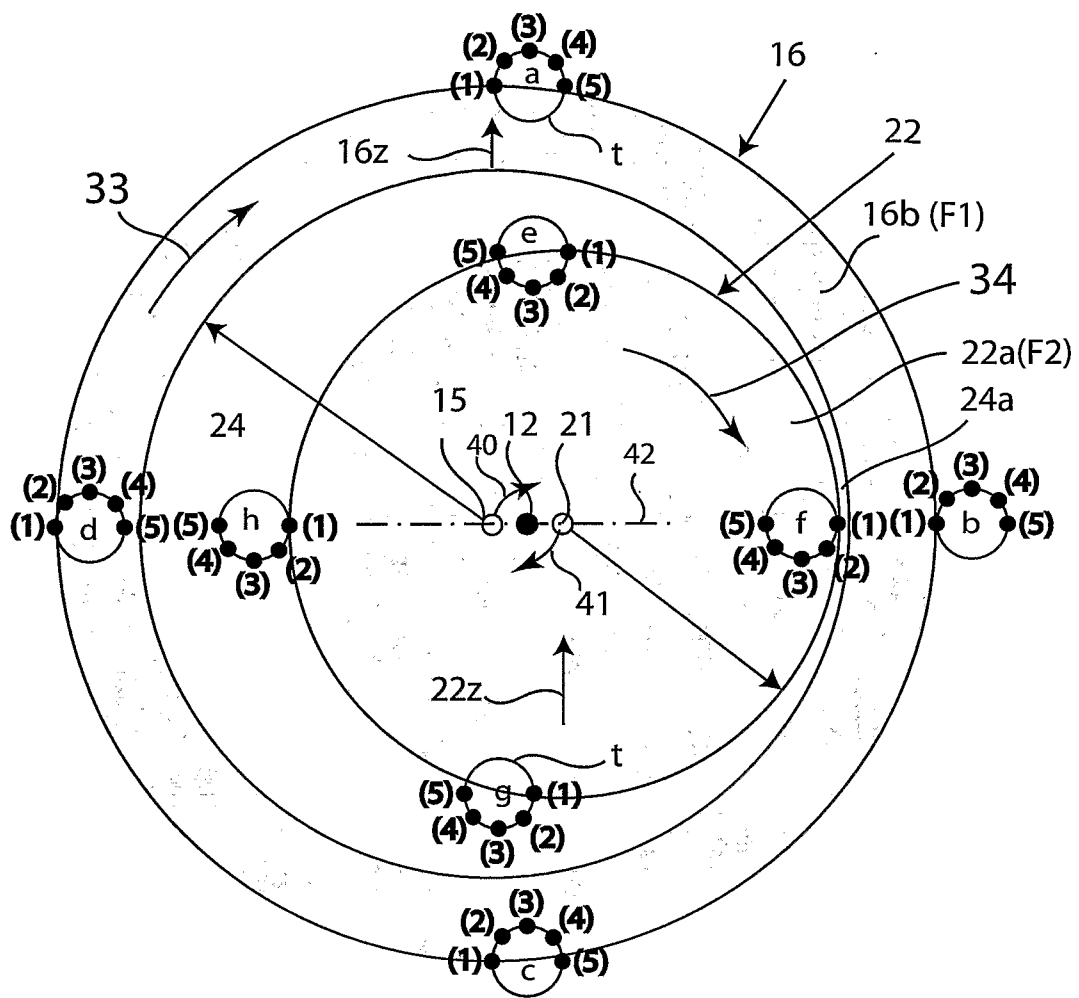


Fig.8

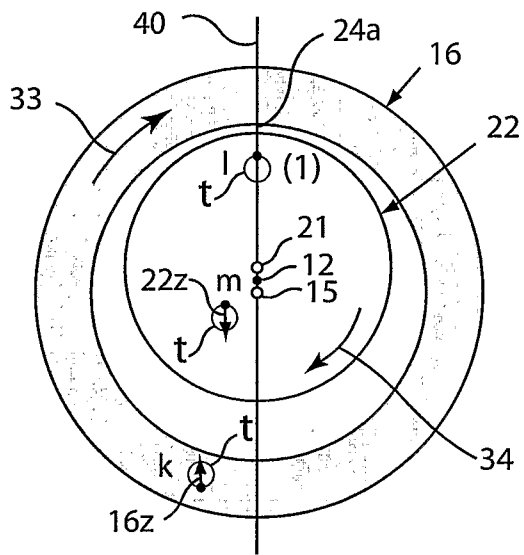


Fig.9

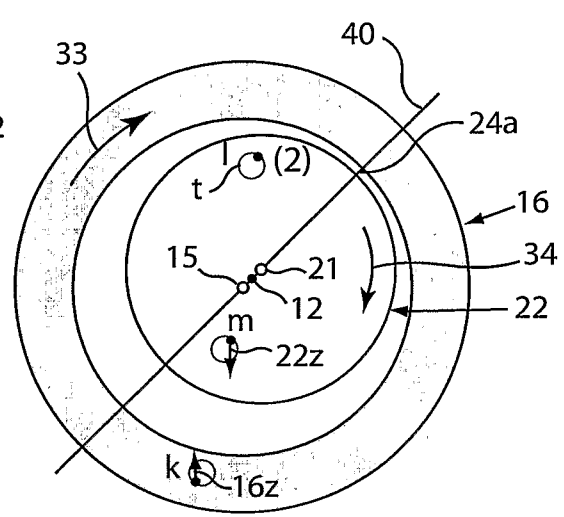


Fig.10

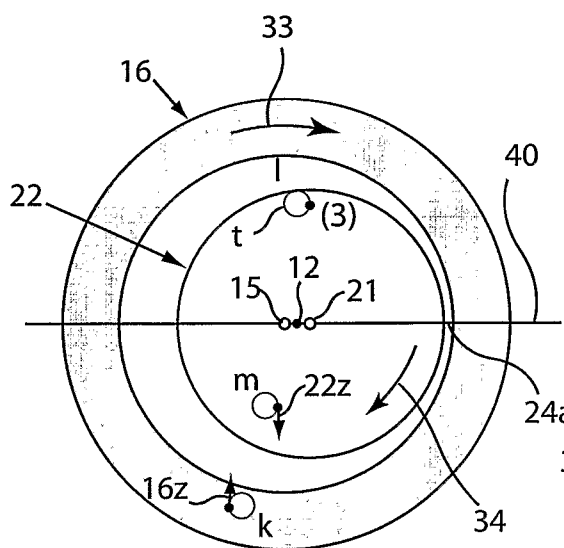


Fig.11

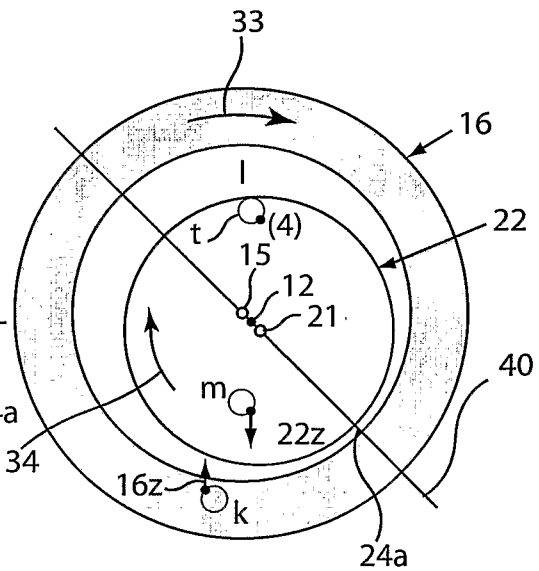
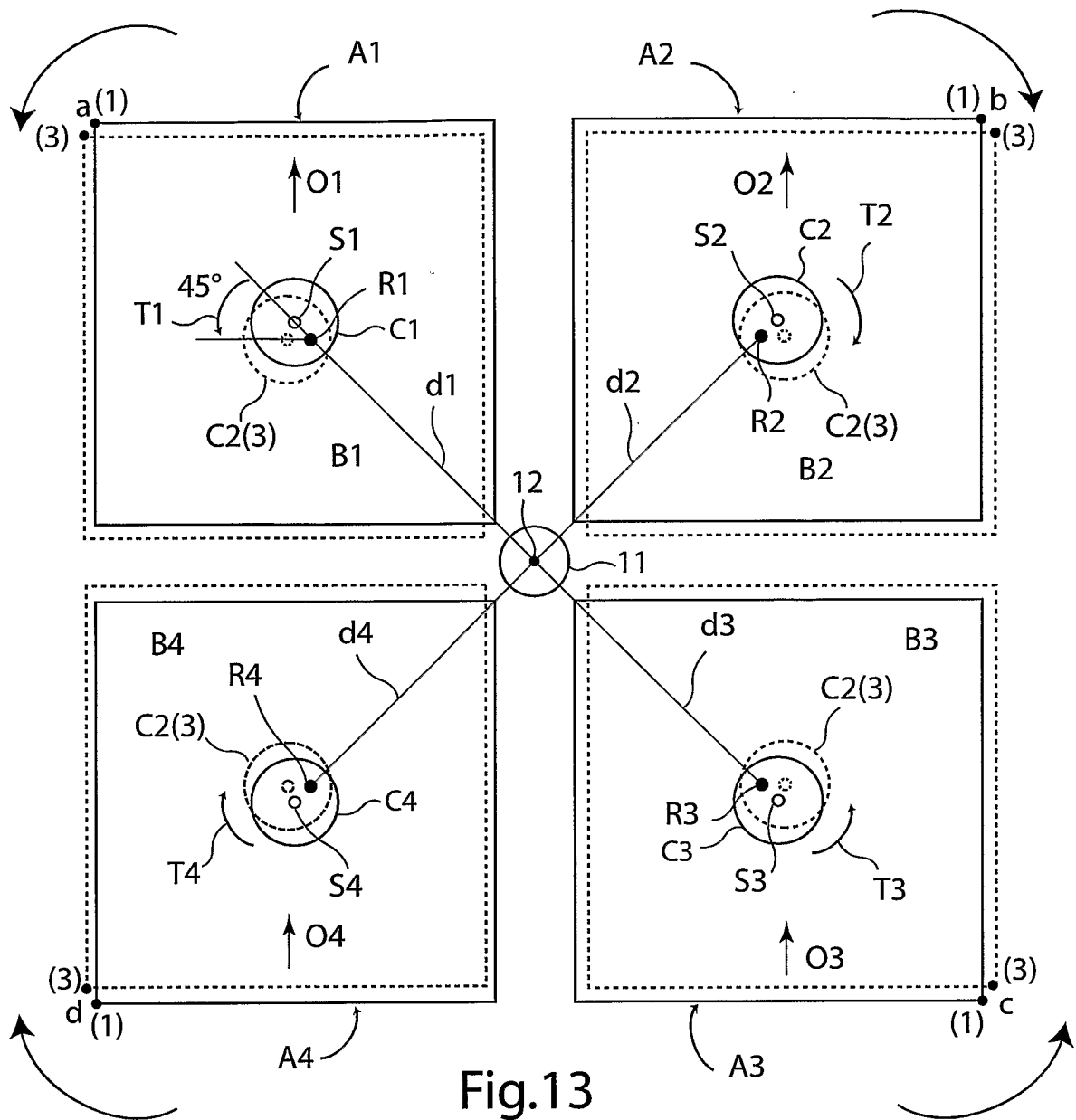


Fig.12



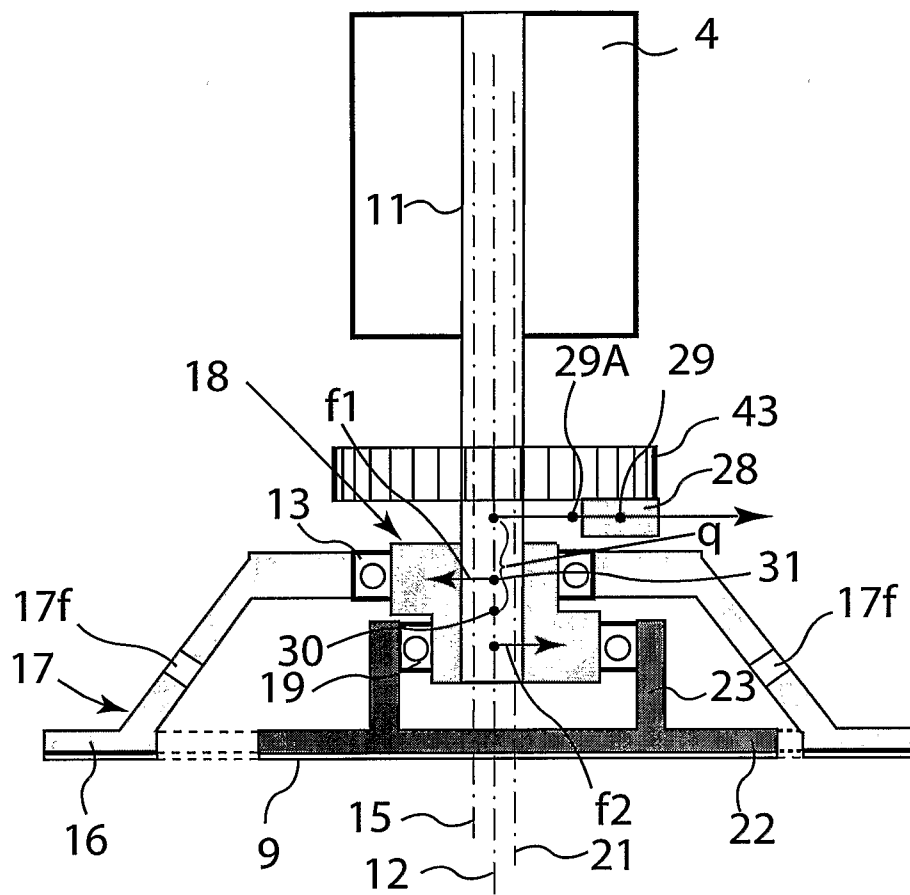


Fig.14

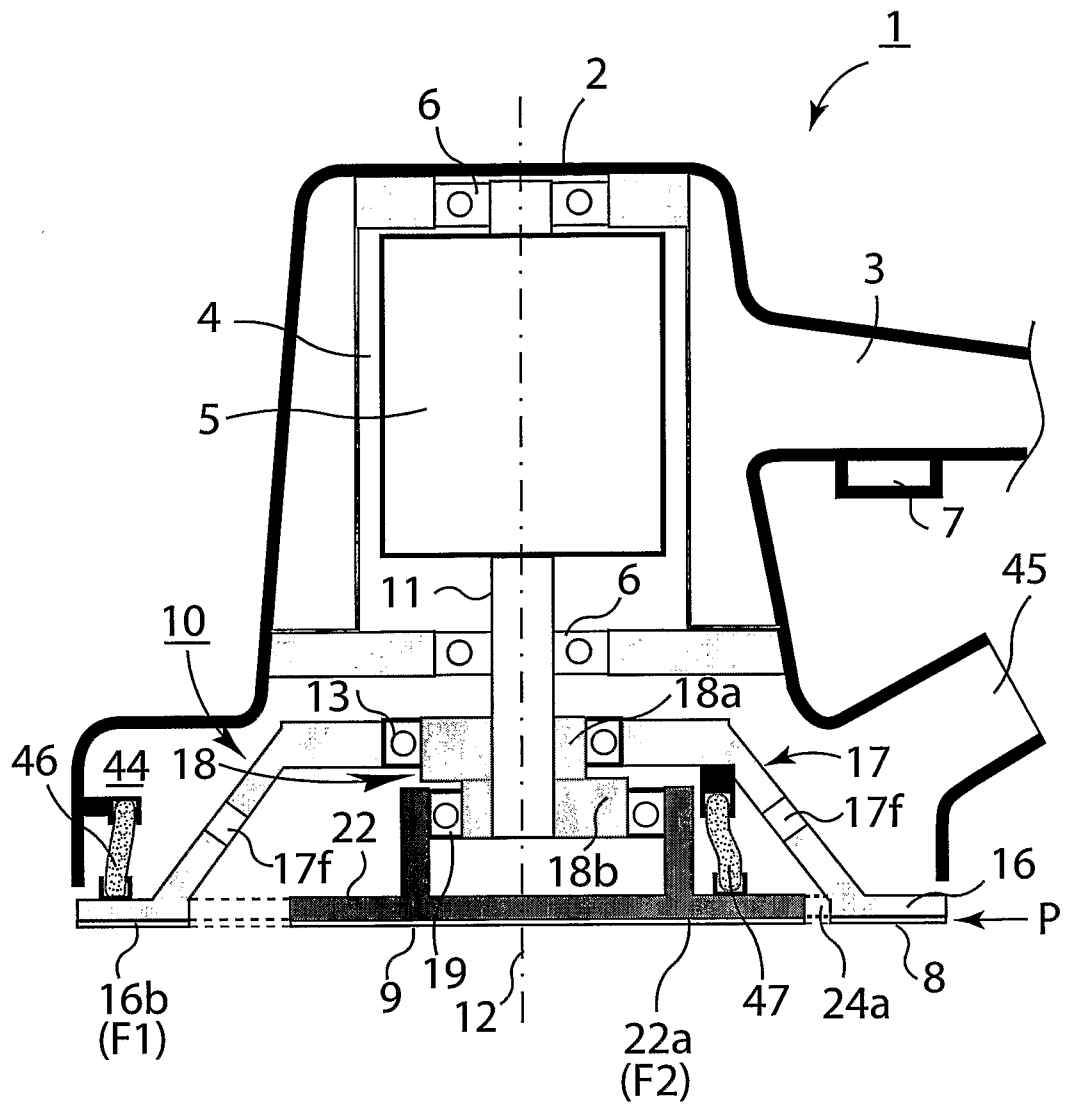


Fig.15

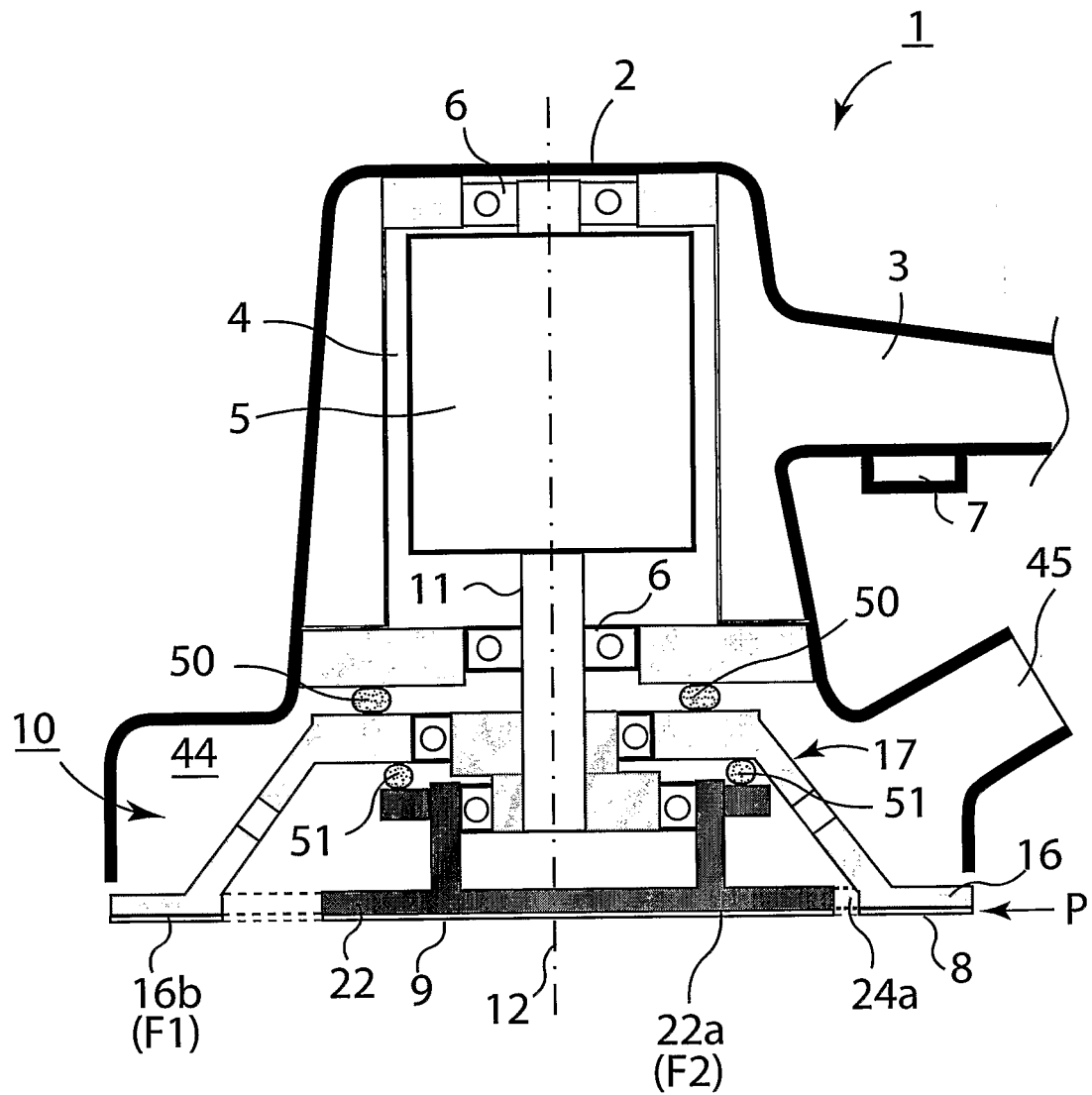


Fig.16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2005/000930

A. CLASSIFICATION OF SUBJECT MATTER

B24B23/03 (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)

IPC⁸ B24B23+, B24B7+, B24B15+, B24B27+

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

Chinese Invention 1985-2006, Chinese Utility Models 1985-2006

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

WPI EPODOC PAJ : vibrat+, oscillat+, shock, orbit+, eccent+, center, shaft, axle, axis

CNPAT: vibrate, orbit, eccentric, axis

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP, A, 2002-233941 (MAKITA CORP) 20 Aug. 2002 (20.08.2002), see column 2, line 6-column 4, line 15, figures 1,2	1,24,25,27
X	WO,A1, 2004-085114 (TECHNOLOGY PARTNERSHIP PUBLIC LIMITED COMPANY) 7 Oct. 2004 (07.10.2004), see page 3, line 24-page 4, line 28, figures 1-5	1,24,25,27
X	US,A, 2759305 (CYCLO MFG COMPANY) 21 Aug. 1956 (21.08.1956), see column 3, line 59-column 12, line 36, figures 1-15	1,24,25,27
X	EP, A1, 1300218 (TECHNOLOGY PARTNERSHIP PUBLIC LIMITED COMPANY) 9 Apr. 2003 (09.04.2003), see column 2, line 47-column 3, line 33, figures 1-4	1,24,25,27
A	CN, A, 1288406 (BOSCH GMBH ROBERT) 21 Mar. 2001 (21.03.2001), see the whole document	1
A	CN, A, 1169902 (BOSCH GMBH ROBERT) 11 Jan. 1998 (11.01.1998), see the whole document	1

☐ 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
24 Mar. 2006 (24.03.2006)

Date of mailing of the international search report

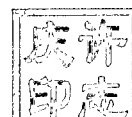
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XU, Zhiqing

Telephone No. 86-10-62085454



INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2005/000930

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