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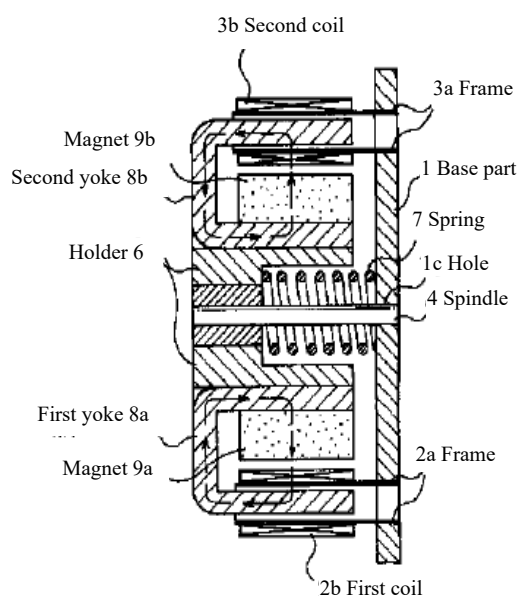
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(54) [Title of Invention] VIBRATION ACTUATOR

(57) [Abstract]

[Object] To realize a vibration actuator having high vibration generation efficiency and high vibration transmission efficiency, which is capable of generating vibration at an arbitrary frequency and at an accurate amplitude.

[Constitution] A vibration actuator comprising: a first and second coil wound so as to protrude above a base part; a spindle supported by a center part of the base part so as to be parallel to the two coils; a first yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the first coil and another end opposes a side surface of the first coil; a second yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the second coil and another end opposes a side surface of the second coil; a magnet provided on respective surfaces wherein the first and second yoke oppose the first and second coil and magnetized in an opposing direction; and an elastic body arranged between the holding means and the base part, the elastic body positioning the holding means so that the coil and the magnet are in opposing positions.



[Scope of Patent Claims]

[Claim 1] A vibration actuator comprising:

a first and second coil wound so as to protrude above a base part;

a spindle supported by a center part of the base part so as to be parallel to the two coils;

a first yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the first coil and another end opposes a side surface of the first coil;

a second yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the second coil and another end opposes a side surface of the second coil;

and a magnet provided on respective surfaces wherein the first and second yoke oppose the first and second coil and magnetized in an opposing direction.

[Claim 2] A vibration actuator comprising: a first and second coil wound so as to protrude above a base part;

a spindle supported by a center part of the base part so as to be parallel to the two coils;

a first yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the first coil and another end opposes a side surface of the first coil;

a second yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the second coil and another end opposes a side surface of the second coil;

a magnet provided on respective surfaces wherein the first and second yoke oppose the first and second coil and magnetized in an opposing direction; and an elastic body arranged between the holding means and the base part, the elastic body positioning the holding means so that the coil and the magnet are in opposing positions.

[Claim 3] A vibration actuator comprising: a first and second coil wound so as to protrude above a base part;

a spindle supported by a center part of the base part so as to be parallel to the two coils;

a first yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the first coil and another end opposes a side surface of the first coil;

a second yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the second coil and another end opposes a side surface of the second coil; and

a magnet provided on respective surfaces wherein the first and second yoke oppose the first and second coil and magnetized in an opposing direction; wherein the holding means is arranged between the spindle and

the yoke and is composed of a holder positioning the first and second yoke so that the coil and the magnet are in opposing positions; and a diaphragm.

[Detailed Description of Invention]

[0001]

[Industrial Applicability] The present invention relates to a moving magnet-type vibration actuator, and more particularly to a moving magnet-type vibration actuator having low loss and high efficiency.

[0002]

[Conventional Art] A vibration actuator is a device that generates vibration in response to an externally supplied current. The vibration actuator is sometimes used as a vibration canceller which cancels out vibration of a main device by generating vibration in an opposite phase to that generated by the main device. It may also be used as vibration generation means for a pager.

[0003] Herein, a description is given of the current state of vibration generation means in pagers and the problems therein. Two types of calling methods are used in pagers: sound-based calling and vibration-based calling. Sound-based calling is designed to generate sound intermittently and to gradually increase in volume. This is achieved by changing the current (voltage) supplied to a speaker, buzzer (oscillator), or the like.

[0004] In vibration-based calling, a vibration motor with an unbalanced weight attached to the rotor is generally used as vibration generation means. The vibration motor generates the necessary vibration by rotating an unbalanced weight attached to a front end of the rotor. A small DC motor capable of being driven by a pager battery is used as the vibration motor.

[0005]

[Technical Problem] However, a vibration motor with the above configuration has the following problems. Cylindrical or flat type DC motors are used, but in order to generate sufficient vibration that can be felt by a user, it is necessary to use a motor that rotates at high speed and with sufficient torque. However, while the demand for thinner and smaller pagers necessitates the use of smaller motors, significantly smaller motors cannot generate sufficient vibration. Therefore, in order to generate sufficient vibration, motors which are somewhat larger must be used. For this reason, some extremely thin pagers do not offer a vibration-based calling mode, and only sound-based calling is available.

[0006] Furthermore, since a DC motor is used as vibration generation means, brushes and other components have a certain lifespan. This makes it impossible to maintain stable performance over a long period of time. In practice, there are problems such as fluctuations in rotation speed over time. Furthermore, there is a problem with DC motors in that electrical noise from the brush parts is generated over a wide frequency band.

[0007] Moreover, in DC motors, the rated speed is fixed, and it is difficult to arbitrarily change the rotation speed if the applied voltage is constant. Therefore, the vibration frequency is determined by the rotation speed, and this vibration frequency cannot be changed. Naturally, in addition to this, neither can the amplitude of vibration be changed. As such, it cannot be changed in any way, even when slow vibrations at low frequency or low amplitude are desired, or when it is desired to gradually increase the amplitude of vibration to ensure a reliable call. Generation of intermittent vibration and the like are also not supported. Thus, there are only a series of vibrations at a constant amplitude.

[0008] Furthermore, since vibration is generated by rotation, it also includes vibration in directions other than those the user is sensitive to (directions perpendicular to the surface of the human body). Therefore, although the efficiency of converting electricity into rotational motion is high, the effective acting force from among the generated vibration is weak and vibration transmission efficiency is low.

[0009] There are brushless motors which do not use brushes despite being driven by DC. However, it is not possible to change the rotation speed in brushless motors, either. Furthermore, these brushless motors require a dedicated electronic circuit for generating a rotating magnetic field, and are inefficient and unsuitable for pagers, which are required to be small and thin.

[0010] A vibration actuator combining an electromagnet and a magnet using a solenoid coil may also be considered. In this case, a non-excitation holding force is exerted wherein the magnet tries to adhere to the iron core of the solenoid coil and stay at a predetermined position. Therefore, the vibration actuator begins to move only when a force greater than this non-excitation holding force is applied. This loss due to the non-excitation holding force has a significant effect when generating low-amplitude vibrations, and there is a problem in that it is difficult to obtain accurate vibrations for minute inputs.

[0011] In view of the foregoing problems, an object of the present invention is to provide a vibration actuator having high vibration generation efficiency and high vibration transmission efficiency, which is capable of generating vibration at an arbitrary frequency and amplitude, and which responds accurately to minute inputs.

[0012]

[Solution to Problem] As a result of intensive research to improve defects expected in conventional vibration actuators, the inventor of the present application has arrived at a configuration capable of eliminating loss caused by non-excitation holding force and has completed the present invention.

[0013] Accordingly, the present invention, which is means for solving the problem, is configured as described below.

(1) Namely, the first means of solving the foregoing problem is a vibration actuator provided with: a first and second coil wound so as to protrude above a base part; a spindle supported by a center part of the base part so as to be parallel to the two coils; a first yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the first coil and another end opposes a side surface of the first coil; a second yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the second coil and another end opposes a side surface of the second coil; and a magnet provided on respective surfaces wherein the first and second yoke oppose the first and second coil and magnetized in an opposing direction.

[0014] (2) Furthermore, the second means of solving the foregoing problem is a vibration actuator provided with: a first and second coil wound so as to protrude above a base part; a spindle supported by a center part of the base part so as to be parallel to the two coils; a first yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the first coil and another end opposes a side surface of the first coil; a second yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the second coil and another end opposes a side surface of the second coil; a magnet provided on respective surfaces wherein the first and second yoke oppose the first and second coil and magnetized in an opposing direction; and an elastic body arranged between the holding means and the base part, the elastic body positioning the holding means so that the coil and the magnet are in opposing positions.

[0015] (3) Furthermore, the third means of solving the foregoing problem is a vibration actuator comprising: a first and second coil wound so as to protrude above a base part; a spindle supported by a center part of the base part so as to be parallel to the two coils; a first yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the first coil and another end opposes a side surface of the first coil; a second yoke supported by the spindle via holding means so as to be movable in an axial direction and arranged so that one end forms a core of the second coil and another end opposes a side surface of the second coil; and a magnet provided on respective surfaces wherein the first and second yoke oppose the first and second coil and magnetized in an opposing direction; wherein the holding means is arranged between the spindle and the yoke and is composed of a holder positioning the first and second yoke so that the coil and the magnet are in opposing

positions; and a diaphragm.

[0016]

[Effect] In the vibration actuator which is the first means of solving the problem, a magnetic circuit is formed by a path of: the magnet opposing the first coil - the first coil - the first yoke. Furthermore, a magnetic circuit is formed by a path of: the magnet opposing the second coil - the second coil - the second yoke.

[0017] When an electric current is sent to the coil in this magnetic circuit, thrust is generated in the yoke on which the magnet is provided as a reaction to the thrust generated in the coil, and the yoke moves in the axial direction of the spindle via the holding means. If the current supplied to the coil is an alternating current, the yoke and base part vibrate according to the waveform of the current.

[0018] In this configuration, the magnet and yoke are integrated in each magnetic circuit, so no non-excitation holding force is exerted, and accurate vibration is generated even for micro input. In the vibration actuator which is the second means of solving the problem, a magnetic circuit is formed by a path of: the magnet opposing the first coil - the first coil - the first yoke. Furthermore, a magnetic circuit is formed by a path of: the magnet opposing the second coil - the second coil - the second yoke.

[0019] When an electric current is sent to the coil in this magnetic circuit, thrust is generated in the yoke on which the magnet is provided as a reaction to the thrust generated in the coil, and the yoke moves in the axial direction of the spindle via the holding means positioned by the elastic body. If the current supplied to the coil is an alternating current, the yoke and base part vibrate according to the waveform of the current.

[0020] In this configuration, the magnet and yoke are integrated in each magnetic circuit, so no non-excitation holding force is exerted, and accurate vibration is generated even for micro input. In the vibration actuator which is the third means of solving the problem, a magnetic circuit is formed by a path of: the magnet opposing the first coil - the first coil - the first yoke. Furthermore, a magnetic circuit is formed by a path of: the magnet opposing the second coil - the second coil - the second yoke.

[0021] When an electric current is sent to the coil in this magnetic circuit, thrust is generated in the yoke on which the magnet is provided as a reaction to the thrust generated in the coil, and the yoke moves in the axial direction of the spindle via the holder positioned by the diaphragm. If the current supplied to the coil is an alternating current, the yoke and base part vibrate according to the waveform of the current.

[0022] In this configuration, the magnet and yoke are integrated in each magnetic circuit, so no non-excitation holding force is exerted, and accurate vibration is generated even for micro input.

[0023]

[Embodiments] An embodiment of the present invention

will be described using drawings. FIG. 1 is a cross-sectional view of an embodiment of the present invention, and FIG. 2 is a front view of an embodiment of the present invention. FIG. 1 is a cross-sectional view illustrating cross section A-A in FIG. 2. FIG. 3 is a cross-sectional view illustrating cross section B-B in FIG. 1.

[0024] In these drawings, a base part 1 is a member for holding the coil and spindle (described later) in a predetermined position. A hole 1c for mounting the spindle (described later) is provided near the center of the base part 1.

[0025] A first coil 2b is a solenoid coil wound around a frame 2a. The frame 2a is fixed to one end of the base part 1. A second coil 3b is a solenoid coil wound around a frame 3a. The frame 3a is fixed to the other end of the base part 1.

[0026] A spindle 4 is mounted in the hole 1c provided in the center part of the base part 1. A holder 6 is provided so as to be movable in an axial direction of the spindle 4 via a bearing 5. Furthermore, the bearing 5 and the holder 6 constitute the holding means and hold the yoke (described later).

[0027] A spring 7 is provided to maintain the holder 6 in a predetermined position (for example, magnetically neutral position) when it is not vibrating. Furthermore, the spring 7 can be replaced by an elastic substance (such as rubber, a coil spring, a plate spring, or an air spring) and is configured so as to be affixed to the holder 6 or to both of the holder 6 and the base part 1.

[0028] A first yoke 8a and a second yoke 8b are composed of a plate-shaped magnetic body and are mounted on the holder 6. Furthermore, one end part of each yoke is provided so as to compose the core of the first coil 2 and the second coil 3, respectively. Moreover, the other end part of each yoke is provided so as to be in a position opposing a side surface of the first coil 2 and the second coil 3, respectively. In addition to a ferromagnetic metal, it is also possible to use various non-magnetic materials mixed with ferromagnetic powders as the material of the above magnetic body.

[0029] A magnet 9a is provided on the first yoke 8a on a part opposing the first coil 2b and is magnetized in an opposing direction. A magnet 9b is provided on the second yoke 8b on a part opposing the second coil 3b and is magnetized in an opposing direction.

[0030] Therefore, a magnetic circuit is formed by a path of: the magnet opposing the first coil - the first coil - the first yoke. Furthermore, a magnetic circuit is formed by a path of: the magnet opposing the second coil - the second coil - the second yoke. This magnetic flux is shown by broken lines in FIG. 1 and FIG. 5.

[0031] Next, the operation of a vibration actuator having the above configuration will be described. When a current in a predetermined direction is sent to the first coil 2b and the second coil 3b, thrust is generated according to Fleming's left-hand rule in the first coil 2b and second coil 3b arranged in the magnetic circuit described above. Then, as a reaction to the thrust, the

movable elements (the holder 6, the bearing 5, the yokes 8a and 8b, and the magnets 9a and 9b) try to move.

[0032] Therefore, when an alternating current is sent to the first coil 2b and the second coil 3b, the movable elements generate vibration according to a current waveform. Furthermore, since the movable elements have magnets and a certain amount of weight, the base part 1 side also generates vibration in a direction opposite to that of the movable elements.

[0033] For example, by sending an alternating current of an audible frequency of about 3000 Hz to the first coil 2b and the second coil 3b, the yokes 8a and 8b and the holder 6 act as a speaker diaphragm to generate sound. In this case, various sounds can be generated by changing the frequency and an amplitude thereof, or by generating sound intermittently. This allows for sound-based calling in a pager.

[0034] Furthermore, the movable elements (the holder 6, the bearing 5, the yokes 8a and 8b, and the magnets 9a and 9b) vibrate when a current of a frequency lower than an audible frequency of about several dozen to 100 Hz is sent to the first coil 2b and the second coil 3b. However, because the movable elements have a certain amount of weight, the base part 1 also vibrates. The vibration of the base part 1 vibrates the entire pager and can transmit the vibration to the user. Furthermore, the vibration is only in a direction perpendicular to the base part 1, which is a direction in which the vibration is easily felt by the user when used in a thin pager. Therefore, use of the vibration is efficient.

[0035] Thus, a single vibration actuator can be used in the pager to perform sound-based and vibration-based calling, and to generate efficient vibration.

[0036] In this configuration, the magnet and yoke are integrated in each magnetic circuit, so no non-excitation holding force is exerted, and accurate vibration is generated even for micro input. Therefore, in the above case, it is suitable for generating various sounds and vibrations by changing the frequency and an amplitude thereof, or by intermittently generating an electric current, and the like.

[0037] FIG. 4 is a waveform diagram illustrating a current waveform in this case. FIG. 4 (a) to (e) shows an example of a current waveform from a signal generating part. Known signal generators can be used as the signal generating part. FIG. 4 (a) is a current waveform when sound is generated, wherein a current of a frequency of several hundred to several thousand Hz is generated intermittently and with varying amplitudes. A current of such a waveform is supplied to the first coil 2 and the second coil 3 to ensure that the yoke 8 vibrates and a reliable call can be made wherein the sound gradually gets louder.

[0038] FIG. 4 (b) is a current waveform when vibration is generated, wherein a current of a frequency of several dozen to several hundred Hz is generated continuously. A current of such a waveform is supplied to the first coil 2 and the second coil 3 to ensure that the base part 1 vibrates, thus enabling a call to be made. Note that

although a sine wave is shown here, various other AC waveforms can be used.

[0039] FIG. 4 (c) is a current waveform when vibration is generated, wherein a current of a frequency of several dozen to several hundred Hz is generated intermittently. A current of such a waveform is supplied to the first coil 2 and the second coil 3 to ensure that the base part 1 vibrates intermittently, thus enabling a reliable call to be made.

[0040] FIG. 4 (d) is a current waveform when vibration is generated, wherein a current of a low frequency of around several dozen Hz is generated continuously. A current of such a waveform is supplied to the first coil 2 and the second coil 3 to ensure that the base part 1 vibrates slowly, thus enabling a call to be made by a soft vibration during the initial time of the call or the like.

[0041] FIG. 4 (e) is a current waveform when vibration is generated, wherein a current of a low frequency of around several dozen to several hundred Hz is generated intermittently with varying amplitude. The base part 1 vibrates intermittently and so that the amplitude gradually increases when a current of such a waveform is supplied to the first coil 2 and the second coil 3, and a reliable call can be made wherein vibrations are small in the initial stage of calling and vibrations are larger later on.

[0042] Furthermore, although not shown in the FIGS., it is also possible to combine sound and vibration by superimposing the current waveform in FIG. 4 (a) and the current waveforms in FIG. 4 (b) onwards. Thus, by making the vibration intermittent, changing the frequency of the vibration, and changing the amplitude (intensity of the vibration), it is possible to make various changes to the vibration as in the case of sound. Additionally, various types of vibrations other than the above can be produced as desired by further combining the above current waveforms.

[0043] These various vibrations can be switched at the user's choice by a selection in the pager's control unit. The vibration can also be configured to be selected arbitrarily according to settings from the caller side.

[0044] Furthermore, use of a spring 7 that determines a position of the yoke when it is at rest allows quick convergence of the vibration of the yoke when the alternating current is no longer supplied. Efficiency is high in the configuration of the present embodiment since no non-excitation holding force is exerted as described above. However, it is necessary to hold the movable elements in place in a predetermined position. For this reason, the spring 7 is used. Additionally, the spring 7 acts without impairing efficiency even during micro vibration of the movable elements.

[0045] In addition to the spring 7 and various elastic materials, it is also possible to use, for example, means for determining a stationary position of the yoke 8 using magnetic force. By using such stationary positioning means for determining a stationary position and not preventing movement, more accurate vibration in accordance with the current waveform can be achieved.

[0046] Therefore, according to the above configuration, in terms of vibration transmission efficiency, use (transmission) of vibrations is highly efficient since, instead of rotation-based vibration, vibration is generated in a direction in which the vibration is directly felt by the user.

[0047] Vibration generation efficiency: Since each yoke forms the magnetic loop having the shortest path, loss is small and higher efficiency can be obtained compared to a conventional device. Additionally, since no non-excitation holding force is exerted, efficiency is extremely high and accurate vibration can be generated even during generation of micro vibration.

[0048] Thinness and smallness: Since the invention is composed of a coil on a base part and movable elements having yoke that also serves as a core of the coil, it is thinner, smaller, and lighter than motors and other devices. Therefore, it is suitable for thin pagers and vibration-based calling can be achieved even in very thin pagers in which only sound-based calling had been possible. Additionally, since a single vibration actuator generates both sound and vibration, there is no need for a dedicated sound generating means (such as a speaker) in the pager, thus enabling miniaturization. Furthermore, as a vibration canceller, it can be arranged precisely at a desired point due to its small size.

[0049] Long life: An alternating current is only supplied to the coil, thus eliminating the need for high-speed sliding parts such as brushes, commutators, and the like to achieve a long lifespan. Therefore, stable sound and vibration can be generated over a long period of time, and no aging problems occur. In addition, DC motors generate electrical noise from brushes, but the present vibration actuator has no such problem.

[0050] Vibration mode: By selecting the current waveform supplied to the coil, an arbitrary frequency and amplitude, and intermittent or continuous vibration can be generated. Accordingly, since arbitrary vibrations can be generated where in the conventional device vibration can only be turned on and off, it is possible to use the vibration to transmit a message determined upon in advance between the related parties.

[0051] Note that while in the embodiment described above, the holding means is composed of the bearing 5 and the holder 6, it is possible to use a material having a low friction coefficient as the holder 6 to provide a holding means which is movable in an axial direction with respect to the spindle 4, thereby eliminating the use of a bearing. Furthermore, a variation is also possible wherein the holder 6 and the spindle 4 are affixed to each other and the bearing 5 is provided between the spindle 4 and the base part 1.

[0052] FIG. 5 is a cross-sectional view of a vibration actuator in another embodiment of the present invention. The same parts as those in the embodiments already described using FIG. 1 to FIG. 4 are marked with the same numbers in FIG. 5, and overlapping descriptions of such are omitted. In the vibration actuator illustrated in FIG. 5, the spindle 4 is mounted in the hole 1c in the base

part 1, and a disk-shaped diaphragm 11 constituting the elastic body is provided in the spindle 4. The holder 6 is attached to a periphery of the diaphragm 11.

[0053] That is, in the present embodiment, the holder 6 is configured so as to be movable in an axial direction by the diaphragm 11 instead of the spring 7 in the previous embodiment. Thus, the diaphragm 11 realizes the functions of the bearing and spring in the embodiment described above. A diaphragm made of metal, resin, or various other materials can be used as the diaphragm 11.

[0054] In the present embodiment, the magnetic circuit having the shortest path is formed in each yoke, resulting in high efficiency. Furthermore, accurate micro vibrations can be obtained without exertion of a non-excitation holding force. In the present embodiment, the diaphragm 11 also functions to maintain the holder 6 in a predetermined position when the holder 6 is not vibrating. The diaphragm 11 may also be composed of various elastic materials (such as rubber, a coil spring, a plate spring, or an air spring) in addition to the diaphragm, and it is sufficient if the diaphragm 11 is capable of holding the spindle 4 and holder 6 in a predetermined position while allowing them to vibrate and allowing quick convergence of the vibration when the current is no longer supplied. This ensures accurate vibration in accordance with the current waveform.

[0055] Accordingly, in the configuration illustrated in FIG. 5, when a current in a predetermined direction is sent to the first coil 2b and the second coil 3b, thrust is generated according to Fleming's left-hand rule in the first coil 2b and second coil 3b arranged in the magnetic circuit described above. Then, as a reaction to the thrust, the movable elements (the holder 6, the yokes 8a and 8b, and the magnets 9a and 9b) try to move. Therefore, when an alternating current is sent to the first coil 2b and the second coil 3b, the movable elements generate vibration according to a current waveform. Furthermore, it can be set to an arbitrary frequency and amplitude for both sound and vibration.

[0056] Furthermore, since the movable elements have magnets and a certain amount of weight, the base part 1 side also generates vibration in a direction opposite to that of the movable elements. Moreover, the vibration of the base part 1 vibrates the entire pager and can transmit the vibration to the user. Additionally, the vibration is only in a direction perpendicular to the base part 1, which is a direction in which the vibration is easily felt by the user when used in a thin pager, and thus efficiency is high.

[0057] In addition to the above-described effects of ~, a new effect is conferred in this configuration wherein configuration can be simplified because bearings and springs are no longer required. FIG. 6 is a characteristic diagram wherein an embodiment of the present invention is used as an experimental example, in which an input power supplied to the coil and an acceleration obtained by the movable elements were measured. As is clear from the characteristic diagram, an accurate response is generated to input even via micro vibration.

[0058] FIG. 7 is a characteristic diagram wherein a typical configuration of a solenoid coil and a magnet is used as a comparative example, in which an input power supplied to the coil and an acceleration obtained by the movable elements were measured. As is clear from the characteristic diagram, an area is generated wherein an accurate response is not generated to input even via micro vibration. For example, an output is not obtained until the input is about 0.03 W. This section is the loss due to non-excitation holding force. Therefore, it can be seen that according to the conventional device, loss is generated and thus accurate micro vibrations are not obtained.

[0059] Consequently, according to the present invention, since no non-excitation holding force is exerted, efficiency is extremely high and accurate vibration can be generated even during generation of micro vibration. The above vibration actuator is suitable for pagers and vibration cancellers, but can also be used in various other applications using vibration. For example, in view of the characteristic wherein an arbitrary vibration can be generated, it can be used in applications such as actuators for measuring instruments.

[0060]

[Advantageous Effects of Invention] As described above, using a moving magnet type vibration actuator wherein magnets are arranged on respective side surfaces of each coil allows a vibration actuator to be realized in which the yoke and the base part vibrate according to the waveform of the electric current when a current is sent to the coil, which has high vibration transmission efficiency and is capable of generating vibration at an arbitrary frequency and amplitude. Furthermore, by allowing the yoke to also serve as the core for each coil, no non-excitation holding force is generated, and thus highly efficient and accurate vibration can be achieved.

[0061] Additionally, a vibration actuator having a configuration wherein the elastic body and the diaphragm allow the yoke to vibrate is highly efficient and can generate vibrations of an arbitrary frequency and amplitude, making it possible to generate accurate vibrations in response to the waveform of the electric current.

[Brief Description of Drawings]

[FIG. 1] is a cross-sectional view of a vibration actuator in an embodiment of the present invention.

[FIG. 2] is a front view illustrating the front side of the vibration actuator illustrated in FIG. 1.

[FIG. 3] is a cross-sectional view illustrating a cross-section B-B of the vibration actuator illustrated in FIG. 1.

[FIG. 4] is a waveform diagram illustrating the current waveform supplied to the coil of the vibration actuator.

[FIG. 5] is a cross-sectional view of a vibration actuator in another embodiment of the present invention.

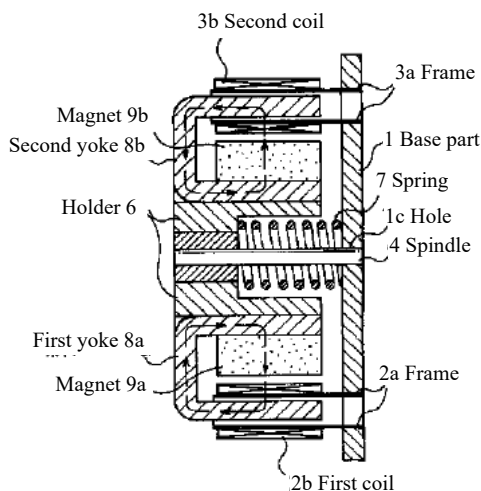
[FIG. 6] is a characteristic diagram illustrating characteristics according to an experimental example.

[FIG. 7] is a characteristic diagram illustrating characteristics according to a comparative example.

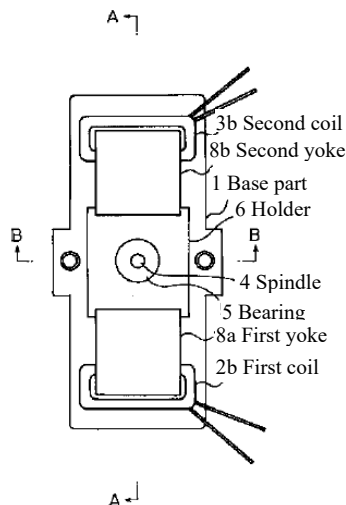
[Reference Signs List]

- 1 Base part
- 2b Second coil
- 3b Third coil
- 4 Spindle
- 5 Bearing
- 6 Holder
- 7 Spring
- 8a First yoke
- 8b Second yoke
- 9a, 9b Magnets

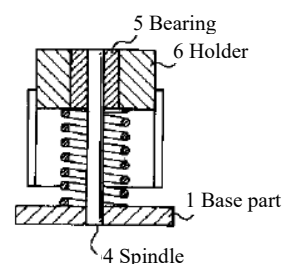
[FIG. 1]



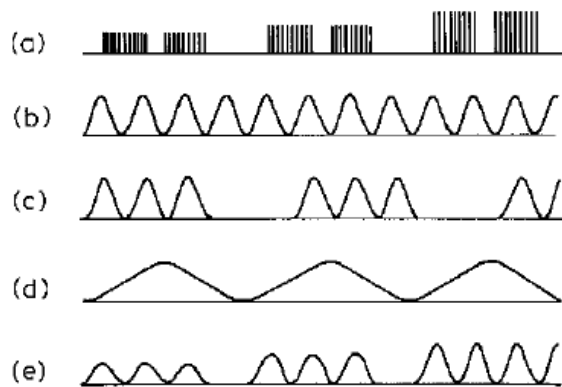
[FIG. 2]



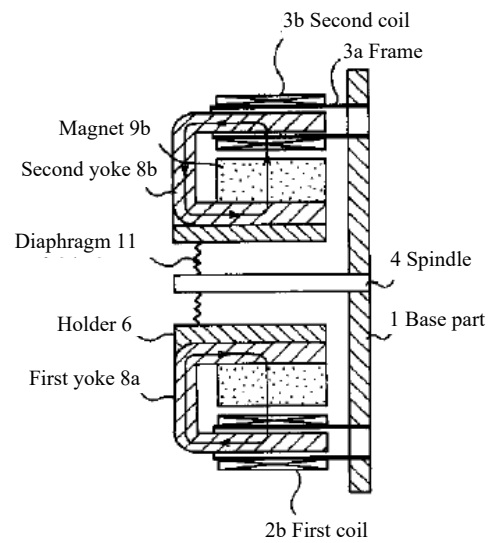
[FIG. 3]



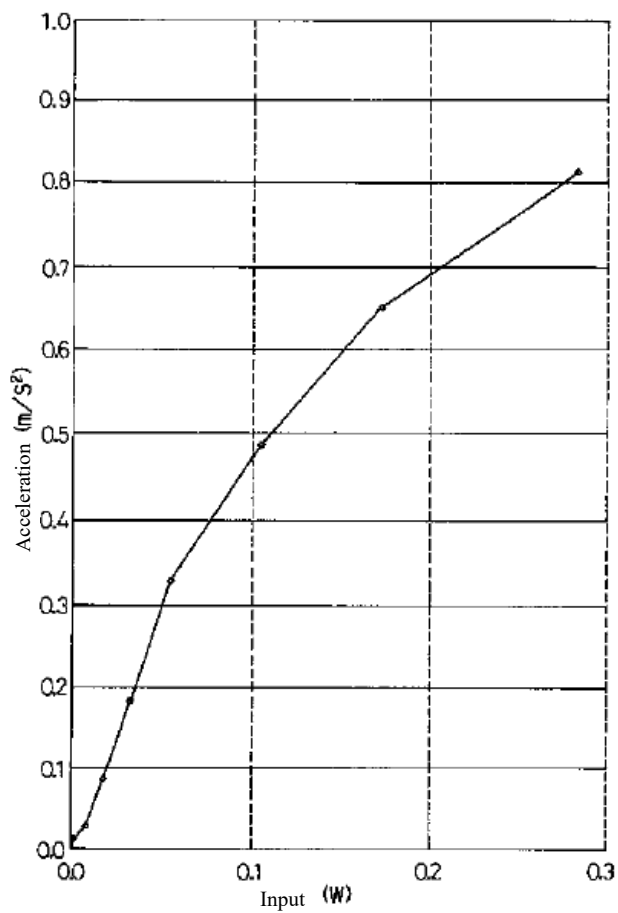
[FIG. 4]



[FIG. 5]



[FIG. 6]



[FIG. 7]

