ELECTROMECHANICAL TRANSDUCING DEVICE

Filed June 21, 1952 2 Sheets-Sheet 1

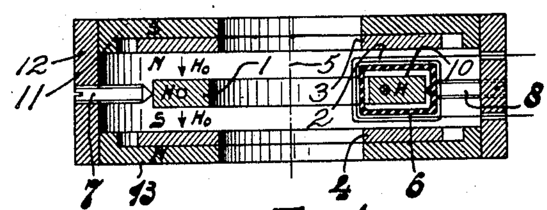

Fig. 1.

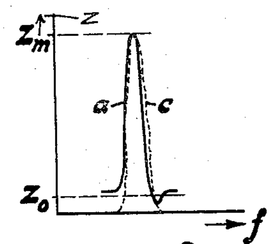

Fig. 2.

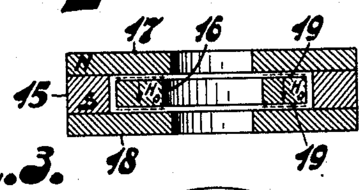

Fig. 3.

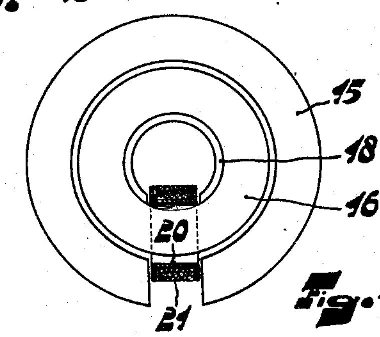

Fig. 4.

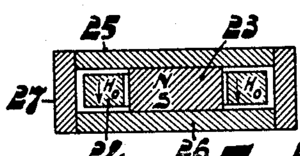

Fig. 5.

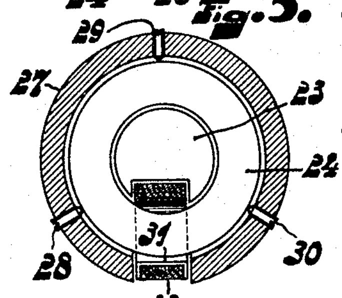

Fig. 6.

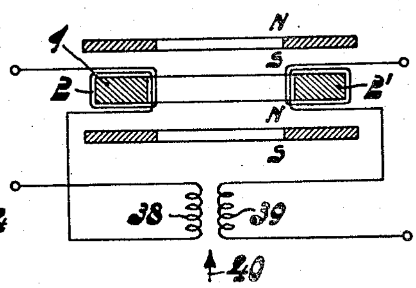

Fig. 7.

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ELECTROMECHANICAL TRANSDUCING DEVICE

Filed June 21, 1952 2 Sheets-Sheet 2

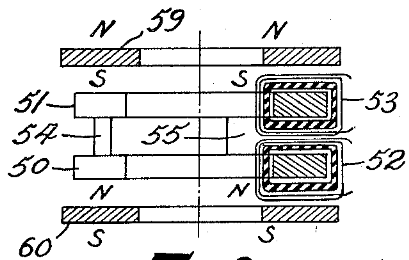

Fig. 8.

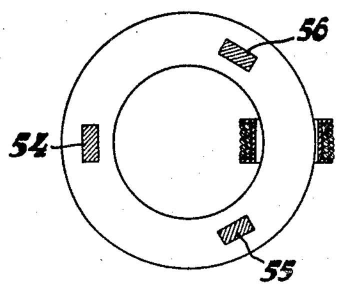

Fig. 9.

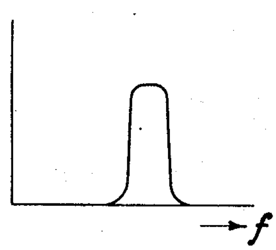

Fig. 10.

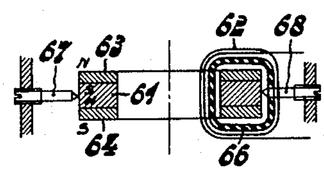

Fig. 11.

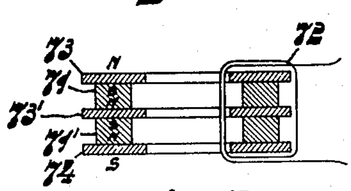

Fig. 12.

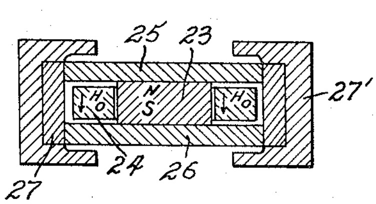

Fig. 6A.

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ELECTROMECHANICAL TRANSDUCING DEVICE

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Application June 21, 1952, Serial No. 294,844

Claims priority, application Netherlands July 2, 1951

10 Claims. (Cl. 310—26)

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This invention relates to electro-mechanical transducing devices, more particularly, to electro-mechanical transducing devices which make use of a member having magneto-strictive properties.

Heretofore, electro-mechanical transducing devices comprised a vibrating member in expansional-vibration, i. e., the diameter of the member varied in accordance with a magnetic alternating field surrounding the member. However, these devices have had the disadvantages that the resonant peak of the vibrations was very broad and, furthermore, that the entire member was vibrating so that it was exceedingly difficult to support the vibrating member without materially dampening or otherwise interfering with the vibrations unless extremely critical flexible supports were utilized.

It is an object of the invention to provide an electro-mechanical vibrating device having a sharp resonant peak.

It is a further object of the invention to provide an electro-mechanical vibrating device having a vibrating member which is relatively easy to support.

These and further objects of the invention will be best understood from the following description.

According to the invention, an electro-mechanical transducing device comprises a vibrating member in torsional-vibration, i. e., the upper surface of the member exhibits a periodically changing twist relative to its bottom surface. This has the advantage that the device has a very sharp resonant peak. Moreover, a torsionally-vibrated member is at rest in its nodal plane so that it can be supported at points of this nodal plane without substantially interfering with the mechanical vibrations. Furthermore, the resonant frequency of the device can be varied over a small range by adjustment of the magnetic fields.

In a preferred embodiment, the electro-mechanical transducing device comprises a magneto-strictive, substantialy radially symmetrical, hollow annular member consisting of a highly magnetically permeable, substantially electrically non-conductive material placed in a uni-directional polarizing field. The annular member is provided with a winding about a portion thereof so that when an alternating current passes through the winding the member is set into torsional-vibration.

The invention will now be described with reference to the accompanying drawing in which:

Fig. 1 is a view, in cross-section, of one form

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of an electro-mechanical vibrating device in accordance with the invention;

Fig. 2 is a curve of the impedance characteristic of the device shown in Fig. 1;

Figs. 3 and 4 are a cross-sectional and plan view, respectively, of another form of electro-mechanical vibrating device according to the invention;

Figs. 5 and 6 are a cross-sectional and plan view, respectively, of still another form of electro-mechanical vibrating device according to the invention;

Fig. 6*a* is a cross-sectional view of a further modification;

Fig. 7 is a schematic view of one form of circuit arrangement for compensating for the initial impedance Z_0 of the device shown in Fig. 1;

Figs. 8 and 9 are a cross-sectional and plan view, respectively, of two mechanically coupled vibrating devices;

Fig. 10 is a curve of the impedance characteristic of the device shown in Figs. 8 and 9.

Figs. 11 and 12 show two embodiments, wherein permanent magnets of non-conductive material rest against the vibrator member.

Throughout the drawings, similar parts are provided with the same reference numerals.

An electro-mechanical transducing device as shown in Fig. 1 comprises a vibrator member **1** arranged in a polarizing magnetic field H_0 produced by a pair of disc-shaped permanent magnetic members **3** and **4** having a direction of magnetization N–S substantially parallel with a central axis **5** of the member **1**.

In accordance with the invention, a winding **2**, of which only a few turns are shown for the sake of clearness, is arranged about a cross-hatched section **10** of the member **1**. An alternating current is supplied to winding **2** so that a tangentially directed magnetic field H is produced in the member **1**. As a result of the fields H_0 and H, the magneto-strictive member **1** is set in torsional vibration, i. e., the upper surface of the member **1** exhibits a periodically changing twist relatively to its bottom surface.

The curve *a* in Fig. 2 indicates the impedance measured between the ends of the winding **2** for different frequencies of alternating current supplied thereto. At the frequency of the alternating current through the winding **2** that corresponds to the mechanical resonant frequency of the member **1** for such torsional vibrations, a considerable impedance Z_m will be measured between the ends of the winding **2**, and at frequencies below and above this resonant frequency, this impedance acquires substantially a constant value Z_0 which depends upon the volume and the permeability of the member 1. The impedance curve may be regarded as the sum of a constant impedance Z_0 and an impedance according to the curve C shown in dash lines in Fig. 2, which curve C corresponds to the impedance of a tuned circuit.

It has been found that if the member 1 is set in torsional-vibration in the aforesaid manner, the sharpness of resonance of curve C is much greater, say 30 to 50%, than if the same member were set in expansional-vibration. Furthermore, damping-free support is possible in the case of torsional vibration because the plane of symmetry of the member 1 (nodal plane) is at rest; consequently, the member 1 may be supported at this plane by means of bolts 7 and 8, for example, gramophone needles. In such a case, preferably three supports are arranged along the periphery of the member 1 is order that adjustment thereof may be as simple as possible. It has also been found that pieces of paper are sufficient to support the member 1. It is generally preferably to provide the winding 2 on a coil form 6 separated from the member 1 so that the winding 2 itself does not damp the vibrations of the member 1.

The permanent field H_0 produced by the flat annular permanent magnets 3 and 4 will, if these permanent magnets are supported by non-magnetic supports, be comparatively weak due to the large reluctance of such supports. Hence, the supporting members 11, 12, 13 for the permanent magnets 3 and 4 preferably consist of ferromagnetic material.

Figs. 3 and 4 show a modification of the device shown in Fig. 1, in which a more compact construction and a stronger polarizing field H_0 is obtained. Fig. 4 is a plan view of the device shown in Fig. 3 with the top disc removed. In Figs. 3 and 4, a permanent magnet 15 of annular shape is arranged about an annular vibrating member 16 so that the polarizing field for the member 16 is produced betwen two ring- or disc-shaped ferromagnetic bodies 17 and 18. By choosing the surface area of the permanent magnet 15 larger than that of the member 16, it is assured that the field H_0 is larger than the residual magnetism of the permanent magnetic material. The member 1 is supported by means of pieces of paper 19, indicated by dash lines, enclosing the member 1 between the plates 17 and 18.

A coil form 20 about which is wound a winding 21 is arranged about the member 16 at an interruption of the permanent magnet 15 and the discs 17 and 18. If the discs 17 and 18 are made from conductive ferro-magnetic material, it is preferable that the winding 21 should be shielded from the discs 17 and 18 by means of electrically conductive screens placed in the vicinity of said winding.

Figs. 5 and 6 show a further modification of the device shown in Fig. 1. In Fig. 5, a disc-shaped permanent magnet 23 is arranged within an annular vibrating member 24, the combination being sandwiched between a pair of ferromagnetic plates 25 and 26, thereby producing a sufficient permanent magnetic field H_0 at the member 24. A cylindrical support 27 contains bolts 28, 29 and 30 for supporting the vibrating member 24, which supports preferably consist of non-magnetic material. If desired, the support 27 may carry a ferromagnetic shunt 27', as shown in Fig. 6a, by means of which the strength of the field H_0 can be adjusted between plates 25 and 26. Similarly to Fig. 3, a coil form 31 about which is wound a winding 32 is fitted in interruptions of the permanent magnet 23, of the ferromagnetic discs 25 and 26 and of the support 27.

By making the support circuit 25—26—27 of the permanent magnet 23 from ferromagnetic material, however, the impedance Z_0 increases. Therefore, it is also advantageous, according to Fig. 11, to place two permanent magnets 63 and 64 of substantially non-conductive material against the vibrator member 61. The winding 62 may then be simply arranged about the assembly of the vibrator member 61 and the non-conductive permanent magnets 63 and 64 without incurring additional Foucault current losses.

Since the mechanical vibration of the member 61 is in the plane of the contact surfaces with the permanent magnets 63, 64 it is not necessary for these magnets 63 and 64 to be rigidly secured to the member 61, it being sufficient that they are pressed against the member 61 by their magnetic attractive power. In this case, the magnets 63 and 64 do not partake in vibration, it is true, so that friction losses occur in said contact surfaces, but these friction losses are found to be small as to barely exhibit a decrease in sharpness of resonance. It is even sufficient for the members 63, 61, 64 to rest by their weight on a fixed base so that clamping by means of bolts 67, 68 is superfluous.

Fig. 7 shows diagrammatically how the initial impedance Z_0 shown in Fig. 2 can be compensated for in the device shown in Fig. 1. For this purpose, two windings 2, 2' are arranged around the vibrating member 1 and are connected to a primary 38 and a secondary 39 winding, respectively, of a transformer 40 having a given transformation ratio. The connections are arranged so that the input current traversing the winding 2, traverses the primary 38 of transformer 15 in the opposite direction to that of the output current traversing the winding 2' and the secondary 39 of transformer 40. The number of turns of the windings 38 and 39 are suitably chosen to produce a voltage across the secondary winding 39 in relation to the input current through windings 2 and 38 corresponding to the said impedance Z_0 to be compensated. Thus at frequencies different from the mechanical resonance of the vibrating member 1 the voltages across windings 2' and 39 compensate each other involving a transfer characteristic of the device corresponding to curve *c* of Fig. 2.

Figs. 8 and 9 show a device comprising two vibrating members 50 and 51 supported at points of their respective nodal planes, an input winding 52 being arranged around the vibrating member 50 and an output winding 53 surrounding the vibrating member 51, while both vibrating members 50 and 51 are mechanically intercoupled by non-magnetic, for example, aluminium, coupling elements 54, 55, 56 which transmit the vibrations of the vibrating member 50 to the vibrating member 51. By suitable choice of the height of the coupling elements 54, 55, 56 and the size of their contact surfaces with the members 50 and 51, it is possible to obtain a band-shaped transmission characteristic as a function of the frequency as shown in Fig. 10, the band-width chiefly depending upon the size of the contact surfaces, that is to say, the smaller the area of the contact surfaces, the looser the coupling, and the narrower the bandwidth. For example, a point or knife blade contact will have practically zero coupling, and the characteristic of Fig. 10 will be practically reduced to a straight line. For simplicity, the windings **52** and **53** are shown in the same plane. However, they may be provided in different planes in order that the height of the coupling elements **54**, **55**, **56** may be as small as possible. A pair of disc-shaped permanent magnets **59**, **60** enclose the vibrating members **50** and **51**. The vibrating members **50**, **51** may be supported by bolts at points along their nodal planes, respectively, or by pieces of paper, as described above in connection with the embodiment illustrated in Fig. 1.

Fig. 12 shows a similar device as shown in Fig. 11, comprising two vibrator members **71** and **71′** whose mechanical resonance frequencies may be slightly different from one another, so that the impedance measured between the ends of winding **72** in the frequency range between these two resonance frequencies varies only slightly with the frequency, in other words it has a band-pass filter characteristic. The winding **72** is loosely arranged on the permanent magnets **73**, **73′** and **74** projecting from the vibrator members **71** and **71′**, so that it does not damp the mechanical vibration. If a sufficiently strong polarizing field is available, the magnet **73′** may, if desired, be omitted.

In the foregoing embodiments, disc-shaped vibrating members are used. However, the invention also applies to devices comprising tubular or other hollow vibrating members having rotational symmetry by giving them different heights and/or diameters.

A suitable material for the vibrating members of the various embodiments shown in the drawing is nickel-zinc ferrite of the high-permeable, substantially non-conductive type having a composition of approximately 18 mol per cent of NiO, 32 mol per cent of ZnO and 50 mol per cent of Fe_2O_3. This and other types of materials such as those described in U. S. Patents Nos. 2,452,529; 2,452,530; 2,452,531; 2,551,711; 2,579,978, are suitable for and may be used for the purpose of this invention.

As a suitable material for the permanent magnets, particularly in the examples shown in Figs. 3, 5, 11 and 12 reference is made to the materials described in a U. S. patent application filed July 7, 1951, Serial No. 239,264. These materials are characterised by a composition of substantially non-cubic crystals of polyoxides of iron and at least one of the metals barium, strontium, lead and, if desired, calcium.

While we have thus described our invention with specific examples and embodiments thereof, other modifications will be readily apparent to those skilled in the art without departing from the spirit and the scope of the invention as defined in the appended claims.

What we claim is:

1. An electro-mechanical vibrating device comprising a magneto-strictive hollow member consisting of a highly megnetically permeable substantially electrically non-conductive material and being substantially radially symmetrical about a given axis of rotation extending through the center thereof, means to produce a uni-directional polarizing field in a direction substantially parallel to said axis of rotation, and a winding wound about a portion of said hollow member and surrounding an axial section thereof so that when alternating current is passed through said winding said member is torsionally vibrated.

2. An electro-mechanical vibrating device comprising a magneto-strictive hollow annular member consisting of a highly magnetically permeable substantially electrically non-conductive material and being substantially radially symmetrical about a given axis of rotation extending through the center thereof, means to produce a uni-directional polarizing field in a direction substantially parallel to said axis of rotation, a winding wound about a portion of said annular member and surrounding an axial section thereof so that when an alternating current is passed through said winding said member is torsionally vibrated about its nodal plane, and means for supporting said member along its nodal plane.

3. An electro-mechanical vibrating device comprising a magneto-strictive hollow annular member consisting of a highly magnetically permeable substantially electrically non-conductive material and being substantially radially symmetrical about a given axis of rotation extending through the center thereof, means including a permanent magnet to produce a uni-directional polarizing field in a direction substantially parallel to said axis of rotation, a winding wound about a sector of said annular member so that when an alternating current is passed through said winding said member is torsionally vibrated about its nodal plane, and means for supporting said member at three points along its nodal plane.

4. An electro-mechanical vibrating device comprising a magneto-strictive hollow annular member consisting of a highly magnetically permeable substantially electrically non-conductive material and being substantially radially symmetrical about a given axis of rotation extending through the center thereof, an annular permanent magnet magnetized in the direction of said axis surrounding said member, a pair of annular ferromagnetic disc-shaped bodies disposed on opposite sides of said member and providing with said magnet a uni-directional polarizing field in a direction substantially parallel to said axis of rotation, and a winding wound about a sector of said annular member so that when an alternating current is passed through said winding said member is torsionally vibrated.

5. An electro-mechanical vibrating device comprising a magneto-strictive hollow annular member consisting of a highly magnetically permeable substantially electrically non-conductive material and being substantially radially symmetrical about a given axis of rotation extending through the center thereof, a cylindrically shaped permanent magnet disposed within said hollow member, a pair of ferromagnetic disc-shaped bodies disposed on opposite sides of said member and providing with said magnet a uni-directional polarizing field in a direction substantially parallel to said axis of rotation, and a winding wound about a sector of said annular member so that when an alternating current is passed through said winding said member is torsionally vibrated.

6. An electro-mechanical vibrating device comprising a magneto-strictive hollow annular member consisting of a highly magnetically permeable substantially electrically non-conductive material and being substantially radially symmetrical about a given axis of rotation extending through the center thereof, means to produce a uni-directional polarizing field in a direction substantially parallel to said axis of rotation, a winding wound about a sector of said annular member so that when an alternating current is passed through said winding said member is

torsionally vibrated, and means for compensating for the impedance measured between the ends of said winding at frequencies different from the resonant frequency thereof.

7. An electro-mechanical vibrating device comprising a pair of spaced magneto-strictive hollow annular members each consisting of a highly magnetically permeable substantially electrically non-conductive material, said members being substantially radially symmetrical about a common axis of rotation extending through the centers thereof, a plurality of non-magnetic coupling elements each affixed to each of said members, means to produce a uni-directional polarizing field in a direction substantially parallel to said axis of rotation, an output winding wound about a sector of one of said members, and an input winding wound about a sector of the other of said members so that when an alternating current is passed through said input winding said members are torsionally vibrated.

8. An electro-mechanical vibrating device comprising a magneto-strictive substantially radially symmetrical hollow annular member consisting of a highly magnetically permeable substantially electrically non-conductive material and having a given axis of rotation extending through the center thereof, two annular permanent magnets of substantially non conductive material provided at both sides of and against said an-

nular member to produce a uni-directional polarizing field in a direction substantially parallel to said axis of rotation, and a winding wound about a portion of said annular member and surrounding an axial section of the assembly of said annular member and said permanent magnets so that when an alternating current is passed through said winding said member is torsionally vibrated.

9. A device as claimed in claim 8, in which the impedance, measured between the ends of the winding, exhibits a band-pass filter characteristic, characterized in that a plurality of ring-shaped vibrator members having different mechanical resonance frequencies are provided between a plurality of ring-shaped permanent magnets, the winding surrounding the assembly of an axial section of vibrator members and magnets.

10. A device as claimed in claim 3 in which the permanent magnet consists essentially of non-cubic crystals of polyoxides of iron and at least one of the metals barium, strontium and lead.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,249,835	Lakatos	July 22, 1941
2,452,531	Snoek	Oct. 26, 1948