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2,880,334

FERROELECTRIC TORSIONAL TRANSDUCER

Filed June 13, 1955

FIG. 1

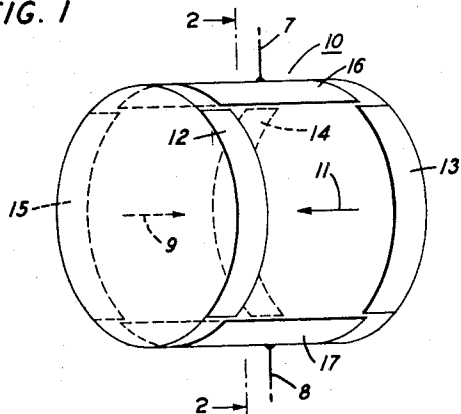


FIG. 2

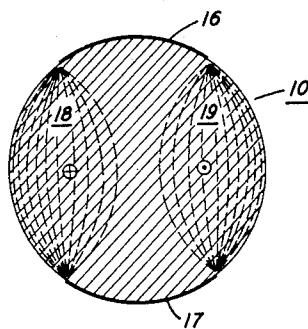


FIG. 3

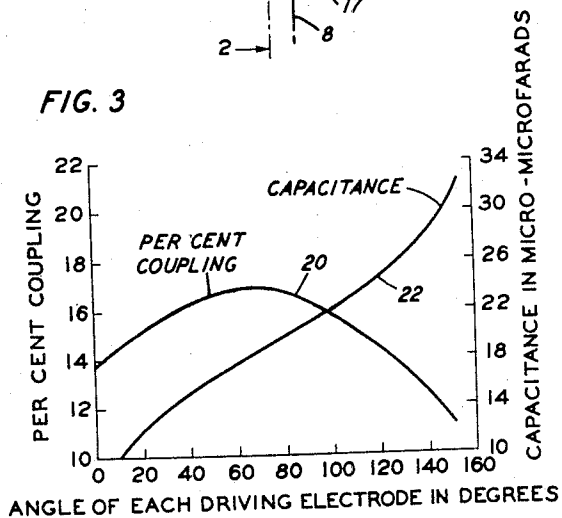


FIG. 6

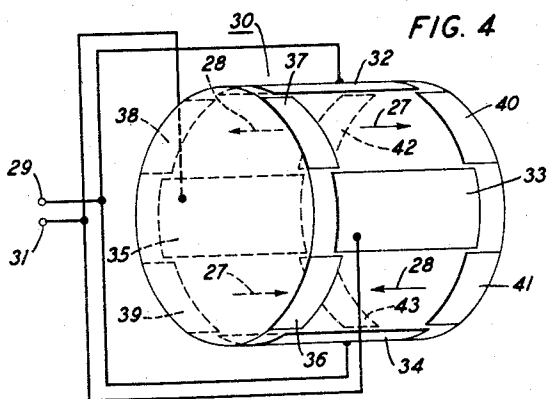
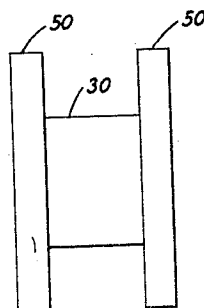
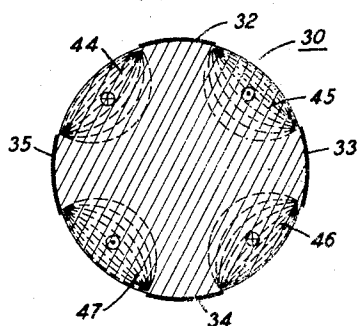


FIG. 5



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1

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FERROELECTRIC TORSIONAL TRANSDUCER

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4 Claims. (Cl. 310-9.6)

This invention relates to cylindrical ferroelectric torsional transducers which may be solid or annular in cross section. More particularly, it relates to transducers of the above noted types having improved efficiency and optimum electromechanical coupling coefficients.

This application is a continuation in part of my copending application Serial No. 351,841, filed April 29, 1953, which matured as patent 2,742,614, granted April 17, 1956, and is directed to transducers similar generically to those disclosed in said copending application but differing in specific design to increase the operating efficiency as well as to provide an increased electromechanical coupling coefficient.

The principal object of the present invention is, accordingly, to provide improved ferroelectric torsional transducers.

Another object is to provide ferroelectric torsional transducers having greater efficiency and greater electromechanical coupling coefficients.

Other and further objects, features and advantages of the invention will become apparent during the course of the following detailed description of the embodiments of the invention illustrated in the accompanying drawings, as well as from the appended claims.

The principles of the invention can be more readily understood from the following detailed description of the above mentioned illustrative embodiments shown in the accompanying drawings in which:

Fig. 1 illustrates, in perspective, one embodiment of the invention;

Fig. 2 is a cross-sectional view of the transducer of Fig. 1 showing the circumferential positioning of the electrodes and the polarization of the ferroelectric element;

Fig. 3 shows curves of percentage coupling and inter-electrode capacitance versus the circumferential extent of each electrode in degrees for the embodiment of Fig. 1;

Fig. 4 illustrates in perspective a second embodiment of the invention;

Fig. 5 is a cross-sectional view of the transducer of Fig. 4 showing the circumferential positioning of the electrodes and the polarization of the ferroelectric element; and

Fig. 6 shows a convenient way of mechanically loading a transducer.

In more detail, Figs. 1 and 2 illustrate one embodiment of a torsional transducer of the invention in which cylindrical element 10 of ferroelectric material comprises the principal component. Fig. 2 is a cross-sectional view of a median transverse plane through the assembly of Fig. 1. Prior to the application of driving electrodes 16 and 17, element 10 is bidirectionally polarized in a longitudinal direction as indicated by the arrows 9 and 11. This polarization is effected by the application of a voltage of appropriate magnitude and polarity between each of the two pairs of polarizing electrodes 12, 13 and 14, 15. Each of these electrodes preferably covers an

2

arc of substantially 110 degrees around the circumference of the element 10. Electrodes 12 and 13 are in alignment with each other on the surface of the cylinder and are diametrically opposite electrodes 15 and 14, respectively. Electrodes 12 through 15 may preferably be of limited width (i.e., the dimension of these electrodes which is parallel to the longitudinal axis or length of element 10), for example, where cylinder 10 is two centimeters in diameter and one and one half centimeters in length, these electrodes need be only approximately one quarter centimeter in width. Element 10 may be of barium titanate, with or without components of lead, calcium or other titanates in percentages of less than approximately twenty percent, as is well known to those skilled in the art, or it may be of potassium niobate. If of a composition including at least eighty percent of barium titanate, it is preferably polarized by heating it above its Curie temperature of substantially 130 degrees centigrade and applying a voltage of substantially thirty volts per mil of electrode separation, the voltage being maintained while the element is cooled to room temperature. If of potassium niobate, element 10 should be polarized as taught in my Patent 2,706,326, granted April 19, 1955.

The resulting polarized regions of element 10 are indicated by the areas designated 18 and 19, respectively, for which areas the polarization is concentrated near the surface but may extend in as shown, in Fig. 2, the circle with a dot in the center (area 19) indicating a direction perpendicular to the plane of the paper and emerging therefrom, the circle with a cross therein (area 18) indicating the opposite direction of polarization.

Following completion of the polarization of element 10, as described above, the polarizing electrodes 12 through 15, inclusive, are preferably removed and the driving electrodes 16 and 17 are applied in any of the numerous manners well known to those skilled in the art, such as painting the required areas with a metallized paint. Whatever method of applying the electrodes is employed, it should be one that does not require substantially raising the temperature of element 10 after the latter has once been polarized.

Electrodes 16 and 17 should, for optimum electromechanical coupling, each cover seventy degrees of arc and should each be substantially three quarters of the length of the cylinder 10 and centrally located between the ends of cylinder 10. Circumferentially, electrodes 16 and 17 occupy the portions of the periphery of cylinder 10 which were not occupied by the poling electrodes 12 through 15, inclusive, as indicated in Figs. 1 and 2. Suitable conductive leads 7 and 8 are connected, by cementing or spot soldering, to the driving electrodes 16 and 17, respectively. A signal voltage applied to the electrodes 16 and 17 causes corresponding torsional vibration of the element 10.

In Fig. 3, curve 20 shows how the electromechanical coupling (percentage of input electrical power converted into torsional vibration or vice versa) of the transducer of Figs. 1 and 2 varies with the angle of the arc covered circumferentially by each of the electrodes 16 and 17, a maximum obviously being reached at the value of seventy degrees of arc for each electrode. Curve 22 shows the variation in the capacitance between the driving electrodes 16 and 17 of the transducer of Fig. 1 with the circumferential arc covered by each of the electrodes.

In Figs. 4 and 5 a modification of the transducer illustrated by Figs. 1 and 2 is shown and differs therefrom principally in the provision of four driving electrodes 32 through 35, inclusive, on the ferroelectric element 30 instead of only two. Diametrically opposed pairs of electrodes 32, 34 and 33, 35 are connected together and each pair is then connected to an input terminal 29 or 31

as shown. Each of the electrodes, 32 through 35, covers, circumferentially, an arc of thirty-five degrees.

In the modified transducer illustrated in Figs. 4 and 5, as for the device of Fig. 1, before the driving electrodes 32 through 35 are applied to element 30, the latter is polarized, by means of polarizing electrodes 36 through 43, inclusive, as described in connection with Fig. 1, except that four portions of the element 30, extending fifty-five degrees circumferentially and located between the positions to which the four driving electrodes are to be applied, are polarized longitudinally, successive portions being polarized in opposite directions as indicated by arrows 27 and 28 in Fig. 4.

Fig. 5 is a cross-sectional showing of a median transverse plane through the element 30. The polarized portions 44 through 47 and their respective directions of polarization are indicated in the manner described above in connection with Fig. 2. Polarizing electrodes 36 through 43 are preferably removed before driving electrodes 32 through 35 are applied.

The construction illustrated in Figs. 4 and 5 not only affords substantially a fifty percent increase in the coupling factor of the transducer as compared with that of Figs. 1 and 2 but also substantially increases the capacitance between the driving electrodes. This is very desirable since, in order to obtain a favorable input impedance at relatively low frequencies, i.e., in the order of twenty to fifty kilocycles, it is necessary to add a shunting inductance which will resonate with the capacity of the transducer at the median frequency to be employed. The size of the inductance necessary to produce resonance may be so large, if the interelectrode capacity is small, that distributed capacity effects in the coil may seriously reduce the efficiency and effectiveness of the transducer. In some instances, indeed, it is entirely impracticable to provide a coil of the requisite inductance.

In Fig. 6 one convenient way is shown of mechanically loading a transducer of the invention to reduce the frequency range over which it can be effectively employed. It comprises, for example, simply the cementing of a steel disc 50 to each end of the transducer 30 of Fig. 4. By way of a typical example, if the diameter of each of the discs 50 is twice that of element 30 (four centimeters), and the thickness of discs 50 is one half centimeter each, a four-fold reduction in the resonant frequency of the transducer is readily obtained, i.e., from 100 kilocycles to 25 kilocycles, for example.

Numerous and varied modifications of the above described arrangements can be readily devised by those skilled in the art without departing from the spirit and scope of the invention. The above described embodiments are, accordingly, to be understood to be representative only.

What is claimed is:

1. A torsional transducer comprising a cylindrical element of ferroelectric material, said element having a plurality of like, longitudinally polarized portions occupying circumferentially an aggregate arc of substantially 220 degrees, each polarized portion being diametrically opposite another of said polarized portions, successive polarized portions around said element being polarized

in opposite directions and a like plurality of like driving electrodes on said element, said driving electrodes being positioned intermediate said polarized portions and having a length substantially three quarters that of said element and centrally positioned thereon, said electrodes occupying circumferentially an aggregate arc of substantially 140 degrees, each electrode being diametrically opposite another of said electrodes, whereby a substantially maximum electro-mechanical coupling is obtained.

2. A torsional transducer comprising a cylindrical ferroelectric element having two diametrically opposed, longitudinally polarized sections of opposite polarity, each of said sections occupying circumferentially an arc of substantially 110 degrees and a pair of diametrically opposed driving electrodes, each electrode substantially covering circumferentially an arc of 70 degrees intermediate said polarized sections whereby a substantially maximum electro-mechanical coupling coefficient is obtained.

3. A torsional transducer comprising a cylindrical ferroelectric element having two orthogonally arranged pairs of diametrically opposite, longitudinally polarized sections, successive sections around said element being polarized in opposite directions, each of said sections occupying circumferentially an arc of substantially 55 degrees and two orthogonally arranged pairs of diametrically opposite driving electrodes, each said electrode occupying circumferentially an arc of substantially 35 degrees intermediate two successive polarized sections, diametrically opposite electrodes being electrically interconnected whereby increased electromechanical coupling and greater interelectrode capacitance are obtained.

4. A torsional transducer comprising a cylindrical element of a ferroelectric material, said element having a first plurality of like, longitudinally polarized portions having the same direction of polarization, a second plurality of like longitudinally polarized portions having the same direction of polarization, said polarization being oppositely directed to that of said first plurality, said first and said second pluralities of portions occupying an aggregate arc of substantially 220 degrees, each polarized portion occupying an arc of substantially the same magnitude and being diametrically opposite another of said polarized portions, successive polarized portions around said element being polarized in opposite directions, and a plurality of like driving electrodes on said element, each driving electrode being positioned intermediate two successive polarized portions and having a length of substantially three quarters that of said element and centrally positioned thereon, said electrodes occupying circumferentially an aggregate arc of substantially 140 degrees, each electrode being diametrically opposite another of said electrodes, alternate electrodes being connected together and the intermediate electrodes being connected together, whereby maximum electro-mechanical coupling and substantially increased interelectrode capacity are realized.

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