Oct. 16, 1956 W. T. HARRIS 2,767,338

MAGNETOELASTIC TRANSDUCER

Filed Feb. 23, 1955

FIG. 1.

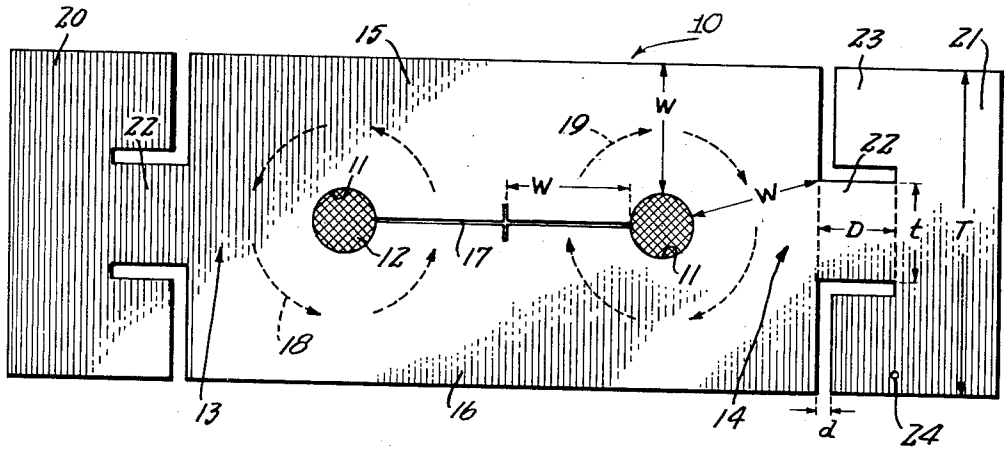


FIG. 2.

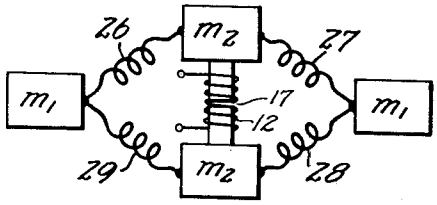


FIG. 3.

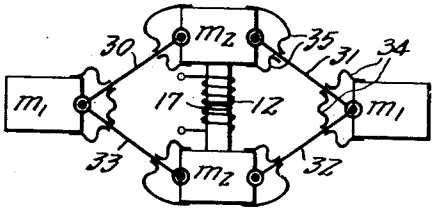
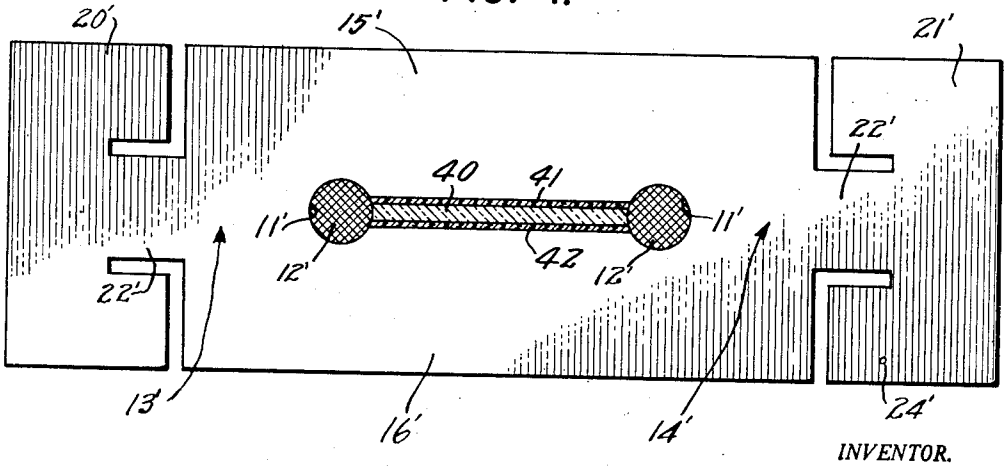


FIG. 4.



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MAGNETOELASTIC TRANSDUCER

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Application February 23, 1955, Serial No. 490,043

13 Claims. (Cl. 310—26)

My invention relates to electromagnetic transducers of the magnetoelastic variety disclosed and discussed in detail in my copending patent application, Serial No. 383,563, filed October 1, 1953.

In said copending application, I discussed the relative merits of various basic transducer types and pointed out the relatively high conversion efficiency achievable with the magnetoelastic transducer. Among the forms disclosed were several employing a consolidated stack of like laminations, each lamination incorporating all the basic elements of the transducer. Such transducers rely primarily on the contraction which results from magnetic forces at a gap in the central part of the flux path excited by a coil. Contraction is accompanied by a resilient elongation and by resonance between particular parts of the laminations. The magnetoelastic principle is to be clearly distinguished from any purely magnetostrictive effect, in that the magnetostrictive effect relies solely upon the material itself, rather than on magnetic forces contributed at a gap. In spite of the higher conversion efficiency obtainable with the structures disclosed in said patent application, the full potential of the magnetoelastic effect could not be achieved with those particular structures.

It is, accordingly, an object of the invention to provide an improved magnetoelastic transducer-element construction.

It is another object to provide a magnetoelastic transducer lamination of inherently greater energy-conversion efficiency than heretofore.

It is a further object to provide a magnetoelastic lamination with particular configuration of slots, so as to define mass areas which can mechanically react with each other to enhance the magnetoelastic effect.

It is a specific object to achieve the above objects with a structure which can couple the reacting mass areas to the basic magnetoelastic structure with high mechanical advantage, thereby achieving high power capacity.

Other objects and various further features of novelty and invention will be pointed out or will occur to those skilled in the art from a reading of the following specification in conjunction with the accompanying drawings. In said drawings, which show, for illustrative purposes only, preferred forms of the invention:

Fig. 1 is a cross-sectional view of a transducer incorporating features of the invention and revealing the plan view of one of the laminations of the core thereof;

Figs. 2 and 3 are drawings schematically suggesting two alternative simplified functional equivalents, to explain the principal mode of operation of the device of Fig. 1; and

Fig. 4 is a view similar to Fig. 1 but illustrating a modification.

Briefly stated, my invention contemplates an improved laminated magnetoelastic transducer construction characterized by higher conversion efficiency than heretofore and incorporating, as an integral part of each lamination, additional mass areas which may react with the basic

magnetoelastic portion of the lamination in order to enhance the conversion efficiency and power-handling capacity. The means for coupling the magnetoelastic portion of the lamination to the reacting mass portions is inherently characterized by high mechanical advantage.

Referring to Fig. 1 of the drawings, my improved transducer is seen to comprise a consolidated stack of like laminations **10**, each of which may be a single integral sheet of non-critical ferromagnetic material, such as silicon steel. The lamination may be of proportions which are rectangular and hence characterized by symmetrical longitudinal and transverse axes. The lamination may be formed with two like symmetricaly located and longitudinally spaced winding openings **11**; after the stack of laminations **10** is consolidated, the turns of winding means **12** are passed through the openings **11** so as to provide electromagnetic coupling to the flux path between the openings **11**.

The structure thus far described may be viewed as having two outer legs **13—14** connecting transversely opposed mass areas **15—16**, which extend centrally toward each other to define a center leg. The center leg is slotted by a thin opening extending between winding openings **11**, thereby defining a flux gap **17** between poles at the center leg. Upon excitation of the winding in openings **11**, flux is circulated generally in two symmetrical paths, designated by dashed arrows **18—19** around the respective openings **11**. The proportions of the described parts of the laminations **10** are preferably such that the minimum width W of each flux path shall be substantially one-half the effective length of the flux gap **17**.

Upon excitation of the described structure, the outer legs **13—14**, which serve to space the transversely opposed mass areas **15—16**, will in effect constitute spring means yieldably connecting the transversely opposed mass areas **15—16**, and with each contraction or expansion of the gap, due solely or primarily to magnetic forces at the gap, these outer spring legs **13—14** will permit transverse excursions of the mass areas **15—16**. At resonance, the conversion efficiency, as between electric-energy input to the coil **12** and mechanical-displacement output at elements **15—16**, is relatively high, and purely magnetoelastic action is involved.

In spite of the high conversion efficiency described above, I provide means whereby the conversion efficiency may be further improved, by employing lamination structure integral with that described. This, in the form shown, comprises two longitudinally opposed mass areas **20—21** connected to the spring means or outer legs **13—14**. The preferred arrangement is such that the point of connection between mass areas **20—21** and the main magnetoelastic lamination body shall be in the central or most (longitudinally) deflected parts of the connecting spring legs **13—14**. Also, I prefer that the connection shall be via a neck section **22**, of limited width *t*, compared with the over-all transverse width T of the lamination; to provide further compliance in the coupling between the longitudinally opposed mass areas **20—21** and the connecting members **13—14**, I prefer that the neck **22** shall be longitudinally elongated, as suggested by the dimension D, shown of the order of magnitude of the width *t* of the neck **22**.

In order to make maximum use of the available volume displaced by the lamination **10**, I show the reacting longitudinally opposed mass areas as including massive side projections or ears **23** extending toward the magnetoelastic body and closely spaced therefrom, as suggested by the dimension *d*. Finally, in order to preserve correct orientation of all laminations when assembled in a stack, I provide a small reference notch or opening **24**, asymmetrically disposed with respect to the lamination body

and preferably located remote from one of flux paths 18—19.

The functioning of my improved lamination will be better understood by reference to Figs. 2 and 3, either of which provides a simplified partially equivalent structure. In the arrangement of Fig. 2, the transversely spaced mass areas 15—16 are identified by the blocks m_2, and the longitudinally opposed mass areas are identified by the blocks m_1. Springs 26—27—28—29 are shown interconnecting these masses, and the poles for the gap 17 are shown integrally carried by the masses m_2. Thus, the masses m_1 may be viewed as connected to each other by spring means via the masses m_2; alternatively, the masses m_2 may be viewed as connected to each other by spring means via the masses m_1. Also, by virtue of the described nature of the basic magnetoelastic element excluding the masses m_1 (20—21), the masses m_2 may be viewed as connected to each other by spring means (26—29, and 27—28), the masses m_1 being merely connected to central parts of such spring means.

In operation of the Fig. 2 arrangement, contraction and expansion of the gap reflects transverse oscillation of the masses m_2 and longitudinal oscillation of the masses m_1. The springs provide compliant close coupling between the two oscillating systems leading to a double peaked resonant system, i. e. two resonant frequencies. If the transverse spread of connections to masses m_2 is much less than the longitudinal spread of connections between masses m_2, then the coupling between the magnetoelastic structure and the longitudinally resonant structure m_1 is characterized by good mechanical advantage, in force magnification.

In the simplified version illustrated in Fig. 3, the same masses m_1 and m_2 will be recognized, as will be the winding 12 at gap 17. Connections between masses are, however, schematically suggested by more or less rigid or stiffly resiliently longitudinally elongated tie rods 30—31—32—33, pinned to the masses m_1—m_2. Springs, as at 34—35, may constantly be stressed to ride the rods; these springs suggest resilient opposition to pivoting of a rod (31) with respect to the masses it connects, and this type support will be understood to characterize all connections to the masses m_1—m_2. In operation, contraction of the gap 17 is accompanied by forced spreading of the masses m_1 in the longitudinal sense, and expansion of the gap 17 forcibly draws the masses m_1 toward each other; the springs 34—35 serve compliantly to couple the resulting modes of oscillation.

It will be seen that, if the proportions of the lamination 10 are of the predominantly elongated character shown in Fig. 1, then, from the analyses depicted in Fig. 2 and 3, good mechanical advantage inherently characterizes the coupling between the magnetoelastically resonant structure (m_2) and the purely mechanically resonant structure (m_1).

In Fig. 4, I show a modified construction having preferably the proportions described in connection with Fig. 1 except for width of the gap between the mass areas 15'—16'; corresponding parts are identified by the same reference characters, but with primed notation. In Fig. 4, the enlarged gap is filled with a sandwich comprising essentially a slab 40 of permanently magnetized material, such as an iron-oxide ceramic or ferrite. To provide yieldable support for the ferrite layer 40, I show two thin pressure-release membranes 41—42, as of cork, slightly spacing the pole faces of masses 15'—16' from the ferrite slab 40. Operation is as described for Fig. 1, except that, of course, no polarizing potential need be applied to winding 12'.

It will be seen that I have described an improved magnetoelastic-transducer construction characterized not only by the high efficiency inherent in the basic magnetoelastic body but also by improved efficiency, by reason of coupling to a further mechanically resonant structure. By exciting the magnetoelastic device transversely, and by coupling the same with good mechanical advantage to a longitudinally resonant structure, I provide for high power-handling potentialities for radiation into a medium of high acoustic impedance.

While I have described the invention in detail for the preferred forms shown, it will be understood that modifications may be made within the scope of the invention as defined in the claims which follow.

I claim:

1. In a transducer of the character indicated, a magnetic core comprising a consolidated stack of like laminations of ferromagnetic material, each lamination including three longitudinally spaced legs joined to each other at opposite transverse ends and defining openings between legs, the center leg having a gap therein of width substantially less than the width of said center leg but sufficient to permit free oscillation of the poles at said gap, a winding passing through said openings, and a pair of longitudinally opposed mass areas connected symmetrically to the respective outer legs of said laminations.

2. A transducer according to claim 1, and including permanently magnetized means supported in said gap.

3. A transducer lamination, comprising a single sheet of ferromagnetic material having two longitudinally spaced like and symmetrically located winding openings therein, said sheet having a thin elongated open flux gap communicating with both said winding openings, thereby defining a pair of transversely opposed mass areas including the poles of said gap, said winding openings being located within the longitudinal limits of said sheet, thereby defining integral connecting legs between the outer limits of said mass areas, and a pair of longitudinally opposed mass areas integrally connected to the longitudinal outer limits of said connecting legs.

4. A transducer lamination, comprising a single elongated generally rectangular sheet of ferromagnetic material having two longitudinally spaced symmetrically located winding openings therein, said sheet having an open elongated flux gap communicating with both winding openings, thereby defining a pair of transversely opposed mass areas including the poles of said gap, said lamination being slotted partially transversely at symmetrically disposed locations longitudinally between said winding openings and the respective longitudinal limits of said lamination; thereby defining, between the slots and winding openings, integral connecting legs between the outer limits of said mass areas; and thereby also defining, longitudinally outside said slotted openings, a pair of longitudinally opposed mass areas integrally connected to the longitudinally outer limits of said connecting legs.

5. A transducer lamination, comprising a single elongated sheet of ferromagnetic material having two longitudinally spaced and symmetrically located winding openings therein, said sheet having a thin longitudinally extending open flux gap communicating with both winding openings, thereby defining two flux-loop paths for circulation respectively about said winding openings and through adjacent portions of said gap, the longitudinal extent of said gap being substantially twice the minimum effective width of one of said paths.

6. A transducer lamination, comprising a single elongated sheet of ferromagnetic material having two longitudinally spaced and symmetrically located winding openings therein, said sheet having a thin longitudinally extending open flux gap communicating with both winding openings, thereby defining two flux-loop paths for flux circulation respectively about said winding openings and through adjacent portions of said gap, the minimum effective width of each of said flux paths being at least one-half the effective longitudinal extent of said gap.

7. A transducer lamination, comprising a single elongated generally rectangular sheet of ferromagnetic material having two longitudinally spaced symmetrically located winding openings therein, said sheet having an open elongated flux gap communicating with both winding openings, thereby defining a pair of transversely opposed

mass areas including the poles of said gap, said lamination being slotted partially transversely at symmetrically disposed locations longitudinally between said winding openings and the respective longitudinal limits of said lamination; thereby defining, between the slots and winding openings, integral transversely extending connecting legs between the outer limits of said mass areas; and thereby also defining, longitudinally outside said slotted openings, a pair of longitudinally opposed mass areas integrally connected to the longitudinally outer limits of said connecting legs; said transverse slots extending from the transverse outer limits of said lamination to define necks of limited width connecting said longitudinally opposed mass areas to said connecting legs.

8. A lamination according to claim 7, in which the effective width of each said neck is approximately one-third the width of said lamination.

9. A lamination according to claim 7, in which the longitudinal extent of each said neck is of the order of the transverse width of each said neck, whereby each said neck may provide a longitudinally resilient connection of said longitudinally opposed mass areas to said connecting legs.

10. A lamination according to claim 7, having an asymmetrically located reference opening in one of said longitudinally opposed mass areas.

11. A transducer lamination, comprising an integral single sheet of ferromagnetic material cut to define two transversely opposed mass areas, two longitudinally opposed mass areas symmetrically placed with respect to said transversely opposed mass areas, spring means connecting said longitudinally opposed mass areas to each other and via said transversely opposed mass areas, said transversely opposed mass areas being closely transversely spaced and defining therebetween an elongated flux gap.

12. A transducer lamination, comprising an integral single sheet of ferromagnetic material and cut to define two transversely opposed mass areas, two longitudinally opposed mass areas symmetrically located with respect to said transversely opposed mass areas, spring means connecting said transversely opposed mass areas to each other via said longitudinally opposed mass areas, said transversely opposed mass areas being closely transversely spaced and defining therebetween an elongated flux gap.

13. A transducer lamination, comprising an integral single sheet of ferromagnetic material and cut to define two transversely opposed mass areas, two longitudinally opposed mass areas symmetrically located with respect to said transversely opposed mass areas, spring means connecting said transversely opposed mass areas to each other with a central spacing between said transversely opposed mass areas defining an elongated flux gap, and means connecting said longitudinally opposed mass areas to said respective spring means.

No references cited.