Dec. 16, 1969 B. SCHWARTZ 3,484,630

ULTRASONIC MAGNETOSTRICTIVE TRANSDUCER ELEMENT

Filed Dec. 11, 1967 2 Sheets-Sheet 1

Fig. 1.

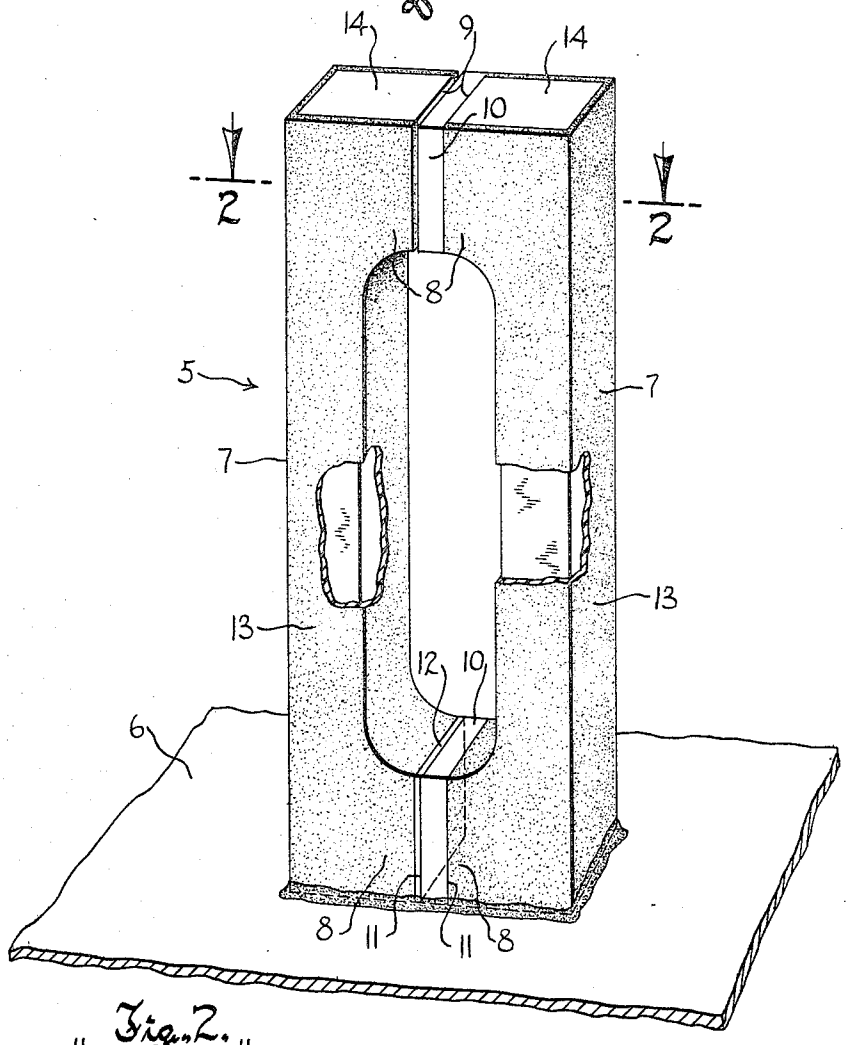
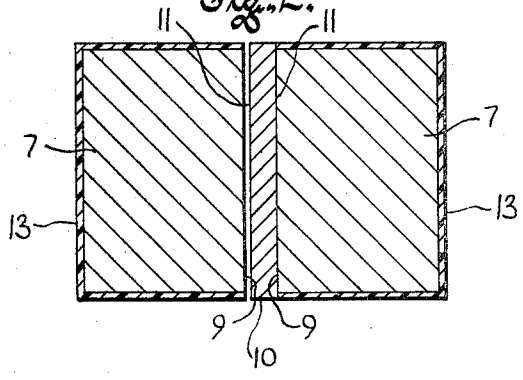


Fig. 2.



Inventor
Benjamin Schwartz
By Schweitzer Jones
Attorneys

Dec. 16, 1969 B. SCHWARTZ 3,484,630

ULTRASONIC MAGNETOSTRICTIVE TRANSDUCER ELEMENT

Filed Dec. 11, 1967 2 Sheets-Sheet 2

Fig. 3.

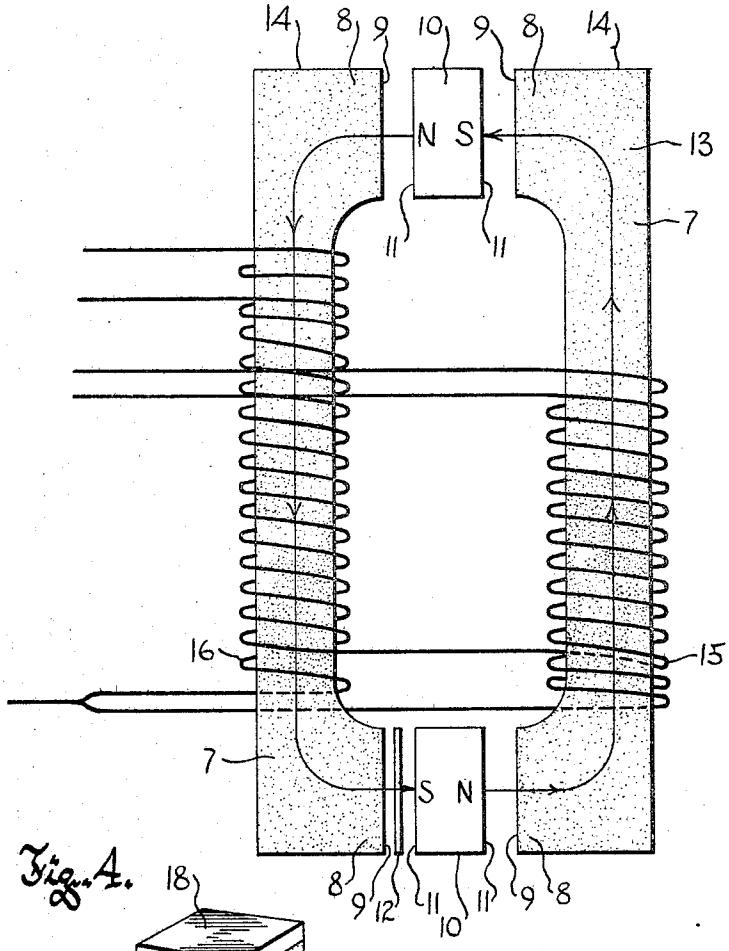
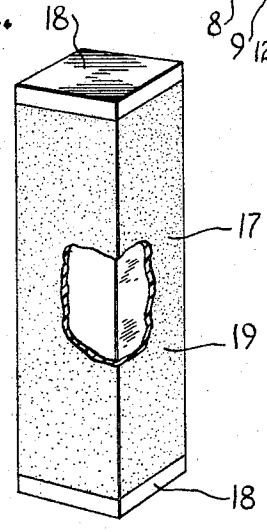


Fig. 4.



Inventor
Benjamin Schwartz
By Schuyler, Jones & Rummell
Attorneys

United States Patent Office

3,484,630
Patented Dec. 16, 1969

3,484,630

ULTRASONIC MAGNETOSTRICTIVE TRANSDUCER ELEMENT

Benjamin Schwartz, Poway, Calif., assignor, by mesne assignments, to DoAll Company, Des Plaines, Ill., a corporation of Illinois

Filed Dec. 11, 1967, Ser. No. 690,716
Int. Cl. H02n 7/00
U.S. Cl. 310—26 3 Claims

ABSTRACT OF THE DISCLOSURE

A pair of side-by-side elongated bars of magnetostrictive ferrite or piezoelectric ceramic with laterally projecting bosses at the end portions of their adjacent sides, have permanent magnets interposed between the opposing faces of the bosses. All other longitudinally extending surfaces of the bars are coated with an epoxy resin that is cured by baking. The shrinkage of the cured epoxy-resin coating which takes place during cooling, prestresses the elongated bars in the transverse direction. This transverse stress coacts with the contraction of the bars in the lengthwise direction brought about by the permanent magnets, to increase the tensile strength of the bars and improves their ability to withstand internal stress.

This invention, like that of application Ser. No. 411,351, assigned to the assignee of the instant application, relates to ultrasonic transducers and has as its purpose and object to provide an improved transducer element.

Ultrasonic transducers convert high frequency electrical power into ultrasonic mechanical vibration and, as pointed out in the Houghton et al. Patent No. 3,256,114, customarily employ elements made of a piezoelectric ceramic or magnetostrictive ferrite. Such transducer elements are highly sensitive to an oscillating electromagnetic field and will expand and contract at the frequency of the oscillatory current used to produce the electromagnetic field. The result is ultrasonic mechanical vibration of the transducer element at an amplitude proportional to the power of the applied electrical energy.

However, as also explained in the Houghton et al. patent, piezoelectric and magnetostrictive transducer elements have notoriously low tensile strength and will crack and break when subjected to high levels of driving power, unless they are preloaded or prestressed in some way. Moreover, such elements are relatively fragile and are apt to break if subjected to even mildly rough handling.

Houghton et al. found that if the piezoelectric or magnetostrictive ferrite element is completely coated with an epoxy resin which has a high shrinkage factor during cooling from the temperature employed in curing the resin, the elements will be suitably preloaded and protected against breakage.

The preferred physical shape of a transducer element is that of an elongated bar. The electrically energized coils employed to produce the oscillatory electromagnetic field are then wound transversely about the bar, with the result that the lines of magnetic flux which result from energization of the coils with high frequency oscillatory current, thread the bar longitudinally and cause it to lengthen and shorten—or, in other words, to vibrate in the lengthwise mode.

While complete encapsulation of a bar-shaped transducer element no doubt improves its ability to withstand higher levels of electromagnetic driving power, I have found that the lengthwise—as well as transverse—compression of the element resulting from its complete encapsulation in a shell or coat of epoxy resin, significantly

reduces its sensitivity. This observation led me to the discovery that the needed increase in tensile strength and desired protection against breakage can be had without diminishing the sensitivity of the element, by combining an epoxy resin coating which is confined to those surfaces of the element where the shrinkage of the resin prestresses the element transversely, with permanent magnets so placed at the ends of the element that the magnetic flux resulting therefrom threads the element longitudinally and causes it to contract.

With these observations and objects in mind, the manner in which the invention achieves its purpose will be appreciated from the following description and the accompanying drawings. This disclosure is intended merely to exemplify the invention. The invention is not limited to the particular structure disclosed, and changes can be made therein which lie within the scope of the appended claims without departing from the invention.

The drawings illustrate two complete examples of the physical embodiment of the invention constructed according to the best modes so far devised for the practical application of the principles thereof, and in which:

FIGURE 1 is a perspective view of a transducer element made in accordance with this invention, and illustrating its preferred embodiment;

FIGURE 2 is a cross sectional view through FIGURE 1 on the plane of the line 2—2;

FIGURE 3 is a diagrammatic view to better illustrate the salient features of the invention; and

FIGURE 4 is a perspective view of a modified embodiment of the invention.

Referring to the drawings, and especially to FIGURE 1, the numeral 5 designates a two-legged transducer element in position on one wall 6 of a tank or vessel (not shown) the contents of which are to be subjected to ultrasonic vibration. The transducer element is cemented to the wall 6 with a suitable epoxy-type adhesive. An especially satisfactory adhesive for this purpose is made and sold by Emerson & Cuming, Inc., of Canton, Mass., under the trademark "Eccobond."

The two-legged transducer element comprises a pair of identical elongated bars 7 of magnetostrictive ferrite or piezoelectric ceramic, preferably the former. The bars 7 have a modified dumb-bell shape with straight longitudinally extending sides and flat-faced bosses 8 projecting from one side at each end thereof. The bars are positioned in side-by-side parallel relationship with their bosses 8 facing one another.

Between the opposing flat faces 9 of each pair of bosses is a permanent magnet 10. The magnets—which are preferably oblong blocks of ferro-magnetic ceramic—are identical in size and shape and their opposite sides 11 are flat and parallel and substantially coextensive with the opposing flat faces 9 of the bosses. Since the thickness of the two magnets, that is the distance between their opposite parallel sides 11, is the same, and since the faces of the bosses on each bar 7 are coplanar, it follows that surface-to-surface engagement between one of the magnets and its respective bosses, would likewise result in surface-to-surface engagement between the other magnet and its flanking bosses. This would effectively tie the two legs of the tranducer element together and constrain them to vibrate in unison, which is undesirable.

For significant reasons, which have nothing to do this invention, it is advantageous to have the two legs of the transducer element vibrate independently of one another. Accordingly, a shim 12 of non-magnetic material—preferably paper—is interposed between one side of the magnet at the bottom or mounted end of the transducer and the face of the adjacent boss. In the interest of clarity, the thickness of the shim 12 is exaggerated in the drawings.

Because of the presence of the shim between one side

of the lower magnet and the adjacent boss, the space between the opposing faces of the bosses at the upper or outer ends of the two bars is slightly greater than the thickness of the magnet therebetween. While this gives the magnet at the outer end of the transducer, a "floating" relationship to the total assembly, the importance of the described construction is that it allows the two legs of the transducer element to vibrate independently of one another.

Obviously, of course, the shim would not be necessary if the magnet at the lower mounted end of the transducer element were slightly thicker than the other; but this would entail making the magnets in two different sizes and would introduce assembly problems. It is, therefore, more advantageous to employ the described construction.

For ease in handling the transducer before it is cemented in place, the ends of the two bars at which the shim **12** is located may be secured together with a suitable epoxy adhesive, but in any event, when the transducer element is cemented to the wall **6**, the bars will be held in fixed relationship at this end.

As illustrated in FIGURE 3, in which the parts are shown separated and not necessarily to proper scale, the magnets **10** are so disposed with respect to polarity, that each bar or leg **7** is longitudinally interposed between opposite magnetic poles. The lines of flux emanating from the magnets thus thread lengthwise through the bars and, in so doing, cause the crystals thereof to rearrange themselves and, by mutual magnetic attraction, produce a contracting force which prestresses the bars longitudinally and actually shortens the bars. The important consequence of this contraction is an increase in the tensile strength of the bars and hence greater ability to resist elongation of the bars when subjected to an oscillating electromagnetic field that produces vibration of the transducer element in the lengthwise mode. As a result, it is possible to employ relatively higher levels of electromagnetic driving force without risking disintegration of the transducer element.

The bars are also prestressed in the transverse direction to give them greater mechanical strength. This is accomplished by a coating **13** of epoxy resin on all longitudinally extending surfaces thereof, save the faces **9** of their bosses, which faces are covered by the magnets. The endmost surfaces **14** of the elongated elements also are not coated with the epoxy resin.

The epoxy resin that is used may be of the type employed by Houghton et al. and which is characterized by very little shrinkage during the curing thereof, but considerable shrinkage during cooling. Examples of the epoxy resin that have these qualities are the "Stycast" and "Eccobond" products made by Emerson & Cuming, Inc., and the "Epon" adhesives made by Shell Chemical Company.

The resin may be applied in any suitable manner and then cured by baking. During the subsequent cooling of the coated elements, the far greater shrinkage of the resin as compared to that of the magnetostrictive ferrite or permanent magnets, with the result that the elements are formed, not only prestresses the elements transversely but also effects some endwise elongation of the elements. This elongation is counteracted and resisted by the aforesaid lengthwise contraction of the elements produced by the permanent magnets, with the result that the elemens are substantially restored to their initial or normal length from which they lengthen and shorten when subjected to an oscillating magnetic field. It is of course this changing length of the elements which takes place at ultrasonic frequency that produces the desired vibration.

The oscillating electromagnetic field is produced by connecting coils **15** and **16** that are wound about the elements, as diagrammatically shown in FIGURE 3, with high frequency electric current derived from any suitable source. Although the manner in which the coils are arranged and connected with the power source forms no part of this invention, it will be seen that the coils **15** are in series and wound in opposite directions, while the coils **16** are in parallel and wound in the same direction.

As also shown in FIGURE 3, the magnetic lines of flux amanating from the permanent magnets unidirectionally traverse the circuit formed by the two legs of the transducer and the magnets. Hence, during successive cycles of the oscillating current flowing in the coils **15** and **16**, the magnetic flux of the electromagnetic field produced by the energized coils threads the elements first in the same direction as the flux from the magnets and then in the opposite diretion.

As previously indicated, the two legged transducer element illustrated in FIGURE 1, is the preferred embodiment of the invention, but by no means the only possible form thereof. Thus, as shown in FIGURE 4, the transducer element may be a single bar **17** of either piezoelectric ceramic or magnetostrictive ferrite. The bar **17** has a uniform cross section from end to end, and is interposed between permanent magnets **18** at the opposite ends of the bar. The sides or longitudinally extending surfaces of the bar are coated as at **19**, with epoxy resin but the end surfaces against which the magnets abut are left uncoated.

In summation, I have found that the ultrasonic transducer element of this invention possesses significant advantages over those heretofore available, not only because it enables the transducer to be driven at high levels of power without risk of fracture, but also because sensitivity to low driving power has not been sacrificed in the attainment of the increase in tensile strength needed to achieve higher power outputs.

What is claimed as my invention is:

1. An ultrasonic transducer element for converting high frequency electrical energy into ultrasonic mechanical vibration, comprising:

(A) a pair of parallel elongated bars of material chosen from the class consisting of piezoelectric ceramic and magnetrostrictive ferrite,

said bars having bosses on the end portions thereof projecting towards one another from their adjacent sides, and said bosses having opposing faces;

(B) a permanent magnet between the opposing faces of each pair of bosses with opposite sides of the magnets contiguous to the opposing faces of the bosses,

said magnets being so disposed with respect to polarity that each elongated bar is interposed between opposite poles of the magnets and thereby magnetically prestressed in the lengthwise direction; and

(C) a coating of epoxy resin on the longitudinally extending surfaces of each bar other than the faces of their bosses,

said epoxy resin coating prestressing the bars in the transverse direction, whereby said coating and the permanent magnets coact to improve the ability of the transducer element to withstand the internal stress incident to subjection thereof to high levels of oscillating electromagnetic fields, without significantly diminishing the sensitivity of the element, said transducer being characterized in that

the distance between the opposing faces of the bosses at one end of the parallel elongated bars is slightly greater than the thickness of the permanent magnet therebetween,

so that one or the other of the opposing faces of the bosses is at all times free of contact with the magnet and the two bars are free to vibrate independently of each other.

2. The ultrasonic transducer of claim **1** wherein the parallel elongated bars are formed of magnetostrictive ferrite.

3. An ultrasonic transducer element for converting high frequency electrical energy into ultrasonic mechanical vibration, comprising:

(A) a pair of parallel elongated bars of material chosen from the class consisting of piezoelectric ceramic and magnetostrictive ferrite,

said bars having bosses on the end portions thereof projecting towards one another from their adjacent sides, and said bosses having opposing faces;

(B) a permanent magnet between the opposing faces of each pair of bosses with opposite sides of the magnets contiguous to the opposing faces of the bosses,

said magnets being so disposed with respect to polarity that each elongated bar is interposed between opposite poles of the magnets and thereby magnetically prestressed in the lengthwise direction; and

(C) a coating of epoxy resin on the longitudinally extending surfaces of each bar other than the faces of their bosses,

said epoxy resin coating prestressing the bars in the transverse direction, whereby said coating and the permanent magnets coact to improve the ability of the transducer element to withstand the internal stress incident to subjection thereof to high levels of oscillating electromagnetic fields, without significantly diminishing the

sensitivity of the element, said transducer being characterized in that

the faces of the bosses on each bar are flat and coplanar and the opposing faces are parallel; the opposite sides of both magnets are flat and parallel and spaced apart the same distance; and being further characterized by

a non-magnetic shim between one side of one of the magnets and the face of the adjacent boss,

whereby the distance between the opposing faces of the bosses at the opposite end of the bars is greater by the thickness of the shim than the thickness of the magnet between said bosses.

References Cited

UNITED STATES PATENTS

2,818,514	12/1957	Goertz et al.	310—26
2,947,890	8/1960	Harris et al.	310—26
3,155,852	11/1964	Harris	310—26
3,174,130	3/1965	Woollett	340—11
3,256,114	6/1966	Houghton et al.	318—118 X
3,351,832	11/1967	Houghton et al.	318—118

MILTON O. HIRSHFIELD, Primary Examiner

D. F. DUGGAN, Assistant Examiner

U.S. Cl. X.R.

340—11

PRINTER'S TRIM LINE

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,484,630 Dated December 16, 1969

Inventor(s) B. Schwartz

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, lines 58 through 60 should read -- piezo-electric ceramic material of which the elements are formed, not only prestresses the elements transversely but also effects some endwise elongation of the elements. This --. Column 3, line 63, "elements" is misspelled.

SIGNED AND
SEALED
JUN 16 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, J
Commissioner of Patent