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METHOD FOR PRELOADING ULTRASONIC TRANSDUCER

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Fig. 1

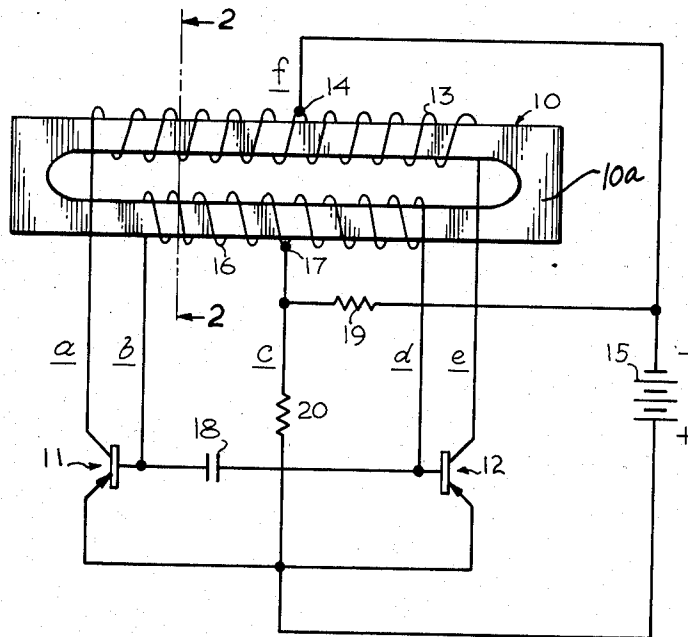


Fig. 3

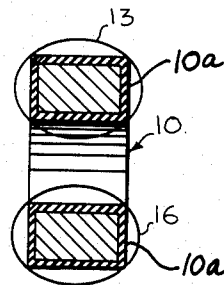
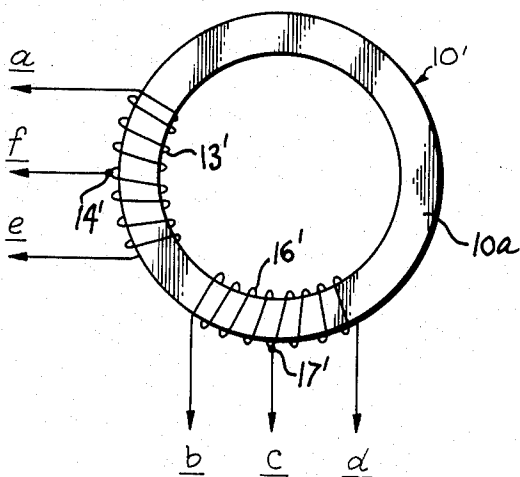


Fig. 2

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METHOD FOR PRELOADING ULTRASONIC
TRANSDUCER

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5 Claims. (Cl. 117-132)

The present invention relates in general to piezoelectric ceramic and magnetostrictive ferrite elements used as transducers in ultrasonic oscillators and more particularly relates to special epoxy-coated transducers of the type mentioned and the process for preparing the same.

Ultrasonic power is generally obtained by driving either a piezoelectric ceramic or a magnetostrictive ferrite transducer, the aforesaid drive being provided by means of an oscillator circuit of which the transducer is an inherent part. More particularly, irrespective of which kind of transducer element is used, the ultrasonic power is produced by converting electrical power to mechanical power in the form of mechanical vibrations of the transducer, the mechanical vibrations corresponding to the electrical oscillations used to produce them. Thus, for sake of example, when an oscillatorily varying magnetic field is appropriately applied to a magnetostrictive ferrite transducer, the transducer is forced to repetitively expand and contract, a well-known phenomenon, with the result that the transducer is caused to vibrate in a manner similar to the applied oscillations.

A major problem connected with power transfers of the type mentioned is that the tensile strength of these transducers is low while their compressive strength is high. This means that unless some scheme is employed to preload the transducer, a transducer will tend to crack and, therefore, fail when operated at the higher power levels. A good many schemes have been tried, probably the largest percentage of them using bolts to create the restraint. However, none of these earlier preloading schemes have proved to be entirely satisfactory for a variety of reasons. Thus, in the case of the preloading produced with the aid of bolts, the activity of the transducer has been sorely restricted due to an electromechanical phase shift created by the restraint itself. Furthermore, where the transducer element is magnetostrictive, eddy current paths are introduced which not only waste power but also deleteriously affect the electromechanical operation of the transducer and its associated oscillator drive circuit. There has, therefore, been a long-felt need for some simple but completely effective way to provide the desired preload for these transducers.

The present invention provides the sought-after solution to the above-mentioned problem of preloading transducers, the essence of the invention residing in the discovery that when the surface of a transducer designed to deliver ultrasonic power is coated with an epoxy-resin and then heat-treated, the transducer becomes properly preloaded. More specifically, the epoxy-resin is applied to the transducer so that its surface is uniformly coated with it. Following this step, the transducer is placed in an oven that has been pre-heated to a predetermined temperature corresponding to the kind of epoxy-resin used. The coated transducer is then baked in an oven for an interval of time also corresponding to the kind of epoxy-resin used, after which the element is taken out of the oven and permitted to slowly cool to the ambient temperature. During the cooling period, the epoxy-resin coating shrinks at a faster rate than the transducer material, with the result that the transducer is uniformly and uniquely preloaded. The transducer may then be

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coupled into the oscillator drive to make the ultrasonic power available.

Aside from the obvious advantages obtained by using an epoxy-resin technique, namely, that supporting mechanical structures and eddy paths are avoided, there is the further additional advantage that a considerable increase in power level can be obtained from this method. More particularly, the transducer will safely deliver four to five times its rated power when preloaded in accordance with the present invention. This is a significant and quite unexpected improvement in transducer development and opens up a new range of uses for them.

It is, therefore, an object of the present invention to provide a new type of preloaded ultrasonic transducer.

It is another object of the present invention to provide a method for simply and effectively preloading ultrasonic transducers.

It is a further object of the present invention to provide a method of preloading ultrasonic transducers that enables them to deliver several times their rated power without failure.

It is an additional object of the present invention to provide an ultrasonic power source capable of safely operating at relatively high power levels.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only and is not intended as a definition of the limits of the invention.

FIGURE 1 is a schematic circuit of an ultrasonic power source that includes a transducer prepared in accordance with the present invention;

FIGURE 2 is a cross-sectional view of the transducer element in FIG. 1 taken along the line 2-2; and

FIGURE 3 illustrates a transducer of different configuration or design than the transducer element of FIG. 1.

Referring now to the drawing, the circuit arrangement shown in FIGURE 1 is of an ultrasonic power source and includes a magnetostrictive transducer 10 in the shape of a core and a pair of transistors generally designated 11 and 12. Transducer element 10 is coated with an epoxy-resin material 10a and is suitably biased by means of either a coil or a permanent magnet, the biasing requirement being so well known and so standardized that it is not shown in the figure. As previously mentioned, the epoxy-resin coating is an important feature of the invention. The collector elements of transistors 11 and 12 are coupled to each other through a winding 13 which is center-tapped at 14. Winding 13 is wound on core 10 over epoxy-resin coating 10a and is to be considered a primary winding. The emitter elements, on the other hand, are shorted or connected directly to each other and also to the positive terminal of a voltage source, such as a battery 15.

A secondary winding 16, center-tapped at 17, is also wound on core 10 over epoxy-resin coating 10a, the two ends of this secondary winding respectively being connected directly to the base elements of transistors 11 and 12. Also connected between the ends of secondary winding 16 and, therefore, between the base elements of the transistors, is a capacitor 18 whose function in the circuit is to reject unwanted modes of oscillation. Accordingly, the value of capacitance of capacitor 18 is selected so that the capacitor will resonate with secondary winding 16 at the same frequency as magnetostrictive transducer 10. Finally, the circuit includes a voltage divider

comprising a pair of resistors 19 and 20 connected in series across voltage source 15. More specifically, resistor 19 is connected between center-tap 17 and the negative terminal of voltage source 15 while resistor 20 is connected between center-tap 17 and the positive terminal of the same voltage source. It should be mentioned that the values of resistance of resistors 19 and 20 are chosen so as to establish the proper operating bias for transistors 11 and 12.

Transducer 10 in cross-section is clearly shown in FIG. 2, the epoxy-resin material 10a with which the transducer is coated as well as primary and secondary windings 13 and 16, respectively, also being clearly shown.

Considering now the circuit operation, when the power is turned on, one of the two transistors, either transistor 11 or transistor 12, conducts more than the other. This is due to the fact that the two transistors are not perfectly identical. Assuming initially that transistor 11 conducts more than transistor 12, an unbalanced current flows in primary winding 13. It will be recognized by those skilled in the arts involved, that the resulting unbalanced current causes or produces a change in dimension of magnetostrictive element 10. The dimensional change, in turn, induces a current in secondary winding 16, the windings being phased in such a manner that, under the circumstances mentioned, the secondary winding causes transistor 11 to go into full conduction while at the same time cutting off transistor 12. As a result, a square current wave and, therefore, a like kind of magnetic field, is applied to the transducer, that is, to magnetostrictive element 10, and since it is itself a resonant element it therefore vibrates at its natural frequency. As it does vibrate, the transducer returns from its initial displacement to its original dimension, then displaces in the opposite direction. It will be recognized that as it displaces in the opposite direction, it induces a reverse current in secondary winding 16. By so doing, transistor 11 is cut off and, therefore, no longer conducts current, transistor 12 simultaneously being caused to go into full conduction. Thus, the resonant cycle is completed and will continuously be repeated since the circuit oscillation is self-sustained by the magnetostrictive feedback.

A set of parameters for a specific circuit arrangement is presented below where the various sub-numerals refer to the circuit elements in the figure. The parameters are as follows:

$R_{19}=120$ ohms;

$R_{20}=5$ ohms;

$C_{18}=4$ microfarads;

Transistors 11 and 12 are 2N441P-N-P transistors;

$E_{15}=12$ volts;

Primary winding 13 contains a total of 14 turns;

Secondary winding 16 contains a total of 8 turns;

Magnetostrictive core member 10 is a magnetostrictive ferrite 7A2 material manufactured and sold by the Ferroxcube Corporation of America, 50 East Ridge Street, Saugerties, New York; and

Epoxy-resin material 10a may be any one of a number of epoxy-resin materials that are presently commercially available.

It should be mentioned at this point that the circuit shown in FIG. 1 may be modified in several respects. Thus, for example, it will be obviously to those skilled in the ultrasonic art that capacitor 18 may be eliminated from the circuit. However, without the capacitor, transducer 10 tends to oscillate at its lowest mode which is determined by the dimensions of the transducer. Again, the circuit would operate just as effectively by reversing the polarity of the applied voltage and by substituting N-P-N transistors for P-N-P transistors 11 and 12. Finally, it will also be recognized that vacuum tubes of the triode type are equivalent in this case to the transistors and may be substituted for them.

Reference is now made to the method by means of

which the epoxy-resin coating is provided on the transducer. In preparation, the curing oven is preheated to a temperature that is between 210° C. and 220° C. At the same time, the transducer is cleaned, two steps being involved. First, the surface of the transducer is sandblasted, thereby providing a smooth substantially dirt-free surface. Second, following the sandblasting, the transducer is ultrasonically cleansed by immersing it in a liquid solvent to which ultrasonic power is applied. As is well known, the ultrasonic vibrations of the solvent causes the dirt to be dislodged from the transducer surface, with the result that, for all practical purposes, the transducer is then perfectly clean. Of course, other cleansing techniques are available and may be used but the cleansing steps mentioned above have been found to be most expeditious and effective. After the transducer has been cleaned in the manner described and then dried in air, the epoxy-resin material is applied to its entire surface area and this is accomplished by painting it on with an ordinary paint brush, the transducer being held during this period by means of a clamp or some other device. In completing the paint job, the transducer is placed on prongs or minimum surface areas so that the epoxy-resin can be applied to those areas that have not yet received it, because of interference by the holding clamp or device or for other reasons. The prongs or minimum surface areas that come into contact with the transducer and the epoxy-resin thereon are pretreated with a release agent that keeps the epoxy-resin from adhering to them. An example of such a release agent is silicone grease.

Now that the transducer surface is completely covered with the epoxy-resin material, the combination of the pronged mechanism and the transducer resting thereon are placed in the oven which, it will be remembered, has been preheated to an is at a temperature of approximately 220° C. The transducer remains in the oven and is cured for several hours, the actual number of hours depending on the particular epoxy-resin used. By the end of the curing time, the epoxy-resin is hard. Consequently, the coated transducer is taken out of the oven and allowed to slowly cool in air for a period of from two to three hours. The transducer is now ready for use and can be expected, as a result of this coating technique, to deliver four to five times the rated power of the transducer. As a concrete example of the improvement that can be achieved in this way, if the rated power is less than 50 watts, then the transducer will produce 200 watts.

It was mentioned earlier that a number of different epoxy-resins are commercially available. However, whichever one is selected for the purposes of the present invention, it should be an epoxy-resin having a high coefficient of thermal expansion in the cured solid state. Stated differently and more specifically, the epoxy-resin should be one that experiences very little shrinkage during the curing step, less than one percent (1%), that is, less than one hundredth ($\frac{1}{100}$) inch per inch. On the other hand, the epoxy-resin material should possess the quality of shrinking at a much more rapid rate during the cooling step than the ferrite constituting the magnetostrictive transducer, preferably three to five times that of the ferrite. When the epoxy-resin has this quality, the desired preload will be uniformly applied throughout the transducer and it will then be capable of operating at greatly increased power levels as set forth above. An example of an epoxy-resin that may be used is known as Stycast No. 2651, manufactured by Emerson and Cuming, Inc. of Canton, Massachusetts. The cure time for Stycast No. 2651 is 2 hours at the oven temperature mentioned, namely, from 210° C.-220° C.

Having described the manner in which the transducer is coated, it should next be mentioned that transducer 10 or its associated drive circuit in FIG. 1 may be modified in several respects. One such modification was indicated earlier when it was stated that capacitor 18 could be

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eliminated from the circuit. Another modification could be made in the shape or configuration of the transducer as is shown in FIG. 3 wherein a ring or annular-shaped transducer 10' is shown that may be substituted for the transducer of FIG. 1. Transducer 10' is also covered with an epoxy-resin coating 10a and, because of its shape, is designed to oscillate or vibrate radially rather than longitudinally when power is applied to it. A primary winding 13' and a secondary winding 16' are also wound on transducer 10', the lines leading from primary winding 13' being designated a, e and f and the lines leading from secondary winding 16' being designated b, c and d. In substituting transducer 10' for transducer 10, lines a-f in FIG. 3 are connected to those points in the drive circuit to which the similarly designated lines in FIG. 1 are connected.

Again, the ultrasonic power source of FIG. 1 may be adapted to use a piezoelectric ceramic transducer that has been epoxy-resin coated rather than a magnetostrictive transducer.

Having thus described the invention, what is claimed as new is:

1. A method of uniformly preloading an ultrasonic transducer element comprising the steps of: applying a coating to all surfaces of the transducer element of an epoxy-resin having a coefficient of thermal expansion in the cured state of three to five times that of the transducer element, heat treating the coated transducer element for an interval of time and at a temperature to effect curing, cooling the coated transducer element to ambient temperature, wherein said epoxy-resin is characterized by low shrinkage during curing followed by greater shrinkage during cooling.

2. The method set forth in claim 1 including the steps of cleaning the transducer element by sand blasting and

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subjecting it to an ultrasonic bath, prior to applying the epoxy-resin coating.

3. The method of claim 1 wherein the epoxy-resin is applied with a paint brush.

4. The method of claim 1 wherein the epoxy-resin has characteristics such that curing is effected at a temperature of the general order of 210° C. to 220° C.

5. The method of claim 2 wherein said epoxy-resin is applied with a paint brush and wherein the transducer element is air-cooled after heat curing.

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