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(54) HIGH POWER PIEZOELECTRIC BENDER

(71) We, MOTOROLA, INC., a corporation organised under the laws of the State of Delaware, United States of America, of Corporate Offices, Motorola Center, 1303 East Algonquin Road, Schaumburg, Illinois 60196, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention pertains to bimorph benders and, in particular, to an improved means for mechanical coupling to such benders.

Piezoelectric bimorph benders are well known in the art, especially when used in transducer applications. Such benders are normally comprised of a pair of circular piezoelectric elements having diametrically opposed surface portions. Electrodes are formed contiguous with each element surface and extending over a substantial area thereof. The two discs are held in fixed spaced relationship by a center vane member sandwiched therebetween, and affixed thereto. Upon application of electrical signals to the electrodes, the bender dishes, wish maximum displacement occurring at the bender's central location.

The bender's mechanical load has commonly been bonded to the central portion of one disc surface. This construction has proven fault prone since, especially at high power levels, the ceramic may be torn from the center vane. Further, since both ceramic discs contribute to the electromechanical energy conversion, coupling to one disc alone does not provide maximum energy transfer to the load.

Effective coupling to the bender would be accomplished if the driver had a hole in its center, such that the load could be attached thereto as with a nut and bolt. Prior art attempts to fabricate a hole in the center of a bender driver have proven unsuccessful, mainly because the hole equalizes some of the dynamic stresses in the bender thereby reducing the electromechanical coupling factor. The loss in coupling factor cannot be tolerated, since the design objective of piezoelectric motors is to make the driver as efficient as possible with a high power handling capability.

It is an object of this invention, therefore, to provide an improved bimorph bender structure which is capable of reliably handling high power levels.

According to the present invention there is provided a bimorph bender comprising a pair of disc members, each disc member formed of a piezoelectric material and having first and second diametrically opposed surface portions, each disc further provided with a centrally located coupling hole defined by a disc coupling hole surface; electrode members contiguous with a substantial portion of each disc member first and second surface portions; a centre vane member, provided with a centrally located coupling hole, for separating the discs in fixed spaced relationship, the coupling holes being aligned to form a coupling cavity; a coupling member comprised of an electrically insulating and mechanically rigid material and insertable in the coupling cavity and a means for affixing the coupling member within the coupling cavity such that the coupling member is firmly attached to the coupling hole surface of each disc, whereby the coupling member provides a means to mechanically couple to the bender.

Briefly, according to one embodiment of the invention, the bimorph bender is comprised of a pair of disc members, each of which is formed of piezoelectric material. The discs have first and second diametrically opposed surface portions, and each disc is provided with a centrally located coupling hole which is defined by a disc coupling hole surface. The electrodes are contiguous with each disc surface, and extend over a substantial portion thereof. A centre vane member interconnects the two discs and separates them in a fixed spaced relationship. The centre vane is also provided with a centrally located coupling hole, and in combination,

the coupling holes are aligned to form a coupling cavity.

A coupling member, formed of an electrically insulating and mechanically rigid material is insertable. The coupling member is affixed within the cavity such that it is firmly attached to the coupling hole surface of each disc. The coupling member provides a superior means to mechanically couple a load to the bender.

In one construction of the improved bender, the coupling member may be provided with a central hole thus allowing nut and bolt connection to the mechanical load.

The invention will now be described by way of example only with particular reference to the accompanying drawing wherein:

Fig. 1 is an exploded view of the preferred bimorph bender with coupling member; and

Fig. 2 is a cut-away view of an assembled bimorph bender according to the invention.

Fig. 1 is an exploded view of a circular bimorph bender 10. Each member is comprised of a pair of circular ceramic discs 12, 14. Each disc is made out of an homogenous piezoelectric, ceramic material. This material has a dielectric constant of 3400 and an electro-mechanical coupling factor K_p of 0.63, even with 5.5 mil thicknesses. Each disc is provided with upper and lower electrodes 16*a*, 16*b*; 18*a*, 18*b*; respectively. It should be understood that Fig. 1 illustrates only the upper electrode 16*a* of disc 12 and the upper eletctrode 18*a* of disc 14. Preferably, the electrodes are of nickel thus providing the highest capacity and highest coupling factor.

A corrugated center vane member 20 is sandwiched between the two discs and, via a thin layer of nonconductive epoxy on the tips of the corrugations, bonds the discs to the center vane maintaining a fixed spaced relationship therebetween. Each disc 12, 14 is provided with a centrally located mounting hole which is defined by disc coupling hole surfaces 22, 24 respectively. Also, the center vane 20 is provided with a central coupling hole whereby, in construction of the bimorph, the holes are aligned to form a coupling cavity.

A cylindrical washer 26 is the coupling member for the bimorph assembly. Cylindrical coupling member 26 has a predetermined diameter which is slightly less than the diameter of the coupling cavity, whereby the coupling member 26 may be inserted therein. The vertical dimension of the coupling member 26 is such that when inserted in the coupling cavity the outer surface of the coupling member 26 is contiguous with the coupling hole surfaces 22, 24 of the discs 12, 14 and contacts a substantial portion of each coupling hole surface. The coupling member 26 is formed of a high specific stiffness material, such as alumina ceramic. In this preferred embodiment, the coupling member 26 is provided with a central mounting hole 28 which extends through the axial center of the cylindrical coupling member 26.

The coupling member 26 is inserted within the coupling cavity and a high stiffness, electrically insulating alumina filled epoxy cements the outer surface of the coupling member 26 to the disc mounting hole surfaces 22, 24 respectively.

In operation, the electrodes are wired in parallel, that is, the upper electrode 16*a* of disc 12 is electrically connected to the upper electrode 18*a* of disc 14, whereas the lower electrodes 16*b*, 18*b* are interconnected. AC signals are applied to the electrodes, whereby, due to the piezoelectric effect, one disc expands radially while the other radially contracts. The result is a dishing of the bender with the direction of dishing dependent on the polarity of the applied signal. The bender displacement is directly proportional to the magnitude of the applied signal, and, their maximum displacement occurs at the central portion of the bender. In prior art benders, the mechanical load was bonded directly to the central portion of an exposed disc surface. The bond of the load to the bender was therefore as good as the bond of the electrode to the disc, which meant that for heavy load conditions the load might strip the electrode off the disc, or, more commonly, the load would rip the ceramic disc off of the center vane.

The bimorph bender according to the instant invention provides an improved means for coupling to the load. In particular, the coupling member 26, which is located at the point of maximum displacement in the bender, may be used for firm attachment to the load, as for example, by nut and bolt if need be. Since the coupling member 26 is affixed to both discs 10, 14 maximum power transfer to the load is accomplished, with a minimum shear force between discs, electrodes, and the center vane.

Also, since the coupling member 26 is fabricated with a high specific stiffness material, the mechanical stress forces on the bender are maintained whereby a high electromechanical coupling factor is achievable. In one embodiment of the invention, a bender was fabrication having a total thickness of 25 mils and a diameter of 1.25 inches. The initial bending coupling factor K_b of the bender was measured at .508, where:

K_b = (induced mechanical energy/total input electrical energy)$^{-2}$.

After drilling a central grounding hole of diameter .256 inches, the K_b was measured as .426. Thereafter, after insertion and cementing in the alumina washer the coupling factor K_b returned to .508. Therefore, the improved bimorph bender maintains a high

coupling factor while providing an improved means of coupling to a mechanical load.

Fig. 2 illustrates a cutaway perspective view of the preferred circular bimorph bender. Shown are the ceramic discs 12, 16 in fixed spaced relation via a center vane 20. Cemented within the central coupling cavity of the bimorph assembly is shown the coupling member 26. The vertical dimension of the coupling member 26 is such that it may be cemented to both the upper and lower discs 12, 16 respectively, via an insulating, high stiffness epoxy 30. It is important that the cementing material used be of a stiff and electrically insulating material to maintain the mechanical stresses across the bender, while electrically insulating the various electrodes. A mounting hole 28 is provided through the axial center of the cylindrical coupling member 26, whereby coupling to a mechanical load is accomplished with greater facility.

In summary, an improved bimorph bender is disclosed which can handle high power levels with reliability and efficiency, and which provides a convenient means for attaching the bender to a mechanical load.

WHAT WE CLAIM IS:—

1. A bimorph bender comprising:

a pair of disc members, each disc member formed of a piezoelectric material and having first and second diametrically opposed surface portions, each disc further provided with a centrally located coupling hole defined by a disc coupling hole surface;

electrode members contiguous with a substantial portion of each disc member first and second surface portions;

a center vane member, provided with a centrally located coupling hole, for separating the discs in fixed spaced relationship, the coupling holes being aligned to form a coupling cavity;

a coupling member comprised of an electrically insulating and mechanically rigid material and insertable in the coupling cavity and

a means for affixing the coupling member within the coupling cavity such that the coupling member is firmly attached to the coupling hole surface of each disc,

whereby the coupling member provides a means to mechanically couple to the bender.

2. The bimorph bender of claim 1 wherein each disc is circular in shape.

3. The bimorph bender of either claim 1 or 2 wherein each disc coupling hole is circular in shape.

4. The bimorph bender of claim 3 wherein the coupling member is cylindrical in shape having a diameter slightly smaller than that of the coupling hole cavity and having a vertical dimension to contact a substantial portion of each disc coupling hole surface.

5. The bimorph bender of claim 4 wherein the coupling member is further provided with a central mounting hole which extends through the axial center of the coupling member.

6. The bimorph bender of any of claims 1 to 5 wherein the coupling member is fabricated of alumina ceramic.

7. The bimorph bender of claim 5 wherein the means for affixing the coupling member within the coupling cavity comprises an alumina filled epoxy cement for cementing the coupling member outer surface to each disc coupling hole surface.

8. The bimorph bender substantially as hereinbefore described with reference to the accompanying drawing.

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a center vane member, provided with a centrally located coupling hole, for separating the discs in fixed spaced relationship, the coupling holes being aligned to form a coupling cavity;

a coupling member comprised of an electrically insulating and mechanically rigid material and insertable in the coupling cavity and

a means for affixing the coupling member within the coupling cavity such that the coupling member is firmly attached to the coupling hole surface of each disc,

whereby the coupling member provides a means to mechanically couple to the bender.

2. The bimorph bender of claim 1 wherein each disc is circular in shape.

3. The bimorph bender of either claim 1 or 2 wherein each disc coupling hole is circular in shape.

4. The bimorph bender of claim 3 wherein the coupling member is cylindrical in shape having a diameter slightly smaller than that of the coupling hole cavity and having a vertical dimension to contact a substantial portion of each disc coupling hole surface.

5. The bimorph bender of claim 4 wherein the coupling member is further provided with a central mounting hole which extends through the axial center of the coupling member.

6. The bimorph bender of any of claims 1 to 5 wherein the coupling member is fabricated of alumina ceramic.

7. The bimorph bender of claim 5 wherein the means for affixing the coupling member within the coupling cavity comprises an alumina filled epoxy cement for cementing the coupling member outer surface to each disc coupling hole surface.

8. The bimorph bender substantially as hereinbefore described with reference to the accompanying drawing.

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