

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets

(11)

Publication number:

**0 225 113
A2**

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: **86309011.4**

(51) Int. Cl.4: **B06B 1/08**

(22) Date of filing: **18.11.86**

(30) Priority: **19.11.85 US 799683**

(43) Date of publication of application:
10.06.87 Bulletin 87/24

(84) Designated Contracting States:
BE CH DE FR GB IT LI SE

(71) Applicant: **WESTINGHOUSE ELECTRIC
CORPORATION**
Westinghouse Building Gateway Center
Pittsburgh Pennsylvania 15235(US)

(72) Inventor: **Helm, Richard Clyde**
9008 Doncoggin Road
Ellicott City, MA 20143(US)

(74) Representative: **van Berlyn, Ronald Gilbert**
23, Centre Heights
London, NW3 6JG(GB)

(54) **Magnetostrictive transducer apparatus.**

(57) A magnetostrictive transducer apparatus for ultrasonic cleaning applications with a magnetostrictive material portion of stacked laminations bonded to a coupling member made of non-magnetic material such as aluminum for operation at a frequency of about 40 kilohertz and a sound level below 90 DBA, with each of the stacked laminations and the coupling member being of about one-half wavelength at the desired frequency of operation.

EP 0 225 113 A2

MAGNETOSTRICTIVE TRANSDUCER APPARATUS

This invention relates to an ultrasonic transducer apparatus to provide ultrasonic sound waves, at frequencies above the audible range through the operation of one or more suitable transducers attached to the bottom radiating plate of a cleaning tank containing a liquid such as water, to develop cavitation of vapor bubbles forming desired pressures and temperatures for scrubbing a workpiece placed in that liquid. Electric power is applied for this purpose at a predetermined desired frequency above the known threshold of cavitation of the particular liquid utilized.

More than half of the ultrasonic cleaning equipment presently sold operates at a higher frequency in the range of 35 kilohertz to 50 kilohertz, which equipment is used for applications demanding emitted sound of 90 DBA or less and/or where the gentle cavitation at these higher frequencies is adequate or required for the desired cleaning job. The present 20 kilohertz equipment is generally not applied in applications where the higher frequency equipment cleaning is adequate because of the higher emitted sound levels, typically 96 DBA or higher.

The transducers used in the present higher frequency equipment are typically of composite or sandwich construction, using discs of a piezoelectric ceramic in the center section for the driving force. The piezoelectric ceramics are used because they have potential efficiencies above 90%. Magnetostrictive metals are generally thought to have much lower potential efficiencies, and are not used for this reason even though they have several advantages when compared to ceramics, such as being more rugged and not subject to breakage from mechanical or thermal shock and having higher power handling capability. The polarization of magnetostrictive transducers can be maintained indefinitely by passing a DC current through the energizing coil winding.

It is known in a prior art to apply magnetostrictive transducer apparatus for the ultrasonic agitation of a liquid, such as disclosed in the specification of U.S. Patent Nos. 3,458,736 and 3,474,271, including thin magnetostrictive laminations bonded to a radiating plate operative with that liquid.

According to the present invention, an ultrasonic transducer apparatus energized by an alternating current having a desired frequency and coupled with a radiating plate of a tank including a liquid for providing a vibration to said liquid comprising a stacked plurality of thin magnetostrictive laminations, with each lamination having a length dimension substantially perpendicular to said radiating plate of about one-half wavelength of said

desired frequency, and a coupling member connected with said radiating plate and bonded to said laminations with an adhesive film and having a length dimension substantially perpendicular to said radiating plate of about one half wavelength of said desired frequency.

Conveniently, the ultrasonic transducer is obtained by providing a stacked plurality of magnetostrictive laminations having a longitudinal dimension of one-half wavelength at the desired operating frequency and bonded to a coupling member of non-magnetic material having one-half wavelength in longitudinal dimension. One or more such transducers, mechanically resonant at the operating frequency, can be coupled to a radiating plate operative with a liquid volume bath for cleaning work pieces. The transducer utilizes thin laminations of magnetostrictive material for efficient electrical to mechanical energy conversion and is bonded to a coupling bar for more efficient mechanical energy transmission to the cleaning bath. The transducer has the power handling capability for the intensity of sound waves required to cause the desired cavitation for ultrasonic cleaning.

The invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 shows an ultrasonic cleaning tank coupled with a plurality of magnetostrictive transducers;

Figure 2 shows a side view of one magnetostrictive transducer including a non-magnetic coupling bar portion and an active magnetostrictive material portion;

Figure 3 shows one lamination section for the active magnetostrictive material portion, which is made and operated for a 40 kilohertz transducer;

Figure 4 shows a detailed sketch of a coupling bar made and operative for a 40 kilohertz transducer; and

Figure 5 shows a bottom view of the ultrasonic cleaning tank shown in figure 1, with the magnetostrictive transducers coupled to the bottom radiating plate and the electrical energization provided for the transducers.

Figure 1 shows a first view of a workpiece cleaning tank 10 including a radiating bottom plate 12 to which is bonded, as by epoxy cement a plurality of magnetostrictive transducer members 14. Each transducer member 14 includes a coupling bar 16, made of non-magnetic material such as aluminum, and an active magnetostrictive material portion 18 comprising a stack of laminations made of nickel or its alloys. The transducer members 14 convert alternating current energy at a

desired frequency such as 40 kilohertz into mechanical ultrasonic energy within the cleaning liquid provided inside of the tank 10. Each transducer member 14 exhibits a change in physical dimension in response to the magnetic field provided by suitable winding coils 20 connected to energize each transducer 14 with a suitable source of electrical energy 21.

Magnetostrictive materials operate most efficiently when they are polarized to a magnetic flux level that gives them the best electromechanical coupling coefficient. A DC current in the transducer energization winding 20 can be used to preset the flux level about which the transducer will operate most effectively. Magnetostrictive transducers can be polarized continuously in use and therefore will not depolarize with time. To make the core of a conventional magnetostrictive transducer, flat sheet laminations of nickel are stacked and clamped together. A window opening 19 is provided within each lamination for the energization winding. Winding guides can be installed to prevent chafing of the coil wire. The greatest length change can be obtained in relationship to a particular magnetic flux change, when the flux level is biased up to where the permeability has started to decrease. In addition the transducer vibrates at the same frequency as the alternating current and in relation to the magnetic field provided by the DC bias.

Figure 2 is a side view of one transducer 14, taken perpendicular to the view shown in Figure 1, to show the coupling bar 16 and the laminated magnetostrictive material portion 18. The dimension of the coupling bar 16 along the longitudinal axis of the coupling bar 16 is about one-half wavelength at the desired operating frequency, such as 40 kilohertz. The active magnetostrictive material portion 18 has a similar dimension of about one-half wavelength. The total transducer structure shown in Figure 2, with the coupling bar 16 bonded by an epoxy adhesive film of about 3 mil thickness to the end of the laminations portion 18 is substantially one wavelength in longitudinal dimension and is mechanically resonant at the desired operating frequency.

In Figure 3 there is shown a sketch of one lamination 24 having a thickness of about four mils to minimize eddy current losses and suitable for operation in a stack of such laminations to comprise the active magnetostrictive material portion 18 of the transducer 14. A suitable stack of such laminations 24 was actually constructed, and the stack was about 0.75 inch thick for this purpose. The transducer module was constructed of 4 mil inch thick laminations of type 233 nickel which was epoxy bonded to the aluminum coupling bar. The laminations were stamped from nickel strip, and the nickel laminations were then annealed in an air

atmosphere to reduce stresses and to form a nickel oxide surface film. The oxide film functioned as electrical insulation, which along with the thin lamination operated to minimize eddy current losses when the laminations are stacked. Each lamination is dimensioned so that, with a window to receive an electrical driving coil, the length is about a half wavelength at the desired frequency and the width is less than a quarter wavelength. Actual laminations 24 having the physical dimensions shown in Figure 3 were actually constructed and operated satisfactorily at a desired frequency of 40 kilohertz.

In Figure 4 there is shown a suitable spoon-shaped coupling bar 16 for operation at 40 kilohertz. The dimensions are shown for a coupling bar 16 that was actually constructed and operated satisfactorily at the desired 40 kilohertz frequency of operation. The coupling bar 16 is designed so that it has a length of about one-half wavelength at the same frequency as a lamination 24. The coupling bar cross section is round, with the middle diameter less than one-quarter wavelength and each end is stepped to a larger diameter. This operational half wavelength of the bar is reduced by the added mass at the ends. The coupling bar 16 is provided to increase the acoustic loading of the magnetostrictive material portion 18 of the transducer 14, by driving a substantially larger area of the tank bottom plate 12.

The coupling bar 16, having a cross-sectional area larger than the stack of laminations and a diameter greater than a wavelength in cleaning liquids, operates to load the transducer active magnetostrictive material to increase the mechano-acoustic energy transfer efficiency and to greatly improve the distribution of the cavitation in the cleaning bath. The coupling bar 16, which is made of aluminum, has very low internal mechanical damping and is an efficient member to couple sound energy from the active lamination stack to the cleaning liquid. Aluminum is a good thermal conductor, such that the coupling bar 16 functions to cool the stack of laminations. The transducer module resonant frequency is the frequency at which the lamination stack and the bar are each an operational one-half wavelength. The resonant frequency is changed slightly when the module is bonded to a stainless steel tank or immersible radiating plate. The resonant frequency of the cleaning liquid load can give rise to several additional resonances. The transducers can be operated with an electrical energy supply generator which tends to power the transducer at a resonant frequency determined by the liquid load or with a generator having a circuit that powers the transducer at its own resonant frequency.

In Figure 5 there is shown a bottom view of the radiating bottom plate 12 of a cleaning tank. A plurality of magnetostrictive transducers 14 are bonded to the bottom plate 12 in position as shown in Figure 1. These are selected to provide a desired acoustic energy transfer to the liquid within the tank and in relation to the power source generator. A low frequency alternating current power supply 22 is connected through a full wave rectifier 23 with a high frequency oscillator signal generator 30 to provide a desired higher frequency energization of the winding coil arrangement 20 coupled through the window opening in the laminated magnetostrictive material portion 18 of each transducer 14. The number of transducers 14 is selected to provide a desired uniformity of acoustic energy within the tank 10. The power supply 22 is operative with the full wave rectifier 23 and the DC bias control 25 to provide a desired DC signal current to polarize the transducers 14 to a preset flux level about which each transducer will operate most effectively. The winding coil arrangement 20 can include a number of turns, such as ten turns, to energize each of transducer groups A, B and C for providing a desired impedance match with the impedance of the signal generator 30.

Several prototype ultrasonic cleaning tanks containing liquid were constructed and operated with the transducer modules of the present invention epoxy bonded to the tank bottom. A preferred transducer module for this purpose was 4 inches long and had a resonant frequency of 38.2 kilohertz. The coupling bar end diameter was about 1.5 inches with a middle section diameter of 1.13 inches, and the stack of nickel laminations epoxy bonded centrally to the bar was about .75 inch thick. Each lamination 24 had a thickness of 4 mils, a length of 2 inches, a width of 0.841 inch and a window opening of 1.190 inch by .327 inch. A typical test tank was 14 inches long by 12 inches wide and 12 inches deep, with between 16 transducer modules and 30 transducer modules bonded to a bottom radiating plate. The layout of the modules on the tank bottom included transducer modules electrically powered and biased by a single wire coil arrangement. These transducer assemblies were operated at power levels of up to an estimated 36 watts per module in a frequency range of 37 kilohertz to 40 kilohertz. For the tests the tanks were filled with tap water including a small amount of detergent. Cavitation intensity and uniformity observed in the water was estimated to be equal to or better than typical piezoelectric 40 kilohertz equipment available in the prior art. The sound level was measured to be 88 DBA.

Claims

1. An ultrasonic transducer apparatus energized by an alternating current having a desired frequency and coupled with a radiating plate of a tank including a liquid for providing a vibration to said liquid, comprising a stacked plurality of thin magnetostrictive laminations, with each lamination having a length dimension substantially perpendicular to said radiating plate of about one-half wavelength of said desired frequency, and a coupling member connected with said radiating plate and bonded to said laminations with an adhesive film and having a length dimension substantially perpendicular to said radiating plate of about one half wavelength of said desired frequency.

2. A transducer apparatus as claimed in claim 1, including said coupling member having a first area connected with the radiating plate and said laminations having a second area bonded to said coupling member, with the first area being larger than the second area.

3. A transducer apparatus as claimed in claim 2, in which the coupling member is arranged to operate to increase the loading of said laminations by providing an increased mechanical energy transfer from the laminations to said liquid.

4. A transducer apparatus as claimed in any one of claims 1 to 3, in which said laminations including a plurality of lamination stacks and one coupling member provided for each lamination stack.

5. A transducer apparatus as claimed in claim 3 or 4, including the coupling member having a cross-sectional middle dimension of less than one-quarter wavelength and each end being stepped to a larger diameter such that the operational about one-half wavelength of said length dimension is reduced by the larger mass of each end.

6. A transducer apparatus as claimed in claim 5, including the coupling member operating to drive a substantially larger area of said radiating plate in relation to said stacked plurality of laminations.

7. A transducer apparatus as claimed in any one of claims 1 to 6 in which the apparatus is adapted for connection to an alternating current power supply, including said stacked laminations bonded to said coupling member being energized by said power supply at a resonant frequency at which the laminations stack and the coupling bar are each substantially an operational one-half wavelength.



