United States Patent

Jacke

[15] **3,698,408**

[45] **Oct. 17, 1972**

[54] **ULTRASONIC PROCESSING APPARATUS**

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[73] Assignee: **Branson Instruments, Incorporated,** Stamford, Conn.

[22] Filed: **June 11, 1971**

[21] Appl. No.: **152,095**

[52] **U.S. Cl.**.....**134/122,** 51/DIG. 11, 118/405, 118/429, 134/1, 259/DIG. 44, 310/26

[51] **Int. Cl.** **B08b 3/10**

[58] **Field of Search**.....134/184, 122, 1; 118/429, 118/DIG. 18, DIG. 19, DIG. 22, 57; 117/DIG. 8; 259/DIG. 44; 51/DIG. 11; 68/3 SS; 310/26

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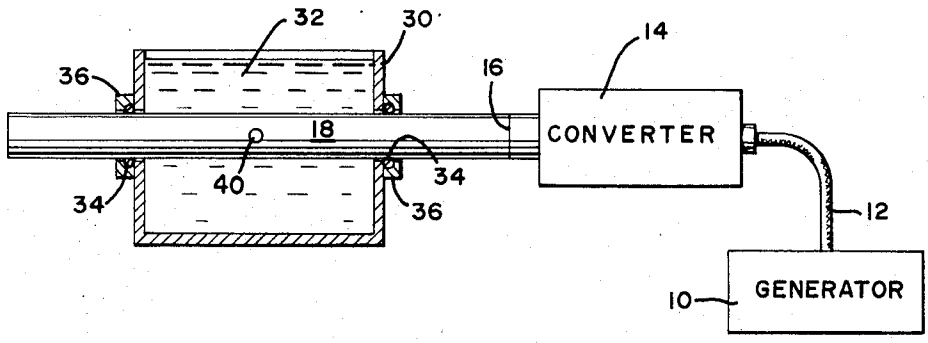
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Primary Examiner—Morris Kaplan
Attorney—Ervin B. Steinberg

[57] **ABSTRACT**

An apparatus for ultrasonically treating (e.g., cleaning, plating) a workpiece comprises a full wavelength resonator or horn supported at its nodal regions. The antinodal region of the horn is surrounded by a suitable treating liquid, typically, a solvent or liquid metal and a workpiece to be treated is immersed in the liquid in proximity to the nodal region of the horn. In a preferred embodiment, the horn is provided with a depression or aperture at its antinodal region and a workpiece to be treated is inserted into the depression or aperture.

12 Claims, 10 Drawing Figures



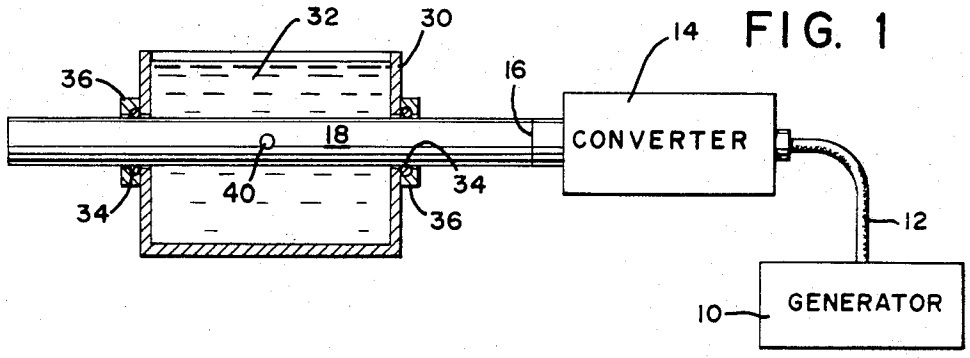


FIG. 1

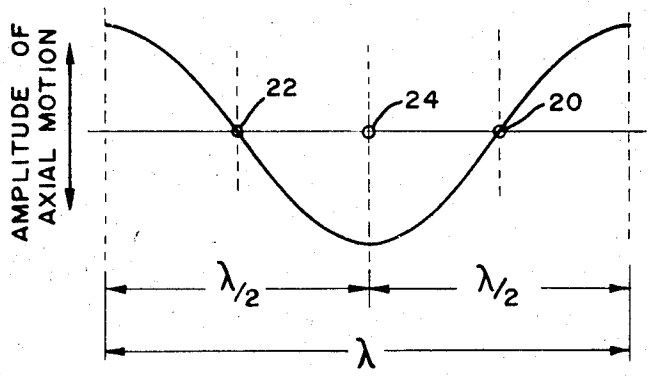


FIG. 2

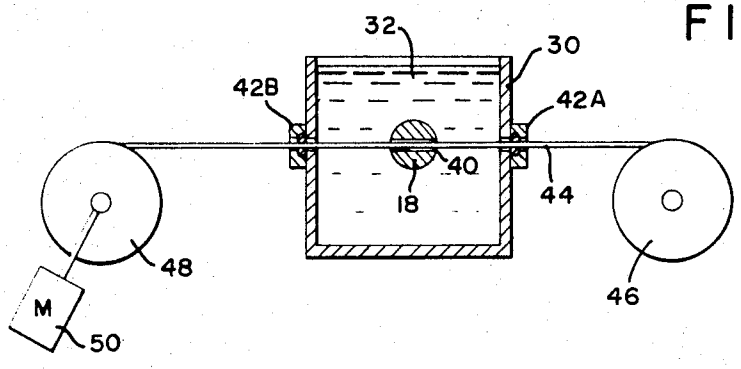


FIG. 3

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FIG. 4

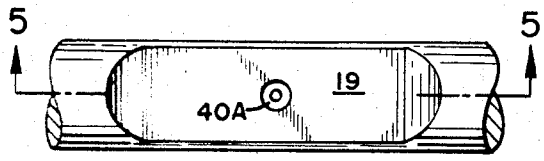


FIG. 5

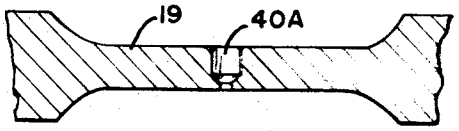


FIG. 6

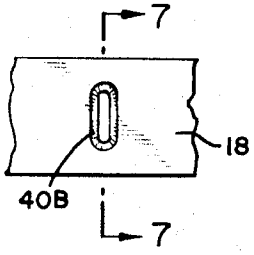


FIG. 7

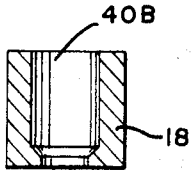


FIG. 8

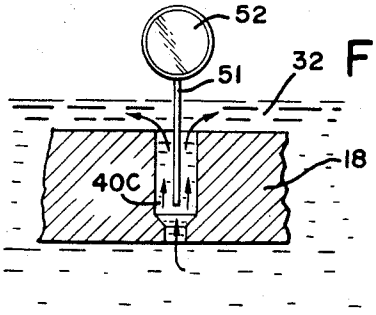


FIG. 9

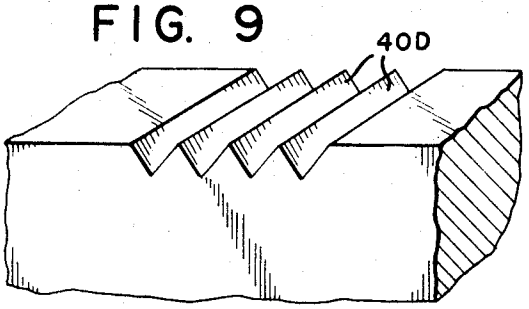
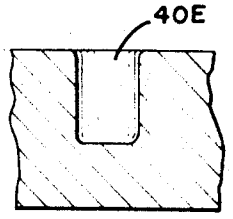


FIG. 10



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ULTRASONIC PROCESSING APPARATUS

The present invention is related to ultrasonic processing apparatus and more specifically has reference to an ultrasonic processing apparatus characterized by subjecting a workpiece to be treated to the action of extremely high intensity ultrasonic energy.

The use of ultrasonic apparatus for cleaning articles by immersing such articles in an ultrasonically cavitated solvent, or subjecting liquids to ultrasonic energy for the purpose of emulsification, atomization and the like is well known. Also, ultrasonic plating and soldering apparatus are known wherein a workpiece to be tinned or plated is immersed in the metal bath which is agitated by ultrasonic energy. In all of the above examples it is desirable that the ultrasonic energy provided be as intense as possible in order to produce, by means of the cavitation of the particular liquid, an abrading or erosion action which mechanically frees the surface of the article from contamination, oxidation, scale and the like.

Most of the heretofore known apparatus make use of a metallic bar, also called "horn," which is rendered resonant by piezoelectric or magnetostrictive transducing means and, when resonant, resonates as a half wavelength resonator. Under these conditions the frontal surface of the resonator is located at an antinodal zone of the longitudinal vibration. An emulsification device of this type is shown for instance in U.S. Pat. No. 3,394,274, S. E. Jacke et al., entitled "Sonic Dispersing Device" issued on July 23, 1968; and an ultrasonic soldering apparatus of this type is shown for instance in U.S. Pat. No. 3,385,262, S. E. Jacke et al., entitled "Ultrasonic Soldering or Plating Apparatus" issued on May 28, 1968.

The present invention is an improvement over the above described arrangement by making use of a horn which is dimensioned to resonate as a full wavelength resonator at a predetermined frequency and which includes means for subjecting a workpiece to be treated to the ultrasonic energy existing at the antinodal region of such resonator. In this manner, the workpiece can be subjected to much higher intensities of ultrasonic energy, thereby achieving a greatly increased performance of the apparatus.

One of the principal objects of this invention is, therefore, the provision of an ultrasonic processing apparatus characterized by improved performance.

Another important object of this invention is the provision of an ultrasonic processing apparatus using a full wavelength resonator with means for exposing the workpiece to be treated to the high intensity ultrasonic energy prevailing at the antinodal region of the resonator.

A further important object of this invention is the provision of an ultrasonic processing apparatus which is extremely well suited for high intensity ultrasonic cleaning, for high intensity ultrasonic plating and tinning, for high intensity ultrasonic processing and the like.

Further and still other important objects of this invention will be more clearly apparent from the following description when taken in conjunction with the accompanying drawing, in which:

FIG. 1 is an elevational view, partly in section, of a typical embodiment of the present invention;

FIG. 2 is a graph showing the amplitude of axial motion of the resonator along its length;

FIG. 3 is a side view, partly in section, of the typical arrangement per FIG. 1;

FIG. 4 is a top view of a portion of a modified resonator or horn;

FIG. 5 is a view along lines 5—5 in FIG. 4;

FIG. 6 is a top plan view of another alternative construction;

FIG. 7 is a view along lines 7—7 in FIG. 6;

FIG. 8 is a further alternative embodiment and indicating also the pumping action exerted upon the liquid as a result of the aperture disposed in the antinodal region of the horn;

FIG. 9 is another alternative embodiment, and

FIG. 10 is a still further embodiment.

Referring now to the figures and FIGS. 1 to 3 in particular, an electrical high frequency generator 10 via cable 12 supplies high frequency electrical energy to an electro-accoustic converter 14 which in response to the applied electrical energy produces accoustic energy, preferably in the ultrasonic frequency range, typically 18 to 100 kHz, at an output surface 16. In order to accomplish this energy conversion, the converter 14 includes piezoelectric or magnetostrictive transducing means as is well known to those skilled in the art. A typical converter suitable for this purpose is shown in U.S. Pat. No. 3,328,610, S. E. Jacke et al., entitled "Sonic Wave Generator," dated June 27, 1967.

The output surface 16 of the converter is coupled to an elongate bar 18, usually called horn, resonator, tool, amplitude transformer, etc. see "Ultrasonic Engineering" (book) Julian R. Frederick, John Wiley & Sons, Inc., New York, N.Y. (1965) pages 87 to 102. The length of the horn 18 is dimensioned to cause the horn to resonate as a full wavelength resonator for accoustic energy traveling longitudinally therethrough at the frequency provided by the converter 14, generally a fixed frequency value. As a full wavelength resonator, the horn, when resonant, exhibits two nodal regions 20 and 22, FIG. 2, of longitudinal motion, and a centrally disposed antinodal region 24 of longitudinal motion. The horn is mounted in a liquid-filled tank 30 in such a manner that a pair of opposite tank walls support the horn at its nodal regions. The escape of liquid 32 is prevented by sealing rings 34 and flanges 36. The sealing arrangement is shown only schematically inasmuch as such sealing means are well known in the art and do not form a part of the present invention.

The liquid 32 may be a cleaning solvent when a workpiece to be processed is to be cleaned, or alternatively it may be a liquid metal, such as tin or solder, when a tinning or soldering process is desired, or it may be any of the other liquid substances suitable for the particular purpose.

A radial aperture or cavity 40 is located in the horn 18 at its antinodal region and, since at this location the horn undergoes its maximum longitudinal vibratory excursion, the liquid disposed in and around this aperture is subjected to a highly intense activity resulting in cavitation.

FIG. 3 shows how the present arrangement may be used advantageously for cleaning wire. Metal wire 44 unwound from a supply roll 46 enters the tank 30 via the seal 42A and is fed through the aperture 40 of the

horn 18. As the wire is exposed to the high intensity ultrasonic energy imparted to the solvent 32, the wire surface is "scrubbed" clean. The wire then leaves the tank 30 via the seal 42B and is wound upon a roller 48 which is driven by a motor 50. Thus, the wire 44 enters the tank 30 which is filled with a cleaning solvent 32, then is subjected to the high energy zone, the antinodal region of the horn where maximum cavitation intensity exists, then leaves this high intensity zone and the tank. Similarly, instead of a cleaning solvent, the liquid 32 can be a plating solution or liquid solder to coat the exposed wire surface under the influence of high intensity ultrasonic energy.

FIGS. 4 and 5 show a modification of the horn 18. The horn is provided with a reduced cross-sectional area 19 in the area of the antinodal region in order to increase the amplitude of vibration. The increase of vibrational amplitude as a function of horn configuration is well understood in the art and described in the book by Frederick supra. Moreover, the aperture 40A is bevelled at the lower end followed by a narrow constriction for the purpose of producing a pumping action for the liquid which, as a result, is drawn through the aperture responsive to the horn motion in this region, i.e., cyclic axial expansion and contraction.

FIGS. 6 and 7 disclose an embodiment which is similar to the one shown in FIGS. 4 and 5, except that the radial aperture 40B is in the form of a slot, the major axis of the slot being transverse to the longitudinal axis of the horn.

FIG. 8 shows an arrangement which may be used advantageously for tinning the leads 51 of an electronic circuit component 52, such as a disk-type capacitor. The horn 18 is mounted slightly below the surface of the liquid 32 in order to enable the body of the component 52 to be held manually, using tweezers, for instance. The liquid 32 is molten solder. The aperture 40C is shaped to cause a pumping action for the surrounding liquid as is indicated by the arrows. As the ends of the leads 51 are dipped into the liquid 32 and inserted into the space provided by the aperture 40C, they are subjected to the cavitation caused by the high ultrasonic energy prevailing at this location. An extremely effective tinning, coating or plating action occurs. Similarly, if the leads 51 are to be cleaned rather than coated, the liquid 32 will be a suitable solvent or etchant. A reciprocating motion mechanism can be used to accomplish the dipping operation in an automated manner.

FIG. 9 shows serrations 40D in the horn's surface at the antinodal region for obtaining increased activity of the liquid, and FIG. 10 shows a blind hole 40E rather than a through hole for the purpose described heretofore.

Instead of sealing rings 34 as indicated in FIG. 1, the horn may be supported also in a manner which permits the escape of liquid as is shown in U.S. Pat. No. 3,385,262 supra.

It will be apparent that the above described apparatus provides a much more concentrated cavitation intensity than is normally experienced with ultrasonic cleaning devices where the energy is diffused over a much larger area with the attendant reduction of intensity per unit area. Therefore, the present apparatus is extremely well suited in such cases where high intensity ultrasonic energy is to be concentrated upon a relatively small portion of the workpiece. Moreover, by selecting the cross-sectional area of the horn in the antinodal region, such as by the use of a stepped horn, the maximum amplitude of the excursion of the horn can be brought to a value which is limited only by the ability of the horn material to withstand the internal stress caused by the vibrations.

What is claimed is:

1. An ultrasonic processing apparatus comprising:
a horn dimensioned to operate as a full wavelength resonator when caused to be resonant at a predetermined frequency, whereby to cause said horn to exhibit a pair of nodal regions and an antinodal region of longitudinal motion;
means disposed for supporting said horn at said nodal regions; a radial aperture disposed substantially in the antinodal region of said horn and being dimensioned for receiving therein a workpiece to be treated, and
means for supporting a treating liquid in contact with said antinodal region of said horn.

2. An ultrasonic processing apparatus as set forth in claim 1, said means for supporting a liquid being a tank; said means supporting said horn being disposed on said tank and causing said antinodal region and aperture to be in contact with the liquid when said tank is filled.

3. An ultrasonic processing apparatus as set forth in claim 2, and means for causing said horn to be resonant disposed outside said tank and coupled to said horn.

4. An ultrasonic processing apparatus as set forth in claim 1, said aperture being shaped to cause the liquid to be subjected to a pumping action.

5. An ultrasonic processing apparatus as set forth in claim 1, and means for feeding a workpiece into said aperture.

6. An ultrasonic processing apparatus as set forth in claim 1, said means for supporting said horn including a pair of walls of said tank.

7. An ultrasonic processing apparatus comprising:
a horn dimensioned to operate as a full wavelength resonator when caused to be resonant at a predetermined frequency, whereby to cause said horn to exhibit a pair of nodal regions and an antinodal region of longitudinal motion;
means disposed for supporting said horn at said nodal regions;
a cavity having a major axis transverse to the longitudinal axis of said horn disposed substantially in the antinodal region of said horn, and
means for supporting a treating liquid in contact with said antinodal region and cavity.

8. An ultrasonic processing apparatus as set forth in claim 7, said cavity being in the shape of serrations.

9. An ultrasonic processing apparatus as set forth in claim 7, said cavity being in the shape of a slot.

10. An ultrasonic processing apparatus comprising:
a horn dimensioned to operate as a full wavelength resonator when caused to be resonant at a predetermined frequency, whereby to cause said horn to exhibit a pair of nodal regions and a medially disposed antinodal region of longitudinal motion;
electro-acoustic converter means coupled to said horn for causing said horn to be resonant;

means disposed for supporting said horn at said nodal regions;

a radially directed aperture disposed substantially in the antinodal region of said horn and being dimensioned for receiving therein a portion of a workpiece to be treated, and

means for supporting a liquid adapted to cause treatment of the workpiece in contact with said antinodal region of said horn.

11. An ultrasonic processing apparatus as set forth in claim 10, and including means for feeding a workpiece into and out of said aperture.

12. An ultrasonic processing apparatus as set forth in claim 10, and including means for feeding a workpiece through said aperture.

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