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(54)

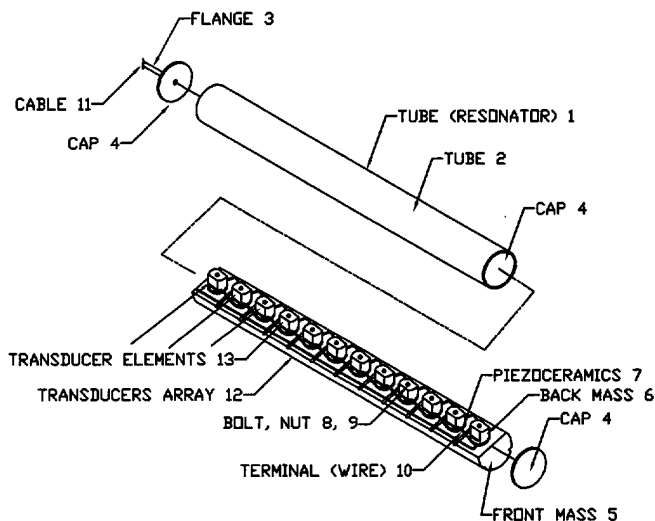
Linear array of sonic and ultrasonic transducers, assembled in the form of complex, integral tube resonator

(57)

This invention presents the tube-encapsulated or tube-fixed linear-array of unlimited number of bolt-clamped Langevin, sonic and ultrasonic transducers, externally or internally radiating acoustic energy into a fluid, for the purposes and applications such as: Ultra-sonic Cleaning, Liquid Processing, Sonochemistry, Medical Therapy and Organic and Inorganic Extractions. All Langevin transducer elements fixed inside or outside of the resonating tube have the same, common

(or integral) front-emitting mass, and each of them has its own piezoceramic layer and back mass on the opposite side, mutually fixed by central bolts. The integral, common front mass of such transducer array is rigidly fixed (welded, bonded, and/or glued) inside or outside of certain arbitrary or round shaped metal pipe, enabling the pipe to radiate multimode sonic and ultrasonic energy externally or internally. In some design cases metal pipe or round shaped tube can be an integral part of the common front emitting mass.

Fig. 2



Description**Summary of the Invention:**

5 **[0001]** This invention presents the tube-fixed linear-array of unlimited number of bolt-clamped Langevin transducers, where all transducer elements have the same, common (or integral) front mass, and each of them has its own piezoceramic layer and back mass on the opposite side, rigidly fixed by its front mass inside or outside of any metal pipe or round shaped tube, where the tube or pipe can also be an integral part of the front transducer mass, enabling the pipe or tube to radiate sonic and ultrasonic energy externally or internally, where the linear array of bolt-clamped Langevin transducers (that have the same, common front mass) is also designed to make optimal coupling and mode transformation between several of important vibration modes, having in the same time very large number of acoustically coupled harmonics, enabling the tube to radiate wide band, multi frequency, sonic and ultrasonic, omni directional waves, and to accept large frequency-sweeping driving, this way presenting an integrated sonic and ultrasonic transducer, which creates high-density complex acoustic field of non-stationary and non-standing, multifrequency, multi-mode, progressive wave structure, excited by specific and complex electric signal, which drives the ultrasonic transducer.

Background of the Invention:

20 **[0002]** It has been quite popular to use vibrations of sonic and ultrasonic waves for liquids agitation, cleaning, mixing, sonochemistry, medical therapy and materials processing purposes. Such ultrasonic devices are basically composed of a fluid container, an ultrasonic transducer, and an ultrasonic power supply. The function of an ultrasonic power supply (ultrasonic generator) is to be an oscillating circuit that generates ultrasonic vibrations for driving ultrasonic transducer, in order to transmit vibrations to the fluid container.

25 **[0003]** There are many different structures of ultrasonic wave transducers and energy transmission systems (power supplies, or ultrasonic generators) for fluids agitation, ultrasonic cleaning and Sonochemistry applications. In most of Prior Art cases, the physical resonator that is in contact with liquid and ultrasonic transducer are connected on the same longitudinal axis. Then, in synchronization with the standing-waves, multiple sine-wave activation of an integer number of $\lambda/2$ wavelength balanced vibrations, the vibrating energy generated longitudinally (or axially) by the ultrasonic wave transducer will transmit, along the structure of the resonator, radiating wave energy in the fluid. Such structure plays a quite important role with respect to the electric energy power supply (ultrasonic generator) and operating frequency, since its operation requires an integer number of half-wavelength agreement with the resonator length. Such (Prior Art) transducer design cannot achieve the generation of ultrasonic waves under multi-frequency and wide band conditions, since in operation it requires an integer number of half wavelengths to correspond to and match the power supply frequency and the length of the resonator. It is restricted by the relatively narrow operating frequency bandwidth, and it will not achieve the generation of ultrasonic waves under multi-frequency regime.

Prior Art:

40 **[0004]** All double piston, single-element or multi-elements sandwich acoustic transducers, piezoelectric and magnetostrictive stacks, and all types of traditional Bolted Langevin Transducers, as well as Ultrasonic Cleaning and Ultrasonic Welding transducers **operating on a constant resonant frequency (or in a relatively narrow vicinity around certain resonant frequency)**, and their Ultrasonic Power Supplies (or ultrasonic Generators) tuned to operate and track the constant resonant frequency, belong to the Prior Art in the field of acoustic, sonic and ultrasonic sources. Double piston and constant resonant frequency oscillating mode (axial both side contraction-extension mode) is an essential characteristic of all **Prior Art** transducers.

European patents regarding Ultrasonic Transducers:

50 **[0005]** Applicant and Inventor: Miodrag Prokic, 2400 Le Locle, www.mpi-ultrasonics.com
 EP 1 060 798 A1, Date of filing: 18.06.1999, Date of publication: 20.12.2000
 EP 1 238 715 A1, Date of publication: 11.09.2002, Bulletin 2002/37

U.S. Patent Documents regarding Ultrasonic Transducers:

[0006]

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25	4,537,511 and 5,200,666			

Brief Description of Drawings:

[0007]

Fig. 1 is a generic outside view of the invention presenting a complex tube resonator.

Fig. 2 is an assembly view of the main internal and external parts of the invention presented on fig. 1.

Fig.3 is a generic cross section view of the invention presented on Figs. 1 and 2.

Description of Preferred Embodiments:

[0008] Please refer to Fig. 1 which relates to a generic external view of the invention in its embodiment, presenting a multi-frequency resonating mode, complex tube resonator 1, made of a tube or a hollow or solid elongated strip made of a long bar of metal 2, consisting of internally, or externally inserted and fixed transducers array 12, of multiple transducer elements 13, in other words, fixed to the internal or external tube surface, presenting electrically in-parallel-connected Langevin transducer elements 13, watertight sealed and closed on both tube ends with metal caps 4 in case of internal transducer array assembling, and ending with flange detail 3 and cable conduit 11, delivering strong vibrations and multi frequency oscillations on the tube resonator external surface 1, while driven by electric signal power supply, activating the complex resonance field of multiple frequencies of the tube resonator 1, to achieve wide-band sonic and ultrasonic waves radiation on the whole external surface towards external fluid, while the same effects can be realized when transducer array is fixed externally radiating towards internal tube space, when the same concept is not limited to only to installing one transducer array.

[0009] After the above-described structure is assembled, it presents the complex resonator 1 module for generating multiple and wide band frequency resonance and radiation of sonic and ultrasonic waves, with its internal elements, components and parts presented on Fig. 2, and Fig 3. Meanwhile, the transducer array 12 is directly and axially fixed to the internal surface of the tube 2 of the resonator 1, to directly produce vibrations, invoking various sonic and ultrasonic frequency wavelengths, exciting various vibration modes, and activating the resonator 1 in order to transmit vibrations outward in the fluid, where the resonator 1 is immersed, and the same effects can be realized when transducer array 12 is fixed to the external tube surface radiating a fluid in internal tube space.

[0010] With the described structural design of the invention (Figs. 1, 2 and 3), the operating coordination of electrical energy converter and operating frequency and the length of the resonator will no longer be an important operating factor. There is no need for balanced integer number of half wavelengths, corresponding to precise wavelengths,

matching the length and other dimensions of the resonator 1, and the resonant frequency of the electric power supply.

[0011] The elongated unit or tube unit 2 of the above resonator 1 for multiple frequency resonance can have a form of a regular cylindrical tube, or it can have a form/s of various polygonal hollow or solid elongated units, tubes, spherical, elliptical, straight, rectangular, arbitrary curve-shaped or similar objects, while one or many transducer arrays can be fixed to the same tube externally or internally.

Claims

1. An axially activated sonic and ultrasonic waves generating and radiating transducers array structure in the form of arbitrary shaped, both ends closed tube, **characterized in that:** it includes a resonator in the shape of a tube or elongated hollowed bar, that can be fully immersed into a fluid being in a container, on the tube surface of the connecting end being directly assembled to a connecting flange and cable conduit, said connecting rack including a central shaft hole corresponding to the electric connecting end of the resonator, on the side of the connecting rack being at least a hole rack, connected to at least one ultrasonic power supply, connected to a hole rack position, meanwhile, the cable of said ultrasonic power supply penetrating the hole rack and being directly connected to the electrical terminals of the internally fixed transducers array, producing multimode, multifrequency and wide-band oscillations of transducers array, activating the resonator tube to oscillate in sonic and ultrasonic domain, while radiating on the entire external tube surface towards surrounding fluid.
2. The axially activated sonic and ultrasonic waves generating and radiating transducers array structure, in the form of arbitrary shaped, both ends closed tube, as recited in Claim 1, wherein the tube mass presents an integral part of the front emitting mass of the transducer array, made from the unique piece of metal.
3. The axially activated sonic and ultrasonic waves generating and radiating transducers array structure in the form of arbitrary shaped tube, as recited in Claims 1 or 2, wherein the tube can be open on its one or both ends.
4. The axially activated sonic and ultrasonic waves generating and radiating transducers array structure in the form of arbitrary shaped tube, as recited in Claims 1 or 2 and 3, wherein the transducer array is fixed to external tube surface, or being its integral part, while radiating multimode sonic and ultrasonic energy into internal tube space filled with fluid, creating multi frequency resonance on the entire internal tube surface.
5. The axially activated sonic and ultrasonic waves generating and radiating transducers array structure in the form of arbitrary shaped tube, as recited in Claim 1 or 2, 3 and 4, wherein the resonating tube can be made of a regular cylindrical tube, or a polygonal, hollow or solid, elongated strip or tube, or other objects similar to a tube, or other curved and spherical hollow objects.
6. The axially activated sonic and ultrasonic waves generating and radiating transducers array structure in the form of arbitrary shaped tube, as recited in Claims 1 or 2, 3, 4 and 5, wherein instead of one transducer array, installed internally or externally, many transducer-array lines can be installed for simultaneous and parallel operation on the same tube or other hollowed object.

Fig. 1

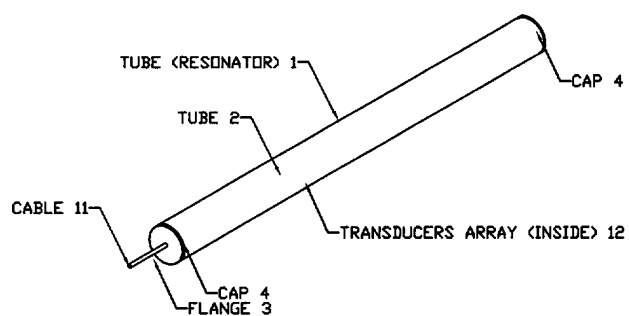


Fig. 2

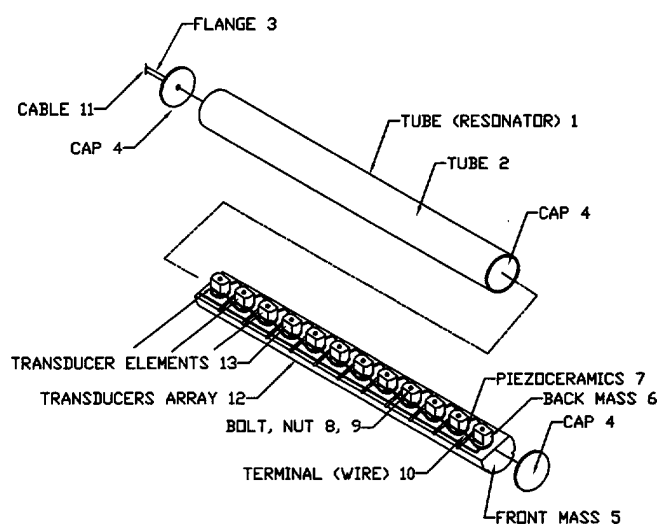
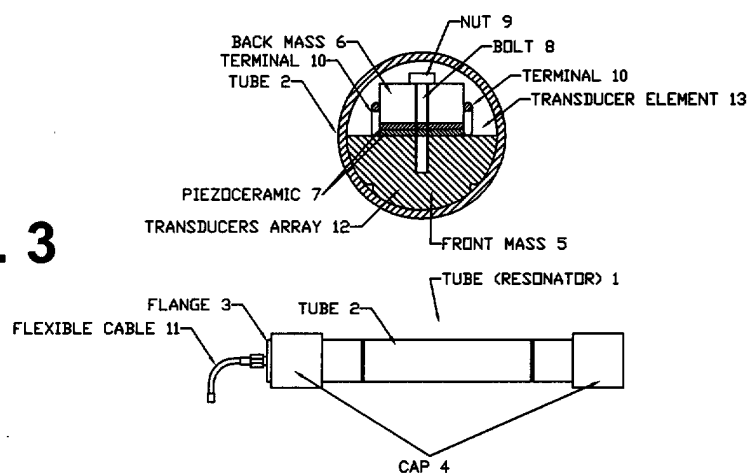


Fig. 3





European Patent
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PARTIAL EUROPEAN SEARCH REPORT

Application Number

which under Rule 45 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

EP 02 40 5863

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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Y	DE 197 24 189 A (BANDELIN ELECTRONIC GMBH & CO) 3 December 1998 (1998-12-03) * column 1, line 24 - line 43 * * column 2, line 62 - column 3, line 42 *	1,5	
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A	US 3 139 603 A (CHURCH DONALD R ET AL) 30 June 1964 (1964-06-30)		
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			B06B G10K
INCOMPLETE SEARCH			
The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims. Claims searched completely : Claims searched incompletely : Claims not searched : Reason for the limitation of the search: see sheet C			
Place of search		Date of completion of the search	Examiner
THE HAGUE		14 February 2003	Swartjes, H
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03 82 (P04C07)



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**INCOMPLETE SEARCH
SHEET C**

Application Number
EP 02 40 5863

Claim(s) searched completely:
1-3

Claim(s) searched incompletely:
5, 6

Claim(s) not searched:
4

Reason for the limitation of the search:

Claim 4 has as technical feature that the transducer array is fixed to the external tube surface. This is in direct contradiction with claims 1, 2 and 3, on which it depends, and where the transducers are internally fixed.

Claim 4 has therefore not been searched.

Claims 5 and 6 have only been searched as far as they do not depend on claim 4.

In all these cases, the objectionable drafting of the claims results in a lack of clarity (see Art. 84 EPC) regarding the definition and extent of the protection sought by the applicant.

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 02 40 5863

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

14-02-2003

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82