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(54) Unidirectional single piston ultrasonic transducer

(57) Unidirectional sandwich transducer which includes a center mass (4) freely placed between two active transducer element stacks (2' and 2") and two end masses (3',3") where all of them are coupled only by rigid stress rod between two end masses and where one of two active transducer element stacks can be replaced by solid and acoustically passive isolator stack. The center mass is performing free and not attenuated single piston oscillations between two active transducer element stacks and two end masses realized by mutually opposite phase polarity of active transducer elements while driven by the same input electrical signal. The center mass is also performing free and not attenuated single piston oscillations between one active transducer element stack and one solid and acoustically passive isolator stack and two end masses. The transducer is using electrical and emitting acoustic energy only when placed in contact with some external mass and shape and size of externally contacted mass have no influence to transducer's center mass vibrations. When center mass is performing single piston movement and when transducer is not mechanically loaded the total transducer length is constant and two end masses are not oscillating. The transducer is ideal for agitating arbitrary distant and arbitrary shaped liquid and solid masses placed in different vessels or pipes transferring its vibrations via waveguide solid rod connected between the transducer and a loading mass. The single piston transducer connected perpendicularly to a solid tube can agitate different radial and circumferential tube vibration modes without the need of exciting longitudinal and axial tube modes. The transducer can also be used as vibration receiver or sensor.

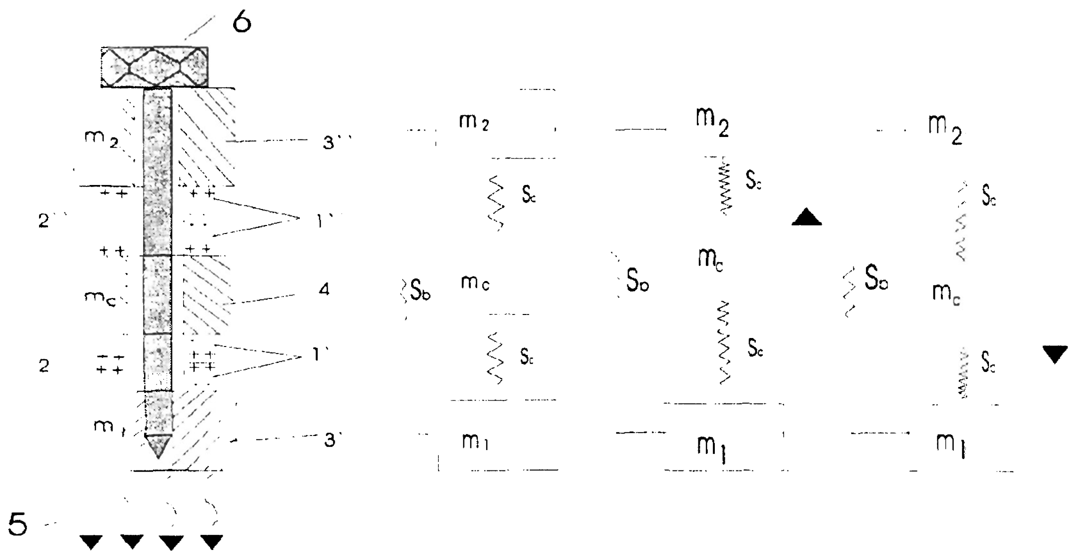

Fig.3.a Fig.3.b Fig.3.c Fig.3.d

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(mechanical) force, or pressure, or quantity of motion. This is possible regarding to the modification of sandwich structure of ultrasonic transducers. Traditional ultrasonic-transducers' sandwich structure (Prior Art) has three parts: one central and active vibration source (piezoceramics stacks) and two end-metal-masses. New and modified sandwich structure (present invention) has two active vibration sources (working in opposition: one is extending, the other is contracting and vice-versa), bounded by three metal masses. This way, only the center mass is performing kind of translating, single piston vibrations, changing only its position (but not dimensions) and two end metal masses are always in stable position (without any change of their dimensions). This is possible because two active vibration stacks that are placed in between three metal masses are mutually compensating each other vibrations, meaning that one of them is in the phase of extension and the other is contracting for the same amplitude. In a conclusion: Three masses sandwich transducer, or single piston oscillating transducer (the current invention) is oscillating structure in which only center mass is performing single piston type vibrations, and end masses are not moving. Of course, there is a kind of pressure-ultrasonic-wave that is permanently travelling from one end mass to other, and vice-versa, like light beam reflecting endlessly between two stable mirrors.

[0005] There are many design options of here described three mass transducers, depending how we are intending to use them. Basically, because of the mechanical law of momentum conservation, three masses sandwich transducer (or single piston transducer), when in a contact with some other (external) mass (or liquid) is producing unidirectional (single piston type) acoustical wave, which is, later on, producing real mechanical vibrations in external media (having all parameters of oscillatory motion such as: amplitude, velocity and pressure, realized inside of external media).

[0006] Traditional, double piston oscillating transducers described in many patents (**Prior Art**) can be represented by some of the mass-spring oscillating structures similar to ones given in Fig. 1(a) and Fig. 2(a). End masses 3 and active (piezoelectric or magnetostrictive) vibrating elements 1 are strongly fixed by stress rod or central bolt 6, applying necessary pressure on active vibrating elements 1. If we neglect all resistive damping, attenuation and friction elements of such mass-spring structures, the most representative simplified, equivalent mechanical circuits, corresponding to Fig. 1(a) and Fig. 2(a), are given on Fig. 1(b) and Fig. 2(b). For traditional double piston, sandwich transducer structures (**Prior Art**) is typical that both of oscillating masses 3, m_1 and m_2, are connected with a common central bolt 6, which also presents active spring element that has stiffness coefficient $\mathbf{S_b}$ (see Fig. 1(b)). In reality, transducer's effective stiffness coefficient $\mathbf{S_{b,c}}$ is the stiffness combined of the central bolt 6 stiffness $\mathbf{S_b}$ with all other elastic parameters $\mathbf{S_c}$ of active vibrating elements 1, belonging to the structures presented on Fig.1(a),(b) and Fig. 2(a),(b). Because of that reason, on the Fig. 1(b),(c),(d), Fig. 2(b) and Fig. 3(b),(c),(d) we use symbol $\mathbf{S_{b,c}}$ for effective stiffness signifying that corresponding spring element is a combination of stiffness parameters of the stress rod or central bolt 6, and active vibrating stack elements 1 (or parallel combination between $\mathbf{S_b}$ and $\mathbf{S_c}$).

[0007] In operation, all traditional transducer structures (**Prior Art:** see Fig. 1(a) and Fig. 2(a)) are oscillating in the contraction-extension, or double (mutually opposite) piston mode, presented on Fig. 1(c) and Fig. 1(d), meaning that both end masses 3 are oscillating in mutually opposite phase. Fig. 2(a) presents simple combination of two traditional transducers given on Fig.1 (described in the European patent: Gould Inc. Inventor: Thompson, Stephen, Publication number: 0 209 238, A2, int. Cl.: H 04 R 17/10, from 21.01.87. This patent is already in a public domain since its owner decided not to extend it). Transducer on Fig. 2(a) gives some more flexibility and oscillating freedom to introduce different driving signals into upper and lower part of one transducer, but basically this is simple mechanical combination of two traditional (Prior Art) transducers presented on Fig. 1(a).

[0008] Vibrating energy 5 of a traditionally known transducer/s (Fig. 1(a) and Fig. 2(a)) is radiated into external medium when (at least) one of oscillating masses 3 is in mechanical contact with external medium (acoustically coupled with external medium). The biggest disadvantage of double piston transducers (Fig. 1(a) and Fig. 2(a)) is in the fact that in the process of mechanical loading, acoustic parameters of external medium, and mechanical coupling with a transducer, are creating significant damping and attenuation, significantly changing the parameters of equivalent oscillatory structures given on Fig. 1(b), (c), (d) and Fig. 2(b). Electroacoustic or electromechanical efficiency of double piston transducers (in any combination similar to Fig. 1(a) and Fig. 2(a)) is very much dependent on shape, size and acoustical and mechanical parameters of externally connected medium. Different and complicated design techniques for resonant and impedance matching are necessary to be applied in order to achieve optimal energy transfer from double piston transducers towards external medium (also subject of **Prior Art**).

[0009] The majority of loading, impedance and frequency matching and mechanical coupling disadvantages of double piston transducers can be avoided if oscillating mass of the transducer is not in a direct contact with external medium (Fig. 3(a)). One of such transducer design (**the current invention**) is presented on Fig. 3(a). Equivalent mechanical, oscillating circuit of this design is presented on Fig. 3(b). The stress rod or central bolt 6 (in Fig. 3(a)) is only and directly connecting two end metal masses 3. The center mass 4, m_c, is freely placed between two active vibrating layers 1 (piezoceramics), and all of them are in the sandwich between two end metal masses 3, m_1 and m_2, mechanically connected by the stress rod or central bolt 6 (which is touching only end masses). Neither center mass 4 (=) m_c, nor active vibrating elements 1 are in contact with stress rod or central bolt 6. Active, vibrating (piezoceramic) layers 1 are electrically polarized opposite to each other (placed in opposite polarity position during assembling) producing single