***Summary***

*A new and unique method for the production of fully optimized spatial and wideband frequency resonation in arbitrary shaped objects of metal or other hard materials i.e. glass, ceramics, polymers, composites, including solid objects containing or in contact with liquids. The method employs a “special metal based resonator” which is custom designed specifically for arbitrarily shaped objects. When mechanically joined then the resulting “resonator/object” item acquires a new overall and optimized natural resonant frequency, including associated frequency harmonics that present natural resonant modes of the resulting “resonator/object” item under vibrations. In addition, MMM, see “EP 1 238 715 A1, Multi-frequency ultrasonic structural actuator”, introduces the necessary spectral complexity to enable an ultrasonic driving (or carrier) signal, specifically modulated by MMM to extend its spectral content, which will induce vibration spatially in every possible resonant mode within the “resonator/body” item. Custom-designed resonator is optimized to operate very well on certain isolated and fixed resonant frequency, being frequency isolated from other resonant modes, meaning that such resonator will operate on its own, natural resonant frequency, or natural resonant vibrating mode (for instance, producing either axial or longitudinal, or radial, or bending and torsional vibrations...). When such customized resonator is fixed to an arbitrary shaped solid body, it will still be able to operate on its own natural resonant frequency, but since being in rigid acoustic coupling with another solid body, it will acquire or couple with other natural resonant modes of the arbitrary shaped body. Consequently, new, resulting frequency spectrum of described mechanical coupling (here described as “resonator/object”) will have number of natural resonant frequency modes. Customized resonator will be vibrated on its dominant, natural resonant mode (or on its carrier frequency). In the same time MMM signal modulation (“EP 1 238 715 A1, Multi-frequency ultrasonic structural actuator”) will be appropriately applied, this way enabling customized resonator to excite many of other natural resonant modes (or harmonics) belonging to the other solid body, or effectively belonging to the mechanical system “resonator/object”.*

MMM presents only (complex, multiple) signal modulation that is electro-acoustically added/injected or superimposed to the main, principal, fixed frequency of the carrier signal. MMM is kind of mathematics and signals processing methodology. In fact MMM (as multiple signals processing concept) could create better, more complex, information-rich acoustic signals (to agitate number of resonant modes), and to transfer information better than other (traditional, usal) single-mode acoustic methods. Of course, we also need to combine MMM with convenient electro-acoustic hardware (or with transducers and resonators).

MMM is general mathematical philosophy and method of signal processing for realizing multi-mode acoustic excitation... multi-mode excitation has more chances to propagate better and longer, compared to single-mode excitation.

Real creation of progressive ultrasonic waves is mostly related to ultrasonic transducers and resonating devices or resonating hardware. However, good, creative and effective combination between MMM signals processing, and convenient electro-acoustic or resonators hardware is bringing big advantages, as we intend to patent.

*The method combines a “special and customized mechanical resonator design” being an external vibrating* ***mode transformer****, which enables the object’s natural resonance frequency and the added-resonator’s natural resonance frequency to be combined into a new and unique overall natural resonance frequency. Mentioned combination of an external custom-designed resonator (or vibrating-mode transformer) and object, which should be ultrasonically treated, can be realized through mechanical fixation of externally fixed ultrasonic converter, directly on the customized resonator, by Welding and/or Bolting, and bespoke Clamping Systems. This way, we can introduce, facilitate and realize efficient resonant vibrating regimes in almost any solid body, or bodies containing fluids.*

*THIS STUFF BELONGS INTO CLAIMS:*

*Practically, it is necessary to select one segment of certain solid object where it will be possible and relatively easy to create conditions for realizing strong, distinctive (localized) and well-isolated partial resonance on desired carrier frequency. To facilitate such objective, it is necessary to attach (to selected segment of a bigger object) certain specifically designed external-resonator and ultrasonic converter. When vibrating mentioned attached resonator, we will start producing strong ultrasonic vibrations on certain carrier frequency. Since added resonator is already coupled or rigidly connected with a bigger solid body, locally produced vibrations will penetrate towards bigger body. Because bigger and arbitrary shaped solid body usually has number of natural resonant frequency modes and harmonics, we can apply specific signal modulations on the carrier frequency ultrasonic signal (coming from ultrasonic power supply or generator towards ultrasonic converter), and this way excite mentioned number of associated, natural resonant modes. This way doing, big solid body will vibrate synchronously on number of ways. Such specific signal modulation, which will enrich produced acoustic spectrum, is known as MMM.*

*Extractions are facilitated in cases when we vibrate solid objects like pipes and reservoirs containing liquids with raw materials to be under processing (practically extracting minerals and complex chemical content from organic and inorganic masses). The extracting agents are ultrasonic cavitation and ultrasonic capillary effects, combined with mechanical agitation and fluid streaming.*

*The method enables a vast overall improvement on all current (ultrasound-based) techniques for stress relief, pipe & equipment cleaning, heat exchangers preventive and inline (real-time) cleaning, sonochemistry, liquids processing, cavitation/capillary based extraction, pharmaceutic liquids processing, liquid metals processing and many other industrial ultrasonic based applications.*

**Claims**

1. The creation of fully optimized spatial and wideband frequency resonation in arbitrary shaped objects of hard materials such as glass, ceramics, polymers and composites.

RESONATE

1. The creation of the resonance according to claim 1. is characterized in that: a combined metal resonator & actuator device is used to produce unique and optimal vibrations in the form of torsional, axial and radial vibrational modes which are then transferred and shared with the arbitrary shaped object (thanks to specifically applied, MMM signal modulation, based on (“EP 1 238 715 A1, Multi-frequency ultrasonic structural actuator”).

RESONATOR FUNCTION

1. The combined metal resonator & actuator device according to claim 2. is characterized in that: the ultrasonic metal resonator part of the device is custom designed specifically and according to the arbitrarily shaped object under consideration (in order to be rigidly fixed and acoustically coupled to the object under consideration).

CUSTOMISED RESONATOR

1. The combined metal resonator & actuator device according to claim 2. is characterized in that: the ultrasonic actuator part of the device uses signals generated from a special and proprietary ultrasonic power generator (Multifrequency, Multimode, Modulated Sonic and Ultrasonic Generator).

MMM ACTUATOR

1. The combined resonator & actuator device according to claim 2. is characterized in that: the ultrasonic metal resonator & actuator device is mechanically coupled to the arbitrarily shaped object and vibrations are transferred spatially-homogeneously throughout the arbitrary object.

RESONATOR / OBJECT COUPLING

1. The custom designed ultrasonic metal resonator according to claim 3. is characterized in that: the ultrasonic metal resonator part of the device has a custom design which is optimized using Finite Element Analysis and other similar types of modelling and interrogation of that arbitrary object.

FEA INTERROGATION

1. The mechanical coupling according to claim 5. Is characterized in that: the resonator & actuator device is coupled to the arbitrarily shaped object by means of welding, bolting, clamping or a customized bracing fixture.

COUPLING METHOD

**Background explanations related to the Claim-1.**

Traditional and usual method for ultrasonic driving of solid objects is to design all elements or parts of such objects to have the same, natural resonant frequency. This is possible only for simple geometry objects. Such mutually frequency-tuned resonating objects in ultrasonic engineering usually have names as: ultrasonic converters, boosters, and sonotrodes.

Arbitrary shaped solid objects (that already exist as being parts of different technological equipment) usually have number of natural resonant frequency modes, and we do not have a chance to transform such object into something what will have certain, desired, single, isolated, well defined resonant frequency mode (because we cannot change the object shape). Even in such cases, we can successfully introduce efficient ultrasonic vibrations (into almost any arbitrary shaped solid body) if we properly select only one specific and convenient segment of that body, and fix there necessary external-resonator parts, and make this spatially localized body-segment susceptible to resonate only on a desired resonant frequency of an attached ultrasonic converter. This way, we will create partial and resonant mode in one part of the arbitrary shaped solid body, and since this spatial segment is rigidly (mechanically and acoustically) coupled with mentioned solid body (belongs to it), we will be able to transfer part of ultrasonic energy towards the total body under treatment. Using specific optimization methods (based on Finite Elements Analysis), we can optimize and maximize energy coupling and transfer from ultrasonically resonating segment towards the complete solid body. In all such cases, we are usually creating resonant mode transformation. For instance, specifically created resonating segment (or localized source of vibrations) is dominantly oscillating radially, and because of its solid acoustic coupling geometry and other elastic and mechanical conditions, we will be able to inject axial, bending, or torsional vibrations into remaining part of the big body (depending on spatial or geometric and spectral complexity of the complete structure). Practically, such externally added resonator is locally creating (or transforming) part of the (arbitrary shaped) body to be convenient for accepting certain desired, single resonant frequency mode, and because of strong mechanical and acoustic coupling (between local resonator and big body), ultrasonic vibrations will continue propagating into a big body. This way we can ultrasonically vibrate almost any arbitrary shaped solid body or fluids reservoirs. Added, external resonators and ultrasonic transducer should be specifically designed and optimized, based on the geometry of the big solid object. We need to find specific, best place where to make described, locally isolated, resonant (or carrier) frequency ultrasonic conditions. Number of specific design options and geometry (of externally added resonator parts) are imaginable to realize mentioned acoustic conditions and coupling, such as by bolting, welding, clamping etc. Patent claims’ items, here, could also be related to geometry and design of externally attached resonating parts.

**Claim-2.**

The improved and novel ultrasound based method is further improved by the use of a power ultrasound generator based on producing customized waveform driving with Multifrequency, Multimode, Modulated Sonic & Ultrasonic Vibrations, also known as MMM (see reference: “EP 1 238 715 A1, Multifrequency ultrasonic structural actuator”).

**Background explanations related to the Claim-2.**

In cases of ultrasonic driving of arbitrary shaped solid objects, we usually deal with number of mutually coupled resonant modes. Even if we create specific conditions that only one segment of such body will locally resonate with a single, isolated frequency mode, for efficient driving of the whole object it is optimal to be able to excite (synchronously) number of other natural resonant frequency modes. By applying proper signal modulations (like frequency, amplitude, phase and different PWM modulations), we can create specific MMM signal shapes with rich frequency-spectrum content. We will still have a stable frequency carrier signal (for driving locally isolated, desired resonant mode) enriched by signal modulation with mentioned wideband frequency content, this way being able to agitate number of natural resonant frequency modes of the arbitrary shaped solid object. This is the meaning of MMM ultrasonic technology (see reference: “EP 1 238 715 A1, Multifrequency ultrasonic structural actuator”).