We can create two patents, such as:

1. **Ultrasonic Reactors for static, batch liquids processing**
2. **Ultrasonic Reactors for real-time flow-through liquids processing**

Working names proposals for this invention are:

"MMM Sonorod",

"MMM Sonicator",

"MMM Sonoprocessor",

"MMM Sonochemistry Reactor"

Author/Inventor:

Miodrag Prokic, company MP Interconsulting, and Ultrasonic World Limited.

In addition, we can state (and make kind of Contract or Agreement or statement, whatever applicable and works to satisfy our interests) that this patent also belongs to our company RSRM (GmbH in Sarnen, Switzerland), for the purposes of business commercialization and technology transfer situations. The reasons are related to the fact that such patents and products are belonging to dual or multiple use technological and processing tools where MP Interconsulting already has other applications and clients realized during last 30 years.

Keywords: **Ultrasonic, Sonochemistry, Shear Fields and Waves, Non Linear Acoustics, Fluid Vortices, Multimode Resonators, Sonic and Ultrasonic Liquid Processing, Liposomes modification and colloidal theory effects, Cavitation, Ultrasonic Irradiation, Oscillating microbubbles, Particle migration, Shear induced diffusion, Membrane separation, Micro channels, Separation process...**

This invention or innovation presents: cylindrical or rectangular bar shaped ultrasonic resonator, or solid-state body that has (in the same time mutually coupled and synchronized) combined axial, radial and different lateral modes resonances, produced by specific geometry of the same resonant body with axial and perpendicular resonating holes and channels.

Here, it is useful to mention that MMM-Sonorod operates the best when driven with unique and specific, MMM-Sonorod ultrasonic generators produced by MP-Interconsulting and Ultrasonic World Limited.

The application field is: Sonochemistry, Liquids Processing and Ultrasonic Cleaning, Non-Linear Acoustics processing, Organic and biological liquids processing, Liposomes modifications and processing, Pharmaceutical liquids processing, microencapsulation in complex liquids.

Mentioned resonating bar (here named MMM-Sonorod) is able to produce and follow low frequency oscillations, ultrasonic frequency oscillations, including forced and frequency sweeping oscillating regimes with different signal modulations, based on the following patent applications:

European Patent Application (related to MMM technology):

EP 1 238 715 A1

Multifrequency ultrasonic structural actuator

Applicant: Prokic Miodrag, MP Interconsulting, 5.03.2001 – 11.09.2002

DISPOSITIF POUR LA GENERATION D'ONDES ULTRASONORES

Inventeurs : Prokic Miodrag et Jean Claude Padoy

N° de publication 2 743 929

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République Française, Institut National de la Propriété Industrielle, Paris, 25.07.97 & 10.04.98, bulletin 98/15

European Patent Application: EP 1 405 679 A1

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

Applicants: Prokic Miodrag, MP Interconsulting, and Lee, Hee-Myong, Ilsan Suntek, 03.10.2002 – 07.04.2004

European Patent Application: EP 1 050 347 A3

Ultrasonic transducer

Applicants: Prokic Miodrag, MP Interconsulting, and Lee, Hee-Myong, Ilsan Suntek, 18.06.1999 - 24.07.2002

European Patent Application: EP 1 060 798 A1

Unidirectional single piston ultrasonic transducer

Applicant: Prokic Miodrag, MP Interconsulting, 8.06.1999 – 20.12.2000

European Patent Application (related to MMM technology):

EP 1 238 715 A1

Multifrequency ultrasonic structural actuator

Applicant: Prokic Miodrag, MP Interconsulting, 5.03.2001 – 11.09.2002

MMM-Sonorod has specifically designed, and properly placed lateral and perpendicular holes (optimized using Finite Elements Analysis) that are presenting secondary resonant sources of ultrasonic vortices, being produced in the same time as principal axial and radial resonating-bar oscillations. This way MMM-Sonorod is producing complex sonic and ultrasonic, wideband and spatially well-distributed field, and strong ultrasonic activity with Shear fields...

In addition, **MMM-Sonorod** has the central (axial) hole where it is realized sequential and progressive –waves pumping and fluid circulating effect, enabled fluid under processing to supply perpendicular and lateral holes that are producing vortices.

MMM-Sonorod can operate in different Continuous Wave, or Periodic Pulse-trains, including arbitrary and forced carrier signal modulations, this way producing wideband and complex spatially distributed ultrasonic field structures.

MMM-Sonorod is producing progressive radial and axial or longitudinal ultrasonic waves, and turbulent and spiraling fluid vortices and Share waves, especially useful for non-linear acoustics' sonochemistry like processing of biological or organic liquids. MMM-Sonorod, when operating continuously or in pulsed-trains modes, is producing non-stationary, transient and circular ultrasonic streaming, vortices and Shear fields and waves, with different size of strong cavitation bubbles (analogical to wideband acoustic, white noise).

MMM-Sonorod, thanks to its geometry or shape and complex acoustic field structure, is producing effects of particles size reduction, particles agglomerations, multiphase liquids mixing and homogenization, forced and accelerated solid particles precipitation and sedimentation. In addition, MMM-Sonorod is producing spherical shaping of complex inorganic, biological and/or organic molecules (mostly based on different turbulent, vortex and spherical ultrasonic field's formations, belonging to non-linear acoustics with Shear fields and evolving transient waving effects). Long, stable, stationary, continuous ultrasonic irradiation (like most of contemporary ultrasonic fluids processing equipment), is not at all producing mentioned vortices and spherical fields formations necessary for non-linear acoustic liquids processing.

Useful citations from literature:

of the mean size of liposome is achieved at the lower frequency. Comparing at the same frequency and total energy, short-time irradiation of strong ultrasound is more efficient than long-time irradiation of weak ultrasound. These results indicate that the small number of cavitation events with stronger physical disturbance on liposome can reduce the size of the liposome more efficiently than the large number of cavitation events with weaker disturbance.

reduce the size of liposome is evaluated.

The ultrasound of lower frequency can reduce the liposome size faster within the frequency range studied here. The short-time irradiation of the strong ultrasound is more efficient than the long-time weak sonication. These two results are understood in terms of the

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at high powers over long periods of time and suggests that a different mechanism may be involved in mild sonication. The observations are consistent with the following mechanism for decreasing liposome size. During ultrasonic irradiation, cavitation, caused by oscillating microbubbles, produces shear fields. Large liposomes that enter these fields form long tube-like appendages that can pinch-off into smaller liposomes. This proposed mechanism is consistent with colloidal theory and the observed behavior of liposomes in shear fields.

Particle migration in laminar shear fields: A new basis for large scale separation technology?

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Highlights

Overview of the current advances in experimentation and modelling results.

Segregation of particle 0.5–10 μm takes place under flow.

These effects can be used to facilitate novel separation technology.

The use of closed channels prior to permeable areas leads to potential energy savings.

Abstract

Particles and droplets of micrometre scale are present in many industrial products and processes, where they can be either part of the product (e.g. emulsion droplets), need to be separated in order to be further utilised in product formulations (e.g. starch particles of specific size or oil from enhanced recovery emulsions) or discarded as waste (such as cleaning liquids that contain small oil droplets or other particulates). In large scale operation the attention is primarily directed toward the throughput of a system, and dimensions of production lines are generally orders of magnitude different from that of the particles or droplets. Whereas the overall flow behaviour in large scale operation is well-understood, that of particles/droplets on micrometre scale is just coming of age, with many new developments in microfluidics and membrane separation adding to the knowledge base.

In this review, we give an overview of the current advances that in our opinion underpin the development of novel as well as improvement of existing separation technologies. For this we highlight the micrometre, and sometimes nanometre scale as is customary in interface and colloid science, but is rather of the beaten path in engineering. We will show that when small scales are taken as a starting point, drastically new approaches may become feasible and offer solutions for large scale separation.

First, we discuss particle behaviour in general terms; the computational models and experimental data from literature both indicate that in defined flow fields, particles segregate based on their size, but the effect of operational parameters on this segregation is not well understood. Next, we relate these findings to membrane and microfluidic separation processes and illustrate with concrete examples how these processes may benefit from this knowledge. In addition to the behaviour of solid particles as discussed for experiments and simulations, we also touch upon the expected effects of deformability of particles and geometry variations on the separation performance.

In a concluding section we estimate dimensions and energy requirements of processes based on these new insights, and show that the amount of energy saved (up to 70% compared to conventional microfiltration) is an important aspect of processes that are designed around particle behaviour in laminar flow fields; therewith highlighting the importance of investigations at the relevant scale.

Keywords

Particle migration
Shear induced diffusion
Membrane separation
Micro channels
Separation process