Abstract: Mixing device and method for mixing a liquid or semi-liquid mass formed by a biological sample to be analyzed and one or more reagents, comprising a mixing chamber (20) able to contain the liquid or semi-liquid mass, mixing means (22), associated with the mixing chamber (20), to mix the liquid or semi-liquid mass in the mixing chamber (20). The mixing device comprises detection means (24) associated with the mixing chamber (20) and suitable to detect one or more physical and/or chemical properties of the liquid or semi-liquid mass contained in the mixing chamber (20), in order to activate the mixing means (22) at an intensity coherent with the physical and/or chemical properties of the liquid or semi-liquid mass.
"MIXING DEVICE AND RELATIVE MIXING METHOD"

FIELD OF THE INVENTION

The present invention concerns a mixing device and the relative mixing method used, preferably but not only, in the biomedical field of laboratory analysis for mixing, in a substantially automatic manner, liquid or semi-liquid masses.

In particular, the present invention is applied for mixing liquid or semi-liquid masses relating to antigen/antibody reagents in corresponding immunological reactions for carrying out analyses on biological samples, or for mixing with chemical reagents.

BACKGROUND OF THE INVENTION

In the field of laboratory analyses, it is known to use mixing devices for mixing liquid or semi-liquid masses, formed by a biological sample to be analyzed and one or more reagents, in order to effect predetermined measurements, such as for example photometric measurements of absorbance and/or transmittance of the liquid or semi-liquid mass, at the end of or during the chemical and/or physical reaction that involves the reagents of the mass itself. In many chemical reactions, such as for example in immunological reactions relating to reagents of the antigen and antibody type, the density and/or viscosity of the liquid or semi-liquid mass is modified both due to the effect of the reaction itself, and also due to the mixing to which the liquid or semi-liquid mass is subjected.

A first known mixing device is based on stirring due to the effect of magnetic elements. This mixing device comprises a mixing container, preferably cylindrical, into which both the desired reagents and also some magnetic elements are introduced, the latter being inert to the reaction, and with the function of stirrers/mixers. The magnetic elements are moved inside the mixing container due to the effect of a magnetic field applied externally to the mixing container. The rotation of the magnetic elements allows to mix the liquid or semi-liquid mass in the mixing container simultaneously with the reaction of the reagents.

A second known mixing device comprises mechanical stirrers disposed in the
mixing container. The mechanical stirrers comprise for example rotating blades kept in rotation by associated drive means at a speed of rotation that can be selectively modified by an operator.

One disadvantage of said known mixing devices is that, since the speed of rotation of the blades or the magnetic stirrers is determined by commands imparted by an operator and for the time decided by the operator, such mixing devices do not take into account, during the temporal evolution of the reaction, any possible variations in the chemical/physical characteristics such as density and/or viscosity of the liquid or semi-liquid mass. This entails a non-efficient or non-optimal mixing of the liquid or semi-liquid mass, causing rather consistent errors in the subsequent measurements. This disadvantage is more obvious in those situations where the reagents are added gradually to the liquid or semi-liquid mass and/or dosed in rigorously measured quantities, with does in the range of micro volumes and therefore with samples which have a limited availability and quantity, substantially preventing the possibility of repeating the mixing and therefore the measurements.

Another disadvantage of said known mixing devices is that, since the rotation of the blades or magnetic stirrers is made in substantially non-optimum conditions, this entails the transfer of excess mechanical energy to the liquid or semi-liquid mass to be mixed. The excess energy determines an unwanted increase in temperature, which contributes to modify the condition and parameters that regulate the chemical/physical reaction, entailing further inaccuracies in subsequent measurements.

Another disadvantage of said known devices is that, during mixing, air bubbles can form that disturb the subsequent photometric measurements of the mixture.

Another disadvantage of known mixing devices is that, if the mechanical blades or the magnetic stirrers are not efficiently cleaned at the end of mixing and the correlated measurements, possible residues left on them can generate a pollution of subsequent measurements: this is also known as carry over sample.

One purpose of the present invention is to achieve a mixing device which allows to mix a liquid or semi-liquid mass according to the real chemical/physical properties of the mass without physical contact between the
liquid to be mixed and the mechanical parts used for the mixing movement.

Another purpose of the present invention is to achieve a mixing device that allows to prevent the transfer of excess mechanical energy to the liquid or semi-liquid mass to be mixed.

Another purpose of the present invention is to achieve a mixing device that allows to detect the actual presence of the liquid or semi-liquid mass in a mixing chamber, where mixing is carried out, in order to be certain that the material distributed is really present therein.

Another purpose of the present invention is to achieve a mixing method that allows to mix a liquid or semi-liquid mass according to the real chemical/physical properties of the liquid or semi-liquid mass and that, during mixing, prevents the transfer of excess mechanical energy to the liquid or semi-liquid mass.

The Applicant has devised, tested and embodied the present invention to overcome the shortcomings of the state of the art and to obtain these and other purposes and advantages.

SUMMARY OF THE INVENTION

The present invention is set forth and characterized in the independent claims, while the dependent claims describe other characteristics of the invention or variants to the main inventive idea.

In accordance with the above purposes, a mixing device according to the present invention is used to mix a predetermined liquid or semi-liquid mass, formed by a biological sample to be analyzed and one or more reagents, subjected to chemical and/or physical reactions, and whose mass can be modified by means of the integration of predetermined quantities of reagents and/or solvents/solutes.

Said mixing device typically comprises a mixing chamber, suitable to contain the liquid or semi-liquid mass to be mixed.

The mixing device also comprises mixing means associated with the mixing chamber and suitable to be selectively activated at a predetermined or predeterminable intensity in order to mix the liquid or semi-liquid mass in the mixing chamber.

According to a characteristic feature of the present invention, the mixing
device also comprises detection means associated with the mixing chamber. The
detection means are suitable to detect physical and/or chemical properties of the
liquid or semi-liquid mass contained in the mixing chamber, such as the mass
and/or viscosity and/or concentration. The detection allows to activate the mixing
means in relation to an intensity coherent with the actual physical and/or
chemical properties of the liquid or semi-liquid mass mixed. In this way, it is
possible to dynamically adapt the intensity of the mixing according both to
chemical reactions, which can modify said physical and/or chemical properties
over time, and also according to possible increases in mass due to the gradual
addition of reagents to the liquid or semi-liquid mass. This also prevents the
transfer to the liquid or semi-liquid mass of excess mechanical energy, allowing
not to modify the ideal conditions of possible chemical reactions and allowing to
effect precise measurements.

According to another characteristic feature of the present invention, the
detection means are suitable to carry out an indirect detection of the physical
and/or chemical properties of the liquid or semi-liquid mass contained in the
mixing chamber.

In a preferential embodiment, the mixing means comprise an actuator of the
piezoelectric type suitable to convert an electric signal entering the actuator,
having a predetermined or predeterminable and modifiable frequency, into
vibratory mechanical energy applied to the mixing chamber. The intensity and/or
frequency of vibration of the mechanical energy generated by the actuator are
correlated to the frequency of the electric signal entering the piezoelectric
actuator.

According to this embodiment, the detection means comprise a piezoelectric
transducer suitable to detect and convert the vibratory mechanical energy
transmitted through the mixing chamber and the liquid or semi-liquid mass
contained therein into a corresponding output electric signal, having a frequency
variable and correlated to that of the vibratory mechanical energy transmitted.

According to a variant of the present invention, the detection means are
suitable to make a direct detection of the physical and/or chemical properties of
the liquid or semi-liquid mass contained in the mixing chamber.

According to another characteristic feature, the mixing device comprises a
processing and control unit connected both to the mixing means and also to the detection means. The processing and control unit is suitable to selectively activate the mixing means, adjusting the intensity of their application according to the data detected in the mixing chamber by the transducer means.

The present invention also concerns a mixing method for mixing in a mixing chamber a liquid or semi-liquid mass. The method provides a step in which the liquid or semi-liquid mass is mixed by means of mixing means associated with the mixing chamber.

The method also comprises a step in which, by means of detection means associated with the mixing chamber, one or more physical and/or chemical properties of the liquid or semi-liquid mass contained in the mixing chamber are detected, so as to activate the mixing means in relation to an intensity coherent with the actual physical and/or chemical properties of the liquid or semi-liquid mass mixed.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other characteristics of the present invention will become apparent from the following description of a preferential form of embodiment, given as a non-restrictive example with reference to the attached drawings wherein:

- fig. 1 is a block diagram of a mixing device according to the present invention.

DETAILED DESCRIPTION OF A PREFERENTIAL FORM OF EMBODIMENT

With reference to fig. 1, a mixing device 10 according to the present invention is used for mixing a liquid or semi-liquid mass in micro volumes, formed by a biological sample to be analyzed and one or more reagents. The device 10 can be used, in this case, in immunological reactions of the antigen/antibody type or in reactions of the globular type.

The mixing device 10 comprises a mixing chamber 20, a piezoelectric actuator 22, a piezoelectric detector 24, a processing and control unit 30 and a phase locked loop unit 36.

The mixing chamber 20 is suitable to contain the liquid or semi-liquid mass to be mixed. The mixing chamber 20 can also be used to carry out one or more measurements, for example photometric, to detect the reaction kinetics of both an immunological and also globular type in said liquid or semi-liquid mass.
The piezoelectric actuator 22 is coupled with a first wall 21 of the mixing chamber 20 and can be selectively activated to convert a periodic input electric signal 19, with a predetermined or predeterminable frequency, into a vibratory mechanical stress 23 entering the mixing chamber 20, with a frequency correlated, for example dependent in linear manner, to said frequency of the input electric signal 19. The input vibratory mechanical stress 23 is applied to the first wall 21, outside the mixing chamber 20, to allow to mix the liquid or semi-liquid mass contained therein without having a mechanical or physical contact with the liquid or semi-liquid mass to be mixed.

The piezoelectric detector 24 is coupled with a second wall 26 of the mixing chamber 20, opposite the first wall 21. The piezoelectric detector 24 is suitable to detect the vibratory mechanical stress 25 exiting from the mixing chamber 20 and to convert it into a corresponding output electric signal 51, analog and bipolar, having a frequency correlated, for example linearly dependent, to the frequency of the output vibratory mechanical stress 25.

The processing and control unit 30 is directly connected, by means of one or more data lines, to the phase locked loop unit 36, comprising an oscillator device of the PLL/VCO type (Phase Locked Loop/Voltage Controlled Oscillator). The processing and control unit 30 can for example comprise a microprocessor or microcontroller having adequate calculation and processing capacities to command the phase locked loop unit 36 by means of a first and a second data line 32, 34 and to control it by means of a control line 37 and to process, directly or indirectly, the output electric signal 51. In this case, the output electric signal 51 is conditioned and converted from its analog format to a digital signal 60 by means of an analog/digital converter 53 (ADC converter) connected to an inlet of the processing and control unit 30. It is understood that the processing and control unit 30, the phase locked loop unit 36 and the analog/digital converter 53 can be incorporated into a single microprocessor or microcontroller having adequate hardware resources.

The phase locked loop unit 36 is suitable to generate, based on the commands received from the processing and control unit 30, a low power electric signal 39, typically a square wave, having a desired frequency substantially coinciding with the frequency of the input electric signal 19.
The mixing device 10 also comprises a high power generator 38, and a first low-pass filter 40 located between the high power generator 38 and the piezoelectric actuator 22. The high power generator 38, for example a stage amplifier of a known type, is connected to the phase locked loop unit 36 and is suitable to generate a high power electric signal 139 obtained by raising the tension of the low power electric signal 39 to adequate values for the tension of the input electric signal 19 of the piezoelectric actuator 22. The first low-pass filter 40 is suitable both to transform the high power electric signal 139 into a bipolar sinusoidal electric signal coinciding with the electric signal 19 entering the piezoelectric actuator 22, and also to eliminate unwanted harmonic components, typically at higher frequencies, introduced by the high power generator 38.

The mixing device 10 also comprises a precision rectifier 52 and a second low-pass filter, suitable to convert the output electric signal 51 generated by the piezoelectric detector 24 into the digital signal 60.

The device 10 also comprises a current sensor 44 connected both to the piezoelectric actuator 22 and also to the processing and control unit 30. The current sensor 44 is suitable to detect the frequency, or rather the current generated at outlet from the piezoelectric actuator 22 and indicative of the intensity and/or frequency of the input mechanical stress 23 generated by the piezoelectric actuator 22.

The device 10 also comprises a feed unit 14 to feed with electric energy the electric/electronic components of the device. In the attached drawing the feed line is indicated by lines of dashes directed toward the components fed.

The mixing device 10 as described herefore functions as follows.

After having introduced into the mixing chamber 20 the liquid or semi-liquid mass to be mixed, having a predetermined mass, concentration and viscosity, together with any possible reagents, the processing and control unit 30 activates, indirectly, the piezoelectric actuator 22, allowing to generate the input mechanical stress 23 at an initial frequency near to the frequency of mechanical resonance of the mixing chamber 20, found for example mathematically according to the density of the material of which the chamber 20 is made.

The processing and control unit 30 supplies a sample frequency to the phase
locked loop unit 36, by means of the first data line 32 and, through the second
data line 34, the entire division of the frequency generated by the phase locked
loop unit 36. The frequency thus generated is acquired by the processing and
control unit 30 by means of the control line 37, allowing to adjust the low power
electric signal 39 with adequate precision to the desired frequency.

The low power electric signal 39 is first converted into a high power electric
signal 139 by the high power generator 38, and then filtered and converted into
the bipolar and sinusoidal input electric signal 19 by means of the first low-pass
filter 40. The input electric signal 19 is then applied to the piezoelectric actuator
22 which, connected to the first wall 21, converts it into the input vibratory
mechanical stress 23, with initial frequency, applied to the mixing chamber 20.
The input vibratory mechanical stress 23 is therefore transmitted through the
mixing chamber 20 generating a vibratory mechanical stress of both the chamber
20 and also the liquid or semi-liquid mass contained therein. This allows to mix
the liquid or semi-liquid mass and produces the output vibratory mechanical
stress 25, which is different from the input stress 23, according to the specific
liquid or semi-liquid mass and/or its specific concentration. The output vibratory
mechanical stress 25 is detected by the piezoelectric actuator 24 and converted
into the output electric signal 51, analog and bipolar, which is transformed into
unipolar and is filtered by means of the precision rectifier and the second low-
pass filter 50 and then transformed into the digital signal 60 by the analog/digital
converter 53.

The processing and control unit 30 detects the actual initial frequency and/or
intensity of the input mechanical stress 23 generated by the piezoelectric actuator
22 and compares it with the intensity and frequency of the output mechanical
stress 25 following its passage through the mixing chamber 20, as detected by the
transducer 24.

The processing and control unit 30 subsequently generates incremental
variations at constant intervals, for example at pitches of 1 KHz, of the frequency
of the low power electric signal 39 and then of the corresponding input
mechanical stress 23, until a predetermined final frequency value is reached,
memorizing for which specific frequency value we obtain the maximum intensity
of the output mechanical stress 25 as detected by the transducer 24.
Said specific frequency value substantially corresponds to a resonance frequency, that is, to an optimum mechanical resonance condition of the mixing chamber 20 and the liquid or semi-liquid mass contained therein, according to its mass and/or concentration. At this functioning frequency, the vibratory agitation produced by the piezoelectric actuator 22 supplies optimum and efficient mixing conditions, adapted in a dynamic manner to the actual mixing conditions. In this way, it is also possible to modify the mass or adapt the mixing according to possible changes in the physical and/or chemical properties of the liquid or semi-liquid mass due to the chemical reactions in progress.

The processing and control unit 30 subsequently activates the piezoelectric actuator 22 with an input electric signal 19 having the same frequency as the resonance frequency, for a time needed to mix the liquid or semi-liquid mass. The processing and control unit 30 possibly modifies the frequency so as to adapt to a possible change in the resonance frequency of the mixing chamber 20 and the liquid or semi-liquid mass, according to a change in its physical and/or chemical properties.

The mixing device 10 according to the present invention allows to mix the liquid or semi-liquid mass in the mixing chamber 20 without the aid of mobile mechanical parts inside the reaction chamber; this mixing is generated by the piezoelectric actuator 22 outside the mixing chamber 20, and therefore obtains a no contact mixing.

Thanks to the effective mixing obtainable, the mixing device 10 according to the present invention also allows to optimize the reactions of the antigen antibody type.

Furthermore, thanks to the effective mixing, the mixing chamber 20 allows to analyze accurately the speed of aggregation measured photometrically, or to discriminate the speeds of aggregation indicating the samples affected by a prozone effect.

It is also possible to clean the mixing chamber 20 by adjusting the intensity and/or frequency of vibration of the vibratory mechanical energy produced by the piezoelectric actuator 22, since it is possible to use ultrasonic frequencies able to render more effective the washing of the mixing chamber 20.

The cleaning can also be carried out by evaporation of the liquid or semi-
liquid mass, produced by activating the piezoelectric actuator 22 at high frequencies.

Another advantage of the mixing device 10 according to the present invention is that it is possible to verify the state of fullness of the mixing chamber 20, allowing to verify that the liquid or semi-liquid mass to be mixed is actually present inside the mixing chamber 20 before beginning the mixing or before adding reagents to the liquid or semi-liquid mass.

Another advantage of the present invention is that it can be used as a homogenizer for biological liquids, such as for example feces, blood or bronchial expectorations.

It is clear that modifications and/or additions of parts and/or steps may be made to the mixing device and relative mixing method as described heretofore, without departing from the field and scope of the present invention.

It is also clear that, although the present invention has been described with reference to some specific examples, a person of skill in the art shall certainly be able to achieve many other equivalent forms of mixing device and the relative mixing method, having the characteristics as set forth in the claims and hence all coming within the field of protection defined thereby.
CLAIMS

1. Mixing device for mixing a liquid or semi-liquid mass formed by a biological
sample to be analyzed and one or more reagents, comprising a mixing chamber
(20) able to contain said liquid or semi-liquid mass, mixing means (22),
associated with the mixing chamber (20), to mix the liquid or semi-liquid mass in
the mixing chamber (20), characterized in that it comprises detection means (24)
associated with said mixing chamber (20) and able to detect one or more physical
and/or chemical properties of the liquid or semi-liquid mass contained in the
mixing chamber (20), in order to activate said mixing means (22) at an intensity
coherent with said physical and/or chemical properties of said liquid or semi-
liquid mass.

2. Device as in claim 1, characterized in that said detection means (24) are able to
make a direct detection of said one or more physical and/or chemical properties.

3. Device as in claim 1, characterized in that said detection means (24) are able to
make an indirect detection of said one or more physical and/or chemical
properties.

4. Device as in any claim from 1 to 3, characterized in that it comprises a
processing and control unit (30), connected both to said mixing means (22) and
also to said detection means (24), able to activate and adjust the intensity of said
mixing means (22) according to the detection made by said detection means (24).

5. Device as in any claim hereinbefore, characterized in that said mixing means
comprise a piezoelectric actuator (22) able to convert an input electric signal (19)
with a predetermined or predeterminable and modifiable frequency into vibratory
mechanical energy (23) applied to the mixing chamber (20) in order to mix said
liquid or semi-liquid mass, wherein the intensity and/or frequency of vibration of
said vibratory mechanical energy (23) are correlated to the frequency of the input
electric signal (19).

6. Device as in claim 5, characterized in that said piezoelectric actuator (22) is
suitable to apply said vibratory mechanical energy (23) outside the mixing
chamber (20) in order to mix said liquid or semi-liquid mass.

7. Device as in claim 5 or 6, characterized in that said input electric signal (19) is
bipolar and sinusoidal.

8. Device as in any claim hereinbefore, characterized in that said detection means
comprise a piezoelectric transducer (24) able to detect and convert vibratory mechanical energy (25) transmitted through the mixing chamber (20) and the liquid or semi-liquid mass contained in the mixing chamber (20) into a corresponding output electric signal (51), having variable frequency and/or intensity correlated with those of said vibratory mechanical energy transmitted (25).

9. Device as in any claim from 4 to 8, characterized in that it comprises a phase locked loop unit (36), connected to the processing and control unit (30) and able to generate a low power electric signal (39) having a desired frequency coinciding with the frequency of the input electric signal (19).

10. Device as in claim 9, characterized in that it comprises a high power generator (38), connected to the phase locked loop unit (36), able to generate a high power electric signal (139) achieved by raising the tension of the low power electric signal (39) to values sufficient for the tension of the input electric signal (19) of said piezoelectric actuator (22).

11. Device as in claim 10, characterized in that it comprises a low-pass filter (38) located between said high power generator (38) and said piezoelectric actuator (22), able both to transform the high power electric signal (139) into said input electric signal (19), and also to eliminate unwanted harmonic components.

12. Device as in any claim from 5 to 11, characterized in that it comprises a sensor (44) connected both to said piezoelectric actuator (22) and also to said processing and control unit (30), able to detect the frequency and/or intensity of the vibratory mechanical energy (23) generated by the piezoelectric actuator (22).

13. Device as in claim 12, characterized in that said sensor comprises a current sensor (44).

14. Device as in any claim from 8 to 13, characterized in that it comprises a precision rectifier (52), connected both to the piezoelectric detector (24) and also to a second low-pass filter (50), able to convert the output electric signal (51) generated by the piezoelectric transducer (24) into a digital signal (60) entering said processing and control unit (30).

15. Device as in any claim from 5 to 14, characterized in that the intensity and/or frequency of vibration of said vibratory mechanical energy, produced by said piezoelectric actuator (22), is adjusted to mix said liquid or semi-liquid mass,
preventing the formation of air bubbles.
16. Device as in any claim from 7 to 15, characterized in that said piezoelectric transducer (24) is able to detect the presence of said liquid or semi-liquid mass in said mixing chamber (20).

17. Device as in any claim from 7 to 16, characterized in that the intensity and/or frequency of vibration of said vibratory mechanical energy produced by said piezoelectric actuator (22) is adjustable so as to clean said mixing chamber (20).

18. Device as in claim 17, characterized in that said cleaning is carried out by evaporation of the liquid or semi-liquid mass.

19. Mixing method to mix in a mixing chamber (20) a liquid or semi-liquid mass formed by a biological sample to be analyzed and one or more reagents, comprising a mixing step in which, by means of mixing means (22), associated with the mixing chamber (20), the liquid or semi-liquid mass is mixed, characterized in that it comprises a detection step in which, by means of detection means (24) associated with the mixing chamber (20), one or more physical and/or chemical properties of the liquid or semi-liquid mass contained in the mixing chamber (20) are detected, said detection step governing the mixing means (22) in correlation to the physical and/or chemical properties of said liquid or semi-liquid mass detected on each occasion.

20. Method as in claim 19, characterized in that in said detection step said detection means (24) are able to detect said one or more physical and/or chemical properties directly.

21. Method as in claim 19, characterized in that in said detection step said detection means (24) are able to detect said one or more physical and/or chemical properties indirectly.

22. Method as in any claim from 19 to 21, characterized in that said mixing means (22) are activated by means of a processing and control unit (30), connected both to said mixing means (22) and also to said detection means (24), in order to adjust the intensity of said mixing means (22).

23. Method as in any claim from 19 to 22, characterized in that said mixing means (22) comprise a piezoelectric actuator able to convert an input electric signal (19) with a predetermined or predeterminable and modifiable frequency into vibratory mechanical energy (23) applied to the mixing chamber (20),
wherein the intensity and/or frequency of vibration of said vibratory mechanical energy (23) are correlated to the frequency of the input electric signal (19).

24. Method as in claim 23, characterized in that said input electric signal (19) is bipolar and sinusoidal.

25. Method as in any claim from 19 to 24, characterized in that said detection means comprise a piezoelectric transducer (24) able to detect and convert vibratory mechanical energy (25) transmitted through the mixing chamber (20) and the liquid or semi-liquid mass contained in the mixing chamber (20) into a corresponding output electric signal (51), having variable frequency and/or intensity correlated with those of said vibratory mechanical energy transmitted (25).

26. Method as in claim 25, characterized in that said vibratory mechanical energy (23) is applied outside the mixing means (20) in order to mix said liquid or semi-liquid mass.

27. Method as in claim 25 or 26, characterized in that in said detection step the processing and control unit (30) detects, by means of a sensor (44), the frequency and/or intensity of the input vibratory mechanical energy (23) generated by the piezoelectric actuator (22) and compares it with the intensity and/or frequency of the vibratory mechanical energy transmitted (25) through the mixing chamber (20) and detected by the piezoelectric transducer (24), and in that the processing and control unit (30) generates subsequent variations in the frequency of the low power electric signal (39) and/or the corresponding vibratory mechanical energy (23), starting from a predetermined initial frequency value until a predetermined final frequency value is reached, memorizing a specific frequency value corresponding to a frequency of resonance in which a maximum intensity of the vibratory mechanical energy transmitted (25) is detected.

28. Method as in claim 27, characterized in that in said mixing step the processing and control unit (30) activates the piezoelectric actuator (22) with an input electric signal (19) having said frequency of resonance, for a time needed to effect the mixing of the liquid or semi-liquid mass.

29. Method as in claim 27 or 28, characterized in that said variations in frequency are made at constant pitches.

30. Method as in any claim from 27 to 29, characterized in that said variations in
frequency are made by means of a phase locked loop unit (36), connected to the processing and control unit (30) and able to generate the low power electric signal (39) having identical frequency as the input electric signal (19).

31. Method as in any claim from 25 to 30, characterized in that said piezoelectric transducer (24) is able to detect the presence of said liquid or semi-liquid mass in said mixing chamber (20).

32. Method as in any claim from 23 to 31, characterized in that the intensity and/or frequency of vibration of said vibratory mechanical energy (23) produced by said piezoelectric actuator (22) is adjustable to clean said mixing chamber (20).

33. Method as in claim 32, characterized in that the cleaning of the mixing chamber (20) is achieved by evaporation of the liquid or semi-liquid mass in said mixing chamber (20).
# INTERNATIONAL SEARCH REPORT

**International application No**
PCT/EP2009/056346

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. B01F11/02 B01F15/00 G01N1/38 G05D11/13

ADD. B08B3/12

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
B01F B08B G01H G01N G05D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**EPO-Internal**

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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| X | Further documents are listed in the continuation of Box C | X | See patent family annex |

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Tel (+31-70) 340-2040, Fax (+31-70) 340-3016

Authorized officer
Krasenbrink, B

Form PCT/ISA/210 (second sheet) (April 2005)
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<td>JP 59 199025 A (TOKYO SHIBAURA ELECTRIC CO) 12 November 1984 (1984-11-12) abstract</td>
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