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(54) **SOUND WAVE MIXING DEVICE BASED ON THREE-FREEDOM-DEGREE RESONANCE SYSTEM**

(57) A three-degree-of-freedom resonance system-based sonic mixing device includes a machine frame (1), a vibration excitation unit (2), a reaction unit (3) and a loading unit (4). The reaction unit (3) is positioned in the middle of the machine frame (1), and is connected with an upper plate (103) and lower plate (101) of the machine frame (1) through second springs (301). The vibration excitation unit (2) is positioned in the middle of the reaction unit (3), and is connected with an upper plate (302) and lower plate (304) of the reaction unit (3) through first springs (201). The loading unit (4) is positioned between the machine frame (1) and the reaction unit (3), and is connected with the machine frame (1) and the reaction unit (3) through third springs (403) and fourth springs (406), respectively. A mixing container (401) may be fixed on the loading unit (4) or on the reaction unit (3), or two mixing containers (401) are fixed on both the loading unit (4) and the reaction unit (3).

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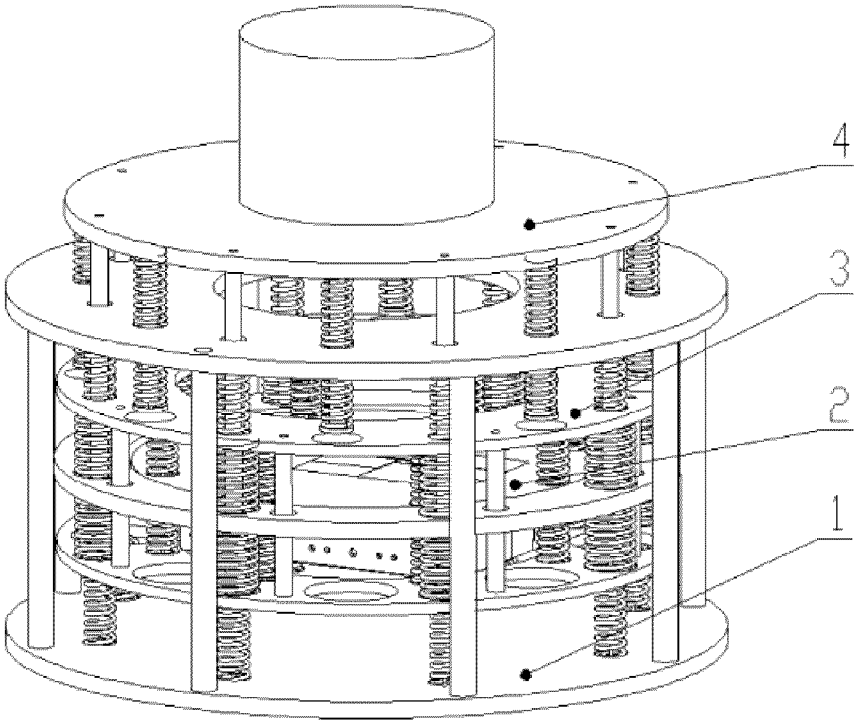

FIG. 1

Description

TECHNICAL FIELD

[0001] The disclosure relates to a mixing device, and particularly to a three-degree-of-freedom resonance system-based sonic mixing device.

BACKGROUND

[0002] Mixing equipment has been widely applied to the industries of chemistry, medicine, batteries and the like. However, most of mixing equipments used at present are paddle mixers, and therefore, mixing time is long; mixing efficiency is low; mixing dead angles exist in a mixing process; materials are not allowed to be added at the same time in a charging process; it is difficult to clean materials after mixing; and production efficiency of an enterprise is greatly influenced.

SUMMARY

[0003] The disclosure is intended to overcome the shortcomings of the conventional art and provide a three-degree-of-freedom resonance system-based sonic mixing device capable of rapidly and efficiently mixing materials.

[0004] In order to solve the technical problem, the disclosure provides a three-degree-of-freedom resonance system-based sonic mixing device, which may include:

a machine frame 1 which may include a lower machine frame plate 101 and an upper machine frame plate 103 fixedly connected with the lower machine frame plate 101;

a reaction unit 3 which may include an upper reaction plate 302 and a lower reaction plate 304 fixedly connected with the upper reaction plate 302 and is supported in the upper machine frame plate 103 and lower machine frame plate 101 of the machine frame 1 through a plurality of second upper springs 301a arranged on an upper surface of the upper reaction plate 302 and a plurality of second lower springs 301b arranged on a lower surface of the lower reaction plate 304;

a vibration excitation unit 2 which may include a fixed plate 202 supported between the upper reaction plate 302 and the lower reaction plate 304 through a plurality of first upper springs 201a arranged on an upper surface of the fixed plate 202 and a plurality of first lower springs 201b on an lower surface of the fixed plate 202; and

a loading unit 4 which may include an upper loading plate 402 and a lower loading plate 407 fixedly connected with the upper loading plate 402 and arranged between the upper reaction plate 302 and the lower reaction plate 304 of the reaction unit 3, and

the lower loading plate 407 being supported between the upper reaction plate 302 and lower reaction plate 304 of the reaction unit 3 through a plurality of fourth upper springs 406a and a plurality of fourth lower springs 406b.

[0005] Preferably, the loading unit 4 may further include a plurality of spring guide posts 404 fixed on a lower surface of the upper loading plate 402;

each spring guide post 404 may pass though the upper machine frame plate 103 to form an upper half part and a lower half part;

the upper half parts of the spring guide posts 404 may be sleeved with a third upper springs 403a which may be supported between an upper surface of the upper machine frame plate 103 and the lower surface of the upper loading plate 402; and

the lower half parts of the spring guide posts 404 may be sleeved with a third lower springs 403b which may be supported between the upper machine frame plate 103 and ends of the lower half parts of the spring guide posts 404.

[0006] Preferably, the upper reaction plate 302 may be fixedly connected with the lower reaction plate 304 through a plurality of reaction columns 303.

[0007] Preferably, the plurality of reaction columns 303 may pass through the plurality of through holes formed in the lower loading plate 407, respectively.

[0008] Preferably, the upper loading plate 402 may be fixedly connected with the lower loading plate 407 through a plurality of loading connecting rods 405.

[0009] Preferably, each loading connecting rod 405 may sequentially pass through the upper machine frame plate 103, the second upper spring 301a, the upper reaction plate 302 and the fourth upper spring 406a.

[0010] Preferably, the plurality of first upper springs 201a and the plurality of first lower springs 201b may be arranged on an upper surface and a lower surface of the fixed plate 202 in an annular array manner, respectively; or

the plurality of second upper springs 301a and the plurality of second lower springs 301b may be arranged on the upper reaction plate 302 and the lower reaction plate 304 in an annular array manner, respectively.

[0011] Preferably, central axes of each first upper spring 201a and each first lower spring 201b may be coincident; central axes of each second upper spring 301a and each second lower spring 301b may be coincident; or central axes of each fourth upper spring 406a and each fourth lower spring 406b may be coincident.

[0012] Preferably, recesses for keeping the first upper springs 201a may be provided in the upper surface of the fixed plate 202, and recesses for keeping the first lower springs 201b may be provided in the lower surface of the fixed plate 202; or

recesses for keeping the second upper springs 301 a may be provided in the upper surface of the upper reaction plate 302, and recesses for keeping the second lower springs 301b may be provided in the lower surface of the lower reaction plate 304; or

recesses for keeping the second upper springs 301a may be provided in the upper machine frame plate 103, and recesses for keeping the second lower springs 301b may be provided in the lower machine frame plate 101; or

recesses for keeping the first upper springs 201a may be provided in the lower surface of the upper reaction plate 302, and recesses for keeping the first lower springs 201b maybe provided in the upper surface of the lower reaction plate 304; or

recesses for keeping the fourth upper springs 406a may be provided in the lower surface of the upper reaction plate 302, and recesses for keeping the fourth lower springs 406b may be provided in the upper surface of the lower reaction plate 304.

[0013] Preferably, the device may further include a vibration excitation device fixed on the vibration excitation unit 2.

[0014] Preferably, the vibration excitation device may be an eccentric mechanical vibration exciter, an electromagnetic vibration exciter or a hydraulic vibration exciter.

[0015] Preferably, a plurality of holes for reducing weight may be formed in the lower reaction plate 304.

[0016] Preferably, the device may further include a mixing container 401 fixed on at least the reaction unit 3 or the loading unit 4.

[0017] Preferably, the lower machine frame plate 101 may be fixedly connected with the upper machine frame plate 103 through a plurality of machine frame upright posts 102.

[0018] Preferably, the first upper springs 201a and the first lower springs 201b may be arranged on the vibration excitation unit 2 in a press-fitting manner; the second upper springs 301a and the second lower springs 301b may be arranged on the reaction unit 3 in the press-fitting manner; or the fourth upper springs 406a and the fourth lower springs 406b may be arranged on the loading unit 4 in the press-fitting manner.

BRIEF DESCRIPTION OF DRAWINGS

[0019] Specific embodiments of the application will be described below with reference to the drawings, wherein

FIG. 1 is a structure diagram of a sonic mixing device according to an embodiment of the application.
FIG. 2 is a sectional structure diagram of a sonic mixing device according to an embodiment of the application.
FIG. 3 is a structure diagram of a machine frame according to an embodiment of the application.
FIG. 4 is a structure diagram of a vibration excitation unit according to an embodiment of the application.
FIG.5 is a structure diagram of a reaction unit according to an embodiment of the application.
FIG. 6 is a structure diagram of a loading unit according to an embodiment of the application.
FIG. 7 is a schematic diagram of overall stress on a sonic mixing device according to an embodiment of the application.
FIG. 8 is a third-order amplitude-frequency response diagram according to an embodiment of the application.
FIG. 9 is a third-order phase-frequency response diagram according to an embodiment of the application.

[0020] Reference numerals in the drawings are listed below:

1: machine frame; 2: vibration excitation unit; 3: reaction unit; 4: loading unit; 101: lower machine frame plate; 102: machine frame upright post; 103: upper machine frame plate; 201: first spring; 202: fixed plate; 301: second spring; 302: upper reaction plate; 303: reaction upright post; 304: lower reaction plate; 401: mixing container; 402: upper loading plate; 403: third spring; 404: spring guide post; 405: loading connecting plate; 406: fourth spring; and 407: lower loading plate.

F indicates a vibration excitation force, and m_i, c_i and k_i indicate a mass of each unit, a damping coefficient and rigidity, respectively.

DETAILED DESCRIPTION

[0021] For making the technical solutions and advantages of the application clearer, exemplary embodiments of the application will further be described below in combination with the drawings in detail. The described embodiments are

not exhaustive but only part of embodiments of the application. Moreover, the embodiments in the disclosure and characteristics in the embodiments may be combined if without conflicts.

[0022] In FIG. 1, a mixing device includes a machine frame (1), a vibration excitation unit (2), a reaction unit (3) and a loading unit (4). The reaction unit (1) is positioned in the middle of the machine frame (1), and is connected with an upper plate (103) and lower plate (101) of the machine frame (1) through second springs (301a, 301b). The vibration excitation unit (2) is positioned in the middle of the reaction unit (3), and is connected with an upper plate (302) and lower plate (304) of the reaction unit (3) through first springs (201a, 201b). The loading unit (4) is positioned between the machine frame (1) and the reaction unit (3), and is connected with the machine frame (1) and the reaction unit (3) through third springs (403a, 403b) and fourth springs (406a, 406b) respectively. A mixing container (401) may be fixed on the loading unit (4) or fixed on the reaction unit (3), or two mixing containers (401) are fixed on both the loading unit (4) and the reaction unit (3). A vibration excitation device of the vibration excitation unit (2) may adopt an eccentric mechanical vibration exciter, an electromagnetic vibration exciter or a hydraulic vibration exciter.

[0023] A working process of the disclosure is as follows: the vibration excitation device only generates a vertical vibration excitation force, bringing the loading unit and reaction unit of the mixing device into forced vibration. When a vibration frequency of the mixing device reaches a third-order natural frequency, a system achieves a resonance effect; the upper loading plate moving with a certain acceleration transmits kinetic energy into the mixing container; low-frequency sonic waves are generated between materials mixed in the container to break boundary layers between the materials; and the materials freely flow to form a numerous micro mixing regions to promote rapid mixing of the materials. During resonance, an amplitude and acceleration of the system are sharply increased; energy required by the system is minimized; and all energy generated by the system is used for effective mixing of the materials. Motion directions of the loading unit (4) and the reaction unit (3) are opposite, and generated acting forces are mutually canceled. After mixing, it is only necessary to take the container out, and the mixing container may be rapidly replaced and is not required to be cleaned on line.

[0024] In FIG. 2, FIG. 3, FIG. 4, FIG. 5 and FIG. 6, the machine frame 1 includes a circular lower machine frame plate 101 and an upper annular lower machine frame plate 103 connected with the lower machine frame plate 101 through a plurality of machine frame upright posts 102.

[0025] The reaction unit 3 is arranged in the machine frame 1. The reaction unit 3 includes an upper annular reaction plate 302 and a lower annular reaction plate 304 connected with the upper reaction plate 302 through a plurality of reaction upright posts 303. The plurality of second upper springs 301a are press-fitted between the upper reaction plate 302 and the upper machine frame 103, and the plurality of second upper springs 301a are uniformly distributed. The plurality of second lower springs 301b are press-fitted between the lower reaction plate 304 and the lower machine frame plate 101, and the plurality of second lower springs 301b are uniformly distributed. Each of the second upper springs 301a and each of the second lower springs 301b form a group, and central axes of the second upper spring 301a and second lower spring 301b in each group are coincident.

[0026] The loading unit 4 includes an annular lower loading plate 407 arranged between the upper reaction plate 302 and the lower reaction plate 304 and an upper loading plate 402 connected with the lower loading plate 407 through a plurality of loading connecting rods 405 passing through the upper machine frame plate 103. The second upper springs 301a and the upper reaction plate 302 and positioned above the upper machine frame plate 103; fourth upper springs 406a are press-fitted between the lower loading plate 407 and the upper reaction plate 302, and the fourth upper springs 406a sleeve the loading connecting rods 405; fourth lower springs 406b arranged correspondingly to the fourth upper springs 406a are press-fitted between the lower loading plate 407 and the lower reaction plate 304; the plurality of spring guide posts 404 are connected to a lower surface of the upper loading plate 402,and lower ends of the spring guide posts 404 pass through the upper machine frame plate 103; parts, positioned on the upper machine frame plate 103, of the spring guide posts 404 are sleeved with third upper springs 403a, and the third upper springs 403a are press-fitted between the upper loading plate 402 and the upper machine frame plate 103; and parts, positioned below the upper machine frame plate 103, of the spring guide posts 404 are sleeved with third lower springs 403b, and the third lower springs 403b are press-fitted between the upper machine frame plate 103 and flanges at lower ends of the spring guide posts 404.

[0027] The vibration excitation unit 2 includes a fixed plate 202 arranged in the lower loading plate 407 and a vibration excitation device connected to the fixed plate 202; and a plurality of first upper springs 201a are press-fitted between the fixed plate 202 and the upper reaction plate 302, and a plurality of first lower springs 201b arranged correspondingly to the first upper springs 201a are press-fitted between the fixed plate 202 and the lower reaction plate 304.

[0028] The device further includes the mixing container 401; and the mixing container 301 is fixed on the upper loading plate 402 of the loading unit 4.

[0029] Recesses for keeping the third upper springs 403a are formed in the upper surface of the upper machine frame plate 103; recesses for keeping the third lower springs 403b are formed in the lower surface; the recesses are formed correspondingly; and holes for the spring guide posts 404 to pass through are formed at the recesses. Recesses for keeping the second upper springs 301a are further formed in the lower surface of the upper machine frame plate 103;

holes for the loading connecting rods 305 to pass through are formed in the upper machine frame plate 103; and recesses for keeping the second lower springs 301b are formed in the upper surface of the lower machine frame plate 101.

[0030] Recesses for keeping the second upper springs 301a are provided in the upper surface of the upper reaction plate 302; recesses for keeping the fourth upper springs 406a are provided in the lower surface; the recesses are provided correspondingly; and through holes for the loading connecting rods 405 to pass through are provided at the recesses. Via holes for the spring guide posts 404 and the third lower springs 403b to pass through are further provided in the lower surface of the upper reaction plate 302; recesses for keeping the first upper springs 201a are further provided in the lower surface of the upper reaction plate 302; recesses for keeping the second lower springs 301b are provided in the lower surface of the lower reaction plate 304; recesses for keeping the fourth lower springs 406b are provided in the upper surface; and the recesses are provided correspondingly. Recesses for keeping the first lower springs 201b are further provided in the upper surface of the lower reaction plate 304. Large holes for reducing weight are provided in the lower reaction plate 304.

[0031] Recesses for keeping the fourth upper springs 406a are provided in the upper surface of the lower loading plate 407; recesses for keeping the fourth lower springs 406b are provided in the lower surface; and the recesses are provided correspondingly. Holes for the reaction upright posts 303 to pass through are provided in the lower loading plate 407.

[0032] Recesses for keeping the third upper springs 403a are provided in the lower surface of the upper loading plate 402.

[0033] The large holes for reducing the weight are provided in the lower reaction plate 304.

[0034] There is one mixing container 401 fixed on the upper loading plate 402 of the loading unit 4.

[0035] There are two mixing containers 401. One is fixed on the loading unit 4, and the other is fixed on the reaction unit 3.

[0036] The motion directions of the loading unit 4 and the reaction unit 3 are completely opposite, the generated acting forces are mutually canceled, and an acting force of a mixer on the ground is zero.

[0037] The mixing device works at the third-order natural frequency, so that the system generates a resonance state. When the mixing device is in the resonance state, the materials in the container generate the low-frequency sonic waves, and all the energy is used for mixing between the materials, so that the materials may be rapidly and efficiently mixed. A resonance amplitude of the system is lower than 15mm, a resonance frequency range is 60 $\pm$ 5*Hz*, and a highest acceleration is 200g.

[0038] When the mixing device works close to the resonance frequency, a sonic wave eddy current of <300μm may be generated in the mixing container to rapidly and efficiently mix the materials.

[0039] In FIG. 7, FIG. 8 and FIG. 9, a working principle of the three-degree-of-freedom resonance system-based sonic mixing device of the disclosure is as follows.

[0040] According to a vibration theory, a single mass body follows a damped forced vibration equation: ma+cv+kx=F, and from a stress diagram of the system in FIG. 6, a forced vibration motion equation of the three-degree-of-freedom system under the action of an additional intermittent vibration excitation force is:

$$\begin{bmatrix} m_1 & 0 & 0 \\ 0 & m_2 & 0 \\ 0 & 0 & m_3 \end{bmatrix} \begin{Bmatrix} a_1 \\ a_2 \\ a_3 \end{Bmatrix} + \begin{bmatrix} c_1 & -c_1 & 0 \\ -c_1 & c_1+c_2+c_4 & -c_2 \\ 0 & -c_2 & c_2+c_3 \end{bmatrix} \begin{Bmatrix} v_1 \\ v_2 \\ v_3 \end{Bmatrix} + \begin{bmatrix} k_1 & -k_1 & 0 \\ -k_1 & k_1+k_2+k_4 & -k_2 \\ 0 & -k_2 & k_2+k_3 \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \\ x_3 \end{Bmatrix} = \begin{Bmatrix} F \\ 0 \\ 0 \end{Bmatrix},$$

in the formula:

m_i -- mass of each unit,
c_i -- damping coefficient,
k_i -- rigidity of the springs in each group,
x_i, v_i and a_i -- displacement, velocity and acceleration of each unit, and
{F} -- vibration excitation force of the system.

[0041] At present, there are many calculation methods for a natural frequency and main vibration mode of a multi-free-of-freedom system, and there have been existing standard computer programs for some of them to select. Common methods include a matrix iteration method, a Dunkerly method, a Rayleigh method, a Ritz method, a subspace iteration method, and the like.

[0042] Theoretically, when the vibration excitation frequency reaches the natural frequency of the system, the system generates resonance, amplitude of the loading unit is highest, a required vibration excitation force may be very weak, and energy consumption is lowest. In the disclosure, phase-frequency response and amplitude-frequency response characteristics of the three-degree-of-freedom vibration system are analyzed under a given set of conditions of mass,

damping and rigidity parameters to find that that, during work at a first-order natural frequency and a second-order natural frequency, the motion directions of the loading unit and the reaction unit are the same, so that the whole mixing device vibrates violently and is unfavorable for mixing work. During work at the third-order natural frequency, the motion directions of the loading unit and the reaction unit are opposite, amplitudes are close, the forces generated by the loading unit and the reaction unit are mutually canceled in the mixing device, and the mixing device generates no acting force on the ground, so that the third-order natural frequency is selected as a working frequency, as shown in FIG. 8 and FIG. 9.

[0043] Compared with the conventional art, the solution has the following advantages.

1) Compatibility with the plurality of material systems, including liquid-liquid, liquid-solid, gas-liquid and solid-solid: the mixing device is particularly suitable for mixing dangerous materials and widely applicable.
2) High mixing quality: on one hand, quality of a single product is improved, and on the other hand, differences between production batches are reduced.
3) Energy saving and high efficiency: a time required by resonant mixing of the materials is only 1/7 of a time required by conventional mixing, in addition, resonant mixing energy loss is low, and applied mechanical energy is all used for applying work for mixing, so that the mixing efficiency is high, and an energy-saving effect is extraordinarily prominent.
4) High safety: a resonant mixing dispersion technology avoids contact between mechanical rotating parts and the materials, there are no paddles in the mixing container, and intrinsic safety of the process is improved.
5) No mixing dead angles: the resonant mixing technology generates a micro sonic wave eddy current in the mixing container to completely mix the materials.
6) Easiness for cleaning: during mixing, the materials are arranged in the mixing container, the container is fixed with the equipment, it is only necessary to take the container out after mixing, and the mixing container may be rapidly replaced and is not required to be cleaned on line.

[0044] Those skilled in the art should know that the embodiment of the application may be provided as a method, a system or a computer program product. Therefore, the application may adopt a form of a pure equipment embodiment, a pure software embodiment or a combined software and equipment embodiment. Moreover, the application may adopt a form of a computer program product implemented on one or more computer-available storage media (including, but not limited to, a disk memory, a Compact Disc Read-Only Memory (CD-ROM), an optical memory and the like) including computer-available program codes.

[0045] Obviously, those skilled in the art may make various modifications and transformations to the application without departing from the spirit and scope of the application. Therefore, if these modifications and transformations of the application belong to the scope of the claims of the application and an equivalent technology thereof, the application is also intended to include these modifications and transformations.

Claims

1. A three-degree-of-freedom resonance system-based sonic mixing device, comprising:

a machine frame (1) comprising a lower machine frame plate (101) and an upper machine frame plate (103) fixedly connected with the lower machine frame plate (101);
a reaction unit (3) comprising an upper reaction plate (302) and a lower reaction plate (304) fixedly connected with the upper reaction plate (302); the reaction unit (3) being supported in the upper machine frame plate (103) and lower machine frame plate (101) of the machine frame (1) through a plurality of second upper springs (301a) arranged on an upper surface of the upper reaction plate (302) and a plurality of second lower springs (301b) arranged on a lower surface of the lower reaction plate (304);
a vibration excitation unit (2) comprising a fixed plate (202) which is supported between the upper reaction plate (302) and the lower reaction plate (304) through a plurality of first upper springs (201a) arranged on its upper surface and a plurality of first lower springs (201b) on its lower surface; and
a loading unit (4) comprising an upper loading plate (402) and a lower loading plate (407) fixedly connected with the upper loading plate (402); the lower loading plate being arranged between the upper reaction plate (302) and lower reaction plate (304) of the reaction unit (3),
wherein the lower loading plate (407) is supported between the upper reaction plate (302) and the lower reaction plate (304) of the reaction unit (3) through a plurality of fourth upper springs (406a) and a plurality of fourth lower springs (406b).

2. The sonic mixing device according to claim 1, wherein the loading unit (4) further comprises a plurality of spring

guide posts (404) fixed on a lower surface of the upper loading plate (402);

each spring guide post (404) passes though the upper machine frame plate (103) to form an upper half part and a lower half part;
the upper half parts of the spring guide posts (404) are sleeved with third upper springs (403a) supported between an upper surface of the upper machine frame plate (103) and the lower surface of the upper loading plate (402); and
the lower half parts of the spring guide posts (404) are sleeved with third lower springs (403b) supported between the upper machine frame plate (103) and ends of the lower half parts of the spring guide posts (404).

3. The sonic mixing device according to claim 1, wherein the upper reaction plate (302) is fixedly connected with the lower reaction plate (304) through a plurality of reaction columns (303).

4. The sonic mixing device according to claim 3, wherein the plurality of reaction columns (303) pass through a plurality of through holes formed in the lower loading plate (407), respectively.

5. The sonic mixing device according to claim 1, wherein the upper loading plate (402) is fixedly connected with the lower loading plate (407) through a plurality of loading connecting rods (405).

6. The sonic mixing device according to claim 5, wherein each loading connecting rod (304) sequentially passes through the upper machine frame plate (103), the second upper spring (301a), the upper reaction plate (302) and the fourth upper spring (406a).

7. The sonic mixing device according to claim 1, wherein the plurality of first upper springs (201a) and the plurality of first lower springs (201b) are arranged on an upper surface and a lower surface of the fixed plate (202) in an annular array manner, respectively; or
the plurality of second upper springs (301a) and the plurality of second lower springs (301b) are arranged on the upper reaction plate (302) and the lower reaction plate (304) in an annular array manner respectively.

8. The sonic mixing device according to claim 1, wherein central axes of each first upper spring (201a) and each first lower spring (201b) are coincident;

central axes of each second upper spring (301a) and each second lower spring (301b) are coincident; or
central axes of each fourth upper spring (406a) and each fourth lower spring (406b) are coincident.

9. The sonic mixing device according to claim 1, wherein recesses for keeping the first upper springs (201a) are provided in the upper surface of the fixed plate (202), and recesses for keeping the first lower springs (201b) are provided in the lower surface of the fixed plate (202);

recesses for keeping the second upper springs (301a) are provided in the upper surface of the upper reaction plate (302), and recesses for keeping the second lower springs (301b) are provided in the lower surface of the lower reaction plate (304); or
recesses for keeping the second upper springs (301a) are provided in the upper machine frame plate (103), and recesses for keeping the second lower springs (301b) are provided in the lower machine frame plate (101);
recesses for keeping the first upper springs (201a) are provided in the lower surface of the upper reaction plate (302), and recesses for keeping the first lower springs (201b) are provided in the upper surface of the lower reaction plate (304); or
recesses for keeping the fourth upper springs (406a) are provided in the lower surface of the upper reaction plate (302), and recesses for keeping the fourth lower springs (406b) are provided in the upper surface of the lower reaction plate (304).

10. The sonic mixing device according to claim 1, further comprising a vibration excitation device fixed on the vibration excitation unit (2).

11. The sonic mixing device according to claim 10, wherein the vibration excitation device is an eccentric mechanical vibration exciter, an electromagnetic vibration exciter or a hydraulic vibration exciter.

12. The sonic mixing device according to claim 1, wherein a plurality of holes for reducing weight are formed in the lower

reaction plate (304).

13. The sonic mixing device according to claim 1, further comprising a mixing container (401) fixed on at least the reaction unit (3) or the loading unit (4).

14. The sonic mixing device according to claim 1, wherein the lower machine frame plate (101) is fixedly connected with the upper machine frame plate (103) through a plurality of machine frame upright posts (102).

15. The sonic mixing device according to claim 1, wherein

the first upper springs (201a) and the first lower springs (201b) are arranged on the vibration excitation unit (2) in a press-fitting manner;
the second upper springs (301a) and the second lower springs (301b) are arranged on the reaction unit (3) in the press-fitting manner; or
the fourth upper springs (406a) and the fourth lower springs (406b) are arranged on the loading unit (4) in the press-fitting manner.

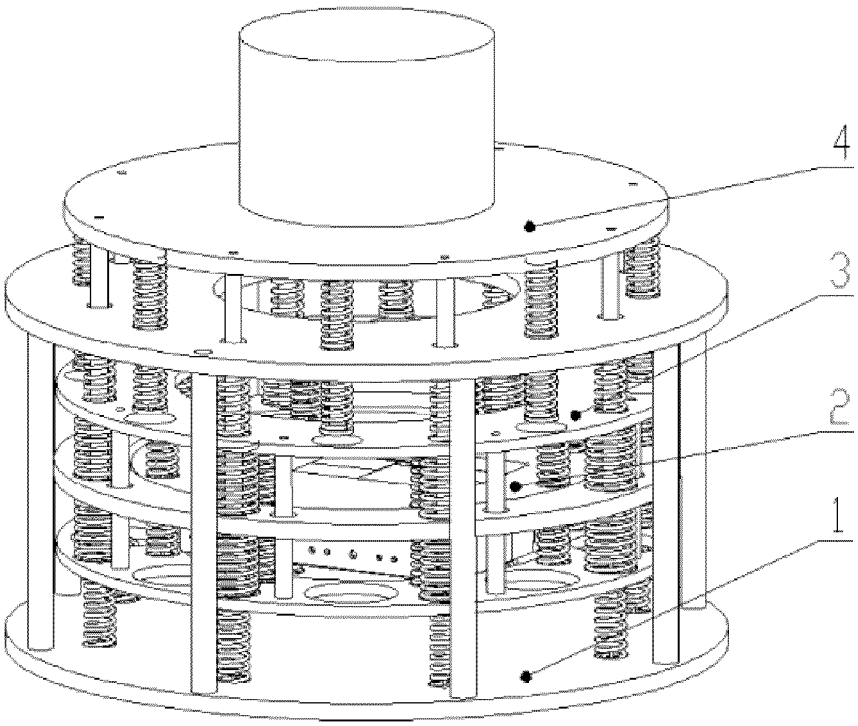

FIG. 1

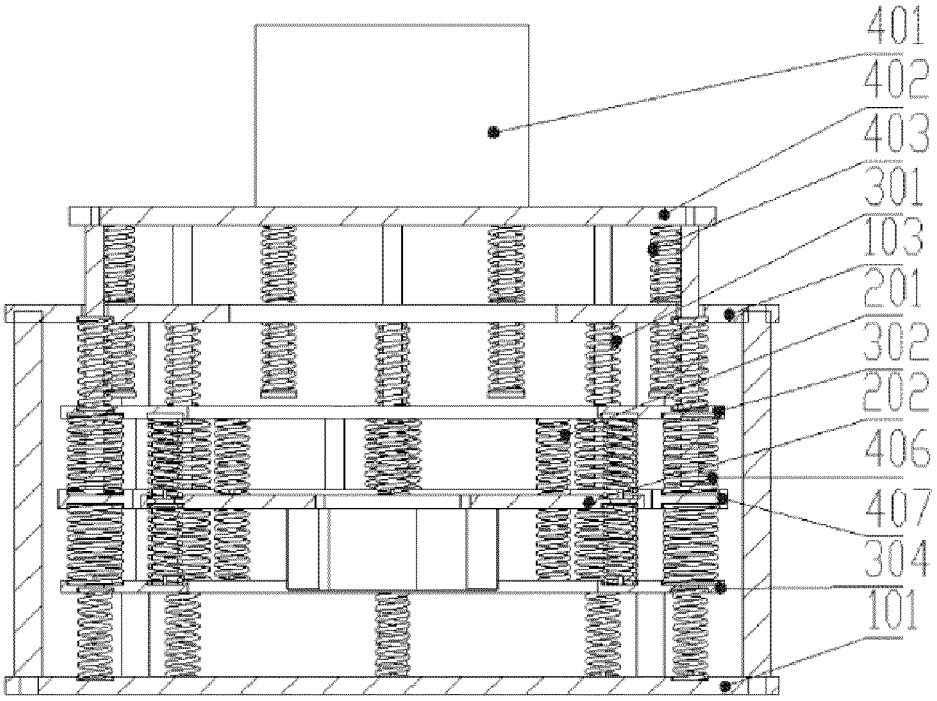

FIG. 2

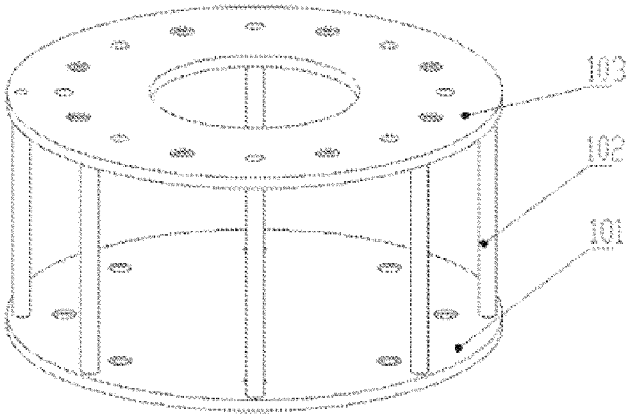

FIG. 3

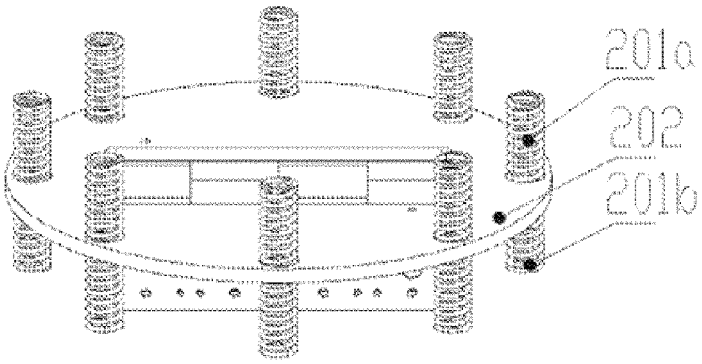

FIG. 4

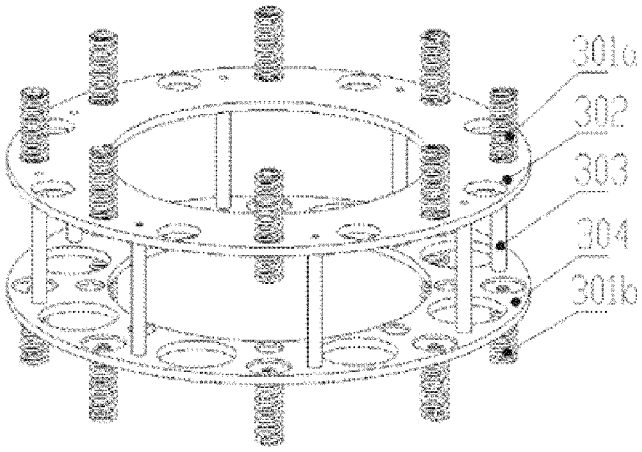

FIG. 5

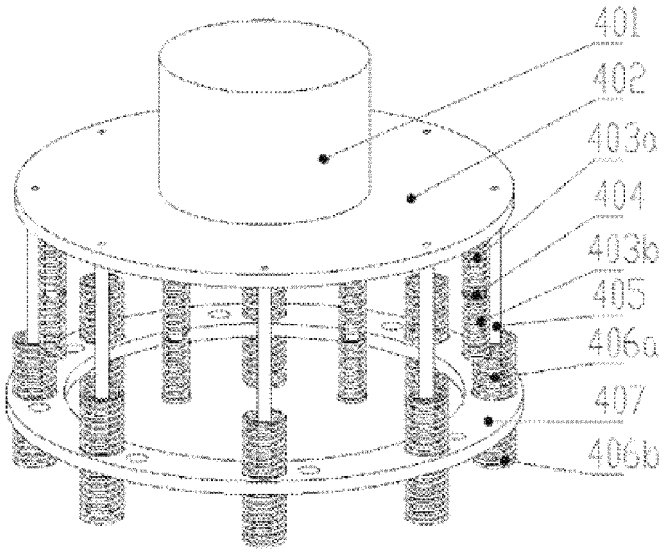

FIG. 6

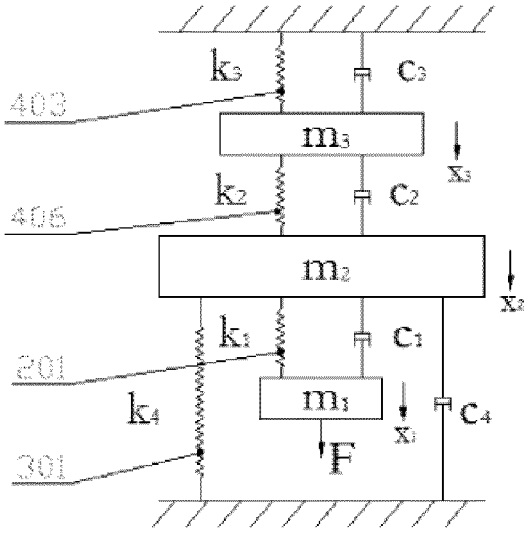

FIG. 7

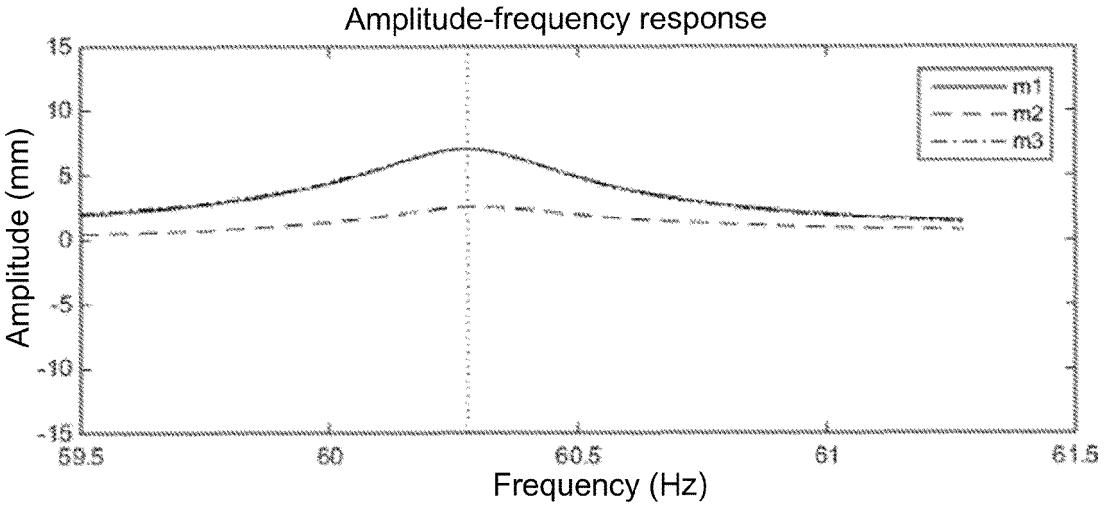
Amplitude-frequency response
Amplitude (mm)
Frequency (Hz)
15
10
5
0
-5
-10
-15
59.5
60
60.5
61
61.5
m1
m2
m3

FIG. 8

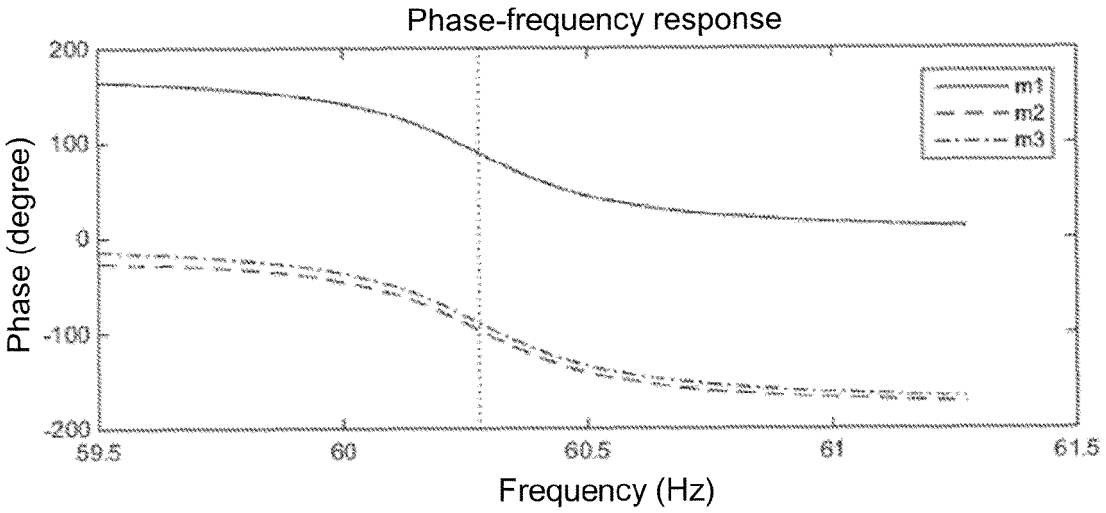
Phase-frequency response
Phase (degree)
200
100
0
-100
-200
59.5
60
60.5
61
61.5
Frequency (Hz)
m1
m2
m3

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2017/082590

A. CLASSIFICATION OF SUBJECT MATTER

B01F 11/00 (2006.01) i

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

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 practicable, search terms used)

CNABS; VEN, CNKI: HANGPENG; three dimensional, sound wave, resonate, tri, three, dimension, vibration, resonator, shaker, mix, agitate, spring, wave

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 106000198 A (HUBEI HANGPENG CHEMICAL POWER TECHNOLOGY CO., LTD.), 12 October 2016 (12.10.2016), description, paragraphs [0027]-[0037], and figures 1-6	1-15
A	CN 202387416 U (LU, Tao), 22 August 2012 (22.08.2012), description, paragraphs [0001] and [0015], and figure 1	1-15
A	CN 206027588 U (HU, Jianjun), 22 March 2017 (22.03.2017), the whole document	1-15
A	CN 204799210 U (FUJIAN XINHAIWAN BUILDING MATERIALS TECHNOLOGY CO., LTD.), 25 November 2015 (25.11.2015), the whole document	1-15
A	CN 2444676 Y (GU, Shancan), 29 August 2001 (29.08.2001), the whole document	1-15
A	JP 1034084 A (IIJIMA KOGYO KK et al.), 10 February 1998 (10.02.1998), the whole document	1-15

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 July 2017 (27.07.2017)	**02 August 2017 (02.08.2017)**
Name and mailing address of the ISA/CN: State Intellectual Property Office of the P. R. China No. 6, Xitucheng Road, Jimenqiao Haidian District, Beijing 100088, China Facsimile No.: (86-10) 62019451	Authorized officer **DIAO, Hang** Telephone No.: (86-10) **010-62084776**

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2017/082590

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 106000198 A	12 October 2016	None	
CN 202387416 U	22 August 2012	None	
CN 206027588 U	22 March 2017	None	
CN 204799210 U	25 November 2015	None	
CN 2444676 Y	29 August 2001	None	
JP 1034084 A	10 February 1998	None	

Form PCT/ISA/210 (patent family annex) (July 2009)