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(54) DEVICE AND METHOD FOR MICRONIZATION OF SOLID MATERIALS

VORRICHTUNG UND VERFAHREN ZUR MIKRONISIERUNG VON FESTSTOFFEN

DISPOSITIF ET PROCÉDÉ DE MICRONISATION DE MATÉRIAUX SOLIDES

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Description

Field of Art

[0001] The present invention relates to a device for micronization of solid materials. The present invention further relates to a method of micronization using said device.

State of the Art

[0002] Micronization is a physical method, in which particles of solid materials of size of millimeters are reduced to the size of micrometers by grinding. The surface of the material is thus multiplied many times, which greatly improves the application possibilities, quality and utility value of the material.

[0003] Micronized materials are commonly used in pharmaceutical industry, in preparation of pigments, agricultural fertilizers, in production and processing of plastics, in production of artificial stone and its products, in chemical industry, food industry, construction and many other industries.

[0004] It is common practice that the input particle size of the micronization material should not be greater than about 2 mm. Therefore, most of the materials must be pre-milled sufficiently, which increases the price of the final product.

[0005] For micronization of materials on an industrial scale, various technologies are currently used, however, they are rather technologically, energetically and financially demanding. In practice, the most often used micronization devices are based on technologies of a pin mill, tribomechanical activation and jet milling.

[0006] The pin mill comprises two metal discs disposed on a vertical or horizontal axis within the cylindrical grinding chamber. Each of the discs has wreaths of metal pins so that the wreaths of the first disc are fitted between the wreaths of the opposite disc.

[0007] If both discs are rotating in the pin mill, the device is called disintegrator. Each of the discs has its own shaft and a separate drive.

[0008] The ground material is supplied through a hopper into the center of the mill between the two discs rotating at 3000 to 5000 revolutions per minute in the opposite directions. By centrifugal force, the ground material is thrown towards the edge between the rows of pins, collides with them and is grinded into fine particles that are centrifugally removed from the grinding chamber.

[0009] The resulting product has a particle size in the range of a few micrometers to hundreds of micrometers according to grinding conditions.

[0010] The pin mill has a wide range of applications, its advantage is in his performance and in a very fine grinding. It is suitable for grinding both dry and damp substances, sticky and hygroscopic drugs, waxy substances, plant materials and materials with higher oil content.

[0011] The disadvantage is that the particles often stick to the walls, that the pins deteriorate and that the device is heated. This is partly compensated by the fact that the rapid movement of the discs generates a vacuum, which is used to cool both the device and the material as well as to shift the grinded particles.

[0012] In a pin mill, materials with a hardness of up to grade 4 according to the Mohs hardness scale can be grinded.

[0013] Pin mill technology is described, for example, in US3219286 A and US5845856 A.

[0014] Tribomechanical activation is based on a principle of a pin disintegrator. The material particles are grinded between two counter-rotating rotors with specially shaped surfaces located inside the grinding chamber on a horizontal axis. Due to very high rotor speeds of up to 40000 revolutions per minute on each of them, oppositely rotating artificial cyclones with speeds up to several times exceeding the speed of sound are created in the interior of the grinding chamber.

[0015] The particles of the ground material are broken and crushed by frontal collisions among themselves, mostly without direct contact with the body of the mill. The result is very fine dust, consisting of electrically charged particles of particle size ranging from a few micrometers up to tens of micrometers.

[0016] The limiting factor of industrial use of this technology is the size of the mill, in particular the size and weight of its inner discs. Other disadvantages include high energy consumption and very high noise levels of 120 dB.

[0017] Tribomechanical activation can be used for micronization of materials with a hardness of up to grade 4 according to Mohs hardness scale.

[0018] The technology of tribomechanical activation is described, for example, in WO2000064586 A1, EP1329434 B1 and EP2689855 A1.

[0019] In jet mills, very high kinetic energy is imparted to the particles of ground material by an inflow of compressed air, steam or other medium, which is injected into the grinding chamber at supersonic speeds by a plurality of convergent or convergent-divergent nozzles positioned around the circumference of the grinding chamber. The ground material is micronized by repeated collisions among the particles, partly by collisions with the walls of the grinding chamber and partly by friction between the particles and the walls of the grinding chamber.

[0020] The micronized material is carried away by the flow of the used medium through the opening in the center of the grinding chamber.

[0021] The advantage of jet milling is in the high efficiency, in the purity of the micronized material and its homogeneity. As no heat is produced during jet milling, it is possible to micronize thermolabile materials and materials exhibiting a great tendency to form agglomerates.

[0022] Jet mills are rather energy-saving; energy consumption is about one-quarter of the consumption of other types of mills. The working pressure is in the range of

2-12 bar, the resulting particle size of the micronized material is in the range of a few micrometers to tens of micrometers, depending on the operating conditions and the type of material.

[0023] The devices themselves are small, but it is necessary to provide them with a powerful compressor. The disadvantage of the jet milling is that the acquisition costs are high and that a high degree of pre-milling of materials prior to micronization is necessary.

[0024] In practice, several types of jet mills are used in various modifications, namely a spiral jet mill, a jet mill with an oval chamber, and a fluidized bed jet mill.

[0025] Spiral jet mill comprises a flat cylindrical grinding chamber equipped with a system of 6-20 Laval nozzles on its circumference, the nozzles being all oriented in the same tangential direction inside the grinding chamber, the direction given by angles between 30° and 75°. Compressed air or other medium at a supersonic speed enters the grinding chamber through the nozzles, creating an artificial cyclone rotating in the grinding chamber at a supersonic speed in one direction.

[0026] The ground material is simultaneously introduced into the grinding chamber by a hopper leading into an ejector disposed on the lid of the grinding chamber. Compressed air or another medium is supplied into the ejector. This medium acquires the supersonic speed by passing through an injector, which is built in the ejector, and so the ground material is introduced from the ejector into the grinding chamber at the supersonic speed.

[0027] An artificial cyclone with particles of ground material is created in the grinding chamber, the artificial cyclone rotating at the supersonic speed in one direction, wherein the particles of the ground material are deflected from their rotational movement by tangential flows of the medium entering through the nozzles, the particles breaking and crushing by collisions from many sides among each other, thereby micronizing the ground material.

[0028] The largest particles are pushed towards the periphery of the grinding chamber by centrifugal force, where they circulate until they are so fine that they are carried away through the opening in the center of the grinding chamber into the separator. The ground material remains in the working chamber for about 10 to 20 seconds, the carrier medium remains there for only a hundredth of this value.

[0029] Spiral jet mills are mainly used for micronization of materials with a hardness of up to grade 4 according to the Mohs hardness scale, but after application of special abrasion-resistant layers to the inner walls of the grinding chamber, they can also be used for materials with higher hardness grades.

[0030] Spiral jet mill technology is described, for example, in US2032827 A, US7789331 B2 and US4018388 A.

[0031] Jet mill with an oval chamber has a grinding chamber formed of a wide oval closed tube where the nozzles are located only at the bottom and the medium flowing from the nozzles is oriented only in one direction. Particles of the ground material are broken and crushed by many collisions among each other, the fine particles being carried away by the outflowing medium at the top of the mill, and the large particles being forced by the centrifugal force back into the grinding zone at the bottom, where the ground material is supplied.

[0032] Jet mills with oval chamber are used to micronize solid materials including plastics with a hardness of up to grade 4 according to the Mohs hardness scale.

[0033] The oval chamber jet mill technology is described, for example, in US3508714 A and US4198004 A.

[0034] A fluidized bed jet mill consists of a grinding chamber without movable parts in the form of a closed elongated cylinder, wherein there are 3 to 6 Laval nozzles disposed in the lower part of the chamber, the nozzles being disposed in a horizontal plane exactly opposite to each other, the nozzles providing a medium with a supersonic speed, which brings the ground material to a fluid state.

[0035] The ground material is supplied into the mill from the upper part of the grinding chamber, from where it falls to its lower part, where it is broken and crushed by frontal collisions of the particles of the material in the flow of the medium entering through the nozzles, wherein the particles basically do not come into contact with the nozzles or with the walls of the grinding chamber.

[0036] The micronized particles are carried by the air flow back to the upper part of the grinding chamber, where an air sorter is placed - the finely grinded fraction is passed further to the separator, while the larger particles are returned to the bottom of the grinding chamber for further grinding.

[0037] Fluidized bed jet mills are used to micronize materials of any hardness.

[0038] Fluidized bed jet mill technology is described, for example, in US5133504 A and US5732893 A.

Disclosure of the Invention

[0039] It is an object of the invention to provide a micronization device based on a combination of pin-mill technology, tribomechanical activation, and jet milling, which is further based on a particle size reduction achieved by mutual collisions of particles of material and eliminates the drawbacks of the above-mentioned devices.

[0040] To achieve this goal, a micronization device is provided, which comprises a cylindrical grinding chamber without moving parts, means for supplying the ground material into the grinding chamber at a supersonic speed, means for supplying the carrier medium into the grinding chamber at a supersonic speed, wherein said means for supplying the carrier medium are arranged so that the carrier medium supplied through said means produces at least two artificial cyclones in the grinding chamber, the cyclones rotating simultaneously, at supersonic speeds and in opposite directions, with a common axis of rotation of the at least two cyclones, so that the common axis of rotation is identical to the central axis of the grinding chamber.

[0041] The grinding chamber is free of moving parts, i.e., the device does not work on the principle of rotating parts at high speeds, thus eliminating overheating and high noise.

[0042] The carrier medium may be compressed air or any other suitable medium. Means for supplying the carrier medium to the grinding chamber at supersonic speed may include nozzles or injectors.

[0043] The means for supplying the carrier medium also include a source of carrier medium and all accessories necessary to supply the carrier medium to the grinding chamber.

[0044] Rows of means for supplying the carrier medium are positioned side by side along the circular part of the circumference of the grinding chamber and are directed into the interior space of the grinding chamber.

[0045] Each row of means for supplying the carrier medium is arranged in a plane, the planes of the individual rows being parallel to the plane of the side wall, respectively to the planes of the side walls.

[0046] The means for supplying the carrier medium are arranged in at least two rows along the circular part of the circumference of the grinding chamber.

[0047] Preferably, the means for supplying the carrier medium are distributed in rows at distances and angles, at which the optimum frequency and quality of the frontal collisions of particles of the material in the grinding chamber is provided.

[0048] The distance between the rows is preferably given by the diffusion angle of the means used to supply the carrier medium into the grinding chamber at a supersonic speed. Preferably, the distances may be in the range of 5-20 mm, more preferably in the range of 7-15 mm, even more preferably in the range of 10-13 mm.

[0049] Preferably, the means for supplying the carrier medium are inclined at the same angle and in the same direction in a first row, and at the same angle and in the opposite direction in each adjacent row, i.e. in each of the two adjacent rows, the means may be inclined at the first angle in the first row and at the second angle in the adjacent row; the first and the second angle being of the same size and opposite orientation, the angles being measured in planes parallel to the planes of the side walls of the grinding chamber and relative to the normals of the tangents touching the grinding chamber circumference at the points where the means enter the grinding chamber.

[0050] Angles may range from 30 to 75 degrees.

[0051] At least two, preferably at least three, injectors or nozzles are arranged in each of at least two rows of means for supplying the carrier medium.

[0052] The means for supplying the carrier medium arranged in the first row and the means for supplying the carrier medium arranged in the adjacent row can be placed side by side or can be shifted with respect to each other. However, they remain arranged in rows, the rows formed in planes parallel to the planes of the side walls of the grinding chamber.

[0053] By supplying the carrier medium into the grinding chamber through the means for supplying the carrier medium of the first row, a first cyclone is formed in the grinding chamber, the first cyclone rotating along the circular part of the circumference of the grinding chamber with a rotation axis corresponding to the center axis of the cylindrical grinding chamber, with the intensity of the flow decreasing radially towards the axis of rotation. By introducing the carrier medium into the grinding chamber through the means for supplying the carrier medium of the adjacent row, a second cyclone is formed in the grinding chamber, the second cyclone rotating again along the circular part of the circumference of the grinding chamber with a rotation axis being identical with the axis of rotation of the first cyclone and with the center axis of the cylindrical grinding chamber, with the intensity of the flow decreasing radially towards the axis of rotation. Since the means for supplying the carrier medium in the second row are inclined at an angle with the orientation opposite to the orientation of the angle in the first row, the flow directions of the first and the second cyclones are the opposite, thereby causing at least partial interference of the cyclones and the formation of a turbulent flow.

[0054] At the same time, synchronously, the ground material is supplied into the grinding chamber at a supersonic speed.

[0055] Preferably, the ground material to be grinded is supplied into the grinding chamber from opposite positions through the openings in the grinding chamber, the openings being arranged in the circumference of the grinding chamber or on its side walls.

[0056] The means for supplying the ground material into the grinding chamber are preferably arranged such that the ground material is supplied into the grinding chamber in the direction substantially corresponding, or parallel, respectively, to the flow direction of the carrier medium or in a direction substantially perpendicular to the flow direction of the carrier medium.

[0057] The means for supplying the ground material into the grinding chamber at a supersonic speed may comprise at least two hoppers adapted to supply the ground material into at least two ejectors, the ejectors being adapted to accelerate the supplied ground material to the supersonic speed.

[0058] Thus, the ground material is preferably supplied into the grinding chamber from opposite positions, by the hoppers leading into the ejectors, the ejectors entering the grinding chamber through the openings in the grinding chamber, the openings being disposed either in the circumference of the grinding chamber or on its side walls.

[0059] High-speed medium, such as compressed air or other medium, is supplied into the ejectors. In a preferred embodiment, the high-speed medium is the same medium as the carrier medium. Before entering the grinding chamber, the high-speed medium passes through injectors or nozzles, the injectors or nozzles being built inside the ejectors, thereby obtaining the supersonic speed. In a preferred embodiment, the injectors or nozzles are identical to those used in the grinding chamber for supplying the carrier medium. The injectors or nozzles are positioned in front of the place where the ground material coming from the hopper enters the interior of the ejector. Thus, the ground material is accelerated to the supersonic speed, and the accelerated material enters the grinding chamber through the openings in the grinding chamber, through which the ejectors enter the grinding chamber.

[0060] As mentioned above, it is common practice that the size of input particles of material for micronization should not be greater than about 2 mm.

[0061] The micronization device of the present invention allows micronization of larger particles, e.g. 2-4 mm, 4-8 mm, etc.

[0062] The design of the ejectors allows the material with a particle size greater than 2 mm, e.g. 2-4 mm, 4-8 mm, etc., to be supplied into the grinding chamber at the supersonic velocity.

[0063] The ejectors should therefore have an inside diameter which is four times larger than the largest particle size of the ground material entering the grinding chamber. This ensures that the supplied ground material passes through the ejectors without being trapped. The person skilled in the art will be able to determine this dimension from the presumed particle size, because he will be aware of the particle size, to which the device should be dimensioned.

[0064] For example, if micronization of particles of 2-4 mm is expected, it is preferred that the ejectors have diameters in the range of 15-20 mm. If micronization of particles of 4-8 mm is expected, it is preferred that the ejectors have diameters in the range of 30-35 mm.

[0065] The ejectors can be equipped with flanges in their upper parts, allowing the adjustment, maintenance and replacement of the nozzles installed inside the ejectors.

[0066] In the grinding chamber, the ground material is preferably entrained by a co-rotating artificial cyclone of the carrier medium. Thus, artificial cyclones with particles of ground material are formed in the grinding chamber, which rotate substantially next to each other, at supersonic speeds and in opposite directions. At least partial interference of the cyclones occurs, causing a turbulent flow and resulting in multiple frontal collisions of the particles and thus in micronization of the ground material.

[0067] In a preferred embodiment, the device further comprises a central part formed by a flat cylinder, the central part further comprising side walls formed by lids, an outer ring and an inner ring, an interspace created between the outer ring and the inner ring, and an opening for supplying the carrier medium, the opening being disposed in a circular part of the circumference of the central part. The grinding chamber is arranged inside the central part and it is formed by the inner ring and by the lids on the side walls.

[0068] Preferably, the carrier medium is first supplied through the opening in the circular part of the circumference of the central part and in the outer ring into the interspace, and then enters the grinding chamber at supersonic speed from the interspace through the means for supplying the carrier medium arranged in the inner ring.

[0069] However, the carrier medium can be supplied directly to each of the means for supplying the carrier medium into the grinding chamber, without entering the interspace between the outer ring and the inner ring.

[0070] The device further comprises at least one opening in the center of at least one of the side walls of the grinding chamber for outflow of the micronized material from the grinding chamber by the flow of the carrier medium. Preferably, the device comprises two openings in the centers of the two side walls.

[0071] In the grinding chamber, the particles of ground material are crushed by intense and repeated frontal collisions against each other, until they are so fine that they are carried away either through a single opening in the center of one of the side walls or simultaneously through both openings in the centers of the two side walls of the grinding chamber to the separator.

[0072] In the separator, the micronized product is sorted for further processing; the larger particles are returned to the grinding chamber for further grinding.

[0073] Thus, in a preferred embodiment, compressed air or other medium at a supersonic speed is supplied into the grinding chamber through the nozzles positioned in the rows adjacent to each other, the nozzles having opposite orientation in each of the adjacent rows, and, simultaneously, ground material is supplied into the grinding chamber at supersonic speed and from mutually opposite positions, such that in the grinding chamber, artificial cyclones with particles of ground material are created, the artificial cyclones rotating substantially next to each other, at supersonic speeds and opposite directions, which results in multiple frontal collisions of particles and thereby in micronization of the ground material.

[0074] The present invention further relates to a method of micronization using the device as described above. For micronization, the carrier medium is supplied into the grinding chamber at a supersonic speed by means for supplying the carrier medium into the grinding chamber in order to create at least two artificial cyclones rotating simultaneously, at supersonic speeds and in opposite directions, with a common axis of rotation, the common axis of rotation corresponding to the center axis of the grinding chamber, and, at the same time, ground material is supplied into the grinding chamber at a supersonic speed by means for supplying the ground material into the grinding chamber. Subsequently, the ground material supplied into the grinding chamber is micronized by multiple frontal collisions of the particles of the material in the flow of the at least two artificial cyclones rotating at supersonic speeds and in opposite directions.

[0075] After micronization, the micronized material may be carried away from the grinding chamber by the flow of the carrier medium through an opening in the center of at least one of the side walls of the grinding chamber; preferably it may be carried away through both openings in the centers of the two side walls.

[0076] The ground material may be supplied into the grinding chamber through at least two hoppers into at least two ejectors, whereby high-speed medium is supplied through the at least two ejectors for acceleration of the ground material to supersonic speed. Preferably, the high-speed medium for the acceleration of the ground material is the same medium as the carrier medium.

[0077] The ground material may be supplied into the grinding chamber in a direction substantially corresponding to the direction of the flow of the carrier medium, or in a direction substantially perpendicular to the flow direction of the carrier medium.

[0078] Preferably, the carrier medium is first introduced through the opening in the central part and in the outer ring into the interspace, and then enters the grinding chamber at supersonic speed from the interspace through the means arranged in the inner ring.

[0079] The carrier medium may be supplied directly to each of the means for supplying the carrier medium into the grinding chamber without entering the interspace between the outer ring and the inner ring.

[0080] In a device, the micronization takes place without increasing temperature of the device or of the ground material, and without significant increase of the ambient noise level.

Brief description of figures

[0081] An embodiment of the invention is described in detail with references to the following figures, in which:

figure 1 is a front view of the micronization device

figure 2 is a side view of the micronization device

figure 3 is a cross-sectional view of the micronization device

figure 4 illustrates the positioning of the nozzles in the circumferential ring of the grinding chamber.

Examples

[0082] Figures 1 and 2 illustrate a front and a side view of the micronization device, according to which the device comprises a flat cylindrical container comprising a central part 19 with a grinding chamber 30 inside, and lids 9 attached at both sides. Ejectors 6, 7 and hoppers 4, 5 are mounted on said lids. Each of the lids has an outlet opening 8 with a short pipe in its center. Everything is fixed to the base 10.

[0083] Compressed air required for operation in the grinding chamber is supplied through the inlet opening 1 in the outer shell. Compressed air is also supplied through inlets 2, 3 into the pair of ejectors 6, 7 for supplying the ground material into the grinding chamber 30.

[0084] The ejectors 6, 7 have an inner diameter four times larger than the size of the largest particle of the ground material, i.e. 16 mm, because the particles of the ground material entering the micronization device are 2-4 mm in size. The ejectors are provided with flanges in their upper part for adjusting, maintenance and replacement of nozzles installed within the ejectors for acceleration of the medium passing through them to the supersonic speed. In each of the ejectors 6, 7, a nozzle is installed in front of the place where the ground material coming from the hopper 4, 5 enters the interior of the ejector 6, 7; the nozzle being of the same type as are the nozzles disposed in the grinding chamber 30.

[0085] The ground material is supplied into the grinding chamber 30 by the compressed air, at supersonic speed, through the hoppers 4, 5 leading to the ejectors 6, 7, simultaneously and synchronously from both opposite sides of the grinding chamber 30.

[0086] The micronized material is carried away from the grinding chamber 30 by the air flow through the outlet openings 8 in the centers of side lids 9 for further processing into the separator.

[0087] Figure 3 shows that the micronization device does not contain any movable parts and comprises two concentric rings, an outer ring 35 and an inner ring 32, and the inlet opening 1 for inlet of the compressed air into the interspace 27, the inlet opening 1 being disposed in the circumferential shell of the outer ring, and two rows 33, 34 of nozzles, the two rows being disposed in the inner ring 32, wherein each row comprises three nozzles 331, 332, 333 and 341, 342, 343, the nozzles in the first row 33 and the nozzles in the second row 34 being oriented in the opposite directions.

[0088] The grinding chamber 30 is defined by the inner space of the inner ring 32. The compressed air flows from the interspace 27 into the grinding chamber 30 at supersonic speed through the nozzles 331, 332, 333, 341, 342, 343 that are disposed in the rows 33, 34 on the circumference of the inner ring 32.

[0089] The ground material enters the interior of the grinding chamber from the ejector 6 at supersonic speed through the inlet opening 29 and the micronized material is carried away from the grinding chamber 30 through the outlet opening 8 in the center of one of the side walls.

[0090] Fig. 4 shows a detail of positioning of the nozzles in rows 33, 34 in the inner ring 32 of the grinding chamber 30 as well as the directions of the flow of the compressed air from the nozzles towards the interior of the grinding chamber 30.

[0091] The nozzles are located in two adjacent rows 33, 34 in the inner ring 32 of the grinding chamber 30. In each of the rows, three Laval nozzles 331, 332, 333, 341, 342, 343 are installed with the same inclination angle of 60° relative to the tangent.

[0092] Thus, six Laval nozzles 331, 332, 333, 341, 342, 343 lead into the grinding chamber 30 in total; the three nozzles 331, 332, 333 in the first row 33 are inclined to the right and the other three nozzles 341, 342, 343 in the adjacent row 34 are inclined to the left.

[0093] Thus, each row of nozzles produces a rotating air cyclone in the grinding chamber 30; the two air cyclones so created rotate in the grinding chamber 30 at the same time, at supersonic speeds and in the opposite directions.

[0094] The ground material is supplied to each of the rotating air cyclones, simultaneously and synchronously, and at supersonic speeds, from the hoppers 4, 5 and further through the ejectors 6, 7 with the nozzles, the nozzles being of the same type as the nozzles installed in the grinding chamber 30.

[0095] The ground material to be milled enters the grinding chamber 30 at the supersonic speed through the inlet opening 29, or through at least two inlet openings 29, respectively, and it is entrained by the air cyclone rotating at supersonic speed in the corresponding direction, or by the air cyclones rotating at supersonic speeds in the corresponding directions, respectively.

[0096] Thus, air cyclones with particles of ground material are created in the grinding chamber 30, the cyclones rotating at supersonic speed and opposite to each other, resulting in very intense and multiple frontal collisions of the particles and thus in the micronization of the ground material.

[0097] Two types of materials were processed in the above described micronization device with a grinding chamber 30 having an internal diameter of 204 mm: natural limestone having a hardness of grade 3 of the Mohs scale of hardness, and a natural granodiorite having a hardness grade of 7 of the Mohs scale of hardness. In both cases, fractions of 0-4 mm from quarries in the Czech Republic were used as starting materials. In both cases, micronization took place under the same conditions, i.e., with compressed air at 6 bar and temperature of 20°C.

Example 1

[0098] Particles with size of less than 2 mm were first separated by sieving from the original limestone fraction of 0-4 mm, and only the 2-4 mm fraction thus formed was used as ground material to be grinded. A micronized limestone with an average particle size d_{50} = 38.5 μm was obtained from the 2-4 mm fraction by using the above-described device in the first and the only grinding cycle.

Example 2

[0099] Particles of size of less than 2 mm were first separated by sieving from the original granodiorite fraction of 0-4 mm, and only the 2-4 mm fraction thus formed was then used as ground material. From the granodiorite fraction of 2-4 mm, micronized granodiorite with an average particle size of d_{50} = 113,8 μm was obtained by using the above-described device in the first and the only grinding cycle.

Industrial applicability

[0100] The device and method of micronization according to the present invention can be industrially applicable in all usual fields, such as the pharmaceutical industry, pigments preparation, agricultural fertilizers preparation, processing of plastics, artificial stone and articles thereof, in construction industry, chemical industry and the food industry, and in other emerging fields.

Claims

1. A micronization device comprising:

- a cylindrical grinding chamber (30) without moving parts,
- means (4, 5, 6, 7) for supplying a ground material into the grinding chamber (30) at a supersonic speed, and
- means (331, 332, 333, 341, 342, 343) for supplying the carrier medium into the grinding chamber (30) at a supersonic speed, **characterized in that** said means (331, 332, 333, 341, 342, 343) for supplying the carrier medium into the grinding chamber (30) are arranged so that the carrier medium supplied through said means (331, 332, 333, 341, 342, 343) creates at least two artificial cyclones in the grinding chamber (30), the at least two artificial cyclones rotating at supersonic speeds and in opposite directions with a common axis of rotation, the common axis of rotation being identical with the central axis of the grinding chamber (30).

2. The micronization device according to claim 1, wherein the means (331, 332, 333, 341, 342, 343) for supplying the carrier medium into the grinding chamber (30) are arranged along a circular part of the circumference of the grinding chamber (30) in at least two rows (33, 34), wherein in each of the two adjacent rows (33, 34), the means (331, 332, 333) are inclined at the first angle in first row (33) and the means (341, 342, 343) are inclined at the second angle in the adjacent row (34), wherein the first and the second angle are of the same size and opposite orientation, the angles being measured in planes parallel to the planes of the side walls of the grinding chamber (30) and relative to normals of tangents touching the circumference of the grinding chamber (30) at the locations where the means (331, 332, 333 , 341, 342, 343) enter the grinding chamber (30).

3. The micronization device according to claim 2, wherein at least two, preferably at least three, injectors or nozzles (331, 332, 333, 341, 342, 343) are arranged in each of the at least two rows (33, 34) of the means (331, 332, 333, 341, 342, 343) and / or wherein the means (331, 332, 333) for supplying the carrier medium arranged in the first row (33) and the means (341, 342, 343) for supplying the carrier medium arranged in the adjacent row (34) are arranged side by side or shifted with respect to each other.

4. The micronization device according to any one of the preceding claims, wherein the means for supplying the ground material into the grinding chamber (30) are arranged so that the ground material is supplied into the grinding chamber in a direction substantially corresponding with the flow direction of the carrier medium or in the direction substantially perpendicular to the flow direction of the carrier medium.

5. The micronizaction device according to any one of the preceding claims, wherein the means (331, 332, 333, 341, 342, 343) for supplying the carrier medium into the grinding chamber (30) comprise injectors or nozzles.

6. The micronization device according to any one of the preceding claims, wherein the means for supplying the ground material into the grinding chamber (30) at a supersonic speed comprise at least two hoppers (4, 5) adapted to supply the ground material to each of at least two ejectors (6, 7), the ejectors (6, 7) being adapted to accelerate the ground material to the supersonic speed.

7. The micronization device according to claim 6, wherein the ejectors (6, 7) enter the grinding chamber (30) in opposite positions through the openings (29) and are located in a circular part of the circumference of the grinding chamber (30) or in its side walls, and / or the ejectors (6, 7) are adapted to supply particles of size greater than 2 mm.

8. The micronization device according to claim 6 or 7, wherein the ejectors (6, 7) comprise injectors or nozzles, said injectors or nozzles being preferably of the same type as injectors or nozzles (331, 332, 333, 341, 342, 343) for supplying the carrier medium into the grinding chamber (30).

9. The micronization device according to any one of the preceding claims, wherein the device further comprises at least one opening (8) in the center of at least one of the side walls of the grinding chamber (30) for carrying the micronized material away from the grinding chamber (30) by the flow of the carrier medium, preferably the device comprises two openings (8) in the centers of the two side walls.

10. The micronization device according to any one of the preceding claims, wherein the device further comprises a central part (19) formed by a flat cylinder, the central part further comprising side walls formed by lids (9), an outer ring (35) and an inner ring (32), an interspace (27) formed between the outer ring (35) and the inner ring (32), and an opening (1) for supplying the carrier medium.

11. A micronization method comprising the steps of

- supplying the carrier medium into the grinding chamber (30) at a supersonic speed by means (331, 332, 333, 341, 342, 343) for supplying the carrier medium into the grinding chamber (30) for creating simultaneously at least two artificial cyclones rotating at supersonic speeds and in the opposite directions, with a common axis of rotation, the common axis of rotation being consistent with the center axis of the grinding chamber (30)
- supplying the ground material into the grinding chamber (30) at a supersonic speed by means (4, 5, 6, 7) for supplying the ground material into the grinding chamber (30); and
- micronization of the ground material supplied into the grinding chamber (30) by multiple frontal collisions of the particles in a flow of the at least two artificial cyclones rotating at supersonic speeds and in the opposite directions.

12. The micronization method of claim 11, the method further comprising a step of carrying the micronized material away from the grinding chamber (30) by the flow of the carrier medium through an opening (8) in the center of at least one of the side walls of the grinding chamber (30), preferably through two openings (8) in the centers of the two side walls.

13. The micronization method of claim 11 or 12, wherein the step of supplying the ground material into the grinding chamber (30) comprises the following substeps:

- supplying the ground material through at least two hoppers (4, 5) into at least two ejectors (6, 7),
- supplying a high-speed medium for acceleration of the ground material to the supersonic speed through at least two ejectors (6, 7), preferably the high-speed medium for acceleration of the ground material is the same medium as the carrier medium; and
- acceleration of the ground material to the supersonic speed in the ejectors (6, 7) by the high-speed medium for acceleration of the ground material.

14. The micronization method of any one of the claims

11 to 13, wherein the ground material is supplied into the grinding chamber in a direction substantially corresponding with the flow direction of the carrier medium or in a direction substantially perpendicular to the flow direction of the carrier medium.

15. The micronization method according to any one of the claims 11 to 14, wherein the carrier medium is first supplied through the opening (1) in the central part (19) and in the outer ring (35) into the interspace (27) and then enters the grinding chamber (30) at a supersonic speed from the interspace (27) through the means (331, 332, 333, 341, 342, 343) arranged in the inner ring (32).

Patentansprüche

1. Mikronisierungsvorrichtung, umfassend:

- eine zylindrische Mahlkammer (30) ohne bewegliche Teile,
- Mittel (4, 5, 6, 7) zum Zuführen des Mahlgutes in die Mahlkammer (30) mit Überschallgeschwindigkeit, und
- Mittel (331, 332, 333, 341, 342, 343) zum Zuführen des Trägermediums in die Mahlkammer (30) mit Überschallgeschwindigkeit, **dadurch gekennzeichnet, dass** die Mittel (331, 332, 333, 341, 342, 343) zum Zuführen des Trägermediums in die Mahlkammer (30) so angeordnet sind, dass das durch die Mittel (331, 332, 333, 341, 342, 343) zugeführte Trägermedium mindestens zwei künstliche Zyklone in der Mahlkammer (30) erzeugt, wobei sich die mindestens zwei künstlichen Zyklone mit Überschallgeschwindigkeit und entgegengesetzten Richtungen mit einer gemeinsamen Drehachse drehen, wobei die gemeinsame Drehachse mit der Mittelachse der Mahlkammer (30) identisch ist.

2. Mikronisierungsvorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** die Mittel (331, 332, 333, 341, 342, 343) zum Zuführen des Trägermediums in die Mahlkammer (30) entlang eines kreisförmigen Teils des Mahlkammerumfangs angeordnet sind in mindestens zwei Reihen (33, 34), wobei in jeder der beiden benachbarten Reihen (33, 34) die Mittel (331, 332, 333) in dem ersten Winkel in der ersten Reihe (33) geneigt sind und die Mittel (341, 342, 343) um den zweiten Winkel in der benachbarten Reihe (34) geneigt sind, wobei der erste und der zweite Winkel die gleiche Größe und entgegengesetzte Ausrichtung haben, wobei die Winkel in Ebenen parallel gemessen werden zu den Ebenen der Seitenwände der Mahlkammer (30) und relativ zu Normalen von Tangenten, die den Umfang der Mahlkammer (30) an den Stellen berühren, an denen die Mittel (331, 332, 333, 341, 342, 343) in die Mahlkammer eintreten (30).

3. Mikronisierungsvorrichtung nach Anspruch 2, **dadurch gekennzeichnet, dass** in jeder der mindestens zwei Reihen (33, 34) der Mittel (331, 332, 333, 341, 342, 343) mindestens zwei, vorzugsweise mindestens drei, Injektoren oder Düsen (331, 332, 333, 341, 342, 343) angeordnet sind und / oder wobei die Mittel (331, 332, 333) zum Zuführen des Trägermediums angeordnete in der ersten Reihe (33) und die Mittel (341, 342 , 343) zur Zuführung des Trägermediums angeordnete in der benachbarten Reihe (34) nebeneinander angeordnet oder gegeneinander verschoben sind.

4. Mikronisierungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei die Mittel zum Zuführen des Mahlgutes in die Mahlkammer (30) so angeordnet sind, dass das Mahlgut in einer Richtung in die Mahlkammer zugeführt wird, die im Wesentlichen der Strömungsrichtung des Trägermediums entspricht oder im wesentlichen senkrecht zur Strömungsrichtung des Trägermediums ist.

5. Mikronisiervorrichtung nach einem der vorhergehenden Ansprüche, wobei die Mittel (331, 332, 333, 341, 342, 343) zum Zuführen des Trägermediums in die Mahlkammer (30) Injektoren oder Düsen umfassen.

6. Mikronisierungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei die Mittel zum Zuführen des Mahlgutes in die Mahlkammer (30) mit Überschallgeschwindigkeit mindestens zwei Trichter (4, 5) umfassen, die dazu ausgelegt sind, das Mahlgut zuführen zu jeder von mindestens zwei Ejektoren (6, 7), wobei die Ejektoren (6, 7) angepasst sind, um das Mahlgut auf die Überschallgeschwindigkeit zu beschleunigen.

7. Mikronisierungsvorrichtung nach Anspruch 6, **dadurch gekennzeichnet, dass** die Ejektoren (6, 7) in entgegengesetzten Positionen durch die Öffnungen (29) in die Mahlkammer (30) eintreten und sich in einem kreisförmigen Teil des Umfangs der Mahlkammer (30) befinden oder in seinen Seitenwänden und / oder die Ejektoren (6, 7) zur Zufuhr von Partikeln mit einer Größe von mehr als 2 mm ausgelegt sind.

8. Mikronisierungsvorrichtung nach Anspruch 6 oder 7, wobei die Ejektoren (6, 7) Injektoren oder Düsen umfassen, wobei die Injektoren oder Düsen vorzugsweise vom gleichen Typ sind wie Injektoren oder Düsen (331, 332, 333, 341, 342, 343) zum Zuführen des Trägermediums in die Mahlkammer (30).

9. Mikronisierungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei die Vorrichtung ferner mindestens eine Öffnung (8) in der Mitte von mindestens einer der Seitenwände der Mahlkammer (30) zum Abtransport des mikronisierten Materials durch den Strom des Trägermediums von der Mahlkammer (30) aufweist, vorzugsweise weist die Vorrichtung zwei Öffnungen (8) in den Mitten der beiden Seitenwände auf.

10. Mikronisierungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei die Vorrichtung ferner einen zentralen Teil (19) umfasst, der als flacher Zylinder ausgebildet wird, wobei der zentrale Teil ferner Seitenwände umfasst, die als Deckeln (9), Außenring (35) und Innenring (32) ausgebildet werden, einen zwischen dem Außenring (35) und dem Innenring (32) gebildeten Zwischenraum (27) und eine Öffnung (1) zur Zuführung des Trägermediums umfasst.

11. Mikronisierungsverfahren, umfassend die Schritte:

- Zuführen des Trägermediums in die Mahlkammer (30) mit einer Überschallgeschwindigkeit durch Mittel (331, 332, 333, 341, 342, 343) zum Zuführen des Trägermediums in die Mahlkammer (30) zum gleichzeitigen Erzeugen von mindestens zwei künstlichen Zyklone, die sich mit Überschallgeschwindigkeit und in entgegengesetzten Richtungen mit einer gemeinsamen Drehachse drehen, wobei die gemeinsame Drehachse mit der Mittelachse der Mahlkammer (30) übereinstimmt;
- Zuführen des Mahlgutes in die Mahlkammer (30) mit einer Überschallgeschwindigkeit durch Mittel (4, 5, 6, 7) zum Zuführen des Mahlgutes in die Mahlkammer (30); und
- Mikronisierung des in die Mahlkammer (30) gelieferten Mahlgutes durch mehrfache Frontalkollisionen der Partikel in einer Strömung der mindestens zwei künstlichen Zyklone, die sich mit Überschallgeschwindigkeit und in entgegengesetzten Richtungen drehen.

12. Mikronisierungsverfahren nach Anspruch 11, wobei das Verfahren ferner einen Schritt des Transportierens des mikronisierten Materials von der Mahlkammer (30) weg durch den Fluss des Trägermediums durch eine Öffnung (8) in der Mitte von mindestens einer der Seitenwände der Mahlkammer (30), vorzugsweise durch zwei Öffnungen (8) in der Mitte der beiden Seitenwände.

13. Mikronisierungsverfahren nach Anspruch 11 oder 12, wobei der Schritt des Zuführens des Mahlgutes in die Mahlkammer (30) die folgenden Unterschritte umfasst:

- Zuführen des Mahlgutes durch mindestens zwei Trichter (4, 5) in mindestens zwei Ejektoren (6, 7),
- Zuführen eines Hochgeschwindigkeitsmediums zur Beschleunigung des Mahlgutes auf die Überschallgeschwindigkeit durch mindestens zwei Ejektoren (6, 7), vorzugsweise ist das Hochgeschwindigkeitsmedium zur Beschleunigung des Mahlgutes das gleiche Medium wie das Trägermedium; und
- Beschleunigung des Mahlgutes auf die Überschallgeschwindigkeit in den Ejektoren (6, 7) durch das Hochgeschwindigkeitsmedium zur Beschleunigung des Mahlgutes.

14. Mikronisierungsverfahren nach einem der Ansprüche 11 bis 13, wobei das Mahlgut in die Mahlkammer zugeführt wird in einer Richtung, die im Wesentlichen der Strömungsrichtung des Trägermediums entspricht, oder in einer Richtung, die im Wesentlichen senkrecht zu der Strömungsrichtung des Trägermediums ist.

15. Mikronisierungsverfahren nach einem der Ansprüche 11 bis 14, wobei das Trägermedium zunächst durch die Öffnung (1) im Mittelteil (19) und im Außenring (35) in den Zwischenraum (27) zugeführt wird, und tritt dann mit Überschallgeschwindigkeit vom Zwischenraum (27) durch die im Innenring (32) angeordneten Mittel (331, 332, 333, 341, 342, 343) in die Mahlkammer (30) ein.

Revendications

1. Un appareil de micronisation comprenant:

- une chambre (30) de broyage cylindrique sans pièces mobiles,
- des moyens (4, 5, 6, 7) pour amener un matériau à broyer dans la chambre (30) de broyage à une vitesse supersonique, et
- des moyens (331, 332, 333, 341, 342, 343) pour amener le milieu porteur dans la chambre (30) de broyage à une vitesse supersonique, **caractérisés en ce que** lesdits moyens (331, 332, 333, 341, 342, 343) pour amener le milieu porteur dans la chambre (30) de broyage sont agencés de sorte que le milieu porteur alimenté par l'intermédiaire desdits moyens (331, 332, 333, 341, 342, 343) crée au moins deux cyclones artificiels dans la chambre (30) de broyage, les au moins deux cyclones artificiels tournant à des vitesses supersoniques et dans des directions opposées ayant un axe de rotation commun, l'axe de rotation commun étant identique à l'axe central de la chambre (30) de broyage.

2. L'appareil de micronisation selon la revendication 1, dans lequel les moyens (331, 332, 333, 341, 342, 343) pour amener le milieu porteur dans la chambre (30) de broyage sont disposés le long d'une partie circulaire de la circonférence de la chambre (30) de broyage sur au moins deux rangées (33, 34), dans laquelle, dans chacune des deux rangées adjacentes (33, 34), les moyens (331, 332, 333) sont inclinés au premier angle de la première rangée (33) et les moyens (341, 342, 343) sont inclinés du deuxième angle dans la rangée (34) adjacente, les premier et deuxième angles étant de même taille et de même orientation opposée, les angles étant mesurés dans des plans parallèles aux plans des parois latérales de la chambre (30) de broyage et par rapport aux normales des tangentes touchant la circonférence de la chambre (30) de broyage aux emplacements où les moyens (331, 332, 333, 341, 342, 343) entrent dans la chambre (30) de broyage.

3. L'appareil de micronisation selon la revendication 2, dans lequel au moins deux, de préférence au moins trois injecteurs ou buses (331, 332, 333, 341, 342, 343) sont disposés dans chacune des au moins deux rangées (33, 34) de moyens (331, 332, 333, 341, 342, 343) et / ou dans lequel les moyens (331, 332, 333) pour alimenter le milieu porteur disposé dans la première rangée (33) et les moyens (341, 342 , 343) pour alimenter le milieu porteur disposé dans la rangée (34) adjacente sont disposés côte à côte ou décalés les uns par rapport aux autres.

4. L'appareil de micronisation selon l'une quelconque des revendications précédentes, dans lequel les moyens pour amener le matériau à broyer dans la chambre (30) de broyage sont agencés de sorte que le matériau à broyer soit alimenté dans la chambre de broyage dans une direction correspondant substantiellement à l'écoulement direction du milieu porteur ou dans la direction substantiellement perpendiculaire à la direction d'écoulement du milieu porteur.

5. L'appareil de micronisation selon l'une quelconque des revendications précédentes, dans lequel les moyens (331, 332, 333, 341, 342, 343) pour amener le milieu porteur dans la chambre (30) de broyage comprennent des injecteurs ou des buses.

6. L'appareil de micronisation selon l'une quelconque des revendications précédentes, dans lequel les moyens pour fournir le matériau à broyer dans la chambre (30) de broyage à une vitesse supersonique comprennent au moins deux trémies (4, 5) adaptées pour alimenter le matériau à broyer chacun d'au moins deux éjecteurs (6, 7), les éjecteurs (6, 7) étant adaptés pour accélérer le matériau à broyer à la vitesse supersonique.

7. L'appareil de micronisation selon la revendication 6, dans lequel les éjecteurs (6, 7) pénètrent dans la chambre (30) de broyage par des ouvertures (29) opposées et sont situés dans une partie circulaire de la circonférence de la chambre (30) de broyage ou dans ses parois latérales, et / ou les éjecteurs (6, 7) sont adaptés pour fournir des particules de taille supérieure à 2 mm.

8. L'appareil de micronisation selon la revendication 6 ou 7, dans lequel les éjecteurs (6, 7) comprennent des injecteurs ou des buses, lesdits injecteurs ou buses étant de préférence du même type que des injecteurs ou des buses (331, 332, 333, 341, 342, 343) pour alimenter le milieu porteur dans la chambre (30) de broyage.

9. L'appareil de micronisation selon l'une quelconque des revendications précédentes, dans lequel l'appareil comprend en outre au moins une ouverture (8) au centre d'au moins l'une des parois latérales de la chambre (30) de broyage pour transporter le matériau micronisé de la chambre (30) de broyage par le flux du milieu porteur, l'appareil comprend de préférence deux ouvertures (8) situées au centre des deux parois latérales.

10. L'appareil de micronisation selon l'une quelconque des revendications précédentes, dans lequel l'appareil comprend en outre une partie centrale (19) formée par un cylindre plat, la partie centrale comprenant en outre des parois latérales formées par des couvercles (9), une bague extérieure (35) et une bague intérieure (32), un espace intermédiaire (27) formé entre la bague extérieure (35) et la bague intérieure (32), et une ouverture (1) pour alimenter le milieu porteur.

11. Un procédé de micronisation comprenant les étapes suivantes:

- introduire le milieu porteur dans la chambre (30) de broyage à une vitesse supersonique par des moyens (331, 332, 333, 341, 342, 343) pour amener le milieu porteur dans la chambre (30) de broyage afin de créer simultanément au moins deux cyclones tournant à des vitesses supersoniques et dans des directions opposées, avec un axe de rotation commun, l'axe de rotation commun étant compatible avec l'axe central de la chambre (30) de broyage;
- introduire le matériau à broyer dans la chambre (30) de broyage à une vitesse supersonique par des moyens (4, 5, 6, 7) pour amener le matériau à broyer dans la chambre (30) de broyage; et
- micronisation du matériau à broyer introduit dans la chambre (30) de broyage par de multiples collisions frontales des particules dans un

écoulement d'au moins deux cyclones artificiels tournant à des vitesses supersoniques et dans des directions opposées.

12. Le procédé de micronisation selon la revendication 11, le procédé comprenant en outre une étape consistant à éloigner le matériau micronisé de la chambre (30) de broyage par l'écoulement du milieu porteur dans une ouverture (8) située au centre d'au moins un des des parois latérales de la chambre (30) de broyage, de préférence à travers deux ouvertures (8) situées au centre des deux parois latérales.

13. Le procédé de micronisation selon la revendication 11 ou 12, dans lequel l'étape consistant à introduire le matériau à broyer dans la chambre (30) de broyage comprend les sous-étapes suivantes:

- alimenter le matériau à broyer par au moins deux trémies (4, 5) dans au moins deux éjecteurs (6, 7),
- fournir un milieu porteur à grande vitesse pour l'accélération du matériau à broyer à la vitesse supersonique à travers au moins deux éjecteurs (6, 7), de préférence le moyen à grande vitesse d'accélération du matériau à broyer est le même que le milieu porteur; et
- accélération du matériau à broyer à la vitesse supersonique dans les éjecteurs (6, 7) par le fluide à grande vitesse pour l'accélération du matériau à broyer.

14. Le procédé de micronisation selon l'une quelconque des revendications 11 à 13, dans lequel le matériau à broyer est introduit dans la chambre de broyage dans une direction correspondant substantiellement à la direction d'écoulement du milieu porteur ou dans une direction substantiellement perpendiculaire à la direction d'écoulement du fluide milieu porteur.

15. Le procédé de micronisation selon l'une quelconque des revendications 11 à 14, dans lequel le milieu porteur est d'abord introduit par l'ouverture (1) dans la partie centrale (19) et dans la bague extérieure (35) dans l'espace intermédiaire (27) et entre ensuite dans la chambre (30) de broyage à une vitesse supersonique de l'espace intermédiaire (27) à travers les moyens (331, 332, 333, 341, 342, 343) agencés dans la bague intérieure (32).

Fig. 1

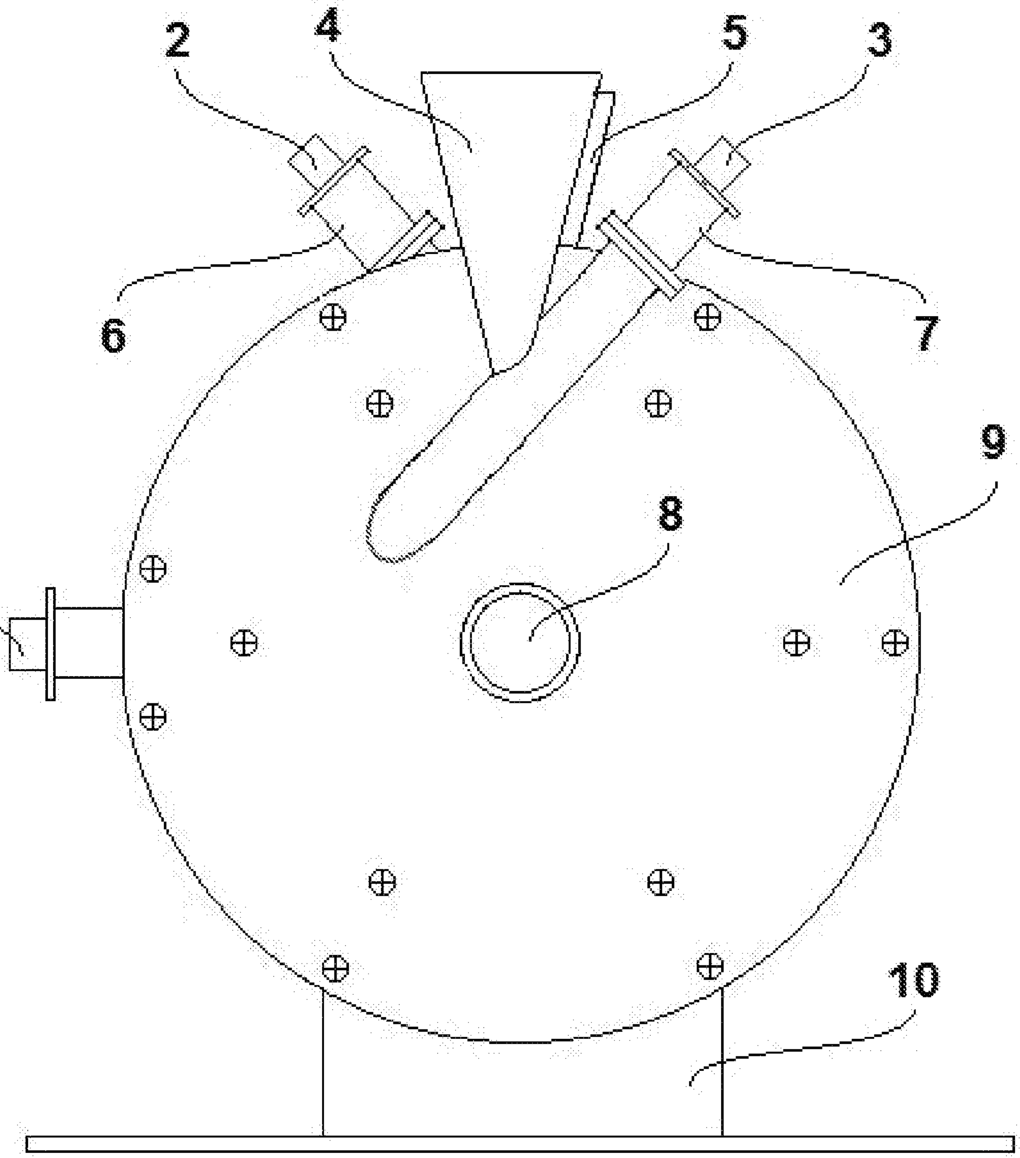


Fig. 2

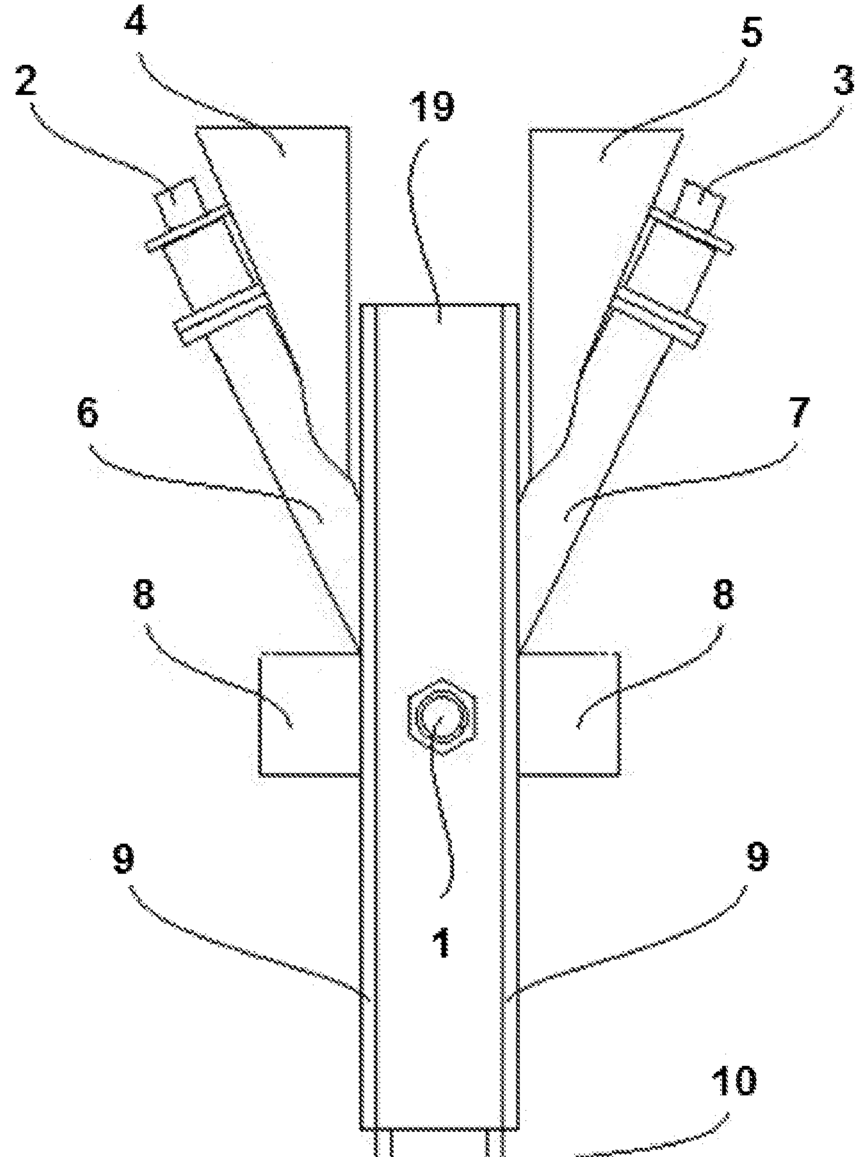


Fig. 3

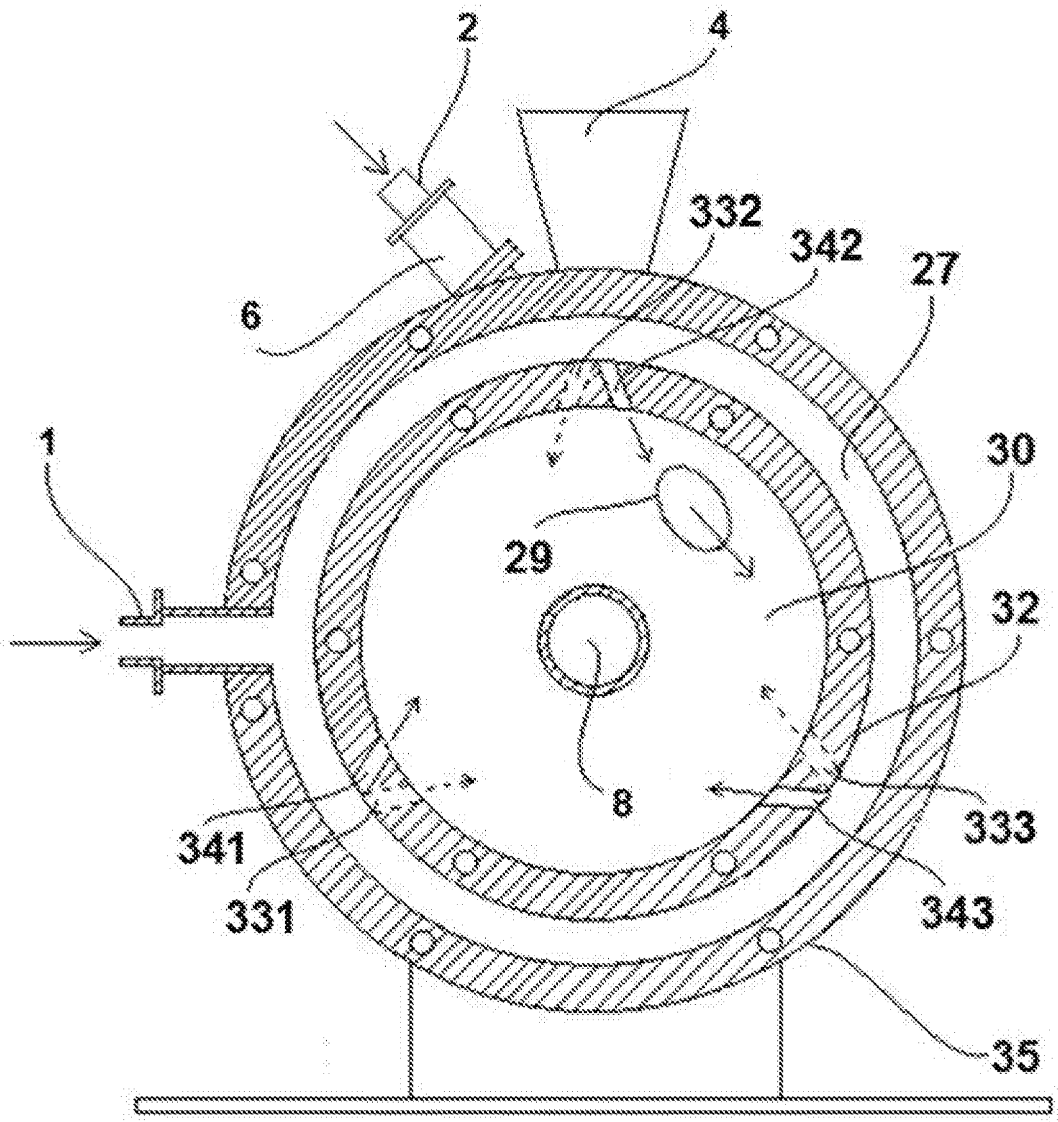
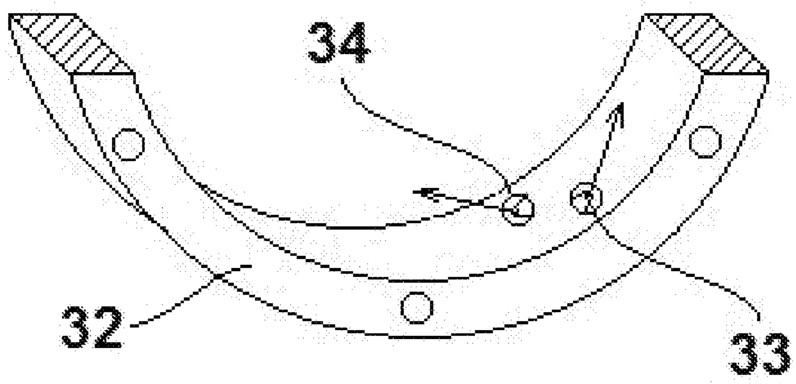


Fig. 4



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