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(54) METHOD OF TREATMENT OF SOLIDS AND A DEVICE FOR CARRYING OUT SUCH METHOD

(57) The subject of the invention is the method of the mechanical treatment of loose solid substances and their mixtures in dry conditions, according to which the loose solid substance with input grain size not exceeding 0.2 mm is mixed with a flowing gas, characterized in that the grains of such a loose solid substance are dispersed in the flowing gas in the quantity of 0,15-8.5 kg/m^3 of gas to create their mixture; the mixture is then supplied into a confined space having the shape of a solid of revolution where working bodies rotate at a speed of at least 50 m/s, and in this confined space the mechanical energy of the working bodies transforms into the kinetic and pressure energy of the mixture, and this mixture is compressed to up to 70% of its original volume and then it is made to perform a turbulent flow using a working body moving in the opposite direction than that of the mixture flow and/or by the expansion of the mixture into a volume at least by 30% larger than its volume during moulding to ensure the mutual collisions of also very fine grains of the solid substance in the mixture at great angles and to make their collisions with the working bodies more effective to attain the intensive disintegration and mechanical activation thereof.

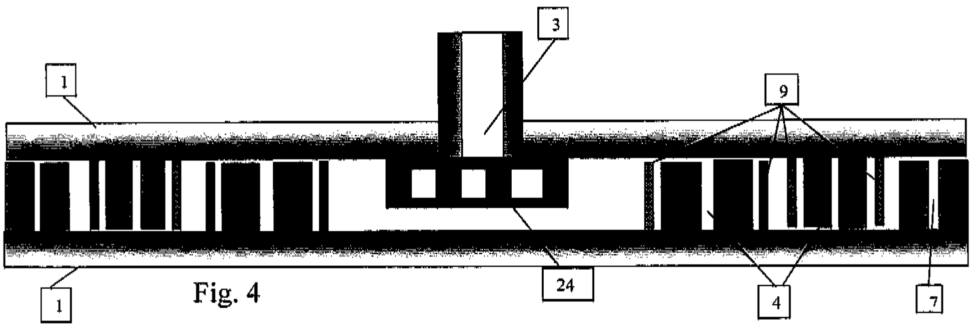

Fig. 4

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Description

Field of the Invention

[0001] The invention concerns a method of mechanical activation, fine and ultrafine grinding of dry loose solid substances with input grain size not exceeding 0.2 mm, in particular loose inorganic substances with input grain size not exceeding 0.2 mm.

Background of the Invention

[0002] Nowadays, grinding of loose substances is performed by several different methods. Among the most widely used methods there is grinding in ball and rod mills and rotary ring or vibrating mills. Among less customary methods of grinding there is grinding in roller mills and runner mills of various types. A new and more efficient method of grinding, during which significant mechanical activation, also referred to as mechanochemical activation, of the treated substances occurs, is performed in high-speed pot/pin mills - disintegrators.

[0003] All the aforementioned methods of treatment have a common problem concerning the efficient refinement and mechanochemical activation of the input raw materials which have a very fine input grain size prior to treatment already. All the aforementioned and commonly employed methods of grinding are used for the refinement of grain size (enlargement of specific surface) by interaction between working bodies and grains of the treated substance. The finer the grain size is, the less efficient interactions that are collisions in fact (dynamic effects of various kinds).

[0004] The long-term experience has resulted in a finding that not only the degree of fineness but also the method of grinding has a significant impact on the technological properties of various substances, such as cements.

[0005] This topic is covered for example by the publication Mechano-chemical modification of cement with high volumes of blast furnace schlag; Sobolev K., March 2004. Grinding of cements in common grinding machines, such as ball or vibrating mills is very demanding in terms of time and energy input, which results in the high prices of cement production. On the other hand, there are ways allowing a better utilization of energy spent on the treatment of solid substances, including building materials. Among the first persons who noticed the effect of mechanochemical activation and its effect on the properties of building products was Estonian engineer J. Hint. He analysed and described the mechanochemical activation of sand-and-lime mixtures, i.e. mixtures the basic components of which are sand and lime, for moulding and subsequent high-pressure steam curing, i.e. building products cured by hydrothermal heating. He was probably the first person who employed in practice the equipment called disintegrators processing large volumes of material. This topic is covered in his thesis: (Hint, J. A.: Disintegrator-Based Method of Production of Silicate and Calcium Silicate Products, CNIPS, Moscow, 1952). This principle is also mentioned in the document GB 2 006 737 A - Method and apparatus for the production of an activated mineral composition that deals with the production of mineral compositions for sealing the walls of wells and tunnels and compacting underlayers, and that describes the options of mechanochemical activation in disintegrator-like equipment or in vibrating mills. As early as at that time, disintegrators were able to provide relatively efficient grinding accompanied by the effect of mechanochemical activation. Nevertheless, the design of the equipment used at that time did not allow the sufficiently intense treatment of materials for the production of full-fledged alternative binding materials due to high abrasion. In addition, this principle is employed in the document EP 0 470948 A2 "Baustoffgemisch zur Herstellung von Form und Fertigteilen sowie Verfahren zur Herstellung der Baustoffgemische" (Building Mixtures for the Production of Moulded (Pressed) and Prefabricated Products and a Method for the Preparation (Processing) of Building Mixtures, Köhler - Pavlik, J, February 1992, Vienna, which uses a number of other materials as basic components that can react with alkaline and calcium substances at wet heating, such as steam curing or high-pressure steam curing. As it can be seen from the aforementioned examples, mechanochemical activation in the disintegrator-like equipment has been used for various applications in the building industry for many years and it is likely that the number of such applications will be increasing. In the former Soviet Union, grinding and mechanochemical activation in the disintegrator-like equipment was used for the treatment of material intended for the manufacture of cement-bonded particleboards.

[0006] The aforementioned treatment is covered in the SU 1616872 A1 patent. The material for cement-bonded particleboards treated the in the manner disclosed in the aforementioned patent can replace (up to 15%) of fresh cement in newly produced cement-bonded particleboards. Treatment in a six-row rotor with the rate of impacts 150-200 m/s is disclosed. This means that the grains (particles) of the material being treated were subjected to at least 6 dynamic pulses at the speed of 200 m/s. But even this degree of transferred energy is not sufficient for the complete activation of the mass of cement-bonded particleboards.

[0007] Finely ground mineral powders are widely used as filling materials in various industries, in particular in the plastic-, rubber-, and paper-making industries, in the chemical industry, in the industry of paints and varnishes, for the production of ceramics and porcelain, metallurgy, in the power sector and in a number of other industries. A wide range of minerals and rock materials are processed by grinding. In addition to carbonate minerals and rock materials, a number of examples of materials with various properties can be presented. Among natural, other than ore-bearing materials, in particular micas, talc, feldspars, silica, gypsum, fluorite, zeolites, mudstones, coals, coke, and others are concerned. Among natural ore-bearing materials, iron and other metal ores that are processed with a view to opening grains and improving the recovery of the useful components during subsequent processing are concerned.

[0008] In addition to raw materials, grinding is used for the processing of a wide range of technogenic materials, such as cement clinkers, metallurgical cinders and sludges, materials originating from burnt-through dumps and products of solid fossil fuels combustion. A majority of technogenic materials treated in this way find usage in the building industry.

[0009] In some cases, mechanochemical activation is now increasingly used in emerging Asian economies. For example, the Chinese patent CN 101053870A, published in 2007, deals with the method of compacting boring sludges by supplying such a sludge together with a binding material into an unspecified high-speed mill working in an unspecified mode where sludge grains are refined and mixed with the binding material. The wet mixture treated in this manner then solidifies spontaneously and can be used for the moulding of various elements that can be used for example in the building industry. It is noted that thanks to this way of processing it is possible, compared to other commonly used methods, to spare a portion of the binding material used for the solidification of boring sludges, that the extractability of harmful substances is low and that the strengths of the materials are sufficient and allow their usage for less demanding building applications (in general similar to those covered in the UK Patent Application GB 2 006 737 A). This Chinese patent also fails to deal with the issue of the production of full-fledged hydraulic binding materials for building applications, the rather that in a majority of cases boring sludge originates from rock materials that are not a suitable input material for the production of such building materials.

[0010] The European patent EP2291248 discloses the production of hydraulic binding materials from suitable materials using mechanical pulses, collisions of the particles of the treated material with working bodies that occur at speeds exceeding 200 ms^{-1}. On the other hand, the dependence of the treatability efficiency of individual components on the specific values of energy employed for mechanical pulses is not defined. In addition, the effect of a high intensity alternating magnetic field on the particles of substances broken by a powerful mechanical pulse is disclosed here.

[0011] During our research, we discovered that under certain conditions, in addition to the speed of the working components of the equipment and the nature of collisions, it is the effect and properties of the environment where the treatment is performed that matters a lot. The effect of environment on the efficiency of grinding and mechanical activation is usually negative as during the commonly used methods of the treatment of grain size, for example, useless whirling of the environment consumes a significant portion of energy invested in the process and prevents small particles from colliding with the working bodies due to the fact that the gaseous environment is compressed in front of the working body and flows around the working body together with fine grains of the material being treated. The higher the speed of the working bodies, the higher the resistance of the gaseous environment and the less efficient grinding and the higher losses caused by the resistance of air. A certain breakthrough occurs when the speed of sound is exceeded when a portion of fine grains of the treated material can collide with the surface of the working bodies again. However, attaining supersonic speeds is demanding in terms of both technical solution and energy. Moreover, the collisions of the working bodies with the grains of the treated material is accompanied by an excessive wear of the working bodies. Therefore, some solutions try to remove or minimize the effect of gaseous environment by, for example, grinding in vacuum or at least under a significantly reduced pressure. However, this is technically demanding, and such solutions have never been put into practice.

[0012] On the other hand, under certain conditions it is possible to utilize the properties of the environment at subsonic speeds for a considerable reduction in the wear of the working bodies and making grinding more effective, namely in particular in the case of materials with fine input grain size. The essence of this invention is based on the aforementioned findings.

Summary of the Invention

[0013] The subject of the inventions is a method of mechanical treatment of loose solid substances, in particular of loose inorganic substances, namely including mixtures thereof, in dry conditions, according to which the loose solid substance with input grain size not exceeding 0.2 mm is mixed with flowing gas, the essence of which is based on the fact that the grains of such a loose solid substance are dispersed in the flowing gas in the quantity of 0.15-8.5 kg/m^3 of gas to create their mixture; the mixture is then supplied into a confined space having the shape of a solid of revolution where working bodies rotate at a speed of at least 50 m/s, and in this confined space the mechanical energy of the working bodies transforms into the kinetic and pressure energy of the mixture, and this mixture is compressed into up to 70% of its original volume and then it is made to perform turbulent flow by a quick change in the direction of the mixture flow and/or by the expansion of the mixture into a volume at least by 30% larger than its volume during moulding to ensure mutual collisions of also very fine grains of the loose solid material in the mixture at great angles and to make their collisions with the working bodies more effective to attain the intensive disintegration and mechanical activation thereof.

[0014] Preferably, the mixture is supplied into a confined tapered space canalizing its movement for at least one more adiabatic compression accompanied by the acceleration of the flow of the mixture to the maximum value of the critical speed of flow in the smallest cross-section of the limited tapered confined space and then the mixture is made flowing turbulently by means of a working body moving upstream the flowing mixture and/or by the expansion of the mixture behind the exit from the tapered confined space, where the resulting turbulent flow is accompanied by at least some of the following effects: the occurrence of a wake, the tearing of vortex wakes, the occurrence of shock waves and the occurrence of effects similar to cavitation, to ensure mutual collisions of also very fine grains of the solid substance in the mixture at great angles to make their collisions with the working bodies more effective and to disintegrate the internal structure of the grains of the solid substance by shock waves for their intensive disintegration and mechanical activation.

[0015] Preferably, the mixture is accelerated again by channelizing its movement into a confined tapered space at least once, then it is let to expand into a gradually extending space, by which the mixture is accelerated up to supersonic speeds for additional increase in its kinetic energy and then the mixture is made flowing turbulently by means of a working body moving upstream the flowing mixture and/or by the expansion of the mixture behind the exit from the tapered confined space, accompanied by the occurrence of a wake, the tearing of vortex wakes, the occurrence of shock waves and the occurrence of effects similar to cavitation, to ensure mutual collisions of also very fine grains of the solid substance in the mixture at great angles to make their collisions with the working bodies more effective and to disintegrate the internal structure of the grains of the solid substance by shock waves for their intensive disintegration and mechanical activation.

[0016] Preferably, the mechanical treatment of solid substances and mixtures thereof in dry conditions is performed in an item of equipment the essence of which rests in the fact that it contains a mixing chamber for the preparation of a mixture of gas and disintegrated solid substance, two rotors facing one another, of which at least one rotates with the peripheral speed of at least 80 m/s with reference to the other one, with the supply of the mixture of gas and disintegrated substance from the mixing chamber towards the centre of the rotors where at least one of the rotors is fitted with a group of working bodies arranged as confusers or convergent or convergent-divergent nozzles for the quick dynamic compression of the mixture into a volume being up to 70% of the original volume, for the canalization and acceleration of its flow where such working bodies are arranged in at least one concentric circle with the centre in the centre of the rotor and with expansion space with the volume ensuring the gas expansion arranged behind each working body. For the purposes of this patent application, a confuser refers to a tapered nozzle that may include the angle of curvature that changes in steps. A convergent nozzle then refers to a nozzle with an infinitely changing angle of curvature of the surfaces, i.e. without step changes.

[0017] Preferably, the mechanical treatment of solid substances and their mixtures in dry conditions is performed in the equipment the essence of which rests in the fact that in at least on one of the rotors the working bodies are installed in at least two concentric circular rows with the centre in the centre of the rotors that describe a circle during their movement around the centre of the rotor and the axis of each confuser or nozzle forms an angle γ with the tangent of the respective circle in the point of installation of the working body on the rotor ranging between 0 and 25°.

[0018] Preferably, the mechanical treatment of solid substances and their mixtures in dry conditions is performed in the equipment the essence of which rests in the fact that the working bodies are installed on at least one rotor in at least two concentric circular rows with the centre in the centre of the rotors and describe a circle during their movement around the centre of the rotor and they are arranged in the shape of an asymmetric confuser or a bevelled nozzle, the axis of which forms an angle γ with the tangent of the respective circle in the point of installation of the working body on the rotor ranging between 0 and 25°.

[0019] Preferably, the mechanical treatment of solid substances and mixtures thereof in dry conditions is performed in the equipment the essence of which rests in the fact that the working bodies forming confusers or nozzles are fitted at the discharge with vacuum ejector adapters (8), the axes of which are identical, parallel or form an angle δ with the direction of the axes of the nozzles, the values of which can be up to 15°.

[0020] Preferably, the mechanical treatment of solid substances and mixtures thereof in dry conditions is performed in the equipment the essence of which rests in the fact that behind the outlet from the confuser or nozzle in its axis a pin (11) is fitted at a distance corresponding to up to 2/3 of the length of the confuser or nozzle, where the axis of the pin is perpendicular to the rotor plane and the widest dimension in the section parallel to the rotor plane corresponds to no more than the width of the inlet opening of the nozzle to create a very intensive turbulent flow and/or to adjust the direction of the flow of the mixture and treated substance.

[0021] Preferably, the mechanical treatment of solid substances and mixtures thereof in dry conditions is performed in the equipment the essence of which rests in the fact that it contains a mixing chamber to create a mixture of gas and dispersed solid substance, two counter-rotating rotors with the supply of a mixture of gas and solid substance from the mixing chamber towards the centre of the rotors where at least one of the rotors is fitted with a working body forming a barrier arranged as an annulus; and in the plane that is perpendicular to the surface of the rotor that passes through its centre, the cross-section of the rotor has the shape of a trapezoid, the longest side of which forms the base of the annulus, and which forms with the surface of the counter-rotating rotor or with the surface of the neighbouring working bodies placed accordingly on the counter-rotating rotor a confuser or a convergent or convergent-divergent nozzle for a quick dynamic compression of the mixture, with expansion space with the volume ensuring the mixture expansion arranged behind each working body.

[0022] Preferably, the compression of the mixture of the treated substance and gas is performed by the working bodies fitted on the rotors with various shapes designed to function as rotary compressor blades that are fitted in at least two rows forming concentric circles of unequal diameter with the centre of the rotors so that the working bodies in the row that is closer to the centre of the rotors have the function of accelerating blades that accelerate the flow of the mixture away from the centre of the rotors towards their perimeter and the longest dimension of which in the section parallel to the rotor surface forms an angle α with the tangent of the circle in the respective row in the point of the working body installation ranging between 5 and 75° in the direction of movement of the working bodies, and the working bodies in the following row with a larger diameter are fitted on the opposite rotor in a way allowing them to act as decelerating blades that decelerate the flow of the mixture away from the centre towards the perimeter of the rotors, and with the longest dimension in the section parallel to the surface of the rotor forming an angle β with the tangent of the circle of the respective row in the point of installation of the working body ranging between 5 and 75° in the direction that is opposite to that of the working bodies movement to compress the mixture of the treated substance and gas between these rows of working bodies associated with turbulent flow and to provide an expansion volume outside the row of the working bodies with a larger diameter allowing the intensive disintegration of the grains of the treated substance.

[0023] Preferably, the mechanical treatment of solid substances and their mixtures in dry conditions is performed by the equipment the essence of which rests in the fact that the surface of at least one of the rotors and/or working bodies arranged as an annulus is fitted with open expansion chambers having a concave shape to provide a very intensive turbulent flow in the confined space caused by the expansion of the mixture and by the movement of these chambers around the centre of the rotor.

[0024] Preferably, the mechanical treatment of solid substances and mixtures thereof in dry conditions is performed in the equipment the essence of which rests in the fact that the expansion chambers have different shapes and/or volume and if fitted onto the rotor in at least two concentric circular rows, they have their volumes that are decreasing for every individual chamber in every following row towards the rotor perimeter, and the total volume of the chambers differs from the total volume of the chambers in the previous row by no more than 30%.

[0025] Preferably, the mechanical treatment of solid substances and mixtures thereof in dry conditions is performed in the equipment the essence of which rests in the fact that at the perimeter of at least one of the rotors at least two accelerating blades are arranged that form with the tangent of the rotor perimeter in the point of installation thereof on the rotor an angle ranging from 10° to 90° to provide and control the speed of a flow of the mixture of gas and solid substance and to control pressure in the working space between the counter-rotating rotors.

[0026] Preferably, the mechanical treatment of solid substances and mixtures thereof in dry conditions is performed in the equipment the essence of which rests in the fact that the canalization, dynamic compression and acceleration of the flow of the treated substance and gas and its subsequent turbulent flow are provided by the working bodies fitted on the rotors in at least three rows forming concentric circles with unequal diameters with the centre of the rotors, and the working bodies in the row with the smallest diameter and in the row with the largest diameter, the number of which is equal in each of these rows, are installed on one rotor in a way that the two nearest working bodies from each of these rows are arranged as a confuser or a convergent or convergent-divergent nozzle to accelerate the flow and provide the fast dynamic compression of the mixture into 70% of the original volume at the most, and between these rows on the opposite rotor, a circular row of working bodies is arranged that have the character of pins in the shape of cylinders, semi-cylinders, triangular or multiangular prisms or connecting pieces of these shapes that move against the nozzles at the speed of at least 80 m/s.

[0027] Preferably, the working bodies and shaped compression chambers disclosed in the aforementioned patent claims are mutually combined and the working bodies disclosed in the previous patent claims can also be combined within one row of the working bodies having the shape of a circle with the centre on the axis of rotation of the rotors.

[0028] To attain efficient grinding and mechanical activation of solid substances with a fine input grain size and also to reduce the wear of the working bodies in high-speed mills of the type equipped with a single rotor or the disc-and-pin mills equipped with two rotors, it is advisable, according to the present invention, to perceive the mixture of gas and treated substance as a whole and not to study only interactions of individual grains of the treated substance with the mill working bodies as it was done previously.

[0029] The basic step of this method is the transfer of the mechanical energy of the mixture of the gaseous environment and treated substance in uplift, namely as a whole by means of the rotating rotor and/or working bodies fitted onto the rotor, where such mechanical energy is converted into the pressure and kinetic energy of the mixture. To eliminate the useless dissipation of energy, this process is performed in a rotary-shaped confined space defined for the purposes of the patent application as a rotary space that is substantially delimited by two discs with the identical axis of rotation which have the function of the rotor and stator or by two rotors rotating in the same direction at unequal speeds, or better by two counter-rotating rotors rotating at the same or different speeds. In a majority of cases, the confined space of the rotary shape has the shape of a cylinder or annulus but can also have the shape of opposite hollow blunted cones or spherical segments.

[0030] The dynamic compression and acceleration of the mixture of gas and treated substance is the necessary but not sufficient condition of the acceptably efficient refinement of the treated substance. The flow of the mixture of gas and treated substance must be accelerated as much as possible and the gaseous environment must be dynamically compressed, i.e. the mechanical energy must be transformed into the kinetic and pressure energy with the highest possible efficiency; also its flow must be canalized and it is necessary to ensure that the accumulated kinetic and pressure energy is transformed to the greatest extent into the increment of the new surface and the increase of the intrinsic energy of the treated solid substance.

[0031] The required flow canalization, the dynamic compression of the mixture and its acceleration is provided by the working bodies in the form of confusers, convergent nozzles or convergent-divergent nozzles, and the working bodies are formed or where applicable arranged in a way that allows them to fulfil the function of confusers or nozzles, and/or it is created similarly as in radial turbochargers by means of working bodies having the function of compressor blades. For the canalization of the flow, its acceleration and the dynamic compression of the gaseous component of the mixture, working bodies in the form of a throttling barrier with the shape of an annulus with a trapezoidal cross-section can be utilized. In this case, to attain the sufficient compression and acceleration of the mixture flow, a supplementary compression or suction effect provided by the working bodies with the function of accelerating blades arranged on at least one rotating rotor can be used.

[0032] Expansion is then allowed in the space behind the confuser, nozzle or throttling barrier. Confusers and nozzles can be supplemented by ejector adapters to make the canalization of the flow of the mixture and its acceleration more effective. Preferably, open concave expansion chambers can be created on the surface of the rotors or working bodies in the shape of an annulus. The use of the supplementary elements such as ejector adapters or expansion chambers results in a canalized flow of the mixture with a view to transferring the maximum of the kinetic and pressure energy of the mixture into the surface-tension energy of the solid substance, i.e. the disintegration of grains and the formation of new grains with a significantly larger total specific surface and also into the intrinsic energy of such newly created grains in the form of defects in the structure of such grains resulting in a so-called activation of solid substance.

[0033] Dynamic compression for the purposes of the present invention refers to the compression of the mixture being a mixture of gas and treated substance moving in a confined tapered space during which the gaseous component of the mixture is compressed, and its density changed and intrinsic energy increased. To be able to describe at least approximately the processes occurring during the canalization, compression and acceleration of the flow of the mixture, we disregard the effect of the solid environment on the properties of the gaseous component of the mixture and we also disregard aerostatic pressure the effect of which is negligible considering the small size of the confusers or nozzles compared to the pressure developed by the transformation of the mechanic energy of the working bodies. On the other hand, we cannot disregard the change of the value of intrinsic energy during compression that is manifested by a gas temperature increase and then by its decrease during expansion upon discharge from the tapered confined space.

[0034] Considering the fact that the flow of the mixture is fast and that practically no exchange of thermal energy between the mixture and ambient environment occurs, we can regard the dynamic compression of the mixture as adiabatic. The entire description of the processes related to the canalization, dynamic compression and acceleration of the flow of the mixture is relatively complex and it is based on three basic equations - the equation of state in the following form

$$\rho = m/V = M_m . p/R.T$$

the continuity equation for coercible gas for a contact mass flow rate in the following form

$$Q_m = dm/dt = \rho S \upsilon = const.$$

and the Bernoulli's equation in the following shape

$$\upsilon^2 /2 + g.h + (\chi/\chi-1) . p/q = const.$$

Respectively, (if aerostatic pressure is disregarded)

$$\upsilon^2 /2 + (\chi/\chi-1) . p/q = const.$$

with the constant weight of gas (or the mixture, where applicable) m = const., that flows through any cross-section of the confined space, through the confuser, nozzle or diffuser in our case, per unit of time and with variable density $\rho \neq$ const., V $\neq$ const. Where individual quantities are marked as follows:

Molecular weight of gas in the mixture .... M_m
Thermodynamic temperature of gas ......T

(continued)

Avogadro constant .... N_A
Universal gas constant .... R
Amount of gas substance in the mixture .... n
Ratio of specific heats .... χ
Mean speed of particles in the mixture....... υ
Pressure of gas in the mixture .... p
Weight of the mixture ..... m
Volume of the mixture V
Mass flow rate of the mixture .... Q_m
Density of gas in the mixture .... ρ
Time .... t

[0035] As it can be seen from the Bernoulli's equation, it is possible not only to very efficiently canalize the flow of compressible fluid (i.e. a mixture of gas with finely dispersed solid substance) during the passage through a confuser or nozzle, but also to accelerate them and impart a great deal of kinetic energy to the mixture of gas and dispersed solid substance. This approach guarantees a very efficient transfer of mechanical energy to compressible fluid. To describe the process of tearing vortex wakes, the occurrence of shock waves, turbulences and cavitations in the fluid by mathematical symbols is very difficult. To describe the movement and trajectories of the grains of various sizes of the solid substance in this mixture, the probability of their mutual collisions and the effect of shock waves and cavitation effects on the grains is even more difficult and at least for the time being, we are not able to describe this process using mathematical symbols.

[0036] With this method of treatment, a synergistic combination of several physical phenomena and mechanisms of grinding, which usually function individually in various types of mills, in particular in jet, vortex and cavitation mills, occurs. For larger and heavier grains, also other effects, similar to those occurring in pin mills are important, i.e. the collisions of grains with the surface of the working bodies at high speeds occurring at various angles. It is the combination of all the aforementioned mechanisms that allows the high efficiency of grinding and mechanochemical activation of fine-grained substances, the similar treatment of which in other equipment is either impossible whatsoever, or much less efficient and excessively demanding in terms of energy. If the aforementioned effects, in particular collisions, occur at very high speeds in a confined space between two counter-rotating disk rotors or disk rotors that rotate at different speeds and at best also in a more compact environment, such collisions are much more frequent and the entire process is much more efficient and results in a destruction of even very fine grains during their mutual collisions and tearing very small particles from their surfaces similarly, as in the case of cavitation in a liquid environment. A great acceleration of the flow of the mixture of gas and the solid substance dispersed in it can be attained by its passage through a confuser or nozzle. Unlike in a liquid environment, a gaseous environment is easily compressible. Considering the maximum critical speed of flow rate in the narrowest cross-section of the nozzle that is limited by the sonic speed in a given environment, also the maximum rate of the flow of the mixture of gas and treated substance is limited at least by the cross-section of the tapered confined space (of the confuser or nozzle), which follows from the continuity equation for a flowing compressible liquid stating that the weight of a compressible liquid passing through any cross-section of a confuser or nozzle per unit of time is equal. To accelerate the flow rate of the fluid to attain supersonic speeds, namely up to several times higher than the critical speed, it is necessary to use working bodies in the shape and with the function of a convergent-divergent nozzle, such as expansion nozzle.

[0037] Similar effects, i.e. the collisions of fine grains at high speeds no matter whether on the border of laminar flows or during whirling in a turbulent flow, occur in jet mills and vortex mills. Such collisions are very frequent and occur at high speeds. Nevertheless, a low weight of the grains also means a low energy of individual collisions which usually is not sufficient to overcome the surface-tension energy of the grain, which means that no disintegration occurs. The efficiency of such equipment is relatively low and only in exceptional cases, a central collision of two grains occurs, i.e. a collision when the grains move practically along the same trajectory but in opposite directions regardless of the fact that the flow of the gaseous medium is very fast. A great deal of energy in standard grinding equipment is transferred into heat.

[0038] This technology has several advantages compared to methods so far commonly used for the processing of similar materials. The main advantage is that this method allows further disintegration and decrease of the size of the grains of substances with a very fine input grain size with a relatively high efficiency that, considering the excessive energy consumption, cannot be efficiently treated by means of various types of standard grinding, starting with ball up to jet and vortex mills, and not even the treatment in standard high-speed pin mills, in which the main working mechanism is a very fast collision of the grain of the treated substance with the working body is able to ensure a sufficiently effective treatment.

[0039] The method according to the present invention makes the dry fine and ultrafine grinding of loose solid substances with a fine input grain size more effective. The best utilization of finely ground materials is in the building material industry. The main purpose of this industry is the production of cements based on Portland clinker and to a lesser extent, the production of lime. The production of Portland clinker as well as the production of lime are processes requiring large amounts of raw materials, in particular limestones. The production of Portland clinker and lime has a similar basis, i.e. the thermal decomposition of limestones that produces CaO and in the case of Portland clinker also the sintering of CaO with other aluminosilicate components at high temperatures. The thermal decomposition of limestones is a very demanding process in terms of energy accompanied by a large amount of CO_2 emissions. Therefore, there is a need for replacing the products resulting from these production processes in binding materials to the greatest extent with other substances (for example by the method disclosed in the present patent application, such as treated energy by-products, concrete-type recycled products or other materials with a lower demand for energy and carbon footprint) that are less expensive and the production of which presents a lower burden on the environment compared to commonly used materials.

Brief description of Drawings:

[0040] The method of treatment of solid substances as well as the equipment for the treatment of solid substances will be easily understood from the examples of embodiments and enclosed figures in which:

Fig. 1 represents a convergent-divergent nozzle with basic parameters,
Fig. 2 represents the suitable embodiments of working bodies
Fig. 3 represents a sectional view of a suitable embodiment of the equipment according to the present invention
Fig. 4 represents a sectional view of another embodiment of the equipment according to the present invention
Fig. 5 represents a view of the arrangement of working bodies on the equipment rotors according to the present invention
Fig. 6 represents a sectional view of another possible embodiment of the equipment according to the present invention
Fig. 7 represents a sectional view of yet another embodiment of the equipment according to the present invention
Fig. 8 represents a plan view of yet another embodiment of the equipment according to the present invention
Fig. 9 represents a plan view of yet another embodiment of the equipment according to the present invention
Fig. 10 represents a plan view of yet another embodiment of the equipment according to the present invention
Fig. 11 represents a plan view of yet another embodiment of the equipment according to the present invention
Fig. 12 represents a view of the working bodies forming nozzles

Examples of Embodiments of the Invention

[0041] The present invention will be disclosed using specific embodiments and by reference to certain drawings which are not limiting in any way; the present invention is limited only by the patent claims. The disclosed drawings are only diagrammatic and are not regarded as limiting. The size of any elements in the drawings can be scaled up and such elements may not be drawn true-to-scale for illustrative purposes. Dimensions and relative dimensions do not correspond to real scale down used during the explanation of the invention.

[0042] In addition, expressions such as the first, the second and similar expressions used in the disclosure and patent claims are used to distinguish between similar elements and may not necessarily be used to describe consecution or temporality or space, superiority or in any other way. It is necessary to understand that the expressions used in this way are interchangeable under certain circumstances and that the embodiment of the invention as disclosed here is able to perform in different sequences than disclosed or illustrated here.

[0043] Moreover, expressions such as up, down, the first, the second and similar ones used in the disclosure and patent claims are used for descriptive purposes and may not necessarily describe the required situation thereof. It is necessary to understand that expressions used in this way are interchangeable under certain circumstances and that the embodiment of the invention as disclosed here can be operated also in other orientations than disclosed or illustrated here.

[0044] It must be noted that the expression "including" used in the patent claims cannot be interpreted as limiting the patent claim exclusively to the expressions that follow; therefore, it means that other elements or steps are not excluded. It is necessary to interpret the expression as the introduction of the property, unit, steps or parts being introduced that are referred to, which however does not exclude the presence or supply of one or more additional properties, units, steps or components or groups thereof.

[0045] The basic parameters of a convergent-divergent nozzle suitable for use in the equipment according to the invention are illustrated in Fig. 1, and they are accordingly applicable to a confuser or convergent nozzle. In Fig. 1, the inlet opening d_1, the outlet opening of the convergent portion d_2, and the outlet opening of the divergent portion d_3 can be seen. The length of the convergent portion is marked as l, the length of the divergent portion as l_2, , and the total length as l_1. Fig. 2 shows the most widely used preferred types of working bodies with the function of nozzles, confusers, and other supplementary elements.

Example 1: The treatment of fluid flue ashes resulting from the combustion of solid fossil fuels with the grain size not exceeding 0.1 mm.

[0046] Fluid flue ashes as such, or where applicable with additives, are dispersed in the mixing chamber in the quantity of 4.1 kg/m^3 of air and the mixture is supplied by sucking between two counter-rotating rotors 1 with the diameter of 800 mm and each with the peripheral speed of 100 $m.s^{-1}$, where one of the rotors is fitted with a distribution basket 24 and two circular rows of working bodies with the function of a convergent nozzle 5, while the other rotor is fitted with three rows of working bodies with the function of a convergent-divergent nozzle 6. The first row of the convergent-divergent nozzles, the axis of which forms an angle γ 20 = 0° with the tangent of the row in the point of installation of the nozzle, has the diameter of 650 mm with 20 nozzles with the inlet cross-section with the width $\mathbf{d_1}$ = 30 mm, the smallest cross-section with the width $\mathbf{d_2}$ = 15 mm, the length of the convergent portion **l** = 35 mm and the total length of the nozzle $\mathbf{l_1}$ = 45 mm. The second row of the convergent-divergent nozzles, the axis of which forms an angle γ 20 = 0° with the tangent of the row in the point of installation of the nozzle, has the diameter of 725 mm with 22 nozzles with the inlet cross-section with the width $\mathbf{d_1}$ = 25 mm, the smallest cross-section with the width $\mathbf{d_2}$ = 8 mm, the length of the convergent portion **l** = 30 mm and the total length of the nozzle $\mathbf{l_1}$ = 40 mm. The third row of the convergent-divergent nozzles, the axis of which forms an angle γ 20 = 0° with the tangent of the row in the point of installation of the nozzle, has the diameter of 780 mm with 20 nozzles with the inlet cross-section $\mathbf{d_1}$ = 25 mm, the smallest cross-section $\mathbf{d_2}$ = 7.5 mm, the length of the convergent portion **l** = 35 mm and the total length of the nozzle $\mathbf{l_1}$ = 45 mm. On the opposite rotor, on which the distribution basket is installed, the first circular row with the diameter of 687.5 mm is arranged and fitted with working bodies with the function of a convergent asymmetric nozzle with the inlet cross-section with the width $\mathbf{d_1}$ = 35 mm and the outlet cross-section with the width $\mathbf{d_2}$ = 10 mm. This approach results in finely ground, mechanically activated fluid flue ashes suitable for the production of hydraulic binding materials.

Example 2: The treatment of bed-type fluid flue cinder resulting from the combustion of solid fossil fuels, the median of the grain-size distribution curve of which exceeds 1.0 mm.

[0047] The grains of the treated bed-type flue cinder are first refined on a double-cylinder shear mill up to the maximum grain size not exceeding 0.2 mm and then supplied together with a flow of air in the quantity of 3.6 kg/m^3 into the equipment according to the present invention, similar to that shown in Fig. 3 with the difference that it has six rows of working bodies. The created mixture is supplied between two counter-rotating disc rotors 1 with the diameter of 840 mm, where the rotor, through which the material passes into the working space between the rotors, is fitted next to its centre with the inlet distribution basket 24 with the diameter of 170 mm in the form of a circular row of ten massive blades, the longitudinal axis of each of which forms an angle 17.5° with the radial in the point of installation of each of the blades. This rotor 1 rotates with the peripheral speed of 100 m/s. On the opposite rotor 1, which rotates in the opposite direction with the peripheral speed of 125 m/s, a circular row is arranged with the diameter of 400 mm having 24 massive blades in the shape of prisms, the longitudinal axis of which forms an angle 23° with the radial in the point of installation of each of the blades, which ensure the preliminary refinement of the coarser grains of material by collision, its acceleration and maintaining an even distribution of grains of the solid substance in uplift. Obviously, the mutual peripheral speed of the two rotors 1 in this example of embodiment is 225 m/s. In addition, the working space of each of the rotors1 is fitted with additional three circular rows of working bodies which have the shape and function of a convergent-divergent nozzle, the axis of which forms with the tangent of the circle of the respective row in the point of installation of the nozzle 5 an angle γ 20 = 5°, and a cylindrical pin 18 is arranged behind each of the nozzles at a distance of a half of the length of the nozzle $\mathbf{l_1/2}$. In the external row of the working bodies on each of the rotors 1 the working bodies have the shape and function of an asymmetric convergent-divergent nozzle 23, and the shorter side of the nozzle is always on the side more distant with reference to the centre of the rotor. The first row of working bodies with the diameter of 600 mm is arranged on the same, which means the first rotor, as the inlet 3 of material into the space between the rotors and is fitted with 18 nozzles with the width of the inlet cross-section $\mathbf{d_1}$ = 36 mm, the width of the narrowest cross-section $\mathbf{d_2}$ = 16 mm, the width of the outlet cross-section $\mathbf{d_3}$ = 18 mm, the length of the convergent portion of the nozzle **l** = 36 mm, and the total length of the nozzle $\mathbf{l_1}$ = 46 mm. The second row of nozzles with the diameter of 650 mm is arranged on the second rotor and is fitted with 20 nozzles with the width of the inlet cross-section $\mathbf{d_1}$ = 36 mm, the width of the narrowest cross-section $\mathbf{d_2}$ = 12 mm, the width of the outlet cross-section $\mathbf{d_3}$ = 18 mm, the length of the convergent portion of the nozzle **l** = 36 mm, and the total length of the nozzle $\mathbf{l_1}$ = 46 mm. The third circular row with the diameter of 700 mm is arranged on the first rotor and is fitted with 20 nozzles with the width of the inlet cross-section $\mathbf{d_1}$ = 36 mm, the width of the narrowest cross-section $\mathbf{d_2}$ = 8 mm, the width of the outlet cross-section $\mathbf{d_3}$ = 18 mm, the length of the convergent portion of the nozzle **l** = 36 mm, and the total length of the nozzle $\mathbf{l_1}$ = 46 mm. The fourth row of nozzles with the diameter of 740 mm is arranged on the second rotor and is fitted with 40 nozzles with the width of the inlet cross-section $\mathbf{d_1}$ = 25 mm, the width of the narrowest cross-section $\mathbf{d_2}$ = 12 mm, the width of the outlet cross-section $\mathbf{d_3}$ = 14 mm, the length of the convergent portion of the nozzle **l** = 26 mm, and the total length of the nozzle $\mathbf{l_1}$ = 36 mm. The fifth row with the diameter of 780 mm is arranged on the first rotor and is fitted with 46 nozzles with the width of the inlet cross-section $\mathbf{d_1}$ = 25 mm, the width of the narrowest cross-section $\mathbf{d_2}$ = 8 mm, the width of the outlet cross-section $\mathbf{d_3}$ = 14 mm, the length of the convergent portion of the nozzle **l** = 26 mm, and the total length of the nozzle $\mathbf{l_1}$ = 36 mm. The sixth circular row of working bodies with the diameter of 800 mm is arranged on the second rotor and comprises 50 nozzles with the shape and function of an asymmetric convergent-divergent nozzle 23 with the width of the inlet cross-section $\mathbf{d_1}$ = 30 mm and the width of the outlet cross-section $\mathbf{d_2}$ = 12 mm, where the shorter side of the nozzle has the length of 30 mm and the longer side of the nozzle has the length of 34 mm and the axis of each of the nozzles forms an angle 12° with the tangent to the circle of the row in the point of installation of the nozzle. This treatment results in finely ground, activated bed-type fluid flue cinder suitable for the production of hydraulic binding materials.

Example 3: Grinding and activation of Portland clinker with additives.

[0048] Portland clinker together with additives - natural pozzolana (shale roasted at 850 °C) and recycled bottle glass or window glass in the mass ratio of 4 : 3 : 3, preliminary refined in the shear double-cylinder mill to attain the grain size of 0.2 mm is mixed in the mixing chamber with air in the quantity of 2.25 kg/m^3 and the mixture is supplied to the working space of the equipment according to the present invention, between two rotors 1, which are parallel and positioned at a mutual distance of 30 mm. The rotor 1, opposite to the first rotor 1 with the supply of material into the working space is fitted with a deflector 2 and three rows of working bodies in the shape of an annulus and with the cross-section in the shape of an antiparallelogram 24, the rotor 1 with the supply of material is then equipped with two rows of working bodies 11 in the shape of an annulus with a trapezoidal cross-section (see Fig. 4). The trapezoidal cross-section of the working bodies creates with the surface of the counter-rotating rotor the function of an asymmetric convergent-divergent nozzle, and the width of the working bodies, or where applicable the length of the base of the trapezoidal cross-section reduces towards the perimeter by 10% in each successive row, but the height of the working bodies towards the rotor perimeter remains unchanged and is always 27.5 mm. The diameter of both rotors that counter-rotate is 820 mm and each rotates with the peripheral speed of 115 m/s. On the surface of the rotors as well as working bodies concave compression chambers 17 are fitted, see Fig. 8, the size of which reduces towards the perimeter of the rotors but the total volume of the chambers on the surface of the rotors between individual annuli remains constant. The diameter of the first annulus is 600 mm and the base with the trapezoidal cross-section has a length of 50 mm. The diameter of the second annulus is 650 mm, the diameter of the third annulus is 700 mm, the diameter of the fourth annulus is 740 mm, and the diameter of the fifth annulus is 770 mm. The vacuum ensuring the supply of the treated material with air between the rotors is provided by a row of 60 working bodies with the function of accelerating fan blades 13, arranged at the external perimeter of one of the rotors so that they form a circular row with the diameter of 810 mm. The accelerating blades form an angle α 16 = 32° with the tangent to the rotor perimeter in the point of installation of the blade. This treatment results in blended cement in which blast-furnace slag is fully replaced by recycled bottle or window glass.

Example 4: Production of a fertilizer or fertilizer components with long-term extractability.

[0049] A mixture of rock materials rich in biotite, dolomite, and phosphorite, coarsely ground to grain size not exceeding 200 μm is mixed with air in the mixing chamber of the Venturi tube in the quantity of 2.4 kg/m^3 and supplied between two parallel counter-rotating rotors 1 at a perpendicular distance of 36 mm of the double-rotor counter-rotating high-speed mill, which has a diameter of 800 mm, equipped with the input basket 24 and with the peripheral speed of each of the rotors being 90 m.s^{-1}, where the first row of working bodies with the diameter of 500 mm is arranged on the rotor that is opposite to the inlet rotor and is provided with 32 massive blades in the shape of prisms 13, the longitudinal axis of which forms an angle 32° with the radial in the point of installation of each of the blades, to accelerate the mixture of air and grains of the solid substance material and its even distribution in the working space; the three additional rows are arranged as working bodies 11 in the shape of an annulus with the cross-section in the shape of an antiparallelogram on both rotors (see Fig. 5 and 9), the cross-section of which with the surface of the opposite working bodies fitted on the counter-rotating rotor has the shape and function of a symmetric convergent-divergent nozzle. The first annulus installed opposite one another on both rotors have the diameter of 650 mm, the width of the base with a trapezoidal cross-section of 50 mm and the height of 16 mm, the second row in the shape of an annulus that are arranged one opposite the other on both rotors has a diameter of 700 mm, the width of the base with a trapezoidal cross-section of 50 mm and the height of 17 mm, the third row of working bodies in the shape of an annulus, installed opposite to one another on both rotors have the diameter of 750 mm, the width of the base with a trapezoidal cross-section of 40 mm and the height of 17,5 mm. On the surface of the working bodies in the shape of an annulus with a trapezoidal cross-section, concave chambers 17 facing the surface of the counter-rotating annulus are fitted, and the first row of the working bodies in the shape of an annulus with the cross-section in the shape of a antiparallelogram on the surface of the annulus fitted on each of the rotors 68 open concave chambers are created, and on the second row of the working bodies in the shape of an annulus with the cross-section in the shape of an antiparallelogram on the surface of the annulus on each of the rotors 94 open concave chambers are created, and on the third row of the working bodies in the shape of an annulus with the cross-section in the shape of an antiparallelogram on the surface of each of the rotors 166 open concave chambers are created. The last external circular row with the diameter of 780 mm that is arranged on the rotor counter-rotating with reference to the rotor with the supply of material into the working space and is formed by 50 working bodies with the shape and function of an asymmetric convergent-divergent nozzle 23 with the width of the inlet cross-section $\mathbf{d_1}$ = 30 mm and the width of the outlet cross-section $\mathbf{d_2}$ = 12 mm, where the shorter side of the nozzle has the length of 30 mm and the longer side of the nozzle has the length of 34 mm and the axis of each of the nozzles forms an angle 12° with the tangent to the circle of the row in the point of installation of the nozzle. By this treatment, powder K - Mg - P fertilizer is produced with a slow release of nutrients into soil.

Example 5: Grinding and activation of screen undersize material resulting from demolition concrete recycling.

[0050] The screen undersize material resulting from demolition concrete recycling with the grain size ranging from 0 to 2 mm, in which in particular the hydrated minerals of a binding material (so-called hardened cement paste) are accumulated, is preliminary refined in a double-cylinder mill to attain a grain size smaller than 0.1 mm and is mixed in the mixing chamber of the Venturi tube type with air in the quantity of 4.2 kg/m^3 and supplied between two counter-rotating rotors 1, each with the diameter of 800 mm and the peripheral speed of 110 m/s. One of the rotors is fitted with four circular rows of working bodies with the trapezoidal cross-section creating convergent nozzles 4 with the width of inlet cross-section $\mathbf{d_1}$ = 40 mm and that of outlet cross-section $\mathbf{d_2}$ = 12 mm, and the length of the nozzle $\mathbf{l_1}$ = 40 mm, while the first two rows include 30 working bodies 18 each and the second two rows include 40 working bodies 18 each. The opposite, counter-rotating rotor is fitted with two circular rows of working bodies - pins 18 in the shape of prisms, the wider base of which has the length of 10 mm and the shorter base of which has the length of 6 mm and with the height of 10 mm and which engage between the rows of the working bodies on the opposite rotor, where the first row with the diameter of 700 mm includes 90 working bodies, while the row with the diameter of 760 mm is fitted with 120 working bodies. This treatment generates a finely ground substance with pozzolana and potentially hydraulic properties suitable as an additive for concretes or as a component of blended cements, or where applicable as a component of the raw material intended for Portland clinker firing process.

Example 6: Very fine grinding of shale burnt at 850 °C.

[0051] Shale burnt at 850 °C, preliminary ground to attain a grain size not exceeding 0.15 mm is mixed in the mixing chamber of the Venturi tube type with air in the quantity of 4.6 kg/m^3 and the resulting mixture is supplied between two counter-rotating rotors 1 (see Fig. 11), each of which rotates with the peripheral speed of 115 m/s 1 and each of which has the diameter of 820 mm. One of the rotors is fitted with three circular rows of working bodies 13 with the function of accelerating compressor blades and the other, counter-rotating rotor is fitted with two circular rows with working bodies 14 with the function of decelerating blades in a way that the rows of working bodies engage with each other, and in the first circular row of accelerating blades, which has a diameter of 600 mm, 40 working bodies are fitted with the function of accelerating blades, in the second row with the diameter of 700 mm, 60 working bodies with the function of accelerating blades are fitted, while in the external row of accelerating blades, which has the diameter of 800 mm, 90 working bodies with the function of accelerating blades are fitted. In the first row of decelerating blades with the diameter of 650 mm, 52 working bodies with the function of decelerating blades are fitted and in the second row of decelerating blades with the diameter of 750 mm, 76 working bodies with the function of decelerating blades are fitted. The working bodies 13 with the function of accelerating blades in the first row, fitted on the first rotor, form an angle α 15 = 32° with the tangent of the circle of the row in the point of their installation, the working bodies 14 with the function of decelerating blades fitted in the first circular row on the counter-rotating rotor form an angle β 16 = 65° with the tangent of the circle of the circular row in the point of their installation, the working bodies 13 with the function of accelerating blades, fitted in the second circular row on the first rotor form an angle α 15 = 45° with the tangent of the circle of the circular row in the point of their installation, the working bodies 14 with the function of decelerating blades fitted in the second circular row on the counter-rotating rotor, form an angle β 16= 56° with the tangent of the circle of the row in the point of their installation and the working bodies 13 with the function of accelerating blades fitted in the third (external) circular row of working bodies on the first rotor form an angle α 15 = 42° with the tangent of the circle of the row in the point of their installation. This treatment results in the material with super-pozzolana properties, suitable as a component for blended Portland cements, or a component for concrete limiting the risk of alkaline reaction of aggregates (even if unsuitable aggregates are used), or as a basis for demanding geopolymeric products.

[0052] The principal methods of industrial applicability are disclosed in the previous paragraphs.

Claims

1. A method of treatment of solid substances, according to which a loose solid substance with an input grain size not exceeding 0.2 mm is mixed with flowing gas, **characterized in that** the grains of such a loose solid substance are dispersed in the flowing gas in a quantity of 0.15-8.5 kg/m^3 of gas to create their mixture; the mixture is then supplied into a confined space having the shape of a solid of revolution where working bodies rotate at a speed of at least 50 m/s around the axis of this space, and in this confined space the mechanical energy of the working bodies transforms into the kinetic and pressure energy of the mixture, and this mixture is compressed into up to 70% of its original volume and then it is made to perform a turbulent flow by a quick change in the direction of the mixture flow and/or by the expansion of the mixture into a volume at least by 30% larger than its volume during moulding to ensure mutual collisions of also very fine grains of the loose solid material in the mixture at great angles and to make their collisions with the working bodies more effective to attain the intensive disintegration and mechanical activation thereof.

2. The method of treatment of solid substances according to claim 1, **characterized in that** the flow of the mixture is canalized by its supply into a confined tapered space where the mixture is adiabatically compressed at least once more, and then the flow of the mixture is accelerated to the greatest extent in the place of the smallest cross-section of the confined tapered space to attain the value of the critical speed of flow and then the mixture is made to flow turbulently using a working body by a change in the direction of the flow of the mixture and/or by the expansion of the mixture to a space that is by at least 30 % larger behind the discharge from the tapered confined space.

3. The method of treatment of solid substances according to claim 1 or 2 **characterized in that** the mixture is supplied into a confined tapered space for acceleration, then it is let to expand in a gradually extending confined space, by which the mixture is accelerated up to speeds exceeding the critical speed for additional increase in kinetic energy of the mixture and the mixture is subsequently made to flow turbulently by a change in the direction of the mixture flow and/or by expansion of the mixture into a space, larger by at least 30% behind the outlet from the gradually extending confined space.

4. An equipment for treatment of solid substances with input grain size not exceeding 0.2 mm, **characterized in that** it comprises a mixing chamber with the supply of dry loose solid substance, two opposite rotors (1), of which at least one rotates with the peripheral speed of at least 80 m/s with reference to the other one, with the supply (3) of the mixture of gas and solid substance connected to the mixing chamber with the outlet facing the centre of the rotors (1), where at least one of the rotors (1) is fitted with a group of working bodies designed as confusers (4) and/or convergent nozzles (5) and/or convergent-divergent nozzles (6) for fast dynamic compression of the mixture into no more than 70% of the original volume and to canalize and accelerate its flow, and the working bodies are arranged in at least one concentric circle with the centre in the centre of the rotor (1), where behind each of the working body, an expansion space (12) is arranged to generate a turbulent flow of the mixture.

5. The equipment according to claim 4, **characterized in that** at least one of the rotors (1) is fitted with working bodies forming a confuser (4) and/or convergent nozzle (5) and/or convergent-divergent nozzle (6) arranged in at least two concentric circular rows with the centre in the centre of the rotors (1) that describe a circle during their movement around the centre of the rotor (1), while the axis of the confuser (4) and/or convergent nozzle (5) and/or convergent-divergent nozzle (6) created by the working bodies forms an angle γ (20) ranging between 0 and 25° with the tangent of the respective circle in the point of installation of the working body on the rotor (1).

6. The equipment according to claim 4, **characterized in that** at least on one of the rotors (1) the working bodies are arranged in at least two circular rows with the centre in the centre of the rotors (1), describing during their movement around the centre of the rotor a circle, and forming at least one asymmetric confuser (7) or a bevelled nozzle (8), the axis of which forms an angle γ (20) ranging between 0 and 25° with the tangent of the respective circle in the point of installation of the working body on the rotor (1).

7. The equipment according to any of claims 4 to 7, **characterized in that** the working bodies forming confusers (4) and/or convergent nozzles (5) and/or convergent-divergent nozzles (6) are fitted at their outlet with ejector adapters (9), the axes of which are identical or parallel to or form an angle δ (21) not exceeding 15° with the direction of the axes of the working bodies.

8. The equipment according to any of claims 4 to 7, **characterized in that** in the axis behind the outlet from the working bodies forming a confuser (4) or a nozzle, is positioned, at a distance corresponding to no more than 2/3 of the length of the confuser (4) and/or the convergent nozzle (5) and/or the conver-

gent-divergent nozzle (6) created by the working bodies, a pin (10), the axis of which is perpendicular to the plane of the rotor (1) and the widest dimension in the section parallel to the plane of the rotor (1) of which corresponds to no more than the width of the inlet opening created by the working bodies of the respective confuser (4), convergent nozzle (5) or convergent-divergent nozzle (6), behind which it is placed to create a very intensive turbulent flow and/or to canalize the flow of the mixture of gas and treated substance.

9. The equipment for treatment of solid substances with grain size not exceeding 0.2 mm, **characterized in that** it includes a mixing chamber with the supply of gas and with the supply of dry loose solid substance, two rotors (1) facing one another; the mixing chamber is fitted with the supply (3) of the mixture of gas and solid substance (1), where at least one of the rotors (1) is fitted with a working body formed as a barrier (11) in the shape of an annulus, and in the plane perpendicular to the surface of the rotor (1), which passes through its centre, the working body has a trapezoidal cross-section, with the longest side creating the base of this working body, and this working body creates, together with the surface of the counter-rotating rotor or with the surface of the neighbouring working bodies fitted accordingly on the counter-rotating rotor a confuser (4) and/or a convergent nozzle (5) and/or a convergent-divergent nozzle (6) to ensure the compression of the mixture, and behind each of the working bodies, expansion space (12) with the volume providing the expansion of the mixture is arranged.

10. The equipment according to any of claims 4 to 9, **characterized in that** the surface of at least one of the rotors (1) or working bodies arranged as an annulus (11) is provided with open expansion chambers (17) having a concave shape to provide a very intensive turbulent flow in the confined space caused by the expansion of the mixture and by the movement of these chambers around the centre of the rotor.

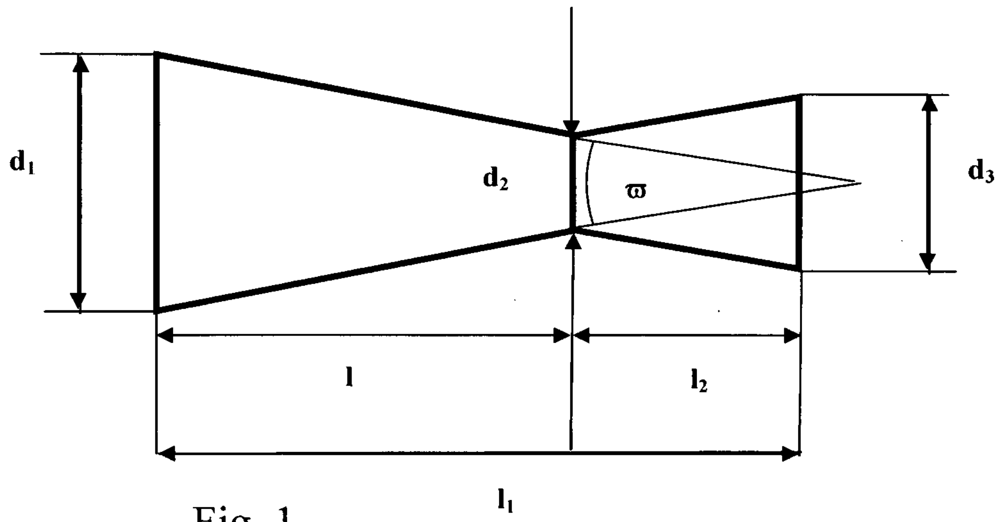
11. The equipment according to claim 10 **characterized in that** the expansion chambers (17) have different shapes and/or volume and being fitted on the rotor (1) in at least two concentric circular rows, they have their volumes that are decreasing for every individual chamber (17) in every following row towards the rotor perimeter, while the total volume of the chambers in each row differs from the total volume of the chambers in the previous row by no more than 30%.

12. The equipment for treatment of loose solid substances, **characterized in that** the compression of the mixture of treated substance and gas is performed by the working bodies fitted on the rotors in various shapes with the function of rotary compressor blades that are fitted in at least two rows forming concentric circles with unequal diameters with the centre of the rotors, so that the working bodies in the row that is closer to the centre of the rotors have the function of accelerating blades (13) that accelerate the flow of the mixture away from the centre of the rotors towards their perimeter and the longest dimension of which in the section parallel to the rotor surface forms an angle α (15) ranging between 5 and 75° with the tangent of the circle of the respective row in the point of installation of the working body in the direction of movement of the working bodies, while the working bodies in the following row with a larger diameter are arranged on the opposite rotor as decelerating blades (14) to decelerate the flow of the mixture away from the centre of the rotors towards their perimeter, and the longest dimension of the working bodies formed as decelerating blades in the section parallel to the surface of the rotor forms an angle β (16) ranging between 5 and 75° with the tangent of the circle of the respective row in the point of installation of the working body in the direction that is opposite to that of the working bodies to compress the mixture of the treated substance and gas between these rows of working bodies associated with a turbulent flow and to provide expansion volume outside the row of the working bodies with a larger diameter allowing the intensive disintegration of the grains of the treated substance.

13. The equipment according to any of claims 4 to 12, **characterized in that** at the perimeter of at least one of the rotors at least two accelerating blades (13) are arranged that form an angle ranging from 10° to 90° with the tangent of the rotor perimeter in the point of their installation on the rotor to provide and control the speed of flow of the mixture of gas and solid substance and to control pressure in the working space between the counter-rotating rotors.

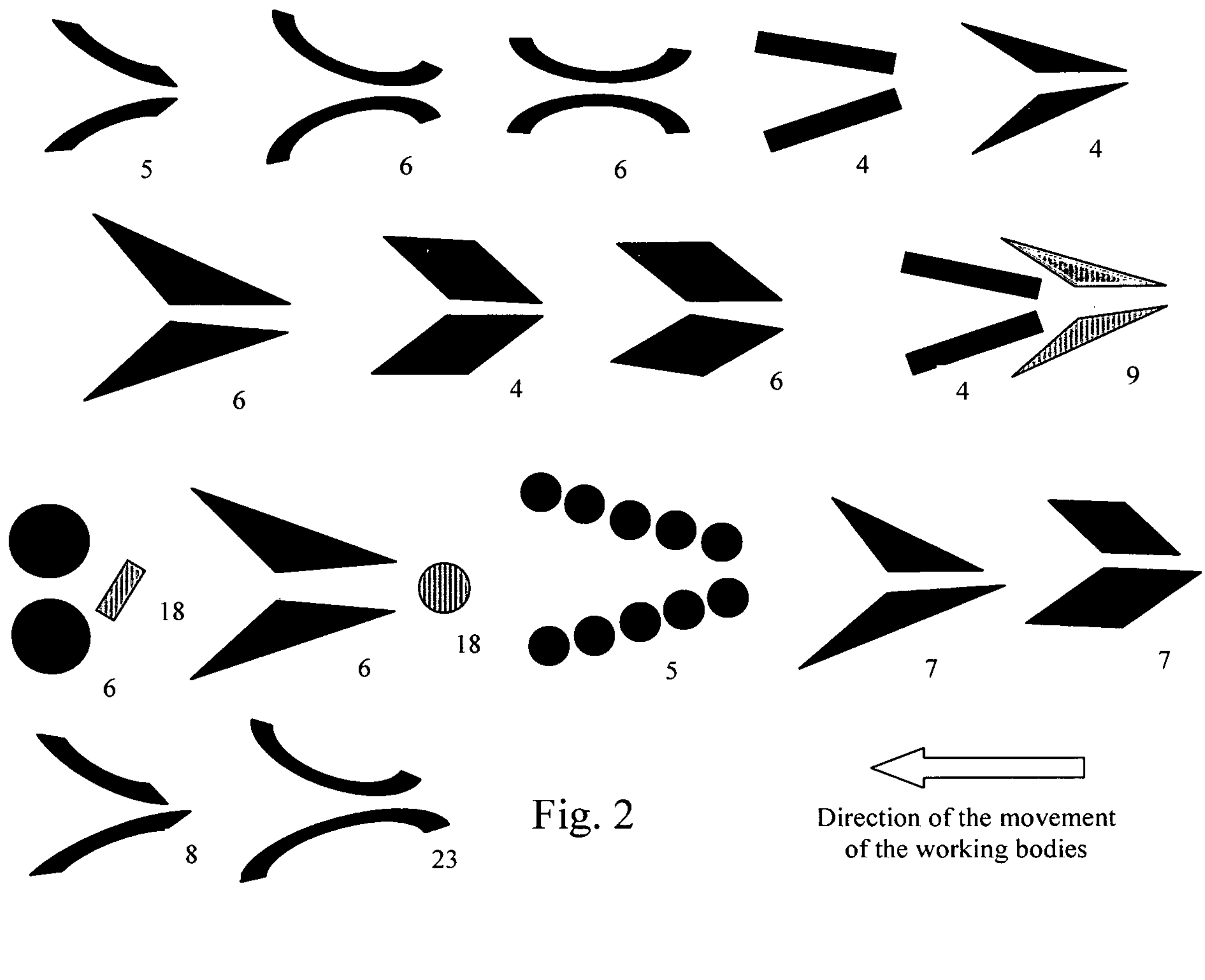
14. The equipment according to any of claims 4 to 12, **characterized in that** the canalization, dynamic compression and acceleration of the flow of the treated substance and gas and its subsequent turbulent flow is provided by the working bodies fitted on the rotors in at least three rows forming concentric circles with unequal diameters with the centre of the rotors, so that the working bodies in the row with the smallest diameter and in the row with the largest diameter, the number of which is equal in each of these rows, are fitted on one rotor in a way that the two nearest working bodies from each of these rows are arranged as a confuser (4) or a convergent (5) or a convergent-divergent nozzle (6) to accelerate the flow and to ensure the fast dynamic compression of the mixture into the maximum of 70% of the original volume and between these rows on the opposite rotors a circular row of the working bodies is arranged that has the character of pins (18) in the shape of cylinders, semi-cylinders, triangular or multiangular prisms or connecting pieces of these shapes that move with reference to the nozzles at the speed of at least 80 m/s.

15. The equipment according to any of claims 4 to 12, **characterized in that** the working bodies and shaped compression chambers disclosed in the aforementioned patent claims are mutually combined and the working bodies disclosed in the previous patent claims can also be combined within one row of the working bodies having the shape of a circle with the centre on the axis of rotation of the rotors.



d_1
d_2
ϖ
d_3
l
l_2
l_1

Fig. 1



5
6
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23
Direction of the movement
of the working bodies

Fig. 2

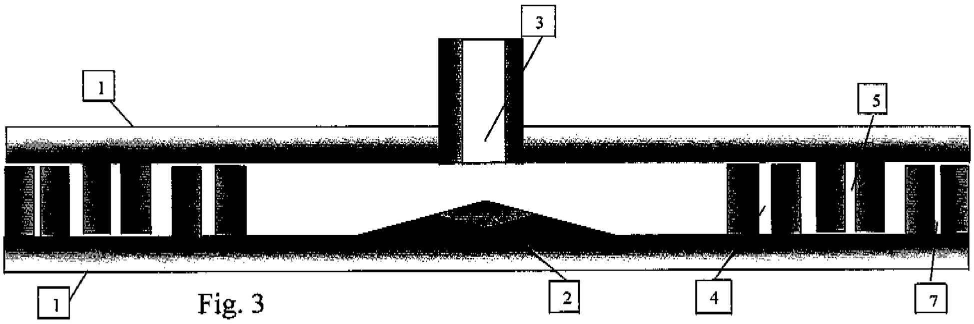

Fig. 3

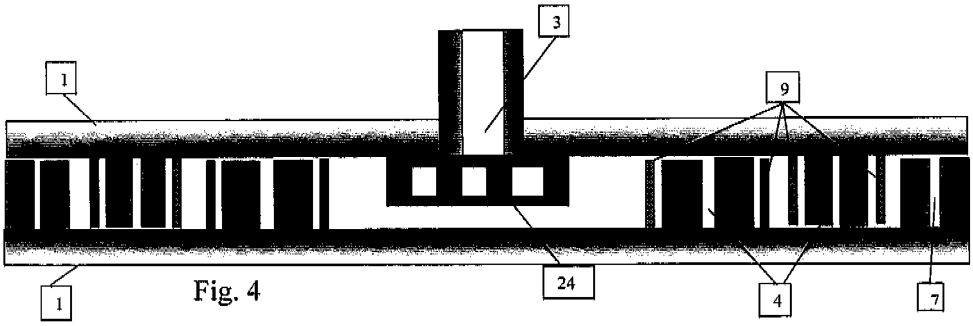

Fig. 4

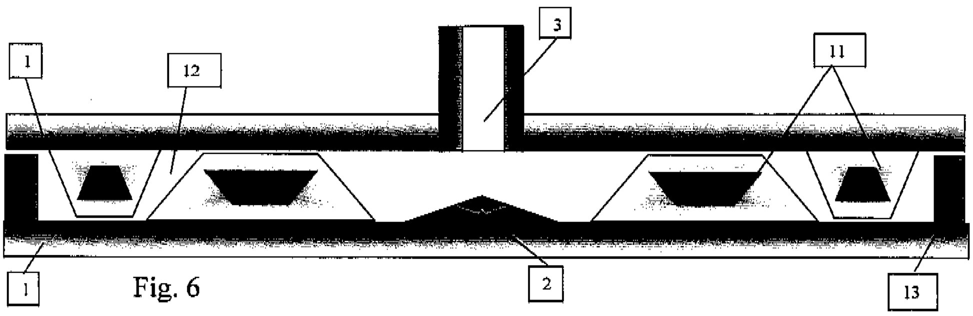

Fig. 6

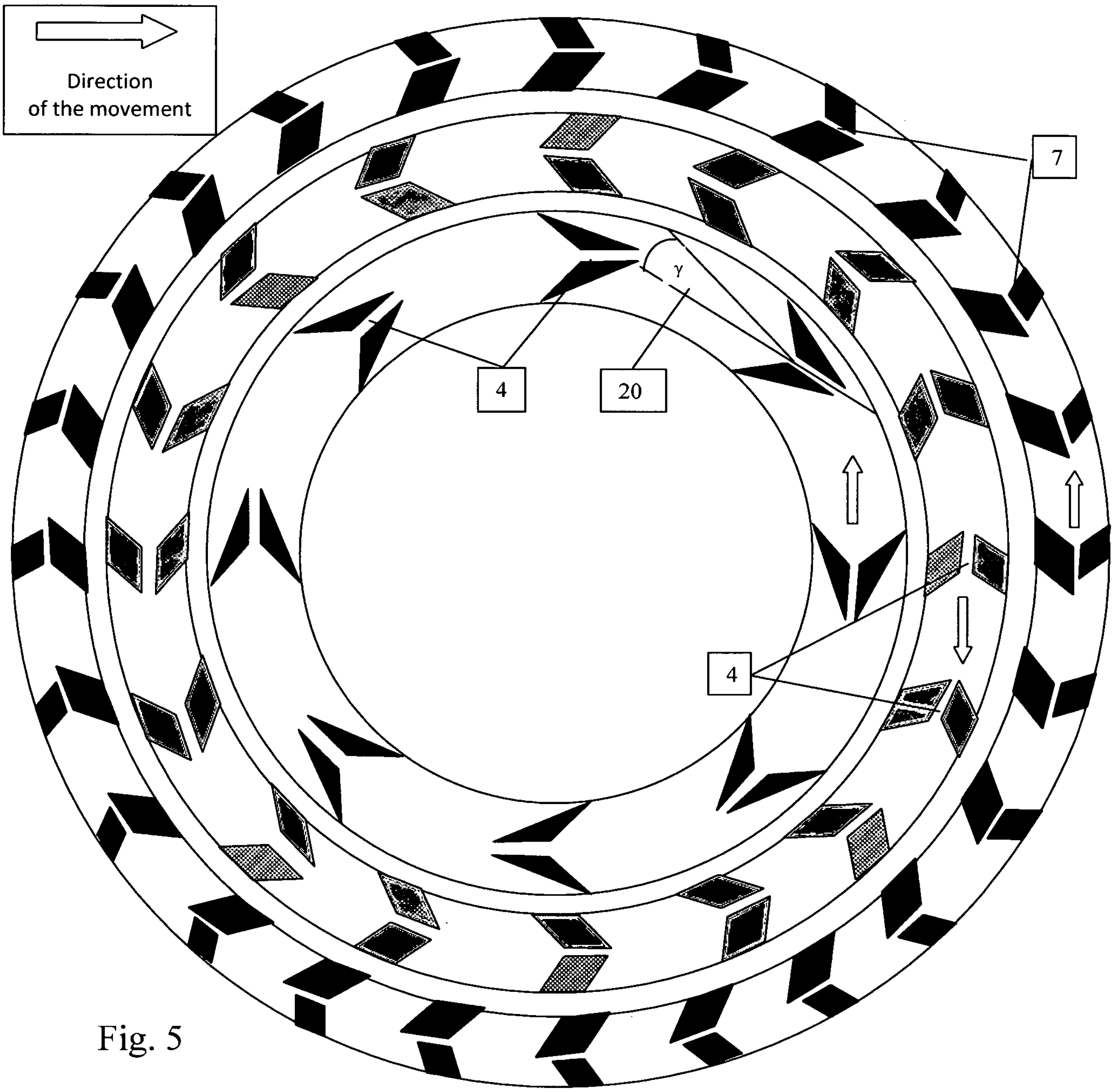

Fig. 5

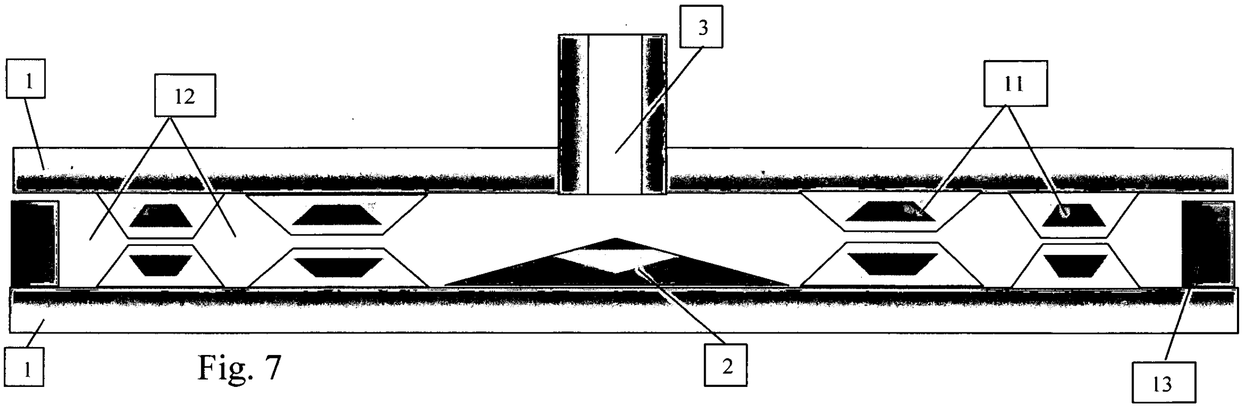
1
12
3
11
1
2
13

Fig. 7

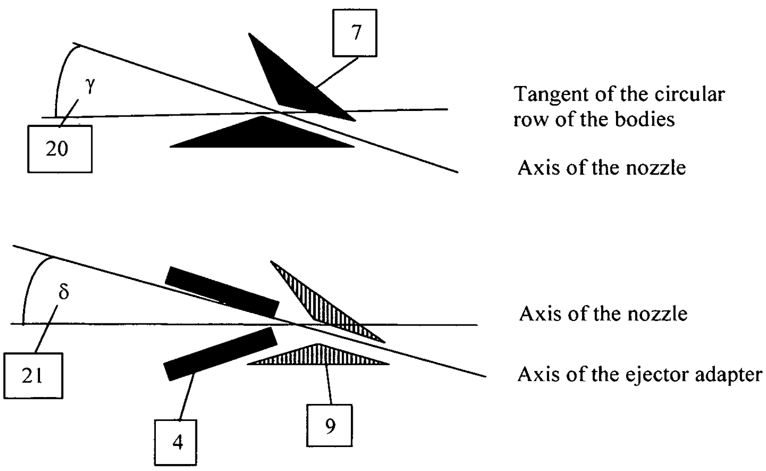
γ
7
20
Tangent of the circular row of the bodies
Axis of the nozzle
δ
21
4
9
Axis of the nozzle
Axis of the ejector adapter

Fig. 12

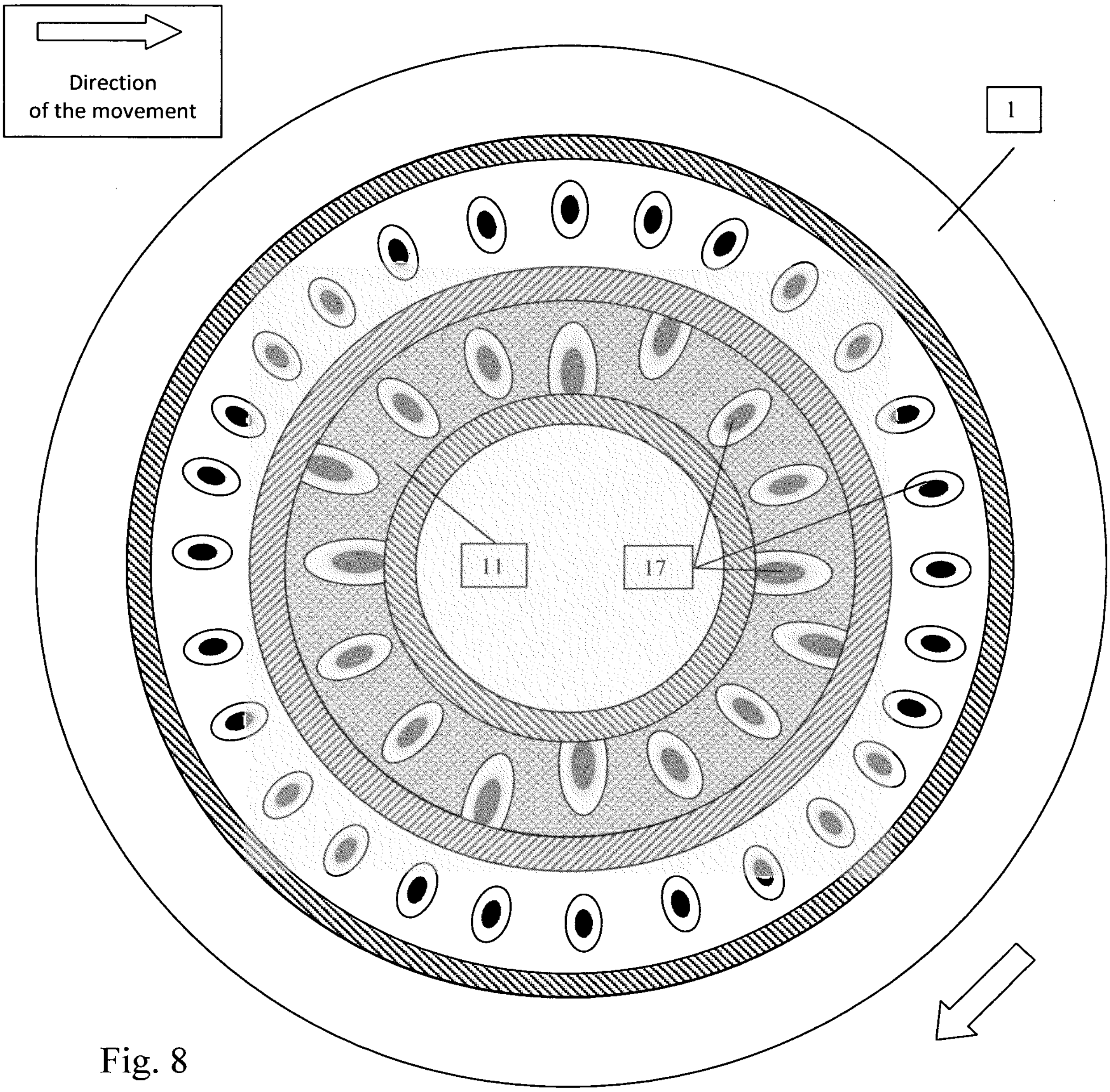

Fig. 8

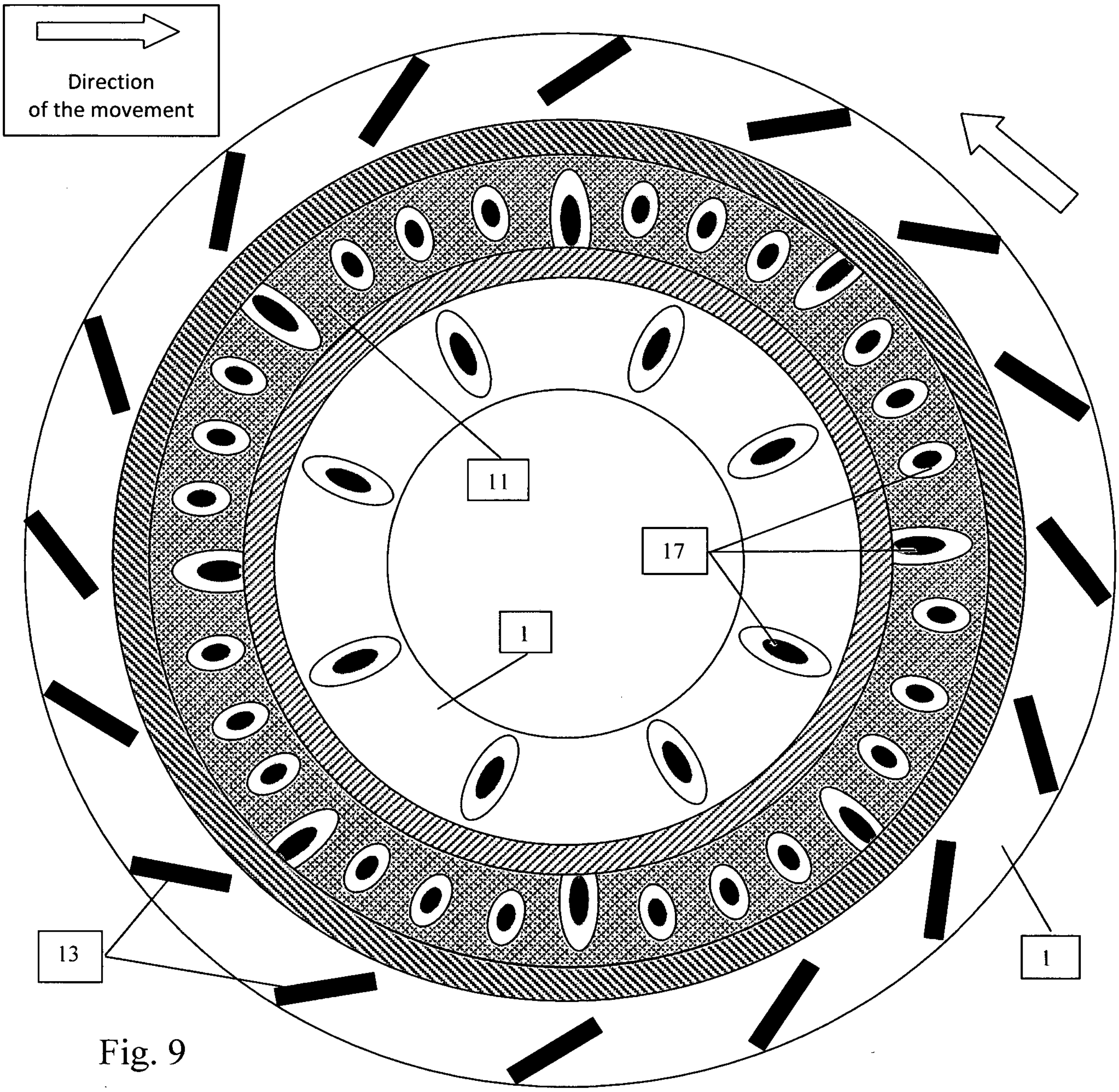

Fig. 9

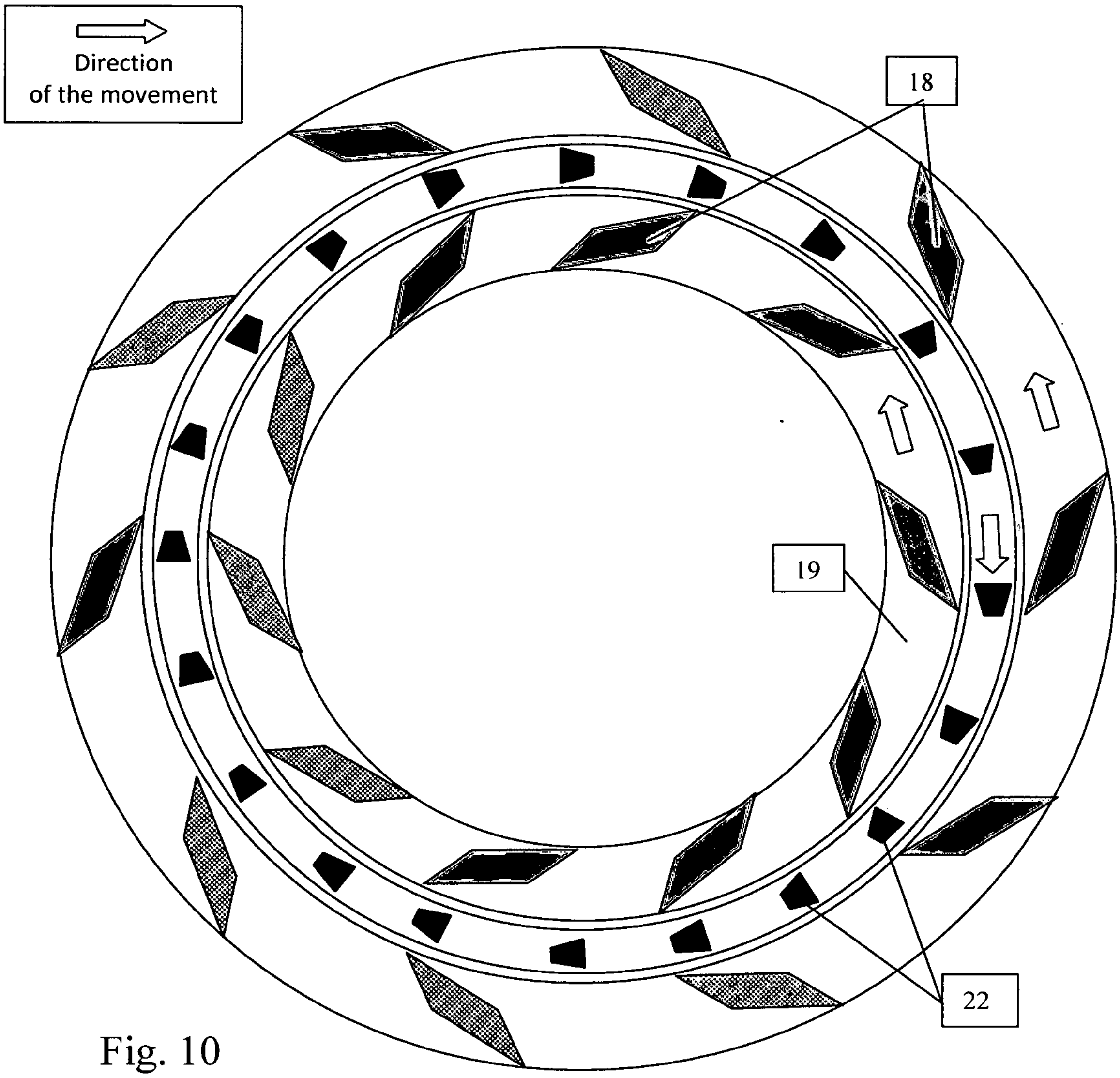

Fig. 10

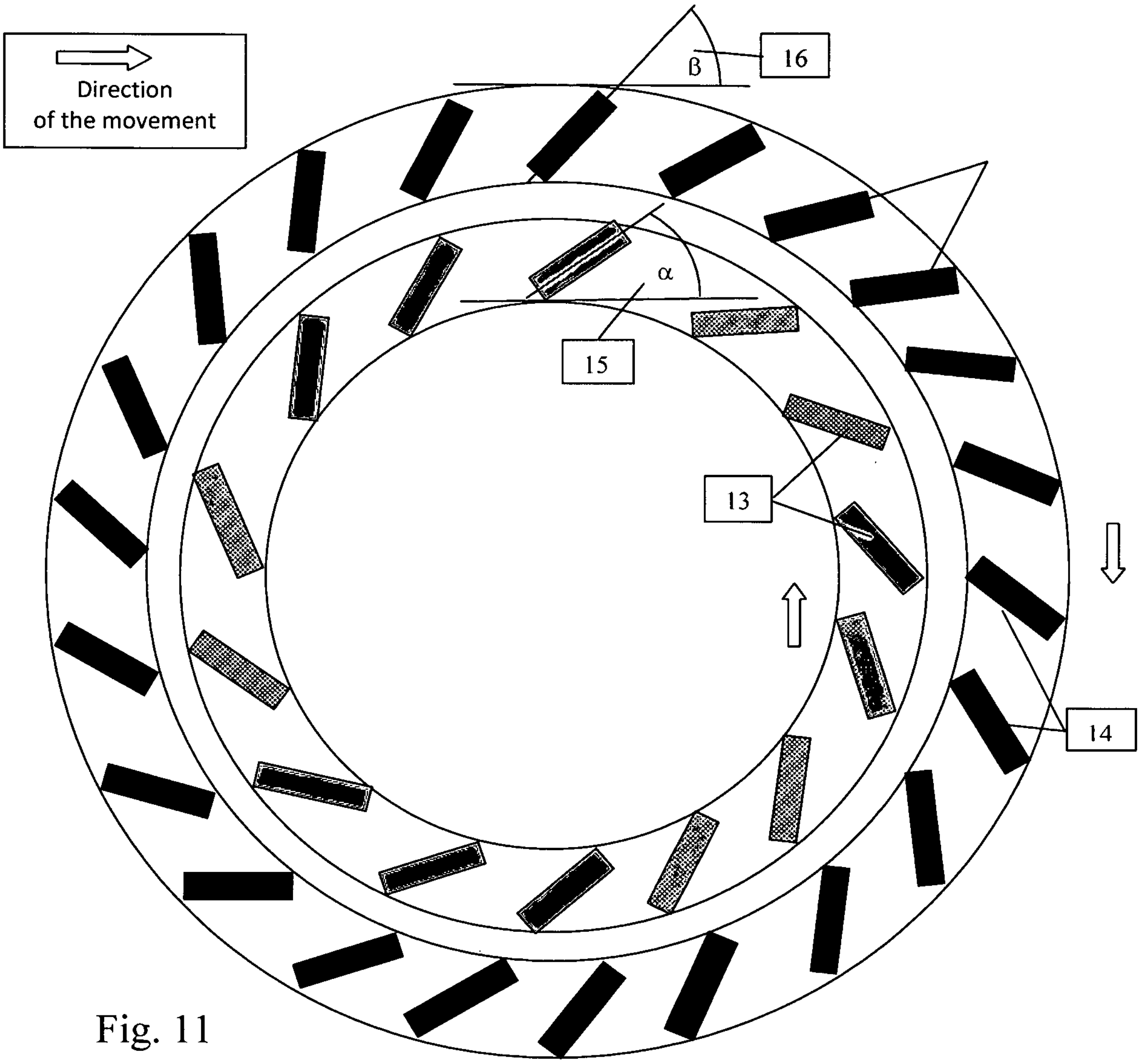

Fig. 11

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EUROPEAN SEARCH REPORT

Application Number
EP 19 46 6007

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 1 772 974 A (ALBERT WHITE WILLIAM) 12 August 1930 (1930-08-12) * page 1, line 100 - page 2, line 52; figures 4,5 * -----	12-15	INV. B02C13/20 B02C13/22 B02C13/24 B02C13/28
X	WO 99/51352 A1 (KONTYAEV ALEXEI VYACHESLAVOVIC [RU] ET AL.) 14 October 1999 (1999-10-14) * page 3, line 28 - page 5, line 21; figures 1,2 * -----	4	
A	WO 2012/025770 A2 (CREOGEN D O O [HR]; LELAS ANTONIO [HR] ET AL.) 1 March 2012 (2012-03-01) * page 3 - page 4; figures 1-6 * -----	1-15	
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TECHNICAL FIELDS SEARCHED (IPC)

B02C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	14 January 2020	Swiderski, Piotr

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