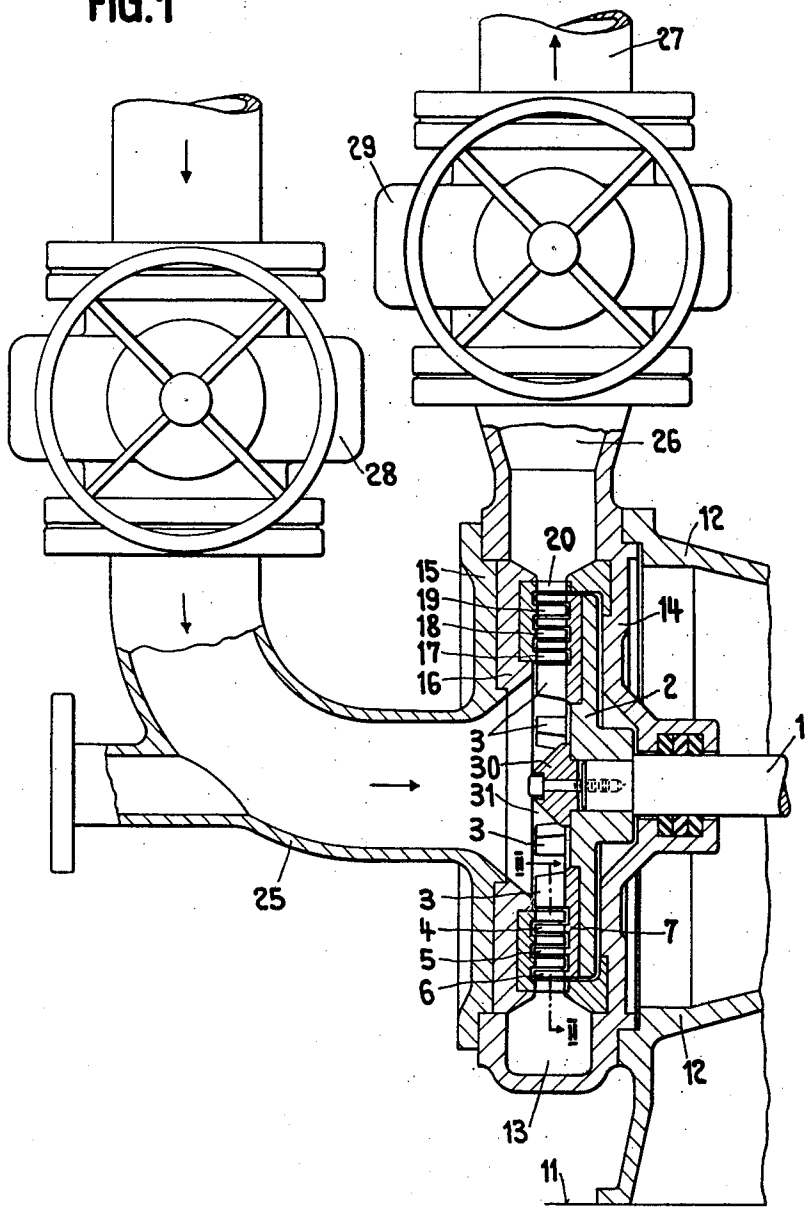
Nov. 6, 1962 P. WILLEMS 3,062,457

METHOD AND APPARATUS FOR SUBJECTING MATERIAL TO CYCLIC STRESSES AT HIGH FREQUENCY

Filed June 4, 1958 2 Sheets-Sheet 1

FIG.1



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Filed June 4, 1958 2 Sheets-Sheet 2

FIG.2

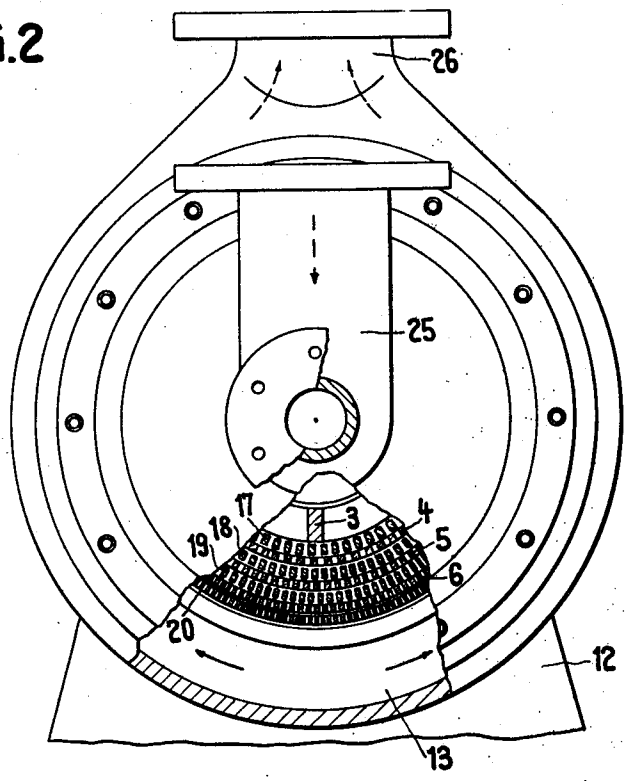
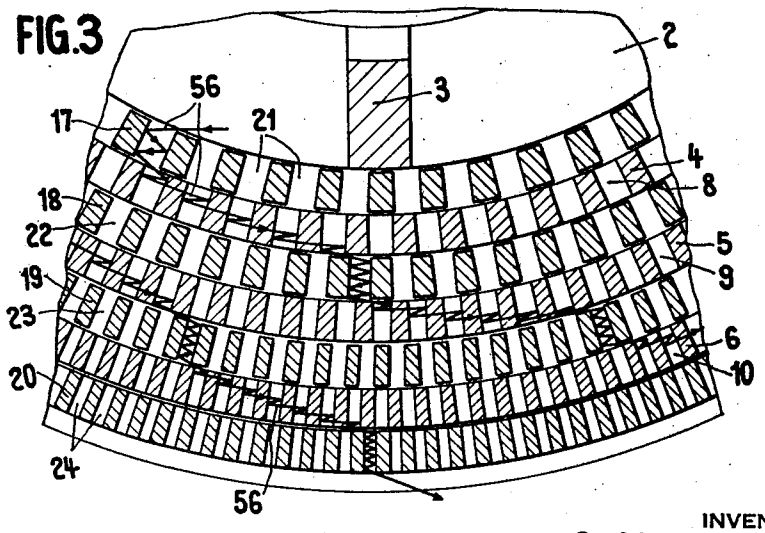


FIG.3



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METHOD AND APPARATUS FOR SUBJECTING MATERIAL TO CYCLIC STRESSES AT HIGH FREQUENCY

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8 Claims. (Cl. 241—1)

This invention relates to a method for changing the structure of gaseous, liquid or solid substances or mixtures of such substances, also of fibrous and elastic agglomerations of materials in a continuous process by means of compounded physical and kinematic effects at frequencies within the acoustic range and up to high supersonic frequencies, for solving, mixing, atomizing, disintegrating, decomposing, pulping, fiberizing, homogenizing, and refining such substances and for initiating and carrying out chemical reactions and processes.

A known apparatus for dispersing, homogenizing, decomposing, pulping and fiberizing substances includes rigid disintegrating tools which rotate in opposite directions. The material treated is allowed to move unimpeded in a radially outward direction between the disintegrating tools. According to the method of this invention the material to be treated is distributed in continuous flow in a plurality of acoustic chambers which form a kinematic chain with the material contained therein. The material is forced through the acoustic chambers and subjected to oscillatory pulses at high frequency during its passage through the acoustic chambers.

This invention further relates to an apparatus for carrying out the above novel treating method, the apparatus being broadly characterized by a kinematically operating generator comprising acoustic treating chambers bounded by oscillating walls.

In a preferred manner of carrying out this invention the material is sequentially subdivided into a rapidly increasing number of elementary portions by relative displacement of the acoustic chambers at high velocity, whereby the particles of the material are gradually atomized. The particles of reduced size obtained in this manner are forced through the individual acoustic chambers of relatively small individual size (for instance 100 to 500 mm.^{3}) by positive pressure which is periodically applied at high frequencies and has to overcome counter pressures, the particles being thereby subjected to extremely high accelerations. The oscillatory pressure is exerted on the particles contained in the treating chambers at frequencies in the audio-frequency range and in the supersonic frequency range. Preferably, the particles are treated during their passage through the chambers for time intervals ranging from fractions of a second up to several seconds, and every particle is subjected either in a treating chamber, or when passing from one chamber to another, to oscillatory stresses increasing in frequency and intensity and to increasing acceleration. The particles of the material treated in any individual acoustic chamber are released in the direction of pressure increase in the chamber into another acoustic chamber through an opening which is periodically opened for a short time. This opening is so small and it is open for such a short time that passage of a particle from one treating chamber to another is accompanied by disintegration of the material to particle sizes in the order of microns or less, or until the individual fibers of a fibrous material such as cellulose are separated from each other. Pressure, acceleration, pulses and oscillations are generated, and the material is transferred from one chamber to another by forces set up in a kinematic chain consisting of the walls

of the acoustic treating chambers and the material treated in the chambers.

In addition to the primary sonic or supersonic pulses which are produced by movement of the walls of the chambers past each other, secondary pulses and waves are produced in the treating chambers by the oscillation of the walls. Thus, interference waves are produced within the material filling the acoustic treating chambers. The frequencies of the interference waves are much higher than the frequency of the primary pulses. When the material treated is practically enclosed in one acoustic chamber during a certain length of time and is prevented from flowing freely through the kinematic system, the material is subjected to mechanical treatment in the acoustic treating chambers to an extent not known and not possible with the treating methods and treating apparatus known up to now.

Apparatus for carrying out the method according to this invention is shown by way of example in the attached drawings in which

FIG. 1 shows a side-elevational axial section of an embodiment of such apparatus having a horizontal generator shaft;

FIG. 2 is a front elevational view of the apparatus of FIG. 1, partially in section on line II—II; and

FIG. 3 is a view of a detail of FIG. 2 on a larger scale.

The generator shown in FIGS. 1 to 3 is adapted for operation at high sonic and supersonic frequencies. It has a rotor **2** fixed on a horizontal shaft **1**. The rotor carries an inner annular row of vanes **3** for centrifugal acceleration of the substances to be treated, and three annular rows of oscillating blades **4**, **5** and **6** mounted on an annular disc **7** fixedly inserted into the rotor **2**. The oscillating blades consist of steel, nickel, titanium, molybdenum, chromium or of alloys of such metals.

As best seen from joint consideration of FIGS. 1 and 3, the blades have their greatest dimension or length in the direction of the axis of the shaft **1**, and their radial width is substantially greater than their circumferential thickness. Their narrow longitudinal edges are approximately parallel to the axis of rotation. Each blade thus has the shape and the oscillating properties of a tine of a tuning fork, and its free end is adapted to oscillate preferentially in an approximately tangential path.

Circumferentially adjacent pairs of blades **4**, **5** and **6** define acoustic treating chambers **8**, **9** and **10** therebetween. The number of acoustic chambers having each a volume of 100 to 500 mm.^{3} increases from row to row in a radially outward direction. Row **4** has 72, row **5** has 124, and row **6** has 180 acoustic chambers **8**, **9** and **10** respectively. A conical cap **30** fixed on the shaft **1** projects into the central cavity **31** between the vanes **3**, whereby complete filling of the cavity **31** and proper guiding of the material are ensured. The cap **30** also prevents clogging of the cavity **31**.

A collecting conduit **13** surrounds the generator and is attached to the casing **12** of the generator by means of flanges **14** and **15**. The generator casing **12** is mounted on a supporting structure **11** in a manner not shown in detail. The flange **15** carries the stator **16** which has four annular rows of oscillating blades **17**, **18**, **19** and **20** similar to the rotor blades **4**, **5**, **6**, and made of a material capable of oscillation such as the above-mentioned metals or alloys. The row of stator blades **17** closely fits between the rows of rotor blades **3** and **4**, the row of stator blades **18** between the rows of rotor blades **4** and **5**, and so on.

When the rotor **2** turns, the rows of rotor blades move past the rows of stator blades without normally touching them. Each pair of circumferentially adjacent stator blades **17**, **18**, **19**, **20** defines an acoustic treating chamber

21, 22, 23, 24 of 100 to 500 mm.³. In the embodiment shown in FIGS. 1–3, row 17 has 60, row 18 has 90, row 19 has 168 and row 20 has 200 acoustic treating chambers. The surfaces of the stator and rotor carrying the blades are parallel. If the distance between the faces carrying the blades increases in a radially outward direction, the volume of the acoustic chambers and the axial length of the blades will increase towards the periphery. Due to this increase in volume, tearing of the material and cavitation are obtained when the material is conveyed towards the periphery of the rotor.

The material to be treated is drawn in by the action of the vanes 3 in the central cavity 31 of the generator. The material is forced into the acoustic treating chambers under pressure and is disintegrated into fine particles. The feeding or pumping vanes 3 may be omitted and replaced by means located outside the generator, such as a pressure pump or a head of liquid upstream of the generator, or a suction pump downstream of the generator. Sufficient suction may also be created by the rotating rows of blades of the rotor.

In order to create pulses and oscillations propagated in the treating space in the manner of waves, and in order to obtain easy control of the dwell time of the material in the sound-generator, an inlet pipe 25 is connected to the ring shaped flange 15. The collecting conduit 13 has a discharge nipple 26 through which the material discharged from the acoustic treating chambers 24 may flow into a discharge pipe 27. A first control valve 28 arranged in the inlet pipe 25 and a second control valve 29 between the discharge nipple 26 of the generator and the discharge pipe 27 permit adjustment of pressure conditions in the generator. Instead of the valve 29 a standpipe may be connected to the generator outlet and open into a container located at a level above the generator. The counter pressure thus produced in the stand-pipe may be adjusted by providing alternative outlet openings at different levels.

The generator shown in FIGS. 1 to 3 may be modified in various manners. For instance, the longitudinal edges of the blades 4, 5, 6, 17, 18, 19, 20 may extend in coaxial conical surfaces. Relative axial displacement of the rotor and stator of the generator will then adjust the gap width between the rows of oscillating members. In a very small gap a rubbing and milling effect may be superimposed upon the effects of periodic high-frequency pressure variation. This is of great utility in treating fibrous materials. The radial distance between individual cooperating blades of the stator and rotor or between groups of such oscillating blades may be varied so that some of the oscillating members provide a milling and rubbing treatment whereas the remaining oscillating members advance the material through the apparatus. In this manner, an effect similar to that of a pug mill is obtained.

The operation and effect of the generator may be varied within a wide range by selecting the shape of the cooperating blades. A shearing effect is obtained by sharp edges of the cooperating oscillating members. If the edges are rounded off, a beating effect is obtained. When the leading faces of the blades are rounded off, or when the blades have a drop-shaped cross section with the rounding or the tip in the direction of rotation, working of thixotropic materials, such as cellulose dispersions of high concentration is substantially facilitated. It has been found that the apparatus of this invention can produce dispersions of cellulose up to concentrations of 10% and more.

In order to obtain such favorable results not feasible with known apparatus, the generator is preferably so constructed that the innermost row of oscillating blades encloses relatively large chambers between adjacent blades, such particularly large chambers being able to receive the lumps of the cellulosic substance as it is fed from a preliminary digester directly to the generator. The material is transferred by the oscillating blades under high pressure to the acoustic chambers between the outwardly adjacent oscillating blades. The outer row has a greater number of acoustic chambers. A third row of oscillating blades and acoustic chambers has a still greater number of acoustic chambers. The number of concentric rows of alternating blades and acoustic chambers may be increased as desired in order to obtain the required results and the required degree of disintegration of the material treated.

Since the thickness of the blades decreases from row to row towards the periphery of the generator, the natural frequency of oscillation of the blades changes correspondingly. The action of the blades is comparable to that of a multiple tuning fork. The oscillations of the blades are excited by the blades of adjacent rows passing closely at high relative velocity. The acoustic chambers between the oscillating blades are analogous to a whistle, and more particularly to a Galton pipe.

The apparatus has many acoustic chambers and may theretofore be termed a Galton-organ, wherein the acoustic chambers of the different rows are arranged concentrically, or approximately concentrically, and wherein the frequency varies from row to row in accordance with the dimensions of the oscillating blades, their natural frequencies, and the widths of the acoustic chambers. The material flowing intermittently outward through the apparatus from the innermost row of acoustic chambers is treated by pulses created by the meeting or crossing of the oscillating blades and acoustic chambers of one row with the oscillating blades and acoustic chambers of one or two adjacent rows, the frequency of the pulses depending on the number of meetings or crossings per unit time.

As will be explained below the pulses have very high specific intensity. The intensity of the pulses depends primarily on the total energy supplied to the generator, on the number and the distance of adjacent acoustic chambers of the same row of oscillating blades, and on the total number of oscillating blades and acoustic chambers of the generator. A row which encircles a smaller row of oscillating blades and acoustic chambers and has narrower acoustic chambers and thinner blades than the smaller row, produces pulses at a higher frequency. The material outwardly flowing through the apparatus is thus subjected to pressure variations at increasing frequencies, and very high supersonic frequencies may be obtained as illustrated in the numerical example given below.

In this example the apparatus according to the invention has three rows R_1, R_2, R_3, of oscillating members and acoustic chambers on the rotor and three similar rows St_1, St_2, St_3 on the stator, as follows:

	R_1	St_1	R_2	St_2	R_3	St_3
Inner diameter, mm	140	190	209	226	245	262
Outer diameter, mm	189	208	225	244	261	280
Outer circumference, mm	594	653	707	767	820	880
Number of acoustic chambers	6	60	72	90	124	168
Circumferential width of acoustic chambers, mm	------	6	5	4	3	2.2
Circumferential thickness of blades, mm	12	4.88	4.82	4.52	3.6	3.04
Total cross section of chambers in cm.²	------	54	54	54	54	54
Frequency, kilocycles per second	------	18	216	324	558	1,041.6

NOTE.—Total chambers 520. Frequency 2,157,600. Speed n=3,000/min. Mean opening period of chambers 1/600 sec.

The physical effects occurring in the apparatus and explained below may occur simultaneously or separately.

(1) *The effect of periodically varying pressure on the material in the acoustic chambers.*—The primary sonic or supersonic oscillatory pulses produced by the meeting or crossing of the blades of adjacent rows as the shaft 1 rotates, are propagated in a radial direction in the acoustic chambers which are substantially radially disposed about the axis of the apparatus. The frequency of the oscillations is determined by the frequency of meetings or cross-

ings of blades. In an aqueous liquid, the pulses are propagated at a velocity of about 1500 m./sec. Simultaneously, secondary waves of frequencies up to supersonic frequencies are produced in the acoustic chambers by the vibrations of the oscillating blades adjacent the acoustic chambers. Such secondary waves travel transversally to the radial direction, that is in a tangential or circumferential direction, through the acoustic chambers and through the material contained in the chambers at a velocity also of the order of 1500 m./sec. The frequency of the secondary waves is primarily determined by the natural frequency of the oscillating blades.

The sound waves emitted from one oscillating blade bounding an acoustic chamber are reflected by the opposite oscillating blade in the same acoustic chamber. Thereby interference waves are set up in the acoustic treating chambers the frequency of which is often very much higher than the natural frequency of the oscillating members. The frequency of two secondary waves emitted by adjacent oscillating blades enclosing an acoustic chamber and propagated in opposite directions is increased by the crossing and interference of such waves, while the amplitude of the interference wave decreases as the frequency increases.

In order to obtain maximum treatment of the material by the pulses and oscillations occurring in the acoustic chambers, the material is retained in the chambers for a short time interval (for instance during $\frac{1}{140}$ sec.) by the oscillating blades of an adjacent row which intermittently block the chamber openings. Even when closing is not complete, the radial movement of the material is suddenly braked or its speed broken whenever the material flows from one acoustic chamber to another one. If the material is held in the chambers of FIGS. 1 to 3 for $\frac{1}{140}$ sec., the opening period during which the material is allowed to flow out of the chambers is of the order of $\frac{1}{600}$ sec. Consequently, only extremely small quantities, a few mg. at a time, can pass during each opening period into the next chamber, and are discharged from the chambers and disintegrated.

The stream of material from one row of chambers is broken by the oscillating blades of the next outer row, and the material is not only subjected to the above mentioned pulses and oscillations within the chambers but the material is further subjected to cavitation effects which increase with increasing diameter of the rows whenever passing from one chamber to another. By the temporary containment of the material in a chamber formed by vibrating walls, the material can pass into a chamber of the next outer row of oscillating blades and acoustic chambers only after being transported over a certain circumferential distance in the first chamber. During its passage through the apparatus, the material travels along a spiral of successive stages **56** (FIG. 3). The pitch of each stage corresponds to the radial advance of the particles contained in the chamber during one opening period of the chamber (that is $\frac{1}{600}$ sec. in the example referred to above) whereas the peripheric advance of the particles in one chamber of the rotor is a function of the circumferential velocity and of the rate of radial advance of the substance. This radial advance is controlled by flow control at the inlet and/or outlet of the apparatus, as explained above.

With a suitably high number of oscillating blades and with sufficiently high rotating speeds, frequencies of over 20,000 cycles per second, for instances frequencies of 1,000 to 10,000 kc. may be obtained. Further, by proper choice of the number of chambers and of the frequency of interaction between the oscillating blades, particles weighing but a few milligrams each may be produced in the chambers by high frequency pulses. The oscillations of the blades produced are transmitted to the material contained in the adjacent chambers. The sizes of the acoustic chambers and of the blades preferably decrease towards the periphery of the generator, and blades having the form of needles attached to the carrying rings may be used. The axial length of oscillating needle-shaped members of very small cross section may be very small. With oscillating members of the size of needles a disintegration of organic tissue material to individual cells is possible.

At the discharge end of the generator, the material may further be treated by pulses and waves of different frequencies, preferably in a space of concave surface, for instance of parabolic section. This concave surface may be made of a material such as steel, which has a suitable natural frequency for maximum reflection of pulses and waves. For good reflection, the surface may be given a mirror finish.

The gap width between the oscillating members may be adjusted in such a way that cellulose fibers of smaller size than the adjusted gap width are only subjected to oscillating pulses in the chambers, but the fibers are not sheared and consequently not damaged. However, if shearing of the fibers is desired, the gap width may be reduced to extremely small values.

(2) *The kinematic treatment.*—(*a*) With every oscillation of two oscillating blades, a small quantum of the material treated is forced into an acoustic chamber of the outwardly adjacent row. Within each acoustic chamber the velocity of this small quantum is suddenly increased. Assuming for instance that the combined flow section of the acoustic chambers is ⅓ of the total section of the row, the flow velocity of the small quantum of material is suddenly increased by a factor of three.

The overall flow velocity depends on the controlled inlet and outlet velocities. These may be adjusted by means of the control valve **29**. If the dwell-time of the material in the apparatus is increased by a factor of 10 by throttling the outlet, the dwell time of the material in the individual acoustic chambers is also increased by a factor of 10, provided that the total width of the chambers remains constant, for instance ⅓ of the circumferential length of the row of chambers. The volume of the quanta produced may be calculated from the radial velocity. The number of quanta produced per unit time equals the total frequency of the generator.

(*b*) A diffuse bouncing effect is produced by the material being thrown by one oscillating blade against the edge and the flanks of the oscillating blades of the next row. This diffuse bouncing effect is a function of the compound acceleration of the material, the tangential component of acceleration being a linear function of the rotating speed whereas the radial component of acceleration increases with the second power of the rotating speed.

(*c*) Multiple diffuse reflection due to the interaction of the above mentioned kinematic effects causes intensive turbulence within the acoustic chambers and effective homogenizing of the material.

(*d*) The multiple diffuse reflection causes intensive friction between particles and an increase in temperature within the generator, if the duration of the treatment is sufficiently long. The friction aids the disintegration of the material.

The flow section of the acoustic chambers, the thickness and the material of the oscillating blades, the number of the latter per row, the number of rows of oscillating blades and acoustic chambers, the diameter of the rows and the rotating speed may be selected to suit requirements. An increase of the distance between the oscillating members or blades of a row increases the volume of the acoustic chambers. The energy applied to the row is thereby increased, with a resulting increase of the amplitude of the acoustic waves in the chambers, but also with a reduction of the operating frequency. It is further possible to radially or peripherally perforate all or some of the oscillating members. This results in additional intensive oscillation produced by interference.

A generator according to this invention comprising six

rows of oscillating blades, namely three rows on the rotor and three rows on the stator, is able to disintegrate a 5% cellulose pulp to individual fibers in one passage through the generator. The cellulose is previously dissolved in a pulper and still contains 30 to 40% of fiber bundles. The single fibers obtained are practically undamaged. Paper and card-board produced from these cellulose fibers has a strength of more than 300% as compared to products made of conventionally disintegrated cellulose. The energy required for treating the cellulose with the method of this invention is smaller than the energy required for carrying out similar known methods.

By accurate measurements it has been found that the power consumption of the generator according to this invention in the examples set out above and described hereinafter is of the order of 40 kw. This total power corresponds to a power dissipation of 84 w. per oscillating member of the generator at a total operating frequency of 2,370,000 c.p.s. Such an output substantially exceeds the power output of piezoelectric, magnetostrictive, and other sound generators.

Examples of the Operation of the Apparatus

It is assumed in this example, that the acoustic treatment apparatus has four concentric rows of oscillating blades and acoustic treating chambers. The innermost of the rows has 24 blades and relatively wide treating chambers. The next row of blades which rotates relative to the first-mentioned row, has 100 members. The next row has 150 and the outermost and last row has 200 blades. The circumferential thickness of the blades and of the chambers changes in this embodiment from row to row and it is assumed that this thickness decreases from 10 mm. at the innermost row to 2 mm. at the outermost row. The difference in rotary speed between the rotor and stator or between two rotors is assumed to be 3000 r.p.m. From these data a total frequency of the generator of

$$\frac{[(24\times 100)+(100\times 150)+(150\times 200)]\times 3000}{60}$$

$$=2{,}370{,}000 \text{ cycles}$$

is obtained.

This total frequency of the generator of 2,370 kc. is transmitted throughout a liquid contained in the generator at a velocity of about 1,500 m./sec., and in solid particles at a velocity of up to 4,500 m./sec.

EXAMPLE 1

11 liters per second, or 40,000 liters of material per hour, are fed through the apparatus described above by the centrifugal accelerating effect of the generator itself. It is possible to regulate the flow in the system by manually or automatically operating valves.

The quantity of material of 11,000,000 mg. per second flowing through the apparatus is treated with 2,370,000 pulses. Since the pressure waves in the supersonic frequency range are propagated through the contents of the apparatus in all directions, each particle is subjected to acoustic treatment at a frequency of 2,370,000 cycles. Mixtures having a higher concentration of solid materials are treated more intensively in the apparatus of the invention than mixtures having a small content of solid material, because the velocity of propagation of acoustic waves in solid particles is about three times higher than in a liquid. It has actually been found by experiment that under similar treating conditions a 6% cellulose suspension is better homogenized than a cellulose suspension having a concentration of 2% only.

In the present example, a mixture of 20% kaolin with water is fed through the apparatus at the above mentioned flow rate. The initial particle size of the kaolin ranges between 20 and 1 mm. The larger particles are reduced by shearing, bumping, smashing, friction and cavitation to a size of the order of millimeters or less when they enter the inner row of relatively coarsely divided oscillating members and chambers. The mixture of water and kaolin is also subjected to the above described high frequency acoustic effects. Many experiments have shown that during a dwell time of one second the kaolin is comminuted by the apparatus to a particle size in the order of microns and is homogeneously suspended in the water.

EXAMPLE 2

Pulp of cellulose, pre-digested with water and obtained from non-sorted waste paper at a concentration of 5%, is fed to the apparatus after removal of dirt and metal particles. The feeding rate is controlled by manual or automatic regulation. The cellulose pulp is subjected to the above described kinematic effects and to the acoustic treatment.

The net capacity of the casing of the apparatus, allowing for the operating parts of the generator, is four liters. The cellulose pulp is continuously fed to the apparatus in the form in which it is obtained from a dissolver, pulper or the like. The flow rate is so adjusted that the contents of the apparatus are replaced every 0.36 second so that 40,000 liters per hour are fed to the apparatus.

It has been found in many experiments that during a dwell time of 0.36 second the particles, such as flakes, agglomerations of fiber bundles, or shives are completely disintegrated to individual fibers with complete reduction of shives. If a lower degree of digestion of the cellulose pulp or highly resistant shives must be taken into consideration, or when finer final distintegration is desired, the treatment may be intensified by recycling, by increasing the rotary speed of the apparatus, or by reducing the radial gap between the rows of blades.

EXAMPLE 3

This example stands generally for chemical reactions, and is concerned with a reaction between a base and an acid whereby a gel is formed.

Hydrated silica suitable as a filler for pigments, paper, rubber, or for use as a stabilizer for emulsions and mixtures of various kinds, is prepared as follows: A liquid alkali silicate such as water glass of the required concentration is fed into the apparatus through the main inlet pipe of the same. The feed rate of alkali silicate is controlled by a regulating valve. An additional inlet pipe coaxial with the main inlet pipe feeds an equivalent amount of acid into the apparatus. The delivery openings of the delivery pipes are near the central cavity for intensive mixing of the reagents. They are homogeneously distributed so that the desired chemical reaction and the formation of the hydrated silica takes place rapidly. By the use of the method of the invention silica of extremely fine particle size is obtained.

The size of the particles produced may be adjusted to the desired value by adjusting the flow rate in the generator. By suitable adjustment of the rotary speed of the rows of blades and of the dwell time of the material in the generator it is possible to obtain silica of the particle sizes required for the production of so-called "impalpable" silica powder.

Further inlet pipes for adding reagents, catalysts and the like may be arranged at suitable portions of the apparatus. Thus, gases may be added to liquids in the generator for chemical reaction or for producing foams.

The shape and the dimensions of the apparatus and of parts thereof may be varied within wide limits in order to obtain desired operating characteristics, without departing from the general principle of this invention.

The rows of oscillating members may define prismatic, round, cylindrical, or otherwise shaped acoustic treating chambers of suitable size, and the direction of the main axis of the chambers may depart from a strictly radial direction. Since it is possible in this way to arrange a greater number of acoustic chambers in a given gen-

erator casing, operating frequencies exceeding the above-mentioned frequencies may be obtained. This makes it possible to further reduce the volume and weight of individual particles obtained by the treatment.

In order to obtain shearing, rubbing and also pan-grinding effects, which when applied to cellulose pulp result in changes of structure, such as swelling and changes in the water content of fibers, the axial section of the rows of cooperating members may be of conical, bell, or stepped shape so that the gap width between adjacent rows may be changed by relative axial displacement of the rows.

The edges of individual oscillating members or the cooperating surfaces of the oscillating members of adjacent rows may be toothed, serrated, roughened or provided with blind holes in order to increase attack on the material treated in the generator. Further, the oscillating members may be corrugated or bent and they may be of elastic material. A high elasticity or resilience of the rows and of the individual oscillating members may be achieved by the partial or exclusive use of elastic materials of construction, such as rubber, plastic materials, spring metal or the like.

The apparatus according to this invention may also be designed as a multistage unit having several axially sequential coaxial treating stages. The material leaving the outermost stator row of the first stage is led radially inward into the central cavity of the rotor of the second treating stage by a flat or conical guide disc which separates the first stage from the second stage. In such a multi-stage apparatus the material may be subjected repeatedly to a similar treatment. It is possible to make the treatment in later stages more intensive than in preceding stages by suitable arrangement and design of the oscillating members and acoustic treating chambers. The discharge rate of a multi-stage apparatus may be controlled in the manner described for the single stage apparatus, such as by provision of a discharge control valve.

The casing of each stage of the multi-stage apparatus may be equipped with an individually controlled outlet. This makes it possible to treat a substance needing particularly intensive treatment in three stages arranged in series, the treated material being discharged from the third stage. Without shutting down, the apparatus may be adapted for treating another material requiring less intensive treatment by simply opening the outlet of the second or of the first stage, and shutting off the outlets of the following stages so that the new material is treated in the first and second, or only in the first stage of the apparatus, while the other stages are rendered inoperative.

While the invention has been described and illustrated with reference to specific embodiments thereof, it will be understood that other embodiments may be resorted to without departing from the spirit and scope of the invention. Therefore, the examples of the invention set forth above should be considered as illustrative and not as limiting the scope of the following claims.

What I claim is:

1. In a method of continuously treating a suspension of agglomerated particles in an aqueous liquid, in combination, causing said suspension to flow in a continuous stream; dividing said stream into a plurality of separate portions of predetermined magnitude; forcing each portion separately under pressure into an entrance zone of a respective one of a plurality of substantially closed chambers, each chamber being substantially filled with an amount of said suspension greater than said portion, while substantially simultaneously releasing a separate portion of said suspension from an exit zone of said chamber under pressure, said zones being spaced from one another in a predetermined direction, whereby said suspension travels in said chamber in said direction at a predetermined rate of travel; substantially closing said chamber; and subjecting said suspension while enclosed in said chamber to cyclic stresses at a frequency selected from the range of sonic and ultrasonic frequencies, said stresses having a rate of propagation in said suspension substantially greater than said rate of travel, whereby said agglomerated particles are separated from each other.

2. In an apparatus for continuously treating a material, in combination, a housing: two support members mounted in said housing for rotation relative to each other about an axis, said members having axially opposite respective faces; and a plurality of axially freely projecting oscillating members on each of said faces, said oscillating members being arranged in coaxial, radially contiguous, annular rows about said axis, alternating rows projecting from one and the other one of said faces respectively, the radial width of said oscillating members in at least one of said rows being substantially greater than the circumferential thickness thereof, and the freely projecting axial length of said oscillating members in at least said one row being substantially greater than said radial width thereof, the members in each of said rows being circumferentially spaced from each other so as to define a plurality of acoustic chambers therebetween, the circumferential thickness of said members in each of said rows being at least substantially equal to the circumferential thickness of the acoustic chambers in the adjacent rows, whereby said acoustic chambers are alternately opened and closed during rotation of said support members relative to each other.

3. In an apparatus as set forth in claim 2, means for passing a material successively through the acoustic chambers at least said one row and of adjacent ones of said rows.

4. In an apparatus as set forth in claim 2, a conduit for feeding said material to the acoustic chambers of one of said rows adjacent said axis; a conduit for withdrawing said material in treated condition from the acoustic chambers of one of said rows remote from said axis; and control means in one of said conduits for controlling the rate of flow of said material therethrough.

5. In an apparatus as set forth in claim 2, the number of oscillating members in said one row being different from the number of members in an adjacent row.

6. In an apparatus as set forth in claim 2, the number of oscillating members in said one row being greater than the number of members in one radially adjacent row, and smaller than the number of members in the other radially adjacent row.

7. In an apparatus as set forth in claim 6, said one radially adjacent row having a smaller diameter than said other radially adjacent row.

8. In an apparatus as set forth in claim 2, means for rotating said support members relative to each other.

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