United States Patent

Dille et al.

[15] **3,643,875**

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[54] FLUID ENERGY GRINDING METHOD AND SYSTEM

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[52] **U.S. Cl.** **241/5**, 241/39

[51] **Int. Cl.** **B02c 19/06**

[58] **Field of Search** 241/5, 39

[56] **References Cited**

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[57] **ABSTRACT**

A fluid energy grinding system wherein a stream of a dispersion of solid particles suspended in gas or vapor is accelerated to supersonic velocity in a nozzle having a divergent discharge section sufficient to produce a standing shock wave along the path of flow of solid particles effecting size reduction of particles.

7 Claims, 4 Drawing Figures

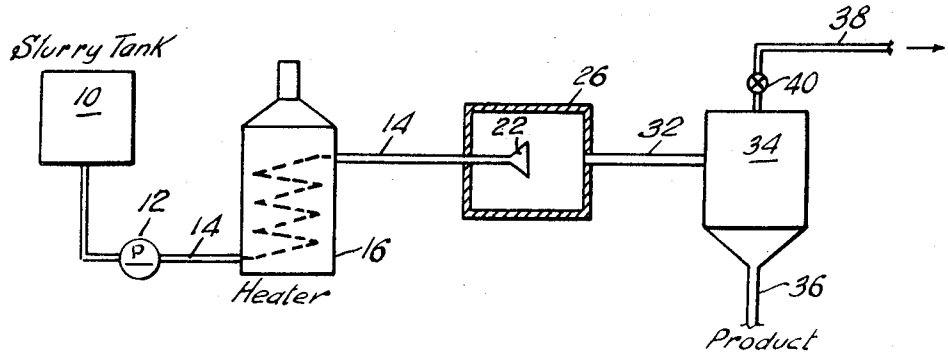


Fig. 1.

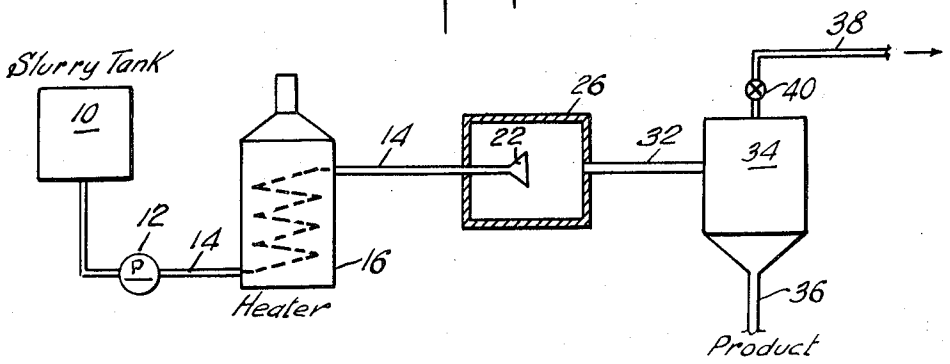


Fig. 2.

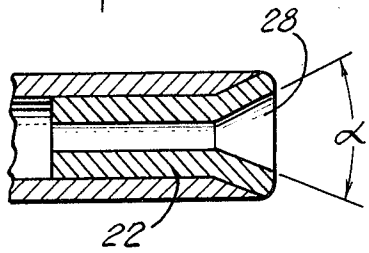


Fig. 3.

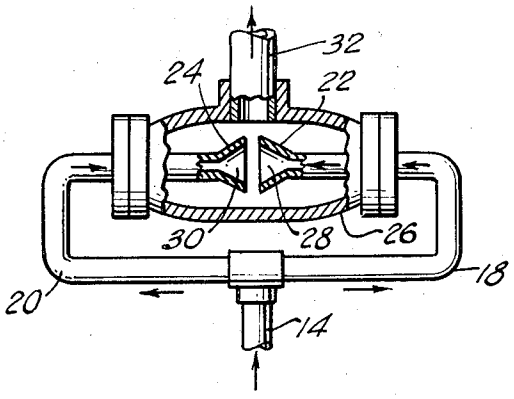
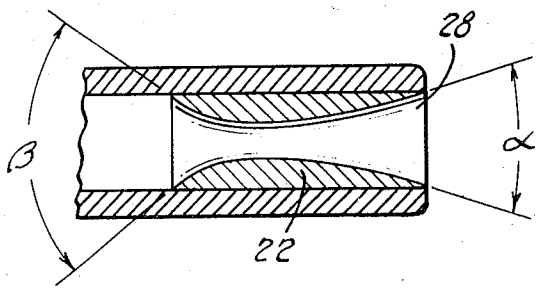


Fig. 4.



FLUID ENERGY GRINDING METHOD AND SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to a novel method and a system in which fluid energy grinding is performed by employing an improved type nozzle therein.

It has been proposed in the past to grind solid particles of material such as coal, talc, barite, aluminum, magnesium, clay and oyster shells by suspending them in a gas and passing the resulting dispersion at high velocity through opposed nozzles.

In a commonly assigned U.S. Pat. No. 2,846,150 issued to L.T. Work on Aug. 5, 1958, which patent is herewith incorporated by this reference, solid particles are dispersed in a gas stream, and ejected as a plurality of intersecting streams affecting particle size reduction by impinging them against one another.

The present invention relates to an improved method and apparatus for fluid energy grinding with nozzles.

SUMMARY OF THE INVENTION

The present invention relates to a method for reducing the size of relatively coarse particles of a frangible solid material by passing a stream of such particles dispersed in an elastic fluid, e.g., gas or vapor, through a divergent nozzle wherein the fluid is accelerated to supersonic velocity and expanded to form a standing shock wave which results in disintegration or size reduction of the solid particles. In one specific embodiment of the process of this invention a flowable mixture or slurry of relatively coarse particles of a frangible solid material in a vaporizable liquid is made up, the mixture is passed through a tubular heating zone providing sufficient heat to substantially completely vaporize the liquid and form a stream of solid particles suspended in vapor and the stream of coarse particles suspended in vapor expanded through a divergent nozzle in which the velocity of the stream is increased to supersonic velocity and rapidly decelerated to subsonic, thereby creating a standing shock wave near the downstream end of the nozzle. The solid particles in the stream pass through the standing shock valve wherein they are subjected to high shearing forces which break up the particles to form smaller size particles. A converging-diverging nozzle is preferred as described in greater detail hereinafter.

The terms "pulverization" and "grinding," as used herein are to be understood to mean reduction in the size of solid particles as produced in the process described herein.

An object of the present invention is to provide an improved process of fluid energy grinding.

Another object of the present invention is to provide an improved process for fluid energy grinding wherein the energy dissipated in a shock wave is utilized for grinding or size reduction of solid particles.

A further object of this invention is to provide apparatus for carrying out the process of this invention.

Other objects and advantages of this invention will become apparent by reference to the accompanying drawings forming a part of this application and illustrating a preferred as well as alternate embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic diagram of a system wherein the apparatus of the present invention is used;

FIG. 2 is a longitudinal cross section of the apparatus for performing the herein disclosed novel method;

FIG. 3 is a plan view, partly in cross section, of a portion of the system showing an alternate apparatus of the present invention; and

FIG. 4 is a longitudinal cross section of another embodiment of the apparatus for performing the herein disclosed novel method.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As illustrated in FIG. **1**, solid particles to be ground are blended intimately with a vaporizable liquid to form a flowable mixture in a slurry tank **10**, which may include an agitator, such as a motor-driven paddle. The concentration of solid material in this flowable mixture or slurry can be up to 70 percent by weight depending upon the characteristics of the solid material and liquid employed in the process.

From slurry tank **10**, the slurry is passed by a pump **12** at a pressure of above about 200 p.s.i.g. through a heated conduit **14** within a heater **16**, such as an oil or gas-fired furnace. The heater **16** provides heat to the flowable mixture in the conduit **14**.

The conduit **14** can be arranged in any desired way within the heater **16** to secure space economy while assuring that the material in conduit **14** is heated to a temperature sufficient to vaporize the liquid in the slurry to form a flowing dispersion. The conduit length and diameter are such that sufficient heat transfer surface is provided for vaporization of the liquid in the slurry. Approximately 1 square foot of surface area for each 10 pounds of slurry passing through the conduit in a 1-hour period of time is generally required. Typically the tubular heating zone comprises from 1,000 to 1,500 feet of ½ inches to 2 inches diameter iron pipe arranged as a nested coil, but other arrangements also can be used, such as straight pipe sections connected by return bends.

For convenience, only one heater **16** is shown. However, for greater efficiency a plurality of cascaded heaters can be incorporated in the system, each successive heater being at a higher temperature.

Many vaporizable liquids can be used as the slurry liquid such as water, kerosene, mineral oil or such liquefied gases as propane, butane and air. Selection of the slurry liquid depends mainly on the nature of the material being ground. Water can be used for relatively stable materials such as coal, coke, talc, barite and oyster shells. Kerosene or oil should be used with metals, which may react with steam.

Within the heater **16**, the slurry in conduit **14** is heated above the vaporization temperature of the slurry liquid so that part way through the conduit there is formed a flowing dispersion of the solid particles in a vapor gas. The term "vapor" as used herein does not preclude super-heated gases as the carrier of the flowing dispersion. This dispersion flows the rest of the way through the conduit **14** at a relatively high velocity, for example, 10 to 100 feet per second, which is sufficient to carry the particles with a minimum erosive effect. Some preliminary grinding of the particles may occur as the particles impinge against one another while flowing through the heater tubes.

The dispersion in conduit **14** can be split into two streams as illustrated in FIG. **3** in which the streams pass through a pair of ducts **18** and **20** to a pair of discharge nozzles **22** and **24**, respectively, projecting from opposite sides of a relatively large diameter reaction chamber **26** to the interior thereof.

The nozzles **22** and **24** have passages **28** and **30**, respectively, therethrough of circular cross section which are axially aligned with one another and are shown with their outlet orifices diametrically opposed to one another at an angle of 180°.

However, all that is required in the method of the present invention is a single discharge nozzle **22** which is directly coupled to the conduit **14** so that the dispersion passes through the discharge nozzle **22** into the interior of the reaction chamber **26**. For simplicity, since the method of this invention can be practised with a single nozzle, the method will be described by reference to nozzle **22** and nozzle passage **28** when the embodiment of FIG. **3** is not specifically being described. With a single discharge nozzle **22**, the reaction chamber **26** must be of sufficient size that the particles leaving the nozzle **22** can dissipate their kinetic energy without eroding any portion of the reaction chamber **26** in the paths of the particles.

Nozzle passage **28** for at least part of its length, has a flared discharge opening, diverging outwardly with respect to the flow of the dispersion therethrough. The nozzle can be flared as shown in FIG. **2**, or convergent-divergent as shown in FIG. **4**. It is important however that the nozzle be such that the supersonic velocity is developed in the fluid passing therethrough and that a standing shock wave is developed in the nozzle. An included angle of about 45° for nozzle **22** is satisfactory, but smaller or larger angles from 15° to 90° can also be used. Preferably the included angle of the divergent section is within the range of 15° to 60°.

The volume of reaction chamber **26** is large enough to reduce the velocity of the solids to a value low enough to prevent undue erosion downstream of the nozzle and permit operation of the nozzle as described. For example, reaction chamber **26** may be located in a pipe Tee having legs of about 4 to 12 inches inside diameter. The ratio of the upstream pressure to the downstream pressure relative to the nozzle, necessary for supersonic velocity in the nozzle is at least four. As the pressure ratio is increased, the extent of grinding of the solid particles is increased.

From reaction chamber **26**, the low-velocity dispersion of particles in vapor passes through conduit **32** into cyclone separator **34**, solids passing off the bottom from product outlet **36** and vapor passing off the top through a valve-controlled conduit **38**. Valve **40** regulates the back pressure on the system. A conventional separator can be employed, such as one of the cyclone type. It is to be understood that for greater separation of the powder from the gas additional stages of cascaded separators can be added to separator **34** as well as a scrubber for a final separation.

While the exact mechanism by which the improvement results is not understood, the following is offered as a possible explanation of the mechanisms involved. A standing shock wave is set up in the nozzle **22** near the exit of the divergent section of the nozzle and this shock wave is largely responsible for grinding the relatively coarse particles of solid material. Upon passage through this shock wave, the solid particles are subjected to extreme shearing forces which result in grinding of the particles. In shock wave there is a rapid adiabatic compression and conversion of the kinetic energy to a pressure as the velocity decreases to a subsonic value.

The following example indicates comparative results when a similar dispersion is ground according to the prior art with two opposing straight nozzles and according to the present invention with diverging nozzles.

EXAMPLE

A slurry containing 40 percent by weight of Talc of which 0.03 percent is retained on a Tyler size 325 mesh, (44 microns), in distilled water was passed into 750 feet of heated half inch iron pipe at a pressure of 1,600 p.s.i.g. and at a rate of 1,800 pounds per hour. The slurry was heated to a maximum temperature of 770° F. at the heater pipe outlet where the discharge pressure was 1,130 p.s.i.g. The resulting dispersion was then passed through opposed flared nozzles having a 5/32-inch inside inlet diameter and a 15/32-inch outside inlet diameter. The outlet opening of the nozzles had a 7/16-inch diameter discharge orifice and subtended an included angle of 45°. Each nozzle had a total axial length of 1⅝ inches and a flared axial length of ⅜ inch. The dispersion was then discharged into the chamber **26** having an outlet connected to a cascaded pair of cyclone separators by a 4-inch IPS pipe.

A similar resulting dispersion, for comparison, flowed through the same system modified by replacing the flared nozzles with straight nozzles having an inside diameter of 5/32 inch and an axial length of 1⅜ inches.

The following Table compares the results of a Klett Turbidimetric analysis (a well-known measurement) of the particle size of a talc product from both a straight and a flared nozzle and the talc feed:

TABLE I

Percent of particles in batch which are smaller than stated size	Feed (μ)	Product of— Flared nozzle (μ)	Straight nozzle (μ)
90	30.0	2.2	10.0
80	25.0	1.5	7.5
70	20.0	1.1	4.5
60	15.0	0.8	3.0
50	10.0	0.6	1.9
40	6.6	0.4	1.3
30	4.0	0.3	0.8
20	2.0	0.2	0.5

A comparison of the figures in Table I shows that the product of the flared nozzle is consistently finer than the product of the straight nozzle. For example, 90 percent of the product of the flared nozzle is smaller than 2.2 microns while only 60 percent of the product of the straight nozzle is smaller than 3 microns. Also at the lower end, 20 percent of the product of the straight nozzle is smaller than 0.5 micron, while 40 percent of the product of the flared nozzle is smaller than 0.4 micron.

Table II below gives quantitative figures showing the quality of fineness of the product of the flared nozzle in contrast to that of the straight nozzle.

TABLE II

Test	Feed	Product of— Flared nozzle	Straight nozzle
Hegeman (top size)	5	7½	5½
Bulk density (lb./ft.³)	17.9	2.3	3.1
Correlated area (m.²/g.)	7.5	58	40
Tapped density (cc./40 g.)	58	536	400
Surface area (m.²/g.)	8.5	70	44
Bulking (ml./g.)	1.2	18.0	18.0
Correlated area (m.²/g.)	8.5	90	60

"Hegeman" is a known measure of the quality or uniformity of fineness of particulate matter. Reference is made to a booklet issued by Sherwin-Williams Company, entitled "Hegeman Grind Gauge Reading Procedure" which is stated to be an abstract of their test method 441. Additionally, reference is made to an article in the "Paint, Oil and Chemical Review," June 22, 1950, pages 34 through 39 by D. Doubleday and A. Barkman of the Sherwin-Williams Co. entitled "Reading the Hegeman Grind Gauge."

The above Table indicates qualitatively, that the flared nozzle product is not only finer than the product of a straight nozzle but that the flared nozzle product is also more uniform as can be seen from a Hegeman Grind Gauge reading of 7½ compared to a 5½ for a straight nozzle. The surface area has also increased along with a decrease in the bulk density.

The present invention encompasses the use of one or more divergent nozzles capable of producing a shock wave with one or more other nozzles not capable of producing a shock wave and having the axes of all the nozzles intersecting one another and having the axes of all the nozzles intersecting one another at a large angle so that the effluent of the nozzles impinge against each other.

Other modifications and variations of the above invention as hereinbefore set forth may be made without departing from the spirit and scope thereof, and therefore, only such limitations should be imposed as are indicated in the appended claims.

We claim:

1. A fluid energy grinding system which comprises a flowing dispersion having relatively coarse particles of a frangible solid material dispersed in an elastic fluid, a converging-diverging nozzle communicating with said flowing dispersion and having a discharge opening diverging outwardly with respect to said flowing dispersion therethrough, means for imparting supersonic velocity to said flowing dispersion and said converging-diverging nozzle including means for producing a pressure drop of at least 75 percent across said nozzle thus

producing a standing shock wave within said diverging discharge opening, the angle of convergence of the converging section of said nozzle being between 45° and 120° and the angle of divergence of the diverging section of said nozzle being between 15° and 90°, said angle of convergence always being greater than said angle of divergence.

2. A system as described in claim 1 wherein a pair of said converging-diverging nozzles are positioned with their discharge openings substantially in opposition to each other.

3. A system as defined in claim 1 wherein the angle of divergence of said discharge opening is from 15° to 60°.

4. A method for reducing the size of coarse particles of a solid material which comprises the following steps in sequence:

a. forming, as a flowing stream, a dispersion of said coarse particles in a gaseous medium,

b. accelerating said dispersion at superatmospheric pressure to supersonic velocity while introducing said dispersion into a zone of gradually decreasing cross-sectional area,

c. introducing the dispersion into a zone of gradually increasing cross-sectional area while effecting a reduction in the pressure of at least 75 percent thereby forming a standing shock wave in said zone of gradually increasing cross sectional area,

d. passing said dispersion through said shock wave, and

e. recovering from said zone of gradually increasing cross-sectional area a dispersion containing particles of reduced size, the rate of decrease of said decreasing cross-sectional area being greater than the rate of increase of said increasing cross-sectional area.

5. The process of claim 4 in which the standing shock wave is produced by regulating the pressure drop and the velocity drop of said flowing stream.

6. A method as described in claim 4, wherein a plurality of said streams are formed having at least one with said gradually increased cross-sectional area and directed to axially impinge against one another at a large angle.

7. A method as described in claim 6, wherein said streams are diametrically, axially impinged against each other at an angle of 180°.

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