This invention relates to the art of fine grinding. More particularly, this invention relates to means for reducing grains, seeds, gums, resins and a wide variety of granular and crystalline material to a specified particle size and finer, with minimum over-grinding effect or excess superfine material in the product.

The object of the invention involves a novel and novel principle of particle size reduction, maintaining the mill or grinding load in a highly fluidal state, approximately 8 percent solids in the grinding zone, to insure utmost freedom of movement of the individual particles, maximum impact velocities, instant removal of the fines from the grinding zone and best conditions for effective reduction and minimum conversion of energy of movement to heat.

The principal object of the invention is to provide pulverizing means for achieving the above enumerated desired results.

It is another object of this invention to provide a pulverizing apparatus designed to have a length to provide a desired given time of retention in the mill of the material to be ground for a given rate of flow, thus determining the degree of grinding and classification by the time of retention of the material in the mill.

Another object of this invention is to provide a mill wherein the material to be reduced is fed into one end of the mill in controlled quantity with a regulated amount of air and leaves the other end, reduced to the wanted particle size, with air to a collector system.

It is a further object of this invention to provide a closed end, horizontal, generally cylindrical mill housing containing an axial grinding rotor with a plurality of independent closed end radial blade units arranged in series having a high velocity in and out flow and intrablade vortex action.

A still further object of this invention is to provide positive flow diversion means in the mill housing wall to adjust and regulate the progress of the material to be reduced from one grinding unit to the next along the rotor and thus regulate the axial flow or progress of the material through the mill and its time of retention in the mill.

Still another object of this invention is to provide a new and improved method of pulverizing and classifying dry solid material.

Other objects of this invention will become apparent as the description proceeds.

To the accomplishment of the foregoing and related ends, this invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principles of the invention may be employed.

The invention is illustrated by the drawings in which the same numerals refer to corresponding parts and in which:

Figure 1 is a vertical elevation of the pulverizer of this invention partly broken away to show the interior of the mill in section;

Figure 2 is a vertical section taken along the line 2—2 and in the direction of the arrows of Figure 1;

Figure 3 is an end elevation partly broken away to show in section the air and material inlet and grit trap, the section being taken along the line 3—3 and in the direction of the arrows of Figure 1;

Figure 4 is a top plan view of the mill;

Figure 5 is an elevation of the deflecting vanes on the interior wall of the mill, this view being in the direction of the arrows of 5—5 of Figure 2; and

Figure 6 is a generally horizontal section taken along the line 6—6 and in the direction of the arrows of Figure 5.

Broadly stated, the invention comprises (1) a method of pulverizing and classifying dry solid material which includes the steps of feeding a controlled supply of dry solid material and gas tangentially to one end of a horizontally disposed generally cylindrical milling area comprised of a plurality of independent annular grinding zones; maintaining a fluidal suspension of the solid material in the gas; continuously grinding the solid at least in part by attrition of particle against particle and particle against gas stream by whirling the fluidal stream of particles of the solid material entrained in the gas at high speed in an arcuate path around the outer perimeter of the annular grinding zones setting up an outer vortex action and whirling a plurality of smaller fluidal streams of particles of the solid material entrained in the gas at high speed around the inner periphery of the annular grinding zones setting up a plurality of inner vortex actions; centrifugally throwing out at least part of the particles through one quadrant of the cylindrical milling area, advancing the solid material sequentially from grinding zone to grinding zone through the length of the milling area by deflecting at least part of the particles angularly downward into the next succeeding annular grinding zone; optionally separating at least part of the higher falling superfine particles from the other lower falling coarser particles and removing these superfines from the milling area by entraining them in an axial gas flow and independently withdrawing these airborne superfine out of the central flueing throw-out area; and whirling the completely ground particles of dry solid material from the opposite end of the cylindrical milling area to a collector system; and (2) one form of apparatus for carrying out this method.

Referring now to the drawings, and particularly to Figures 1 to 4, there is shown the improved classifying pulverizer of this invention. The mill comprises a generally cylindrical horizontal housing 10, preferably provided with a liner 11, which may be smooth or corrugated. Housing 10 is enclosed between two end plates 12 and 14. Positioned immediately adjacent the mill housing is a fan housing 15 enclosed between end plate 14 of the mill housing and end plate 16. End plates 12 and 16 extend to a base or floor and are affixed by floor flanges. An annular opening 17 affords communication between the mill housing 10 and fan housing 15.

A suitable bearing structure is mounted at each end of the mill outside of the end plates. The details of construction of the bearings are within the province of mechanical design and need not be further explained here except to state that the bearings are preferably of the roller or ball bearing type and they are adequately sized to carry the rotor of the mill and fan at the speeds desired and are adequately protected against the entrance of abrasive material into the bearings. Upon the bearings there is mounted a shaft 18 extending through the end plates and running the length of the entire mill forming the axis thereof. The shaft may be rotated by...
3 means of a pulley (not shown) mounted on the projecting end of the shaft and belted to any suitable motor. A motor stand 19 is provided for this purpose. Alternatively, the shaft may be driven directly by direct connection of a motor of suitable design.

The shaft 18 is enlarged and reinforced through part of its length by a tube 20 supported by annular rings 21, 22 and 23 welded or otherwise secured to the shaft. The shaft, tube and annular rings form a rigid unirtary structure upon which the grinding rotor units and fan are mounted.

A rotor end disk 24 is mounted on one end of the tube secured to annular ring 21 and fan disk 25 is mounted on the opposite end of the tube secured to annular ring 23. Fan blades 26 are fitted into the fan disk 25 which is preferably mounted to the rotor by means of a hub and a pair of disks 20. Radial blades 29 are positioned perpendicular to the slotted disk 28. Disks 30 have a diameter reaching to the peripheral of blades 29. The end rotor disks 31 and 32 have a slightly reduced diameter to provide axial flow of material through the housing. The slotted disks 28 and disks 30 are held spaced apart by annular spacer rings 34 and 35 of appropriate length keyed at 37 to tube 20. A similar spacer ring 36 holds fan disk 25 spaced apart from end rotor disk 32. Instead of being in the form of flat plates or vanes as illustrated, radial blades 29 may likewise be in the form of rods mounted perpendicular to the rotor disks.

An air and material inlet duct 38 is provided at the inlet end of the mill. Duct 38 intersects one end of cylindrical housing 10. Flow of air into the inlet is controlled by means of a damper 39 slidably mounted in the top of the duct. The inlet duct 38 is also provided with means for controllably feeding the material to be reduced. In the form here illustrated the feeding means comprises a screw conveyor 40 in a conduit 41 opening at one end into a feed hopper 42 and at the other end into inlet duct 38. Conveyor 40 is driven by means not shown, preferably by variable speed motor means. Air control damper 39 is shown partly open in Figure 4 to show conveyor 40 feeding into duct 38.

A cyclone positioned in the bottom wall of housing 10 under the air and material inlet to collect bits of sand, stone, metal and like heavy extraneous material. The trap comprises a chute or duct 44 sloping downwardly from the bottom of the mill housing and having a damper 45 to control the feeding of material to the housing. This trap will be filled with the material to be reduced but as grist and like material are introduced into the mill it will, because of its greater density, tend to drop to the bottom of the trap adjacent the outlet.

Extending along the remainder of the cylindrical housing 10, 29, 38 and fan housing 15 is an open axial flow chamber 46 enclosing approximately 25 percent of the circumference of the rotor. The axial flow chamber comprises a front wall 47 which extends vertically upwardly tangentially from the cylindrical housing (as best shown in Figure 2), a back wall 48 extending radialiy outward and upwardly from the top of the cylindrical housing and a top cover plate 49. Positioned on the inner side of front wall 49 adjacent to the rotor are flow diversion means, here illustrated as a plurality of ribs or vanes 50 for deflecting the paths of the particles being reduced and advancing the material through the mill. The ribs are preferably in the form of U-shaped channels, as shown in Figure 6, pivotally mounted and adjustable from outside the mill, as for example, by handles 51. The handles may for convenience be grouped in series for movement together. It is not desirable, however, that all of the handles be joined, because as will be explained in detail hereinafter, the angle of deflection of the vanes may vary from inlet to outlet end of the mill.

A duct 54 connected to any suitable source of suction is provided in the top of the axial flow chamber for optional independent removal of superfines from the chamber. A slide damper 55 permits easy closing off of this duct.

Fan housing 15 is in the form of the conventional scroll and is provided with an outlet duct 52 to any suitable conventional collector system.

In the operation of the improved self-classifying pulverizer of this invention the material to be reduced is fed into hopper 42 and is introduced at a controllable rate by means of conveyor 40 into inlet duct 38. At the same time air or other gaseous fluid is introduced into the inlet duct through damper opening 39 at a rate sufficient to maintain the grinding load in a highly fluid state, usually containing the material to be reduced. As the material enters it falls against the rotating blades of the rotor. Because end rotor disks 31 are of reduced diameter the initial flow of both air and material is axial at the periphery of the rotor until it enters the flow chamber 46. Any grit or other dense material drops into the trap 44 and outlet chamber 47. If additional there is no axial flow of either air or material within the rotor itself, along its periphery or within what may be termed the rotor chamber.

As the material to be reduced is carried at high speed around the periphery of the rotor reduction takes place by means of a vortex of the fluid suspension of material in which reduction is principally by impact and attrition of particles upon particle, as described in my earlier Patent 2,994,920 issued September 8, 1942. In that patent it is explained in detail how an outer vortex is set up beyond the tips of the radial blades of the rotor by the action of the blades taking up the air and whirling it around the inside of the cylindrical housing. As the material is fed it is picked up in the whirling air in the grinding chamber and caused to circulate around with the rotor, the material being entrained and conveyed in the air current. The pattern of material entering the pulverizer are picked up by this outer vortex. Milling action occurs due to the inertia of the particles in the air moving at high speed in the vortex. The particles are constantly eroded by the high speed air currents and reduced in size by collision with other particles in its path.

By proper spacing of the radial blades 29 of the rotor intra-blade vortices are also set up. The forward travel of each blade creates a vacuum. Immediately behind the blade there is an inrush of air to fill the vacuum. That air is taken in part from the interior of the outer vortex which is laden with fine pulverized material. Air to fill the vacuum is also partly obtained from about the tip of the next following blade, which air slips from front of that blade, around its tip and back into the vacuum created behind the leading blade of the following blade advancing toward the vacuum compresses and expels the air directly in front of it and this air also rushes in to fill the vacuum at very high speed due to its increased pressure. The result of these several forces will be to produce a somewhat circular high speed vortexic movement between each set of opposing faces of the radial vanes. The inrush of the material-laden air to fill the vacuum created behind each blade causes innumerable high speed impacts and collisions of the particles upon each other which together with the pull against the inlet of the particles in the vortices and the very high speed of the vortical air currents result in an extremely high rapid attrition of the particles in air and convey large quantities of very small particles. Each rotor in this pulverizer is an individual grinding unit and operates individually as if each unit were enclosed in a housing of its own.
For the efficient operation of any pulverizer it is desirable that the finely reduced material of desired size be removed from the attrition zone as rapidly as possible. Each rotor operating as an individual grinding unit discharges its load tangentially at the top of the grinding chamber into the flow chamber and picks it up again at the bottom. The centrifugal throw-out effect of the rotor upon the particles of largest mass tends to throw these particles downwardly against the inner surface of wall 47 of the axial flow chamber. The more finely ground particles of desired size and superfines, which due to their lesser mass are less subject to this throw-out effect, are thrown out at a higher level and are in most operations entrained in an axial air flow entering the air-flow inlet in a registratable amount and flowing through the air flow chamber. For the most part, this is merely a means to move the fines forward in the flow chamber towards the outlet end to minimize continuous recirculation of fines in the rotors.

In some operations it may be desirable to withdraw the airborn fines from the air flow chamber by independent means to eliminate this material from the mill product. In this event any suitable means of suction may be tapped into the top wall of the axial air flow chamber, which is preferably increased somewhat in height, and the suction is regulated and maintained so as to withdraw only superfines.

It is to be understood that the flow chamber is not a classifier, nor are air or air flow used as a classifying means, except when used to remove superfines from the product. Classification is based upon mechanical control of the flow and control of time of retention of the material in the mill so as to produce the wanted particle size. This method of particle size control is not adapted for all materials and all particle size ranges but it is adapted to an exceedingly wide range of materials and processes and provides the most effective and efficient methods of reduction in these fields. It is especially adapted to grinding of flour, sugar, other grain products such as corn meal, seeds, gums, resins and the like.

As previously stated, the individual rotor units in this mill operate individually as if each unit were enclosed in a housing of its own. Each gets its air and material load from the bottom of the flow chamber and discharges tangentially at the top of the rotor chamber into the same flow chamber. Ordinarily, this would produce a continuous recirculation in the same plane, normal to the axis of the rotor. Accordingly, without some positive means to move the material through the mill the material would tend to remain at the inlet end until all of it had been reduced to fines and superfines, thus not using the remaining of the grinding area of the mill and greatly limiting the mill's capacity. Adjustable means for advancing the material through the mill are provided by pivotally mounting deflecting means in the flow chamber, setting the ribs 50 at an angle from the vertical inclined downwardly toward the discharge end of the mill. As the coarser particles are thrown out against the inner surface of wall 47 of the axial flow chamber they are deflected a short distance toward the discharge end of the mill before falling downwardly back into the rotor. The length of time the material will remain in the pulverizer can thus be controlled and varied by adjustment of the angles of deflection of vanes 50.

Because the material initially fed into the mill consists substantially entirely of larger and coarser particles the grinding load is relatively heavy. Accordingly, the deflection of the vanes from vertical toward the inlet end may be relatively great so as to rapidly move the material away from the inlet to provide room for more material. However, the grinding load becomes progressively lighter as the reduction takes place and the finer material advances more rapidly toward the discharge end and, in some instances, because of removal of the superfines. The increasing lightness of the grinding load may be compensated by retarding the rate of advancement by decreasing the angle of deflection of the vanes.

The diameter of the end rotor disks 32 at the discharge end of the mill is reduced to provide an axial flow of air and reduced material at the periphery of the rotor as it leaves the flow chamber and enters the outlet fan housing for discharge to collector system. The mill housing is preferably split horizontally so the top half may be lifted off and the rotor removed for cleaning, servicing, replacing or interchanging parts. The rotor is likewise designed so that the rotor units may readily be turned over to reverse their direction of rotation to provide self-sharpening where cutting edge rotors are desired. Although the self-classifying pulverizer of this invention is contemplated particularly for classification in the ranges about above 10 to 15 microns, it is obviously not so limited.

The mill may be increased in length to provide: (a) ample time of retention of material in the mill, (b) savings in power by the use of less rotative speed and/or (c) a more highly fluidal mill load for high efficiency grinding. Since the mill load is calculated at only about 8 percent solids when the mill is fully loaded the solids would make a layer on the peripheral wall considerably less than the running clearance. Since this is a fluid energy mill the individual particles must be free to attain and maintain high velocities of impact.

The fineness of grind is independent of the rate of feed. It depends only on rate of flow through the mill which may be adjusted and regulated by means of the deflector elements. Thus, except for overloading, variation in loading will not affect the grind.

As many apparently differing embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that we do not limit ourselves specifically to the embodiments disclosed herein.

We claim:

1. A self-classifying pulverizer for dry solid material comprising an elongated substantially cylindrical horizontal mill housing and a fan housing adjacent one end thereof, said mill housing and fan housing being in direct fluid communication, a rotor journaled for rotation horizontally in said mill housing and a plurality of closed end radial blade grinding units mounted on said rotor within the mill housing, radial fan means in said fan housing, an axial air flow chamber mounted in said cylindrical mill housing over approximately one quadrant thereof, said flow chamber being in direct fluid communication with the interior of said housing over that quadrant, and having adjustable means in said flow chamber to progressively advance the grinding load through the pulverizer.

2. A self-classifying pulverizer for dry solid material comprising a substantially cylindrical horizontal mill housing, a material and air inlet to said housing at one end thereof, feeder means for controlling the rate of feed to said inlet and means for regulating the flow of air to said inlet, a grading rotor journaled for rotation horizontally in the mill housing, a fan housing at the
opposite end of the mill housing and in direct communication therewith and a radial fan in said housing, an axial air flow chamber mounted in said cylindrical mill housing over about one quadrant thereof in direct communication with the interior of the housing over that quadrant, and a plurality of deflecting vanes on the inner side of the wall of said flow chamber.

3. A self-classifying pulverizer according to claim 2 further characterized in that said deflecting vanes are pivotally mounted for adjustment of the angle of deflection.

4. The combination of a substantially cylindrical horizontal mill housing, a material and air inlet to said housing at one end thereof, a grinding rotor journaled for rotation horizontally in said housing, a radial fan enclosed in a fan housing at the opposite end of the mill housing and in direct communication therewith, an axial air flow chamber mounted in said cylindrical mill housing over about one quadrant thereof and adjustable means in said flow chamber to progressively advance the grinding load.

5. A self-classifying pulverizer for dry solid material comprising a substantially horizontal cylindrical mill housing; an air and material inlet at one end of said housing; closures at each end of the housing, one of said closures having an annular opening, a rotor journaled for rotation in the housing, a plurality of grinding means on said rotor; radial fan means exterior of the mill housing and a housing enclosing said fan, the fan housing and the mill housing being in direct fluid communication through said annular opening; an axial air flow chamber mounted in said cylindrical mill housing in direct communication with the interior of said housing, adjustable means in said flow chamber to progressively advance the grinding load and suction means to withdraw airborne superfine from said flow chamber.

6. A self-classifying pulverizer for dry solid material comprising an elongated substantially cylindrical horizontal mill housing; an air and material inlet at one end of said housing; closures at each end of the housing, one of said closures having an annular opening; a rotor journaled for rotation in the housing and projecting through the annular opening, a series of closed end radial blade grinding units on said rotor within said housing and a radial fan on the end of said rotor projecting through the annular opening; a housing enclosing said fan, said fan housing being in communication with the annular opening and a discharge outlet from said fan housing; an axial air flow chamber mounted in said cylindrical mill housing over approximately one quadrant thereof, said flow chamber being in direct fluid communication with the interior of said housing over that quadrant and with the fan housing through the annular opening, and adjustable means in said flow chamber for controllably advancing the grinding load progressively from each grinding unit to the next successive grinding unit.

7. A self-classifying pulverizer for dry solid material comprising an elongated substantially cylindrical horizontal mill housing; an air and material inlet at one end of said housing, feeder means for controlling the rate of feed to said inlet and means for regulating the flow of air to said inlet; closures at each end of the housing, one of said closures at the end opposite from the air inlet having an annular opening; a rotor journaled for rotation in the housing and projecting through the annular opening, a plurality of radial blade grinding units on said rotor within said housing and a radial fan on the end of said rotor projecting through the annular opening; a housing enclosing said fan, said fan housing being in communication with the annular opening and a discharge outlet from said fan housing; an axial air flow chamber mounted in the wall of said cylindrical mill housing over approximately one quadrant thereof, intersecting said wall and in direct communication with the interior of said mill housing over that quadrant and in communication with the fan housing through the annular opening, and a plurality of deflecting vanes on the inner side of the wall of said flow chamber.

8. A pulverizer according to claim 7 further characterized in that the deflecting vanes are pivotally mounted for adjustment of the angle of deflection.

9. A pulverizer according to claim 7 further characterized in that a grit trap is provided in the bottom wall of the mill housing at the inlet end thereof.

10. A method of pulverizing and classifying dry solid material which comprises feeding a controlled supply of dry solid material and gas to one end of a horizontally disposed generally cylindrical milling area comprised of a plurality of independent annular grinding zones, continuously grinding the solid material at least in part by attrition of particle against particle and particle against gas stream by whirling a fluid stream of particles of the solid material entrained in the gas at high speed in an arcuate path around the outer perimeter of the cylindrical milling area setting up an outer vortex action and whirling a plurality of smaller fluidic streams of particles of the solid material sequentially from grinding zone to grinding zone through the length of the milling area by deflecting at least part of the lower falling coarser particles into the next succeeding annular grinding zone and withdrawing the completely ground particles from the opposite end of the cylindrical milling area.

11. The method of claim 10 further characterized in that the higher falling superfine particles are entrained in an axial gas flow through the throw-out area and removed from the milling area.

12. The method of claim 11 further characterized in that the airborne superfine is withdrawn directly from the throw-out area independent of the ground mill product.

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