

March 31, 1953

E. H. CUMPSTON, JR
ROTARY GRINDING BALL MILL

2,633,303

Filed March 4, 1949

3 Sheets-Sheet 1

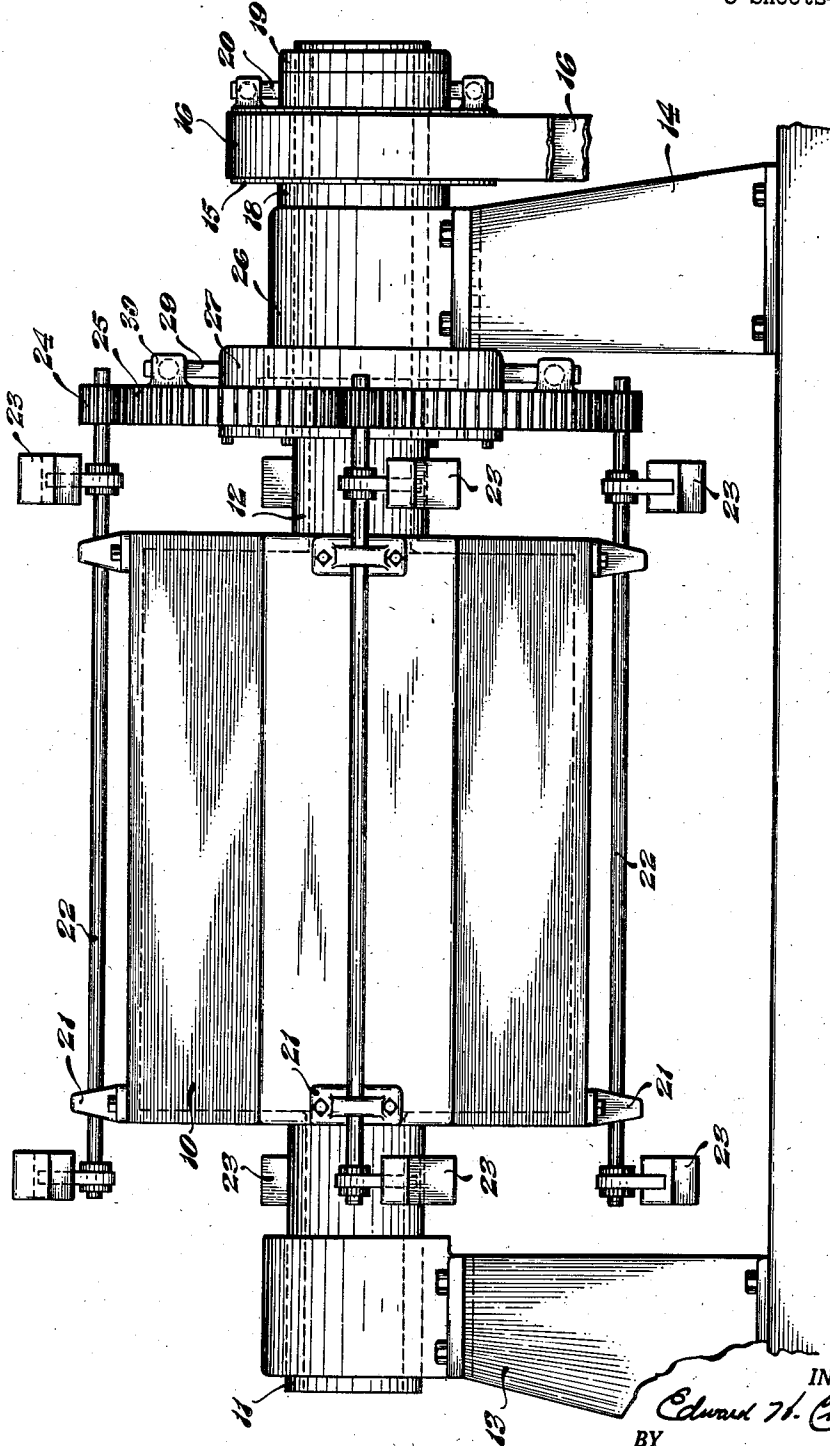


Fig. 1

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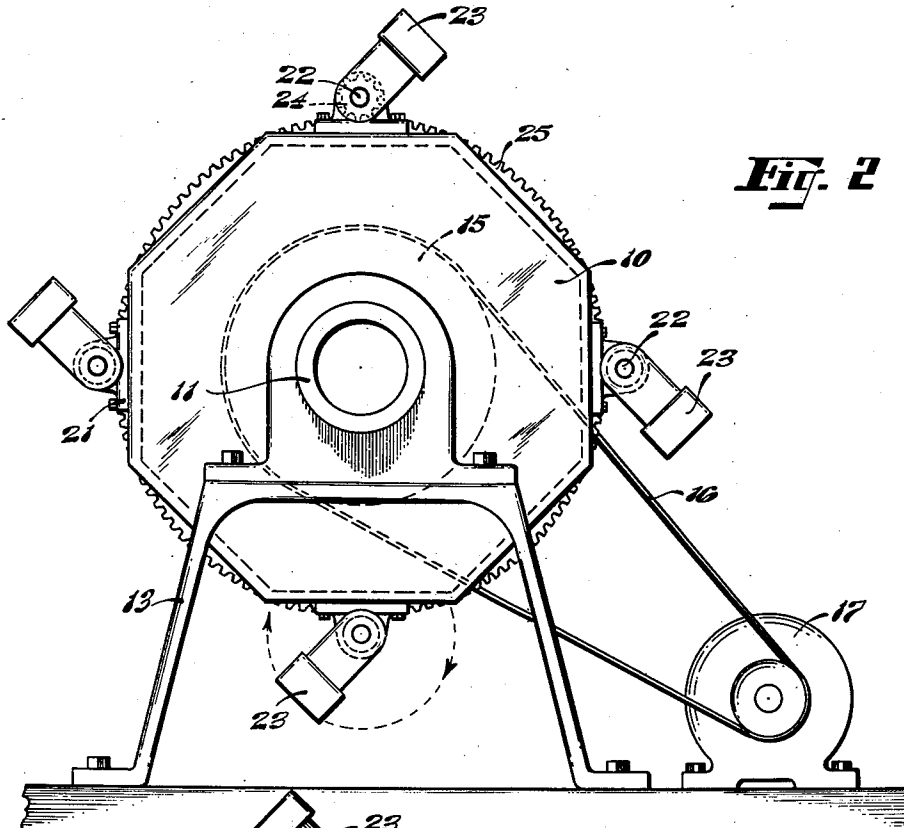


Fig. 2

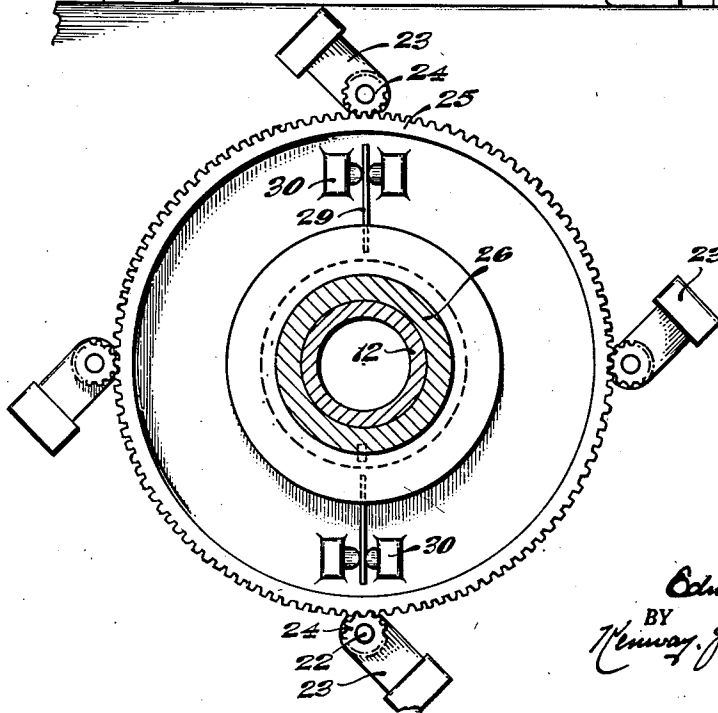


Fig. 3

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3 Sheets-Sheet 3

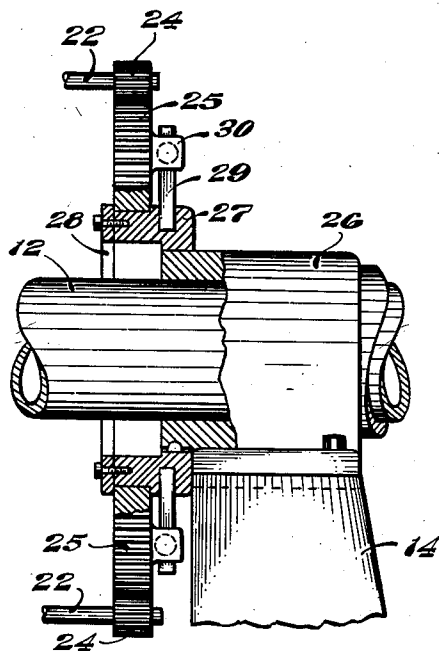


Fig. 4

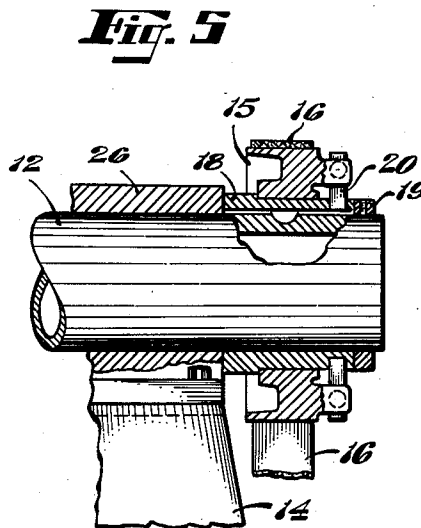


Fig. 5

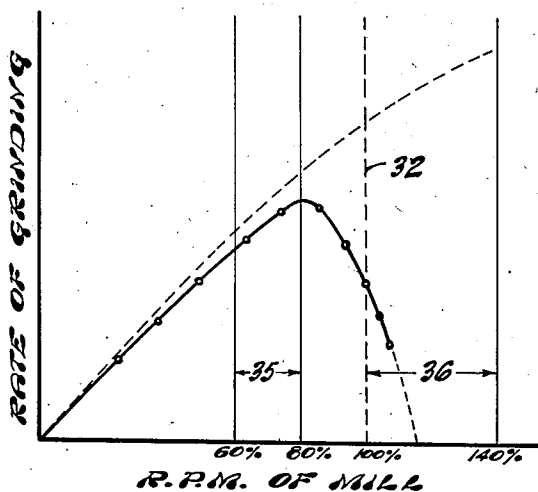


Fig. 7

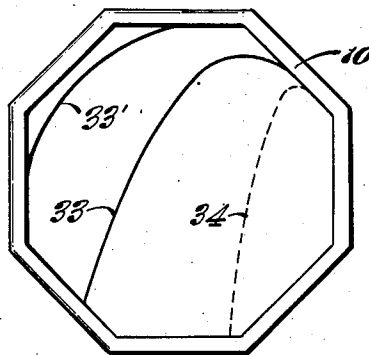


Fig. 6

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UNITED STATES PATENT OFFICE

2,633,303

ROTARY GRINDING BALL MILL

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7 Claims. (Cl. 241-175)

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This invention comprises a new and improved process of comminution or grinding and includes within its scope a novel rotary mill by which the process may be carried out.

In operating a ball mill the speed of rotation should be as high as possible without causing the charge to pack on account of its centrifuging tendency. As the speed of the mill increases, work input and grinding efficiency increase at first in proportion to the speed. Then as packing and centrifuging begin and increase, the work input increases more slowly than the speed of rotation until a critical speed is reached at which the charge begins to cling centrifugally to the shell of the mill. When this condition is reached, grinding efficiency falls off rapidly, the charge merely whirls with the mill and grinding ceases. This critical speed is determined by the equation

$$N = \frac{54.2}{\sqrt{(S-s)}}$$

where S is the radius of the mill and s the radius of the balls both expressed in feet. The combined tendencies of centrifuging and packing limit practical mill R. P. M. to the range of 60 to 80% of this critical speed.

I have discovered that by intermittently interrupting or retarding the rotation of a charge of balls mixed with the material to be ground, I am able to operate substantially above the critical speed as above determined, to utilize greater energy and achieve greater grinding efficiency than heretofore. By interrupting or momentarily reducing the speed of rotation of the surface carrying the charge, its centrifugal effect is reduced and also internal agitation of the charge is increased. The combination of these two effects produces an entirely new and advantageous pattern in the action of the charge.

The novel process of my invention may be carried out with various forms of apparatus constructed and arranged to impart to the charge the desired movement. That best suited for the purpose now known to me comprises a drum driven in rotation about a fixed horizontal axis and having a multiplicity of weights movable upon the sides thereof in fixed opposed direction having components of motion in a plane perpendicular to the axis of the drum and around said axis, thereby alternately accelerating and retarding the rotation of the drum surface carrying the charge. In a preferred form of the mill the weights may be mounted on shafts external to the drum in diagonally opposite or equally spaced locations and these shafts may be rotated at a

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substantially higher R. P. M. than that of the drum itself. Thus the centrifugal force of the weights tends alternately to retard and accelerate the rotation of the drum. This construction has the advantage of being compact and self-contained and of being effective independently of the drum driving mechanism. It also serves as a mechanical structure capable of handling the large forces involved by correct engineering principles.

An optional feature of the invention consists in forming the drum with the solid peripheral wall presenting internal and external polygonal faces thus providing at their lines of intersection within the drum lifting angles for the contents of the mill. By this construction I eliminate the necessity for internal lifting shelves or vanes within the drum which are not only expensive to install but subject to excessive wear in operation.

These and other features of the invention will be best understood and appreciated from the following description of a grinding mill of preferred construction embodying the invention, useful in carrying out the process thereof, and shown in the accompanying drawings, in which:

Fig. 1 is a view in elevation of the complete mill,

Fig. 2 is a corresponding view in end elevation,

Fig. 3 is a diagrammatic view of the other end of the mill partly in cross section,

Figs. 4 and 5 are fragmentary views, partly in longitudinal section, illustrating the supporting and driving mechanism,

Fig. 6 is a diagrammatic view suggesting the position of the charge within the drum, and

Fig. 7 is a graph showing the relationship of drum rotation to speed of grinding.

It will be understood that the present invention is applicable not only to grinding operations carried out in ball mills, but also to grinding operations carried out in pebble, rod or tube mills or, in fact, in any process where the charge is rotated as a mass. For purposes of illustration a novel ball mill suitable for my improved process will now be described.

The mill comprises a drum 10 herein shown as octagonal, but which may be cylindrical, conical or polygonal in shape, or it may be any combination of these shapes. It is mounted for rotation on hollow trunnions 11 and 12 about a fixed horizontal axis. The trunnions are supported by bearings carried upon posts or standards 13 and 14 rising from a suitable base or foundation. The trunnions are hollow so that the material to be

ground may be introduced to the drum and removed therefrom through them.

As herein shown the drum is driven by a pulley 15 which is secured to the trunnion 12 beyond the standard 14 and about which passes a belt 16 connecting the mill with the motor 17. A yielding connection is made between the pulley 15 and the trunnion 12 as best shown in Fig. 5. This includes a sleeve 18 which is keyed to the trunnion and held in place by a ring 19 fast upon the end of the trunnion. The sleeve 18 is slotted at opposite sides to receive the inner ends of flat bar springs 20 which are secured to bosses projecting outwardly from the hub of the pulley 15. This connection provides a cushion between the drum and its driving motor in that the springs 20 are free to yield slightly to the shock of any acceleration or retardation in the rotation of the drum.

The drum is provided on opposite sides with bearing brackets 21 in which are journaled longitudinally disposed shafts 22. These shafts extend beyond the opposite heads of the drum as best shown in Fig. 1, and each shaft is provided with a pair of weighted arms 23 which are arranged to swing in paths which clear the heads of the drum. Each shaft 22 is provided at one end with a pinion 24 and these pinions mesh with a large stationary ring gear 25 mounted concentrically with the trunnion 12 and supported from the stationary bearing 26 thereof. The mounting of the ring gear is best shown in Fig. 4 from which it will be seen that a shouldered collar 27 is keyed to the inner end of the bearing 26 and provides a circular seat for the ring gear which is held therein by a retaining ring 28 bolted to the collar 27. The collar is slotted at opposite points to receive the inner ends of bar springs 29 which extend through bosses 30 projecting outwardly from the ring gear 25. The gear is thus held stationary but permitted to yield when the springs 29 are flexed to cushion shocks imparted thereto by the unbalanced rotation of the weighted arms 23, and non-uniform mill rotation.

The weighted arms 23 are secured to the shafts 22 in opposed phase relation, that is to say, when the weighted arms carried by the shaft at the lower side of the drum extend downwardly, the weighted arms carried by the shaft at the upper side of the drum extend upwardly. The ratio of drum revolution to weighted arm revolution may be determined in accordance with the dimensions of the ball mill, the size and shape of the weighted arms, and the formula for critical speed above given. For example, the drum may have a diameter of 15 inches to 6 feet and may be rotated at 80 to 30 R. P. M. with the shafts 22 geared to rotate at five to ten times the speed of the drum.

In operation the mixed charge of balls and material to be ground is picked up by the internal surface of the drum and spilled in a cascade within some such zone as that indicated by the lines 33 and 34 in Fig. 6, depending upon the speed of rotation of the drum. The effect of the rotating weighted arms 23 is to accelerate the movement of the drum or more specifically the linear speed of the drum surface, during approximately 180° of their rotation while moving in advance of their shafts 22, and to correspondingly retard the motion of the drum while moving through approximately 180° of their path located behind the shafts 22 relative to their direction of drum rotation. The accelerating and retarding effect of the weighted arms is imposed upon the otherwise uniform rotation of the drum im-

parted to it by the motor 17, and as already explained, the intermittent intervals of retardation or deceleration break up the centrifugal tendency of the charge so that a substantial increase in grinding efficiency is secured when the mill is operated at or above the critical speed indicated in Fig. 7. For example, excellent results have been secured in operating a 14 inch ball mill at 113% of the critical speed indicated by the formula.

In the graph of Fig. 7 the solid line curve shows the rate of grinding in pounds per minute of the material ground in relation to the R. P. M. of a conventional ball mill driven uniformly. The line 32 indicates the critical speed calculated by this formula and the normal and usual zone of operation, i. e. 60 to 80% of the critical speed, as indicated by reference character 35. The dash line curve shows the same relation of grinding rate to R. P. M. of a mill operated with intermittent deceleration in accordance with the process of my invention. In this case the zone of operation is increased to 100 to 140% of the critical speed, as indicated by reference character 36, and the rate of grinding of the mill continues to increase as the R. P. M. of the mill is increased to 140° or more of the otherwise critical speed.

The increase in efficiency of the grinding operation carried out in accordance with the present invention is due in part to the fact that the dead spot or zone of the charge is substantially eliminated. It will be understood that when a ball mill is operated at a uniform speed, a definite zone is formed in the charge in which the balls remain substantially at rest with respect to each other and no grinding occurs. It has been found that this dead spot disappears when the charge is intermittently retarded so that its centrifugal effect is reduced, the charge caused to cascade under the influence of gravity more freely and the area of the grinding zone is substantially increased. For example, it may be increased in area from the line 33 to the line 33' as suggested in Fig. 6.

The retarding and accelerating effect of the weighted arms 23 is the more pronounced because of the fact that the effective torque of the arms in the direction of drum rotation is neutralized twice in each rotation of the weights. This occurs when the oppositely disposed weights instantaneously extend radially outwardly or radially inwardly with respect to the axis of rotation of the drum. It is in moving between these two neutralizing positions that the accelerating and decelerating effect of the weighted arms becomes apparent.

The torsional input of the weighted arms is sinusoidal in character and passes through zero twice in each revolution of the arms. The arms as a system balance each other in all positions with respect to the bearings of the mill, a condition which permits the employment of a much lighter construction and insures longer life of the apparatus than would be the case if the system were unbalanced. In the illustrated construction this balance is secured by locating the shafts 22 in diagonally opposite positions on the drum but it will be apparent that the desired balance would be secured by any circumferentially equal spacing of weights; for example three weights spaced 120° apart.

While balls have been referred to for convenience as the grinding elements with which the charge is made up elements of any other shape

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are to be considered as the full equivalent of balls for purposes of the present invention. It would also be within the scope of the invention to construct and arrange the drum for rotation about a somewhat inclined axis or to tilt the axis of the drum.

In carrying out the present invention it is convenient in many cases to employ the standard driving mechanism of commercial ball mills and this usually includes a gear in place of the pulley 15 herein shown. Whether a pulley or gear is employed the yieldable connection, herein shown as the bar springs 20, permits an angular slope of about five or six degrees, for example, on either side from normal driving position at uniform rate. The term rate is used herein as meaning R. P. M. It will be observed that there is substantially no loss in driving energy since the force used in each rearward deflection of the spring bars is applied in accelerating the drum during the ensuing phase of the eccentric weights. In practice the retarding force of the eccentric weights is calculated so that the rotation of the drum is never completely arrested.

Having thus disclosed my invention and described in detail an illustrative embodiment thereof, I claim as new and desire to secure by Letters Patent:

1. A ball mill or the like comprising a drum, stationary bearings supporting the drum for rotation about a fixed horizontal axis, driving means connected to the drum for rotating the same, shafts mounted externally upon the drum parallel to the axis thereof in diagonally opposite locations, means for rotating said shafts at a higher speed of rotation than the drum, and eccentric weights carried by the shafts and set in opposed phase relation to each other.

2. A ball mill or the like comprising a drum, stationary bearings supporting the drum for rotation about a fixed horizontal axis, means for rotating the drum, a series of weights movably mounted upon the drum for motion having components in a plane perpendicular to the axis of the drum and around said axis, and means for moving said weights simultaneously first in the direction of rotation of the drum and then oppositely to its direction of rotation.

3. A ball mill or the like comprising a drum, stationary horizontal bearings supporting the drum for rotation about a fixed axis, eccentric weights mounted for rotation about axes parallel to the axis of the drum on the drum, means for rotating the drum, and mechanism including a yieldable element for rotating the weights.

4. A ball mill or the like comprising a drum, stationary horizontal bearings supporting the

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drum for rotation about a fixed axis, a multiplicity of eccentric weights mounted for rotation on the drum, connections including a yieldingly mounted gear for rotating the weights on the drum, and other connections including a yieldingly mounted pulley for rotating the drum.

5. A ball mill or the like comprising a drum, stationary horizontal bearings supporting the drum for rotation about a fixed axis, shafts mounted on opposite sides of the drum, unbalanced weights carried by each shaft in spaced apart and in opposed phase relation, a pinion on each shaft, and a normally stationary but yieldingly mounted gear meshing with each of said pinions and acting to rotate said shafts and weights as the drum is revolved.

6. A ball mill or the like comprising a drum having hollow trunnions, stationary bearings for said trunnions whereby the drum is supported thereby for rotation about a fixed horizontal axis, a multiplicity of shafts mounted upon the drum in pairs 180° apart, each shaft carrying unbalanced weights at both ends arranged to swing in paths beyond the heads of the drum, a pinion fast to each shaft beyond the weight at one end thereof, and a yieldingly mounted ring gear disposed with clearance about one trunnion of the drum and meshing with the said pinions.

7. A ball mill or the like comprising a drum, stationary bearings supporting the drum for rotation about a fixed horizontal axis, means for rotating the drum, rotary eccentric weights carried by the drum and located with equal circumferential spacing, and means for rotating the said weights at a higher rate than that at which the drum is driven.

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