MILL FOR COMMUNITING SOLID MATERIAL

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The present invention relates in general to rotary mills of the type comprising a rotor adapted to contain the material to be comminuted and having therein means for comminuting the material as the rotor rotates, a primary object of the invention being to provide an improved rotary mill of this type.

More particularly, the present invention contemplates a rotary mill comprising a hollow rotor, preferably rotatable about a horizontal axis, containing one or more rotatable members which comminute the material in the rotor with a crushing action in response to rotation thereof.

Still more particularly, the present invention contemplates a rotary mill wherein the rotor is a hollow cylinder rotatable about its longitudinal axis, which is preferably horizontal, and wherein the hollow cylinder contains one or more rollers or roller members positioned with their longitudinal axes parallel to the longitudinal axis of the cylinder, it being understood that whenever I refer hereinafter to a "roller" or "roller member," I am referring either to a single roller in the cylinder, or to one of a plurality of rollers in the cylinder, unless otherwise specified.

The employment of a roller as the comminuting or grinding means for the material in the cylinder has numerous advantages over the employment of such rotatable members as balls and some of these advantages will be considered at the present time, others being considered hereinafter.

First of all, a roller provides line contact with the cylinder, as opposed to the point contact provided by a ball, and the roller has a smaller surface area than the ball for the same effective contact area with the cylinder. Since the roller has a smaller surface area, it permits a substantial improvement in the proportion of the charge which can be recovered after the grinding operation, particularly when the material being comminuted has a strong tendency to adhere to surfaces within the mill. The advantage of a smaller surface is particularly important when comminuting a mixture of materials some of which have a stronger tendency to adhere to the surfaces than others. Under such conditions rotary mills employing balls may change the composition of the mixture being comminuted drastically, the mixture recovered from the mill being low in the constituents having strong adhesive tendencies and high in constituents having low adhesive tendencies. Conversely, that portion of the mixture which adheres to surfaces within the mill is high in constituents having a strong adhesive tendency and is low in constituents having a low adhesive tendency. By minimizing the surface area for a given effective contact area through the use of a roller, adhesion, and therefore any change in the proportions of the constituents of a mixture being comminuted, is minimized, this being an important feature of the invention.

An important object of the present invention is to provide a rotary mill having magnetic means for biasing the roller radially against the cylinder, the roller and cylinder preferably being horizontal and the roller being magnetically biased against the cylinder in the downward direction so that the magnetic bias supplements the gravitational bias acting on the roller under such circumstances.

More particularly, an important object of the invention is to provide a magnetic biasing means which provides a substantially closed magnetic circuit in order to attain maximum downward bias of the roller against the cylinder, thereby maximizing the effective weight of the roller and accelerating the crushing action of the roller and the cylinder. In this connection it might be well to discuss another advantage resulting from the use of a roller, instead of balls, this advantage being that a roller can very easily be coupled into a magnetic circuit, whereas this is difficult or impossible to do with one or more balls.

Another object of the invention is to provide a mill wherein the roller is coupled into a substantially closed magnetic circuit by means of a yoke below the cylinder, the yoke having poles which are spaced apart longitudinally of the cylinder and which are positioned in close proximity to the cylinder to attain efficient magnetic coupling between the yoke and the roller. A related object is to provide the yoke with poles having concave cylindrical surfaces facing and complementary to the exterior of the cylinder so as to minimize the gap between the poles of the yoke and the roller within the cylinder.

With the foregoing construction, it will be apparent that the yoke and the roller within the cylinder provide a magnetic circuit which is closed except for the gaps between the poles of the yoke and the roller, which gaps may be relatively small. Either or both the roller and the yoke may be permanent magnets. If only one is a magnet, the other may be of a relatively permeable material, such as soft iron or mild steel. If the roller is of relatively soft metal, it may of course be surface-hardened, plated or otherwise encased in a hard outer layer. If the yoke is a magnet, it may, alternatively, be of the electromagnet rather than the permanent magnet type. It will be understood that when the yoke is referred to hereinafter as a magnet, it may be either a permanent magnet, or an electromagnet.

Another object of the invention, and one of considerable importance, is to provide means for adjusting the magnetic field so as to vary the magnetic bias acting on the roller. According to the invention, this is preferably achieved by providing an adjustable shunt in the magnetic circuit. In the preferred form of the invention, this is accomplished by making at least one of the poles of the yoke movable longitudinally of the cylinder toward and away from the other pole so as to vary the spacing or gap between the poles. Either or both poles of the yoke may be made movable longitudinally of the cylinder by providing separate, longitudinally slidable gap or pole members conforming to the external configuration of the cylinder as hereinbefore outlined.

In case the yoke is an electromagnet, the magnetic biasing force may of course be varied by varying the energizing current.

With the foregoing in mind, there are certain additional advantages of the present invention in the preferred use of a single roller in the cylinder, as opposed to a plurality of rollers. One advantage is that much closer coupling between the yoke and the roller can be attained since, with a single roller, the roller diameter can be a substantial percentage of the internal diameter of the cylinder so that the gaps between the yoke poles and the roller are minimized. In this way, the effective weight of the roller is maximized to accelerate the grinding action. The minimum diameter of the roller then is determined by the minimum air gap, and also by the cross section and permeability needed to conduct flux provided by
the permanent magnet. The maximum roller diameter, on the other hand, is limited by permissible infringement on the usable volume of the container. For example I have found that the diameter of the roller may to advantage be made as much as 55 percent of the internal diameter of the cylinder, and in some cases larger. Another advantage is that a single roller presents a smaller surface area for a given effective contact area than does a plurality of rollers, so that adhesion, and changes in the proportions of the constituents of a mixture due to adhesion, are minimized. Also, a single roller may be securely locked magnetically against the side of the cylinder. In addition, the roller prevents a single roller from being ground since the charge being ground is an explosive material. Such locking, with assurance against relative motion of the rollers, would be difficult or impossible with more than one roller. Another advantage of a single roller is that cocking or jamming, encountered when a plurality of rollers is used, is eliminated. Also, the use of a single roller eliminates the reduction in downward grinding force which may result when lateral friction between plural rollers produces a lifting force thereon.

Among further objects of the present invention, it is desirable to provide a rotary mill wherein the cylinder is rotated about its longitudinal axis in a horizontal position merely by placing the cylinder on spaced, parallel, horizontal rolls at least one of which is driven, the yoke poles being positioned between such rolls. In a small mill, the cylinder may serve as a container for transporting the charge being ground, both before grinding and after grinding. It is merely necessary to place the cylinder, with the desired charge and the grinding roller therein, on the rolls to ready the mill for operation.

Another object is to provide a cylinder comprising an open-ended barrel having removable end-closures at one or both ends, and wherein the mating surfaces of the barrel and the end closures diverge outwardly axially of the barrel at a small included angle so that the end closures may be pressed into the ends of the barrel to provide fluid-tight friction seals or fits without the use of packing, seals, or the like. To attain this result, the half-angle of the conical mating surface may be made as small as two degrees. A seal of this type is valuable since it is generally desirable to grind the charge of solid, granular material in a suitable liquid vehicle, i.e., a vehicle which will not dissolve or react with any of the components of the charge. In this way a smooth-flowing slurry is formed permitting accommodation of a charge about 10 times as large as when dry materials are used that tend to pile up under the roller. The vehicle may be water, but in some cases is a substance such as a chloroform, methanol, etc., which may be destructive to resilient seals made of rubber and like materials.

The foregoing objects, advantages and features of the present invention, together with various other objects, advantages and features thereof which will become apparent, may be attained with the exemplary embodiment of the invention illustrated in the accompanying drawings and described in detail hereinafter. Referring to the drawings:

Fig. 1 is an isometric view of a rotary mill which embodies the present invention;
Fig. 2 is a sectional view taken along the arrowed line 2—2 of Fig. 1; and
Fig. 3 is an enlarged sectional view taken along the arrowed line 3—3 of Fig. 2 of the drawing.

In the drawing, the rotary mill of the invention, designated generally by the numeral 12, is mounted on a base 10, the mill being driven by a reversible, variable speed, electric motor 14 mounted on the base. The motor is controlled by a unit 16 on the base 10. The control unit 16 includes a panel 18 having thereon an on-off switch 20, a reversing switch 22, a speed-control knob 24 and a signal light 26 to indicate that the unit is in operation.

Considering the mill 12 in further detail, it includes two spaced standards 28 and 30 carried by the base 10. Extending between and carried by the standards 28 and 30 are spaced, parallel, horizontal rolls 32 either or both of which are driven by the motor 14. In the particular construction illustrated, a sprocket 34 is connected to one of the rolls 32 in the rear side of the standards 28, and a chain 36 engages this sprocket and a sprocket 38 on the motor shaft. In this construction, only one of the rolls 32 is driven, the other being an idling roll, although both rolls may be driven if desired. Carried by the rolls 32 with its longitudinal axis horizontal is a cylinder 40 which, in the particular construction illustrated, is rotated about its longitudinal axis by the roll 32 having the sprocket 34 connected thereto, the other, idling roll 32 being driven by the cylinder. The latter includes an open-ended barrel or tube 42, of substantially non-magnetic material, into the open ends of which are pressed end closures 44, also non-magnetic, having therein tapped holes 46 to receive threaded means, not shown, for pulling the closures from the barrel. The mating surfaces of the barrel 42 and the closures 44 pressed thereinto are conical, diverging outwardly of the cylinder 40 at a half-angle of the order of two degrees. With this construction, the barrel 42 is divided into two sections by a partition 46. A chain 36 engages this sprocket and a sprocket 38 on the motor shaft. In this construction, only one of the rolls 32 is driven, the other being an idling roll, although both rolls may be driven if desired.

Carried by the base 10 below the cylinder 40 and between the rolls 32 is a yoke comprising a yoke member 50 and gap or pole members 52 provided with concave cylindrical surfaces 54 complimentary to, facing, and in close proximity to the exterior of the cylinder 40, the surfaces 54 preferably having a common axis of curvature coinciding with the axis of the cylinder. Preferably, the pole members are made of a material of high magnetic permeability. With this construction, the gaps between the pole members 52 and the roller 48 are minimized, thereby establishing a substantially closed magnetic circuit through the roller 48, the gap members 52 and the yoke 50. If a single roller is used, it will be apparent that the larger the roller diameter relative to the inside cylinder diameter, the smaller will be the effective gaps between the roller and the pole members 52, and the better, therefore, the magnetic coupling therebetween.

In the particular construction illustrated, the yoke member 50 is shown as a simple U-shaped structure, but it will be understood that the configuration of the yoke may vary widely.

To provide a magnetic means for biasing the roller downwardly into engagement with the cylinder 40, thereby increasing the effective weight of the roller and its efficacy in grinding, either or both of the yoke member 50 may be magnets. Either the roller 48 or the yoke member 50 may then induce a magnetic flux around a magnetic circuit or loop comprising the roller, the yoke and the gap member, the circuit being closed, except for the gaps between the roller and the pole 52, which gaps are minimized in the matter hereinbefore discussed to produce a maximum magnetic biasing effect.

If the roller 48 is a permanent magnet, then the cylinder 40 may be either of magnetic materials, or non-magnetic material. Under these conditions, the yoke...
member 50 may be formed of a material, such as soft iron, having a high magnetic permeability in order to induce maximum flux in the magnetic circuit.

Alternatively, the yoke member 50 may be a magnet, either of the permanent magnet type, or, by enclosing it in an energizing coil (not shown), of the electromagnet type. In the latter case, the roller 48 may be made of a magnetic material of relatively high permeability, such as a mild steel, case-hardened to minimize wear, and the cylinder 40 may be made of non-magnetic material to prevent shunting the magnetic field through the cylinder. For example, the barrel 42 and the closures 44 may be made of stainless steel.

In order to adjust the magnetic field to vary the magnetic bias applied to the roller 48, irrespective of whether the roller or the yoke member 50 is a magnet, means 56 is provided for varying the spacing between the gap members 52, thereby providing a variable magnetic gap or shunt. For this purpose, the gap members 52 may be made slidable relative to and in contact with the end surfaces of the body of the yoke member 50 so that these gap members, or pole pieces, may be moved toward and away from each other. To vary the spacing between the pole members 52, two screws 58 are carried by the standards 28 and 30 and have an actuating handle 60 and 62 in threaded engagement with the respective poles. The screws 58 are interconnected to operate in unison by a gear train 64 carried by the standards 30 and one of the screws extends through the standard 30 and carries an actuating knob 66; the other screw also extending through the standard 30 and carrying an indicator 68 for indicating the relative positions of the poles 52. The indicator 68 may be calibrated in any desired units, such as gap spacing, magnetic biasing force, or the like. It will be apparent that, in this construction, the spacing of the pole members 52 may be varied readily to vary the effective weight of the roller 48, thereby to vary the rate at which material in the cylinder 40 is ground.

It will be understood that the slidable poles 52 are made of a material having a high magnetic permeability. For example, they may be made of soft iron. If the roller is a magnet, it may be desirable, in order to extend the range of adjustment of the magnetic bias, to make the magnetic reluctance of the U-shaped member 50 large relative to the reluctance of the gap members 52 when the latter are in their closed positions. This may be done by slotting the member 50, reducing its cross-section by selecting a material of relatively low permeability. Alternatively, the body of the member 50 may be omitted altogether, whereby the yoke will comprise only the gap or pole members 52. In either case the magnetic biasing force is a maximum when the gap members 52 are in contact, and is reduced by separating the gap members.

On the other hand, if the yoke member 50 is a magnet, then magnetic biasing force is a minimum when the gap or pole members 52 are in contact, and increases toward a maximum when the gap is opened.

Although I have disclosed an exemplary embodiment of my invention herein, it will be understood that various changes, modifications and substitutions, some of which have been suggested herein, may be incorporated in the embodiment disclosed without departing from the spirit of the invention as defined by the patent claims hereinafter appearing.

Claim as my invention:

1. In a mill for comminuting material, the combination of:
   a. a hollow cylinder rotatable about its longitudinal axis;
   b. means for rotating said cylinder about its longitudinal axis with the longitudinal axis of said cylinder substantially horizontal; a magnetic roller within said cylinder having a substantially horizontal axis parallel to the longitudinal axis of said cylinder; and magnetic yoke means external to and below said cylinder and magnetically coupled to said roller to form therewith a substantially closed magnetic circuit for biasing said roller downwardly against said cylinder to increase the effective weight of said roller.
2. A mill as defined in claim 1 wherein said cylinder is nonmagnetic.
3. In a mill for comminuting material, the combination of:
   a. a hollow cylinder rotatable about its longitudinal axis; and
   b. a rotor member having a substantially horizontal axis parallel to said longitudinal axis of said cylinder; and magnetic yoke means external to and below said cylinder and magnetically coupled to said rotor member to form therewith a substantially closed magnetic circuit for biasing said rotor member downwardly against said cylinder to increase the effective weight of said roller; and means for varying the magnetic bias applied to said roller.
4. In a mill for comminuting material, the combination of:
   a. a hollow cylinder rotatable about its longitudinal axis; and
   b. a rotor member having a substantially horizontal axis parallel to said longitudinal axis of said cylinder; and magnetic yoke means external to and below said cylinder and magnetically coupled to said rotor member to form therewith a substantially closed magnetic circuit for biasing said rotor member downwardly against said cylinder to increase the effective weight of said roller; and means for varying the magnetic bias applied to said roller comprising adjustable magnetic gap means in said magnetic circuit, said gap means magnetically shunting said roller.
5. In a mill for comminuting material, the combination of:
   a. a hollow cylinder rotatable about its longitudinal axis; and
   b. a rotor member having a substantially horizontal axis parallel to said longitudinal axis of said cylinder; and magnetic yoke means external to and below said cylinder and magnetically coupled to said rotor member to form therewith a substantially closed magnetic circuit for biasing said rotor member downwardly against said cylinder to increase the effective weight of said roller; and means for varying the magnetic bias applied to said roller comprising adjustable magnetic gap means in said magnetic circuit, said gap means magnetically shunting said roller.
6. A mill as defined in claim 5 wherein said yoke member is a magnet.
7. A mill as defined in claim 5 wherein said poles have concave cylindrical surfaces which face said cylinder in close proximity thereto and which have a common axis of curvature substantially coinciding with said longitudinal axis of said cylinder.
8. A mill as defined in claim 5 wherein said means for rotating said cylinder includes two spaced, parallel, substantially horizontal rolls respectively located on opposite sides of said yoke member and on which said cylinder rests with its longitudinal axis parallel to the axes of said rolls, and includes means for rotating at least one of said rolls.
9. A mill as defined in claim 5 wherein said cylinder is nonmagnetic.
10. In a mill for comminuting material, the combination of:
    a. a hollow cylinder; and
    b. means for rotating said cylinder about its longitudinal axis with said longitudinal axis substantially horizontal; a rotor member in said cylinder with its longitudinal axis parallel to said longitudinal axis of said cylinder; and magnetic yoke means magnetically coupled to said rotor member to form therewith a substantially closed magnetic circuit for biasing said rotor member downwardly against said cylinder, said magnetic yoke means including a yoke member below said cylinder and having poles located adjacent to and spaced apart longitudinally of said cylinder and at least one of which is movable longitudinally of said cylinder.
cylinder to vary the spacing between said poles, one of said members being a magnet; and means for moving said one pole longitudinally of said cylinder.

11. A mill as defined in claim 10 wherein said yoke member is a magnet.

12. In a mill for comminuting solid material, the combination of: a rotor; means for rotating said rotor; a rotatable member in said rotor; magnetic means forming with said rotatable member a substantially closed magnetic circuit for biasing said rotatable member downwardly against said rotor, said magnetic means including a yoke member external to said rotor and magnetically coupled to said rotatable member and provided with two poles at least one of which is movable toward and away from the other, one of said members being a magnet; and means for adjusting the magnetic field provided by said magnetic means, including means for effecting said movement of said one pole.

13. A mill as defined in claim 12 wherein said yoke member is a magnet.

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