Sept. 9, 1969 J. S. ECKERT 3,465,974

VIBRATORY MILL

Filed May 13, 1966 2 Sheets-Sheet 1

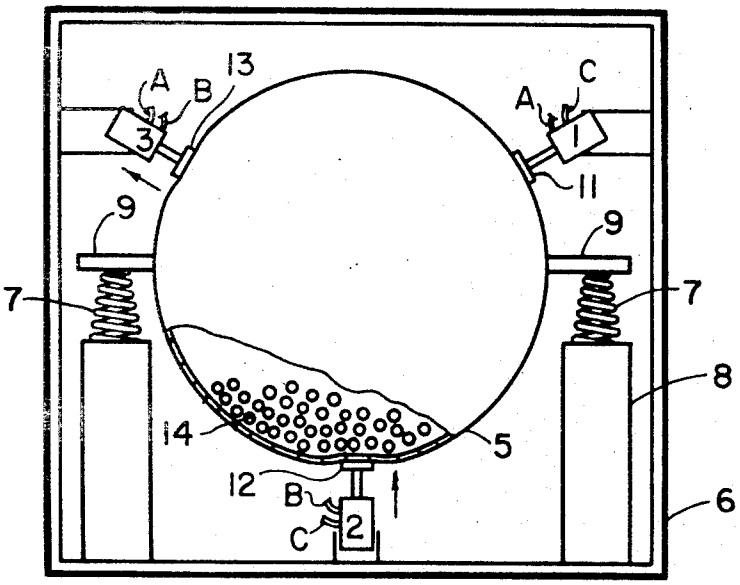


Fig. 1.

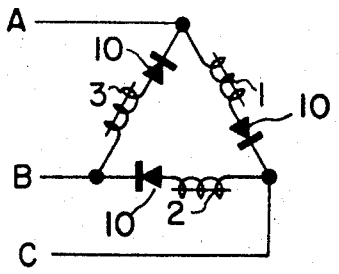


Fig. 2.

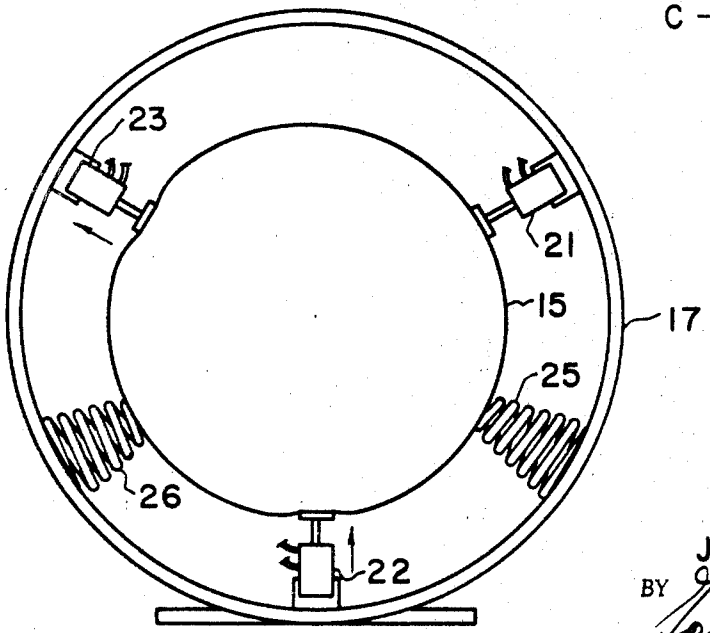


Fig. 3.

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VIBRATORY MILL

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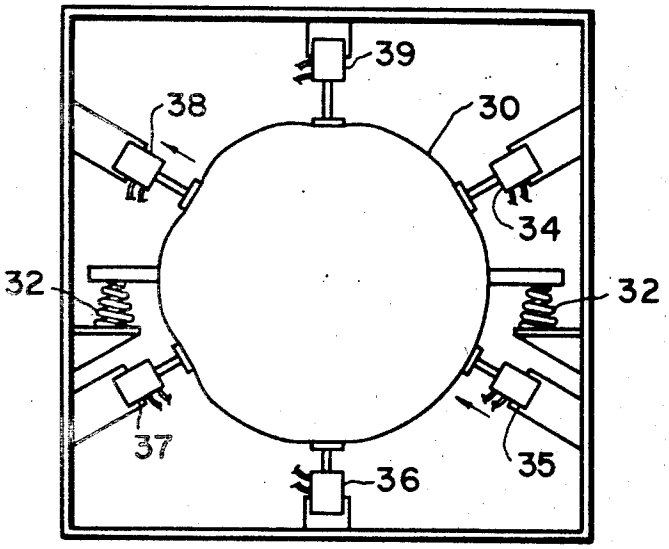


Fig. 4.

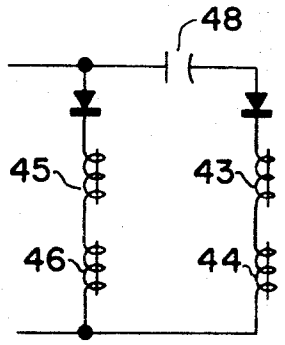


Fig. 6.

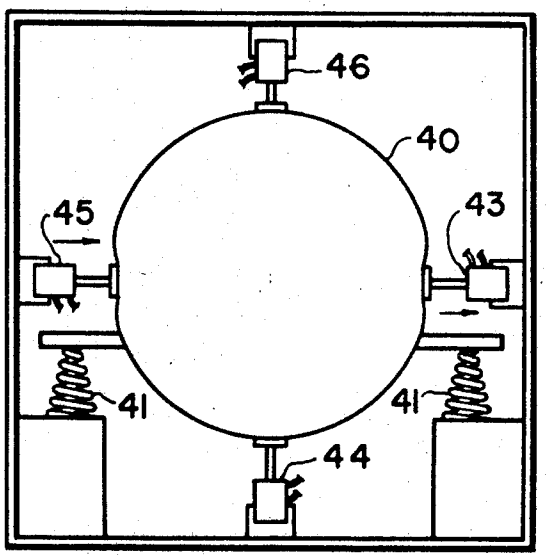


Fig. 5.

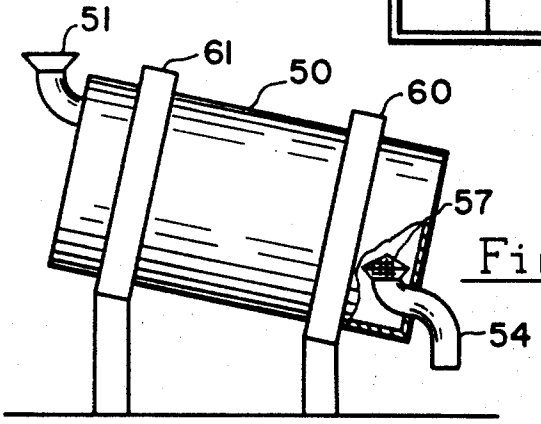


Fig. 7.

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VIBRATORY MILL

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Int. Cl. B02c 9/04, 15/00, 17/00
U.S. Cl. 241—153 3 Claims

ABSTRACT OF THE DISCLOSURE

A vibratory mill including a drum and a plurality of electro-mechanical vibrators driven into and out of contact with the outer periphery of the drum, to vibrate sequentially, discrete portions of the periphery of the drum.

This invention relates to a vibratory drum which contains any usual number of spherical grinding elements of any suitable composition. The material on which the grinding elements act may be entirely solid or it may be a solid suspended in a liquid.

The circumferential wall of the drum of this invention is made of sheet metal or the like, and solenoid vibrators are located at intervals around the drum which flex the wall of the drum in a regulated manner. The drum is not rotated on its axis, but is held in a relatively stationary position. It is desirably supported on springs or other resilient means, although it may be rigidly attached to its base.

There are at least three solenoids located around the circumference of the drum, and there may be as many as eight or more. The solenoids are connected electrically so that they are actuated one after the other in sequence around the drum, and as each flexes the wall of the drum a continuous vibratory wave is set up which travels around the drum again and again. The action of the solenoids is preferably so correlated with the drum structure as to cause the drum surface to resonate.

The circumferential drum surface is usually a cylinder but it may be a truncated cone. The solenoids are usually identical and spaced uniformly around the drum, but this is not necessary. For instance, if there are three solenoids and one is located at the center of the top of the drum, it may be weaker than the other two because the contents of the drum do not press up against this wall. In such an arrangement the two other solenoids may be closer to one another than to the solenoid at the top of the drum.

Usually the solenoids will be aligned in a plane which is perpendicular to the axis of the drum, but this is not necessary. For instance, if there are six identical solenoids they may be arranged in two series in planes relatively close together. The solenoids of each series will then be staggered between two of the solenoids of the other series so that the solenoids are spaced 60 degrees from each other. In this way the vibrating action is more evenly distributed over the length of the drum than when the solenoids are all located in the same plane and this may be desirable in relatively long drums.

The invention is particularly adapted to the vibration of mills operated on a continuous basis in which the material to be treated is fed into the drum at or near one end and removed from the other end or near the other end. In this situation different series of solenoids may operate on two or more widely separated portions of the drum, and in one portion of the drum the vibration may be greater than in another portion, depending upon the most efficient vibration for each stage in the grinding cycle. Thus, as the material passes through the drum it will be acted upon first by one series of solenoids and then by another, as the material passes from one

portion of the drum to the next. The respective solenoids of the different series may be located in the same radial planes, or the solenoids of one series may be staggered with respect to those of an adjacent series.

The vibratory motion imparted to the drum causes the balls or other grinding media adjacent the vibrated portion within the drum to rotate about their own individual axes and to grind the material between them, and the entire bulk of the material adjacent the vibrating portion of the drum (including the grinding elements) is caused to vibrate and tends to rotate around the inner wall of the drum, one portion of the material tumbling over another portion almost continuously. Such vibration in the presence of the grinding elements produces a rapid and intensive grinding action.

The invention is further described in connection with the accompanying drawings, in which:

FIGURE 1 is a section through a vibratory mill equipped with three different solenoid vibrators partly broken away to show balls in its interior;

FIGURE 2 is a diagram showing how these three vibrators are connected into a 3-phase circuit to produce the desired vibration;

FIGURE 3 is a section through a similar drum with similar vibrators, the drum being mounted within a circular support;

FIGURE 4 is a section through a drum with six vibrators to act on it;

FIGURE 5 is a section through a drum with only four vibrators;

FIGURE 6 is a diagram showing how these four vibrators are connected into a split-phase circuit provided by a capacitor; and

FIGURE 7 is a side view of a long drum adapted for continuous operation with two series of vibrators each adapted to operate on a different section of the drum.

In FIGURE 1 the three solenoids **1**, **2** and **3** are located at 120° from each other around the drum **5** which is mounted in the frame **6**. The drum is supported by springs **7** fastened to the standards **8**. The horizontal flanges **9** fastened to the drum are supported by the springs so that the entire drum can vibrate.

FIGURE 2 is a diagram of a 3-phase electric circuit showing the three lines A, B and C of FIGURE 1 connected to actuate coils **1**, **2** and **3** of the three solenoids. Rectifiers **10** are connected with the several circuits. The three lines are supplied with half-wave rectified 3-phase alternating current so that the three solenoids are actuated one after another in quick succession around the drum. Supposing the current to be a 30-cycle current, the vibratory impulse imparted by the solenoids completes a cycle around the drum every one-thirtieth of a second.

The plunger **11** of solenoid **1** (FIGURE 1) is shown completely withdrawn. The plunger **12** of solenoid **2** is two-thirds extended. The plunger **13** of solenoid **3** is one-third retracted. The solenoids are actuated in a clockwise direction so that shortly after the plungers are in the positions indicated in FIGURE 1 the plunger **12** of solenoid **2** is completely extended, the plunger **13** of solenoid **3** is two-thirds retracted in a cycle subsequent to that illustrated in FIGURE 1, and the plunger **11** is one-third extended into the solenoid coil. Thus, as time passes, the three solenoids complete and then repeat their individual cycles in quick succession, each complete cycle succeeding another by one-thirtieth of a second. This sets up a vibratory wave around the drum which activates balls **14** and imparts the desired grinding action to the drum contents. The distance around the drum and the composition of its wall are preferably so adjusted with respect to the length of the solenoid stroke and the operation cycle of the several solenoids that once the desired

vibratory operation has been established, the drum surface flexes, preferably, in resonance with the operation of the several solenoids.

The operation of the equipment shown in FIGURE 3 is identical to that just described. The drum **15** is supported in the rigid supporting ring **17**. The solenoids **21**, **22** and **23** are connected in series just as in the example discussed in connection with FIGURE 1. The springs **25** and **26** support the drum within the ring **17**. A third spring may be used at the top of the drum if desired. Ordinarily this third spring will be weaker than the springs **25** and **26** because it does not support any of the load. It will merely counteract the tendency of the drum to be lifted by the springs **25** and **26**. The springs may be replaced by air cushions or other resilient supports.

The drum **30** of FIGURE 4 is supported by the springs **32** and **33** in a manner similar to that shown in FIGURE 1. The six solenoids **34**, **35**, **36**, **37**, **38** and **39** are actuated in rotation by a rectified six-phase current. This current may be supplied from a central source, or a locally situated converter may be employed for the purpose.

FIGURE 5 shows the drum **40** supported by springs **41**. The four solenoids **43**, **44**, **45** and **46** are actuated in rotation by a split-phase current supplied by any suitable means. FIGURE 6 illustrates one such means in which capacitor **48** produces the two phases. The operation of solenoids **43** and **45** are staggered between the operation of solenoids **44** and **46**, the coils of the respective solenoids being indicated by the numerals **43'**, **44'**, **45'** and **46'**.

Instead of operating two solenoid coils by each phase of the circuit, three or four or more solenoid coils may be operated by each so that six or eight or more solenoids may be located around the drum, as indicated in FIGURE 4, and operated in quick succession by this means. Various circuits may be utilized for operating any desired number of solenoids in quick succession.

FIGURE 7 shows the drum **50** tilted at a slight angle so that material fed into the drum through the hopper **51** and the supply conduit **52** will gradually travel down through the drum to any usual outlet means, such as the outlet **54** located near the bottom end of the circumferential wall to catch the ground contents of the drum as it is thrown up by the rotation of the charge in the drum and falls into the mouth of the outlet. This mouth may be a trough or other suitable collection device. The screens **57** over the trough separate the grinding balls and prevent them from being removed from the drum. Alternatively, the grinding balls may be removed with the ground material after it has left the drum, and be returned through the hopper **51** with fresh material as it is fed to the drum.

The drum of FIGURE 7 is supported in the support rings **60** and **61** by springs in a manner similar to that shown in FIGURE 3. Between each support ring **60** or **61** and the drum there are a plurality of solenoids which operate on the drum surface, one after the other in rotation around the drum. There may be fewer and larger solenoids within the ring **60** than in the ring **61**, and the plungers of these larger solenoids may have a longer stroke than the solenoids within the support ring **61**. Thus, the vibrations towards the feed end of the drum may be of greater magnitude and less frequent than those near the discharge end of the drum. If there are the same number of solenoids within each of the support rings it may be advantageous to align them on the surface of the drum. Alternatively, it may be desirable to stagger them.

Although generally all of the vibrators located around any particular portion of the drum will have the same length of stroke, this is not necessary. Thus, the vibrator **2** of FIGURE 1 which vibrates the portion of the drum which is supporting the material within the drum may have a shorter, slower stroke than the vibrators **1** and **3** which act on a portion of the drum which supports less of the drum contents than the vibrator **2**. Instead of positioning three vibrators as shown in FIGURES 1 and 3, one of the vibrators may act on the center of the top of the drum and two may act on opposite sides of the lower portion of the drum. This arrangement will differ from that illustrated in FIGURE 1 because two of the vibrators will share the load at the bottom of the mill.

Although generally the plungers of the respective vibrators will remain in contact with the drum surface at all times, and may even be fastened to it, they may break contact with the drum as they near the completion of a stroke and make contact again during the next stroke.

Although in the preferred arrangements which are shown, the vibration is produced by solenoids, hammers operated in a desired sequence by air or hydraulically or by other means may be used to vibrate a drum.

It may be desirable to reverse the rotation of the vibratory action from time to time, at more or less frequent intervals.

The invention is covered in the claims which follow.

I claim:

1. A vibratory mill which includes a drum with a substantially circumferential wall and at least three solenoids in each of two series with the plungers thereof adapted to vibrate a portion of the wall, each series being adapted to operate on a portion of said wall adjacent a different end thereof, the several solenoids operating on the drum in quick succession around the circumference of the drum, with an inlet at one end of the drum and an outlet at the other end.

2. A vibratory mill comprising a drum having an outer periphery, means for vibrating discrete portions of the outer periphery of said drum in sequence comprising a plurality of plungers disposed along spaced radii beyond the outer periphery of said drum, said plungers being movable along a path defined by their respective radii from a position in contact with the outer periphery of said drum to a position beyond and out of contact with said outer periphery, a solenoid operatively associated with each plunger and means providing sequential electrical, solenoid-energizing impulses, to consecutive solenoids, thereby causing said plungers to move along their respective paths and sequentially vibrate discrete portions of the outer periphery of said drum.

3. The vibrating mill as defined in claim **2** wherein said means providing sequential electrical impulses includes an electrical circuit operative to split and half-wave rectify multi-phase alternating current.

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U.S. Cl. X.R.

241—175, 284; 259—72