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[54] **MILLING APPARATUS**

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[58] **Field of Search**............. 259/7 X, 8; 241/46.17, 241/46.02, 46, 38, 39, 27

[56] **References Cited**

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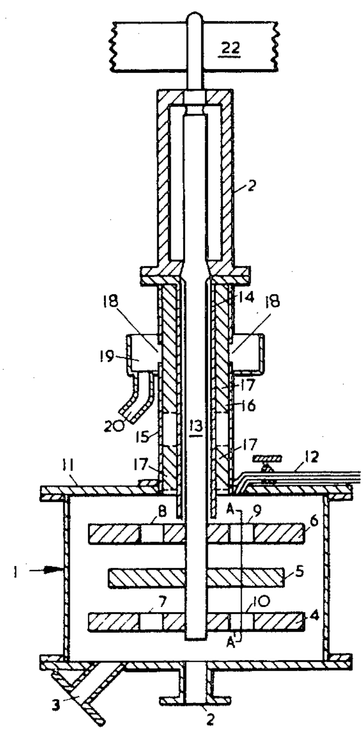
[57] **ABSTRACT**

An apparatus and process for sand milling in which at least three impeller discs are used, at least one of which is of smaller diameter than the impellers discs above and below it and wherein a settling zone of smaller diameter than the milling chamber is provided, there being means to reduce turbulence to the settling zone before recovering milled particulate solid substantially free from milling medium.

12 Claims, 2 Drawing Figures



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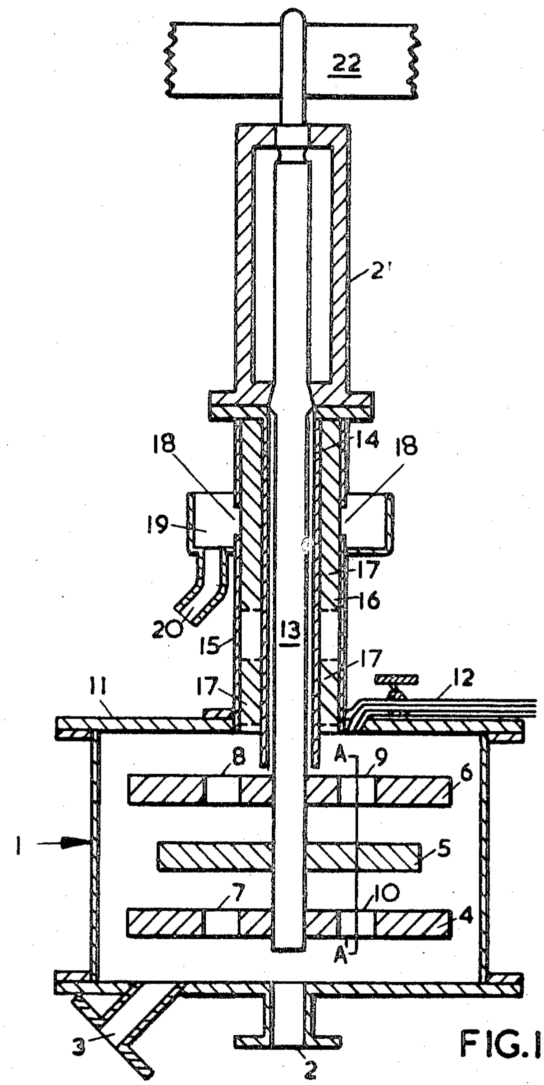

FIG.1

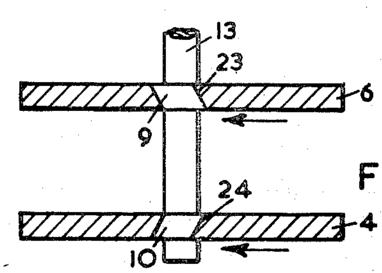

FIG.2

MILLING APPARATUS

The present invention relates to improved mills and processes of the type in which a material to be milled in a liquid is agitated in a milling zone with a particulate milling medium, for example sand or ballotini, by means of impellers which are rotated in a slurry of the particles to be milled, a liquid and particulate milling medium. The milled particles are then normally separated from the liquid.

By the term "mill" and "milling" as used in this specification is included apparatus and processes for the dispersion of particles in the liquid, for example in an organic liquid such as a paint base, irrespective of whether the particles are reduced in size during the process or not.

Accordingly, the present invention is an apparatus for milling particulate solids comprising a milling chamber, an impeller shaft projecting into the milling chamber carrying at least three impeller discs, at least one of which is of smaller diameter than impeller discs above and below it, a settling zone above the milling chamber, the interior of which communicates with, and which is of smaller diameter than, that of the milling chamber, means to reduce the turbulence of liquid or slurry in the settling zone and an outlet or outlets in the settling zone for a slurry of milled particulate solid.

The invention is also a process for milling particulate solid comprising introducing into a milling zone containing (a) particulate milling medium and (b) an impeller shaft carrying at least three impellers, at least one of which is of smaller diameter than the impellers above and below it, a slurry of particles to be milled, rotating the impellers, allowing the slurry of particulate milling medium and milled particles to rise into a settling zone of smaller internal diameter than that of the milling zone, reducing turbulence in the slurry in the settling zone and thereafter withdrawing from the settling zone a slurry of milled particles substantially free from particulate milling medium.

The milling chamber is normally a cylindrical chamber of suitable diameter for the impeller shaft and discs and is provided with an inlet for the slurry of solid to be milled at the lower end of the milling chamber. The upper end of the chamber may be closed with a plate through which the impeller shaft projects and through which access is provided to the settling zone.

The milling chamber may be made of any suitable material and it may, if desired, be lined with material, for example rubber or polyurethane polymer, to prevent erosion and/or corrosion of the surface and consequent contamination of the material in the mill.

The inlet orifice or orifices for the slurry of material to be milled may be in the centre of the base and perpendicular to it or, if desired, it may be off-centre and angled in such a manner to direct the incoming slurry to the most advantageous point in the circulation pattern of the slurry within the mill during milling.

The impeller shaft is normally provided at the end opposite to that carrying the impellers with means to rotate the shaft, for example with pulleys or a gear for connection to an electric motor or the like. The shaft may also pass through one or more bearings before entering the milling chamber and the lower end, may, if desired, also be supported in a bearing in the base of the milling chamber to prevent flexing of the shaft.

The impellers are normally disc-like and rotate in a plane at right angles to the longitudinal axis of the milling chamber and impeller shaft. It has been found that improved results are obtained if there is provided an impeller of smaller diameter between adjacent impellers. Normally, the larger diameter impellers are of such dimensions that the distance between their outer periphery and the interior opposing wall of the milling chamber is in the range of about 1 inch to 5 inches and preferably in the range 1 inch to 2 inches. The optimum distance depends, to some extent at least, on the size of the mill.

It is preferred that the larger impellers are provided with orifices between their upper and lower faces to allow the slurry of particles to pass through the impellers during milling. Suitably, the inner edges of these orifices are positioned as closely as possible to the impeller shaft (consistent with the required mechanical strength) and at least one side, and preferably both opposing sides, of the orifices are so shaped as to direct the flow of slurry through the orifice from the underside of the lower disc and from the upper side of the upper disc during milling in the direction of rotation of the impeller. It is preferred that there should be at least two such orifices in the impellers of greater diameter and particularly at least four, equidistantly spaced around the impeller. The outer edges of the orifices should not, of course, be near enough to the periphery of the impeller to reduce mechanical strength of the impeller excessively.

It has been found convenient, subject to the foregoing provisos, to provide a sufficient number and size of orifices to give a ratio of orifice area in the upper or lower surface of the impeller to the area of the upper or lower surface of the impeller in the range 1:20 to 1:5 and preferably one in the range 1:15 to 1:7.5.

The improvement in milling obtained by the provision of an impeller of smaller diameter between the larger impellers is believed to be due to the modified flow path of the slurry in the mill during milling. For example, it is believed that it is advantageous if the slurry follows a circular path at the surface of the larger impellers and the presence of an impeller of smaller diameter between larger impellers assists in providing two such circular paths, one at the upper surface of the impeller below that of smaller diameter and one at the lower surface of the impeller above that of smaller diameter. Furthermore, where orifices are present in the impellers any tendency for the slurry to pass directly through the mill without adequate residence time in the mill is avoided.

The distance between the outer periphery of the smaller impeller and the interior opposing surface of the milling chamber is suitably in the range 70 to 10 percent of the radius and preferably in the range 50 to 30 percent of the radius of the milling chamber.

The impellers may be made of any desired material of adequate mechanical strength and they may be coated with a second material, for example, to reduce erosion and/or corrosion and consequent contamination of the milled material.

When milling titanium dioxide, where freedom from discolouration is particularly important, impellers made from, or coated with, polyurethane or natural white rubber have been found to be particularly suitable.

The settling zone above the milling zone is of smaller internal diameter than the milling zone and conveniently consists of the volume enclosed between a tubular sheath around the impeller shaft and a concentric tube of larger internal diameter, the lower end of which is supported in a hole in the top plate of the milling chamber which surrounds the impeller shaft and its sheath. The upper end of the settling zone may be open or it may be closed, for example by the lower end of the impeller shaft bearing assembly.

In order to reduce turbulence in the settling zone, it has been found advisable to provide baffles and these may comprise metal plates fixed between the outer surface of the impeller shaft sheath and the inner surface of the tubular sheath defining the settling zone. The use of baffles of this type also provides additional support for the impeller shaft and its associated sheath. Any number of baffles may be provided but it has been found convenient to provide two or four equidistantly spaced around the impeller shaft sheath. It may also be convenient to leave spaces in the baffles along their length to reduce turbulence even more and thus to improve the settling out of the milling medium. The lower edge of the baffles may project down into the milling chamber to reduce turbulence in the settling chamber still further.

At a suitable distance up the settling zone, i.e., at a point where substantially all the milling medium will have settled out, one or more orifices or a weir are provided in the outer wall of the settling zone for the withdrawal of the slurry of milled material substantially free from milling medium. Where a number of baffles have been provided it is preferable to provide an orifice to withdraw slurry from each volume enclosed by two baffles and the outer wall of the settling zone. Suitably the slurry from all orifices is collected in an overflow launder surrounding the outer wall of the settling zone from which it can be discharged for further treatment.

If desired, the lower end of the tube forming the outer wall of the settling zone can project into the milling zone and may be bent in such a way as to reduce further the turbulence transmitted from the milling zone to the settling zone as may the lower end of the tube surrounding the impeller shaft.

In addition, an orifice and associated pipe and valve may be provided in the top plate of the milling zone for sampling, for example to check grinding efficiencies and/or milling medium level in the mill during operation.

When supplying the slurry of particles to be milled either in water or in organic liquids, to the mill and particularly in the case of aqueous titanium dioxide slurries, it has been found convenient to provide slurries containing from 200 to 1,000 and preferably from 400 to 800 g./litre of solid. The average particle size of the TiO_2 in such slurries is normally in the range 2μ to 30μ.

The residence time for the solid to be milled in the mill is preferably one in the range 10 to 40 minutes and particularly one in the range 20 to 30 minutes.

The particulate milling medium in the mill may be sand, for example Ottawa sand, glass ballotini or any other material of suitable particle size and hardness. In particular, milling medium having an average particle size in the range 200μ to 850μ has been found very suitable for milling pigmentary titanium dioxide.

The milling medium rises with the slurry of milled particles into the settling zone and as the turbulence decreases the milling medium, which is of larger particle size than the milled medium, settles under the influence of kinetic forces and/or by gravity and returns to the milling zone. The mill thus requires only a single charge of milling medium although make up quantities may be required from time to time to replace losses and material which has been broken down or eroded and carried out of the mill.

The accompanying Figures describe one embodiment of the present invention in which FIG. **1** shows the milling chamber **1** provided with an inlet orifice **2** for the slurry of material to be milled. An alternative inlet position is shown at **3**. The milling chamber contains three impellers **4**, **5** and **6** of which the first and last are provided with orifices **7**, **8**, **9** and **10**. Impeller **5** is of smaller diameter than **4** and **6**.

The cover plate **11** of the milling zone is provided with a sampling device **12** and through the plate projects impeller drive shaft **13**, impeller shaft sheath **14** and tubular sheath **15** forming the outer wall of settling zone **16**.

Baffles **17** are provided in the settling zone as are orifices **18** for the withdrawal of slurry from the settling zone into launder **19** for discharge via pipe **20**. The upper end of the impeller shaft is supported in bearing assembly **21** and the shaft is driven by pulley **22** when the mill is in operation.

FIG. **2** shows a side view of a section A–A' through impellers **4** and **6** only in which the shape of the opposing edges **23** and **24** of orifices **9** and **10** are shown.

Example

A mill of the type described above was constructed in which the milling chamber had an internal diameter of 20.5 inches, a height of 13 inches and contained three impellers, two of which were 17.5 inches diameter and 1.5 inches thick, the middle one was 13 inches diameter and 1.5 inches thick.

The settling chamber was contained between the impeller shaft sheath having an outer diameter of 3.5 inches and the outer tubular sheath having an internal diameter of 6 inches. The height of the settling chamber from the cover plate of the milling chamber to the bottom of the overflow orifices was 11 inches. The four lower baffles placed equidistantly around the settling zone extended to a height of 4 inches from the top of the milling chamber after which there was a space of 2.75 inches in height before the four upper baffles began. The overflow launder had an internal diameter of 11.5 inches and was 3 inches in height. A charge of 78 kg. Ottawa sand having a particle size in the range 660μ to 850μ was placed in the milling chamber and an aqueous slurry of TiO_2 particles having a particle size in the range 2μ to 30μ at a concentration of 700 g./litre was introduced through a central inlet orifice in the base of the milling chamber at a rate of 1.5 litres/-min. During milling the impeller shaft was rotated at 500 r.p.m. An aqueous slurry of milled TiO_2 particles, 100 percent of which had a mean weight particle size of less than 3μ and containing less than 1 g./litre of milling medium was recovered from the launder throughout the period of milling.

The residence time in the mill of the particulate solid to be milled was about 25 minutes.

What is claimed is:

1. An apparatus for milling particulate solids comprising a milling chamber, an impeller shaft projecting into the milling chamber carrying at least three impeller discs, at least one of which is of smaller diameter than the impeller discs above and below it, a settling zone above the milling chamber the interior of which communicates with, and which is of smaller diameter than, that of the milling chamber, means to reduce the turbulence of liquid or slurry in the settling zone and an outlet or outlets in the settling zone for a slurry of milled particulate solid.

2. An apparatus as claimed in claim 1 wherein there is an inlet for a slurry of solid particles to be milled in the lower end of the milling chamber.

3. An apparatus as claimed in claim 1 wherein the impeller discs are made from, or are coated with, a material selected from the group consisting of a polyurethane polymer and a natural white rubber.

4. An apparatus as claimed in claim 1 wherein the distance between the outer periphery of the large impellers and the interior opposing wall of the milling chamber is in the range 1 to 2 inches.

5. An apparatus as claimed in claim 1 wherein the larger impellers are provided with orifices between their upper and lower faces.

6. An apparatus as claimed in claim 5 wherein the orifices are so shaped as to direct the flow of slurry through the orifices, when rotating, in the direction of rotation of the impeller.

7. An apparatus as claimed in claim 5 wherein each impeller is provided with at least four orifices.

8. An apparatus as claimed in claim 5 wherein the ratio of the orifice area in the upper or lower surface of the impeller to the area of the upper or lower surface of the impeller is in the range 1:5 to 1:7.5.

9. An apparatus as claimed in claim 1 wherein the distance between the outer periphery of the smaller impeller and the interior opposing surface of the milling chamber is in the range 50 percent to 30 percent that of the radius of the impeller.

10. An apparatus as claimed in claim 1 wherein the settling zone is the volume enclosed between a tubular sheath around the impeller shaft and a concentric tube of larger diameter.

11. An apparatus as claimed in claim 10 wherein baffles are provided in the settling zone and comprise metal plates between the outer surface of the impeller shaft sheath and the inner surface of the concentric tube.

12. An apparatus as claimed in claim 11 wherein spaces are provided in the baffles.

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