METHOD FOR FINE CRUSHING OF LUMP MATERIAL

The invention relates to crushing of solid materials and can be used in the mining, building, chemical and other industries for fine crushing of lump materials of any strength, the fine fraction of which ranges from 30 to 10 mm. The inventive method for fine crushing of lump material in a disc mill involves transporting initial material under effect of gravity and centrifugal forces to a crushing area between two corotating discs. The axes of rotation of the discs are positioned at an angle to each other and the working surface thereof is shaped in the form of an inner cone. The discs are rigidly attached to each other and synchronously rotate so that pieces of material which are bound by the discs are additionally forcibly transported to a crushing area. Said invention makes it possible to increase crushing performance and to reduce energy consumption.
Description

FIELD OF THE INVENTION

[0001] The invention relates to a process for crushing hard materials and may be used in the mining, construction, chemical, metallurgical, and other industries for finely crushing lump materials consisting of fine fractions of sizes 30 to 10 mm of any strength.

BACKGROUND OF THE INVENTION

[0002] Several prior art methods are now used for crushing lump materials. The crushing process comprises conveying the initial material to the crushing area, destroying a lump (lumps), and conveying the finished product beyond the crusher. The existing methods, though, use essentially two principal types of lump material destruction - crushing and "free impact," and discharging the resultant material by gravity or centrifugal forces.

[0003] In particular, a lump is destroyed in jaw and cone crushers ("Ore Dressing Manual," Vol. 1, Moscow, 1972, pp. 122-148) by quasi-crushing between working surfaces (jaws and cones) as stresses are applied horizontally. In this case, the initial material is fed in and the finished product discharged vertically by gravity. This process is shown diagrammatically in FIG. 1a. The use of existing fine crushing methods is limited by the low fine fraction output essentially because of the rate of material flow in the crushing area depending on gravity. Eventually, this dependence determines the maximum oscillation frequency of the movable elements (jaws and cones) and, accordingly, the maximum crushing output. Also, these methods are inefficient for fine crushing because of design considerations. For these reasons, industrial processes for grinding material fractions of sizes 30 to 10 mm of medium and high strength are usually performed in ball or tumbling rod mills. Material is crushed in these mills with a high degree of probability and requires significant power inputs one or two orders larger than power inputs needed to crush material to a similar class of particle size in crushers. This fact has a significant effect on the overall costs of the end product.

[0004] A similar approach is used in a method for comminuting materials in roller crushers (roller presses) under high pressure (U.S. Patent No. 4,357,287) in which high intensity stress is created in the material passing between two rollers (FIG. 1b).

[0005] The principal distinction of this method from the preceding one is that the stress is of the volumetric type and that the force is directed at the flow of lump material, which implies a significant increase in crushing efficiency. The method is disadvantageous because it is used for comminuting high-strength materials to a limited extent only.

[0006] Crushing methods by stressed "free impact" include comminution by centrifugal impact apparatuses, hammer mills, and rotary crushers.

[0007] Rotary crushers and hammer mills are designed to crush materials of relatively low strength.

[0008] A method for crushing materials in centrifugal impact apparatuses (see: for example, U.S. Patent No. 4,921,173) (FIG. 1c), lumps of feedstock are charged into the working space vertically by free fall, whereupon a fast-rotating accelerating device causes them to move radially at a high speed. A lump is comminuted by free impact against armor plating. The finished product is discharged by the free fall of the lumps as well. This prior art method is disadvantageous because of its low efficiency when used to comminate materials of a small particle size (under 15 to 20 mm), particularly materials of medium and high strength, because of the small weight of a lump and, therefore, its low kinetic energy.

[0009] Still other prior art methods use disk mills to crush lump materials. The prior art invention closest to the present method in technical idea is the method of U.S. Patent No. 5,836,523 (FIG. 1d) that uses "free impact" stress. Material is destroyed in the reducing apparatus by two disks positioned one above the other and rotating at a high speed in the same direction. The initial material falls through an opening in the top rotor to the bottom rotor whereupon it is flung by centrifugal force to the conical top disk. A lump is destroyed by stresses originating in the lump upon impact. The finished product is removed by centrifugal forces as well through an adjustable gap between the rotating disks. The prior art method helps achieve significant speeds at which the material to be comminuted is charged into the destruction area, and also a high discharge speed of the finished product by centrifugal forces. The prior art method is disadvantageous because of inefficient destruction depending on probability. Stresses developing through impact are not high enough and restrict the application of the method to relatively weak materials.

[0010] The prior art closest to the present invention in technical idea is a crushing apparatus (U.S. Patent No. 1,072,193) comprising a system of two rotating shafts, one of which is hollow and the other solid. The solid shaft is placed inside the hollow shaft such that the axes of revolution of the shafts do not coincide. The shafts are joined by a ball connection that allows the shafts to rotate in the same direction. The ends of the shafts are provided with disks that are the working elements of the crusher. The prior art invention and the claimed apparatus have common features such as rotation of the disks in the same direction and positioning of the disk axes of revolution at an angle to one another.

[0011] The prior art apparatus has the following disadvantages:

1. Significant size of the apparatus, its length six to seven times the diameter of the working element. This is probably attributed to the technological level of the period and, accordingly, the need to increase the ratio of the force levers. Its flat driving belt cannot transmit moments needed to destroy rocks having a
SUMMARY OF THE INVENTION

[0012] It is a technical object of the invention to correct the deficiencies listed above, increase the output of finely comminuted lumps of materials of different strength, reduce electric power inputs required for fine crushing, and to develop a technically simple design of an apparatus for fine crushing of lump materials.

[0013] The above object is achieved in a method for fine crushing of lump material in a disk-type mill, said method comprising charging the initial material by gravity and centrifugal forces to the crushing area between two disks rotating in the same direction and having axes of revolution extending at an angle to one another and each disk having a working surface in the form of an inner cone, crushing lumps of material in the area where the disks are nearest to one another, and discharging the crushed product by centrifugal forces, wherein the disks rotate in synchronism to provide an additional force to push the lumps of material engaged by the disks into the area where the disks are nearest to one another.

[0014] It is reasonable further to comminute the crushed product by directing the lumps of material discharged from the apparatus by centrifugal forces against armor plating.

[0015] The object of the invention is also achieved in an apparatus for fine crushing of lump materials comprising a support and a rotating component mounted thereon and comprising a first disk having a central charging opening and a lower disk having an axis of revolution inclined to the axis of revolution of the first disk, both disks having each a working surface in the shape of an inner cone, wherein, according to the invention, both disks are rigidly interconnected to allow synchronous rotation thereof.

[0016] Furthermore, the second disk may be secured on a stamp having a spherical support surface, the first disk and the stamp with the second disk are mounted on a heavy flywheel pulley such that the stamp bears with the spherical support surface thereof against the inner spherical support surface provided with a driving bolt engaging the groove in the spherical surface of the stamp along the axis thereof to provide a rigid force connection between the two disks and cause synchronous rotation thereof.

[0017] In addition, the first disk is preferably secured on a stack of two plates, with compression springs placed between them to enable them to move upward by spring compression when unbreakable bodies happen to be charged into the apparatus.

[0018] The apparatus may also comprise a cover in the form of a housing having a tapering charging chute and armor plates mounted at the housing perimeter opposite the discharge slit between the disks to comminute the product additionally by impact.

[0019] Also, the disks may have projections and depressions of serrated shape such that the projections of the upper disk engage the depressions of the lower disk.

[0020] It is preferred that the ratio of the disk radius to the stamp length be within the range of 1:1.5 to 1:4, and that the inclination angle of the axes of revolution of the disks be within the range of 0.5° to 3°.

[0021] In the claimed method for fine crushing of lump material in a disk mill (FIG. 1e), comprising directing the initial material into the area between the disks by gravity TP1g, conveying the initial material into the crushing area by horizontal centrifugal forces TP1cf, and discharging the crushed product by gravity TP2cf, lumps are further conveyed in an engaged state TPes, and the lumps are destroyed by forces directed normally to the surface of the working elements and arising in the approach phase of the two disks rotating in synchronism and connected into an integrated system of disks having their axes of revolution extending at an angle to one another.

[0022] Movement of the lumps held securely between the working elements of the crusher as a result of synchronous rotation of, and rigid connection between, the rotating disks causes the lumps of material to be forced into the crushing area and, in this way, applies intensive dynamic force to a lump most effectively to destroy the lump.

[0023] The connection between, and cyclic rotation of, the disks help construct a system of equally effective elements of the crushing process and obtain eventually a high-speed closed sequence of interrelated conveyance and material lump destruction processes matched in time. All essential functions in the process are localized in areas (FIG. 2). In particular, the initial product is conveyed by TP1cf essentially in area A, area B serves for engaged movement TPes and crushing CR1 of a lump, and area C is used for discharging the product by centrifugal forces TP2cf. All these processes occur in parallel, and the efficiency of individual elements of the crushing process and the process in general depends on the number of revolutions of the disk system and may be limited by technical reasons only.
Synchronized rotation of the disks allows serrated working elements to be used, with the projections of the upper disk engaging the depressions of the lower disk, and offering an opportunity for improving considerably the efficiency of lump material crushing owing to bending stresses building up in the lump.

Furthermore, to make the fullest possible use of the kinetic energy carried by crushed material lumps ejected from the apparatus at a high speed, the apparatus is provided at the housing perimeter with armor plates to comminute the finished product lumps weakened during the crushing operation CR1 by impact stresses CR2.

An important advantage of the crushing process pattern used in the claimed method is that a lump can be engaged at a large angle and, therefore, crushed to a greater degree. It is known from experience that lump engagement can be achieved at opening angles $\alpha$ of the working elements of up to 45°.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 (a to d) shows diagrammatically the existing crushing methods, and FIG. 1e is a diagrammatic view of the claimed crushing method.

FIG. 2 is a view of the disk areas where the material is conveyed (area A), engaged for movement (area B), and discharged (area C).

FIG. 3 is a diagrammatic view of the apparatus for performing the claimed crushing method.

FIG. 4 is a detailed diagrammatic view of the claimed apparatus in axial section.

**DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION**

The claimed method for fine crushing of lump material is performed as follows (FIG. 3).

Material falling on a lower disk 4 is moved by centrifugal forces over the surface thereof toward a point of the disk periphery where the lump size and the gap between disks 4 and 5 is identical. As it moves now together with the rotating disks in synchronism, the lump is forced into the area where the disks come nearest to one another (crushing area) and where it is compressed intensively and destroyed. As the lump is destroyed, its size becomes smaller than the width of the gap, and the lump continues moving radially toward the periphery of disks 4 and 5 to a point where its size and the spacing between the disks are identical again. With the disks moving still closer to one another, the lump is compressed again and destroyed. This procedure is repeated several times. When the crushed material becomes smaller than the spacing between the edges of the disks, it is pushed by centrifugal forces out of the crushing area, whereupon it is ejected at a high velocity out of the crushing apparatus against armor plates 14 provided opposite the discharge slit and is destroyed further. In this way, the weakened material lumps are comminuted additionally by intensive impact forces.

Significantly, the type of interaction between a lump in an engaged state and the disks rotating in synchronism helps construct a harmonic curve of stress developing in time and minimize shear stresses, guarantees lump destruction, and reduces the wear of the working elements significantly. Furthermore, the dynamic interaction pattern helps achieve very fine crushing effects.

The claimed method for fine crushing of lump materials can be carried out most effectively in the claimed apparatus (FIG. 4).

The apparatus comprises a bed 22 on which a vertical support that also serves as a sliding friction bearing for the rotary system of the apparatus as a whole is mounted. A bearing bush 16 made of an antifriction material is press-fitted into support 1. A flywheel pulley 2 rotating on support 1 has a stamp 3 inserted therein and having its spherical support surface resting on the inner spherical surface of the flywheel pulley. The cylindrical part of stamp 3 is fitted into bearing bush 16 that has an axis of revolution inclined relative to the axis of the apparatus (axis of an upper disk 7) at an angle $\beta$, the axis of stamp 3 and the axis of the apparatus intersecting at a point 0 that also is the center of the spherical support surfaces of stamp 3 and flywheel pulley 2. A movable lower disk 4 having a working surface in the form of an inner cone is mounted on the upper surface of stamp 3 and fixed in position. The conical projection in the center of disk 4 serves to improve distribution of the material charged into the apparatus. A driving bolt 19 engaging a groove in stamp 3 on the spherical surface thereof to slide therein is press-fitted into the spherical surface of flywheel pulley 2. A package of support plate 5, springs 11, and a pressure plate 6 is mounted on flywheel pulley 2 through spacing bushes 12 by high-strength pins 8. The package is assembled with the help of bolts 10 and tightened by nuts 9 on the pins.

A stationary armor plate 7 having a working surface in the shape of an inner cone and a central material charging opening is mounted on support plate 5 and secured by bolts. A washer 20 fitted at the lower end of stamp 3 is secured in place by bolts and serves to prevent vertical movement of the stamp and the rotary system as a whole.

The apparatus is actuated by an electric motor through a V-belt drive (FIG. 4) or gear drive. Flywheel pulley 2, the V-belt drive, and the electric motor pulley are isolated from the remaining space of the apparatus by a sealed casing 15. The apparatus is covered with a housing 13 provided with a conical chute secured thereon to charge material to be crushed. Armor plates 14 (armor plating) are secured along the full perimeter of housing 13 opposite the slit of the crushing elements for material lumps discharged from the crushing elements at a high velocity to be comminuted further by impacting the armor plates. The bed plates of the apparatus have apertures...
The apparatus operates as follows:

When the electric motor is turned on, its rotation is transmitted by the V-belt train to flywheel pulley 2 that rotates on stationary vertical support 1. The flywheel pulley causes all components associated therewith to rotate. Driving bolt 19 transmits rotation to stamp 3 to cause rotation of lower disk 5 in synchronism with flywheel pulley 2. Support plate 5 on which upper disk 7 is mounted also rotates in synchronism with flywheel pulley 2. Synchronous rotation of lower disk 4 and upper disk 7 produces an effect that forces material lumps into the crushing area B, and the rigid kinematic connection between these disks transmits the full destructive stress from the working elements to the material lumps. Since the cylindrical part of stamp 3 is received in eccentric bearing bush 16, and its spherical part bears against the spherical inner surface of flywheel pulley 2, the axis of revolution of stamp 3 is offset at a specified angle $\beta$ relative to the axis of revolution of flywheel pulley 2. For this reason, the spacing between the surfaces of lower disk 4 and upper disk 7 varies at the periphery of disks 4 and 7 from a minimum value "b" to a maximum value "B" (FIG. 3). Destructive stresses are generated as an engaged lump moves into the area B, where the disks are nearest to one another (FIG. 2). The stresses generated in this area are determined from the ratio $K$ of the radius $R$ of disks 4 and 7 to the length $L$ of stamp 3 ($K = R/L$) and the angle $\beta$. It has been found in practice that the optimal value of $K$ lies within the range of 1:1.5 to 1:4. A ratio less than 1:1.5 cannot produce destructive stresses, and the ratio over 1:4 reduces sharply the particle size of the material crushed. Angle $\beta$ is within the range of 0.5° to 3°, depending on the overall size of the apparatus and the required particle size of the finished product.

A working sample of the apparatus having working elements 200 mm in diameter was built to support the efficiency of the claimed crushing method.

Granite from the Pavlovo deposit having a hardness of 13 units on the scale of Prof. Protodyakonov and ferruginous quartzites of the Mikhailovsky Mining and Ore Dressing Plant having a hardness of up to 20 units on the scale of Prof. Protodyakonov were used as test materials. The results of the tests are given in Table 1. Samples were analyzed at the central laboratory of the Mikhailovsky Mining and Ore Dressing Plant OJSC.

With reference to Table 1, the tests have shown the apparatus to be efficient, with an output that virtually does not depend on the material strength. The actual electric power input, output, and comminuted particle size are almost identical to theoretical calculations.

### INDUSTRIAL APPLICABILITY

Approximation of the results obtained suggests the conclusion that the claimed apparatus manufactured on an industrial scale with a working element diameter of 600 mm and $n = 720$ r.p.m. can replace a first stage crushing mill of type MSHR-3.2x3.1. The apparatus weighs 8 tons at most, or less than 10% of the weight of the mill just referred to, and its installed motor capacity does not exceed 90 kW (compared to the 630 kW motor driving the above-mentioned mill).

### Claims

1. A method for fine crushing of lump material in a disk-type mill, comprising conveying the initial material by gravity and centrifugal forces into the crushing area between two disks rotating in the same direction and having their axes of symmetry extending at an angle to one another, said disks having a working surface each in the shape of an inner cone; destroying the material lumps in an area where the disks come nearest to one another, and discharging the crushed product by centrifugal forces, wherein the disks rotate in synchronism to provide an additional force to convey the material lumps engaged by the disks into the area where the disks come nearest to one another.

2. The method as claimed in claim 1, wherein the crushed material is further comminuted by directing the material lumps ejected from the apparatus by centrifugal forces at armor plating.

3. An apparatus for fine crushing of lump materials comprising a fixed support and a rotary component mounted thereon and having a first disk provided with a central charging opening and a lower disk having an axis of revolution that is inclined to the axis of revolution of the first disk, both disks having each a working surface in the shape of an inner cone, wherein both disks are interconnected rigidly for rotation in synchronism.

4. The apparatus as claimed in claim 3, wherein the second disk is secured on a stamp having a spherical support surface, the first disk and the stamp with the second disk being mounted on a heavy flywheel pulley such that the stamp has its spherical support surface resting against the inner spherical support surface of the flywheel pulley having a driving bolt engaging a groove provided on the spherical surface of the stamp to have the two disks force-connected rigidly and rotating in synchronism.

5. The apparatus as claimed in claim 3, wherein the first disk is secured on a package of two plates, with
compression springs placed therebetween, for moving vertically upon compression of the springs when unbreakable bodies are charged into the apparatus.

6. The apparatus as claimed in claim 3, further comprising a cover in the form of a housing having a conical charging chute and armor plates provided along the housing perimeter opposite the discharging slit between the disks to further comminute the product by impact.

7. The apparatus as claimed in claim 3, wherein the disks are provided with projections and depressions of serrated shape, the projections of the upper disk engaging the depressions of the lower disk.

8. The apparatus as claimed in claim 4, wherein the ratio of the radius of the disks to the length of the stamp lies within the range of 1:1.5 to 1:4, and the angle between the axes of revolution of the disks is within the range of 0.5° to 3°.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

B02C 7/10 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B02C 7/00, 7/04, 7/08, 7/11, 7/14, 13/00, 13/14, 19/00, 19/20

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of database and, where practicable, search terms used)

ESP@SE, ESP@SENCT, RUPTO, USPTO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>Y</td>
<td>US 5836523 A (NORMAN W. JOHNSON) 17.11.1998, the claims, fig. 3</td>
<td>1-2</td>
</tr>
<tr>
<td>Y</td>
<td>US 1072193 A (EDGAR B SYMONS) 02.09.1913, the claims, fig. 1</td>
<td>3, 6</td>
</tr>
<tr>
<td>Y</td>
<td>SU 1729587 A1 (LVOVSKY POLITEKHNICHESKY INSTITUT IM. LENINSKOGO KOMSOMOLA) 30.04.1992, col. 4, line 46 - col. 5, line 12, fig. 1</td>
<td>1-3, 6</td>
</tr>
<tr>
<td>A</td>
<td>SU 1066637 A (GOSUDARSTVENNY NAUCHNO-ISSLEDOVATELSKY INSTITUT KVARTSEVOGO STEKLA) 15.01.1984, the claims, fig. 1</td>
<td>1-8</td>
</tr>
<tr>
<td>A</td>
<td>RU 2249483 C1 (NAUCHNO-ISSLEDOVATELSKOE UCHREZHDENIE INSTITUT KHIMII TVERDOGO TELA I MEKHANOKHIMII SIBIRSKOGO OTDELENIYA ROSSYSKOI AKADEMIII NAUK) 10.04.2005, the claims, fig. 1</td>
<td>1-8</td>
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Name and mailing address of the ISA/Authorized officer:

RU

Facsimile No. Telephone No.

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 4357287 A [0004]
- US 4921173 A [0008]
- US 5836523 A [0009]

Non-patent literature cited in the description