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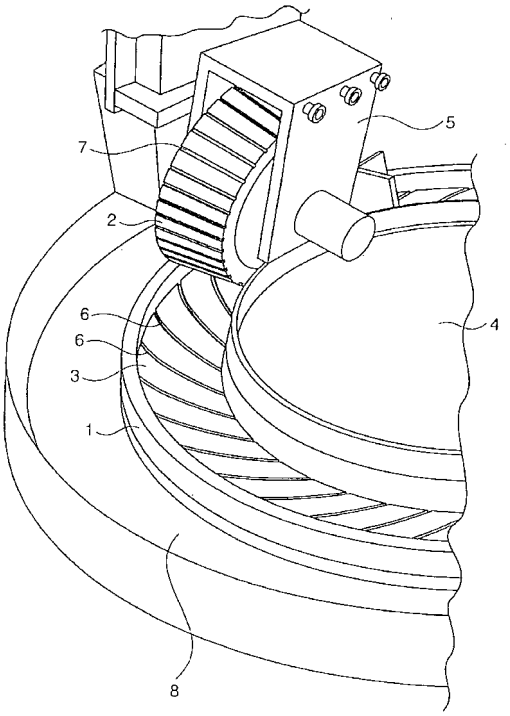
(54) VERTICAL ROLLER MILL

(57) A vertical roller mill which enables the crushing of coal or petroleum cokes is provided. To realize this, a vertical roller mill which includes a rotary table 1 driven to rotate, and a plurality of grinding rollers 2 including free rollers placed at fixed positions on the rotary table 1 so as to surround the rotation center line of the rotary table 1 to bite and crush a raw material to be ground between the rotary table 1 and the grinding rollers 2 with the rotary driving of the rotary table 1, wherein a plurality of oblique slit grooves 6 inclined in the table rotation direction or the reverse rotation direction thereof with respect to the table radius line are provided at predetermined intervals in the perimeter direction on an annular crushing portion 3 on the upper face of the rotary table. Each of the oblique slit grooves 6 is placed in a region of the angle exceeding 45° to the radius line. The grinding rollers 1 have on the outer circumference surfaces thereof slit grooves 7 parallel to a straight line right-angled to the rotation direction or the oblique slit grooves 7 inclined at an angle of 45° or less with respect to the straight line. The feed control of the raw material by the oblique slit grooves 6 provided on the annular crushing portion 3 of the rotary table 1 and the biting and crushing of the raw material by the slit grooves 7 provided on the outer circumference surfaces of the grinding rollers 2 promote the crushing of the raw material to be ground.

[FIG. 2]



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Description

TECHNICAL FIELD

[0001] The present invention relates to a vertical roller mill suitable for crushing coal or petroleum cokes used as a fuel in an electric-power generating boiler.

BACKGROUND ART

[0002] Electric-power generating boilers which still use coal or petroleum cokes as a fuel have been used often. This is because the fuel cost is low and electric-generating capacity adjustment is easy, and not only in China as a developing country, but also in Japan, the considerable part of electric-generating capacity depends on coal and petroleum cokes. However, coal and petroleum cokes have a great disadvantage that the amount of carbon dioxide emissions is large.

[0003] Japan has made a commitment toward the world to reduce 25% of the amount of carbon dioxide emissions in 1990 by 2020. This commitment shows a very difficult numerical value for achievement in which Japanese people and industries need to take great responsibility, but because of having made the commitment, Japan must work toward the aim. For that, the reduction of the amount of carbon dioxide emissions from coal or petroleum cokes used in electric-power generating boilers also becomes a very important measure.

[0004] In other words, since the use of coal or petroleum cokes as an electric-power generating fuel emits a very large amount of carbon dioxide, carbon dioxide emissions are regarded as the root of all evils. However, it is impossible for Japan without natural resources to immediately stop the use of coal among fossil fuels. At least until nuclear power generation or clean alternative energy is prepared, the use of coal cannot be stopped because of its economy, convenience, and abundant and hard-to-exhaust reserves.

[0005] Therefore, how little the amount of carbon dioxide emitted from these fossil fuels can be controlled is the future technical important problem, and the execution of new technical development for solving this problem becomes a very important theme. Then, as part of it, crushing at the crushing stage of coal or petroleum cokes supplied to boilers and the reduction of the amount of carbon dioxide emissions thereby should be considered. Of course, the reduction effect performed by one crushing mill is slight, but globally, there are an infinite number of crushing mills used, and totaling these, it is possible to contribute to the reduction of an enormous amount of carbon dioxide emissions. In Japan, a developed country, in particular, a technical country, it is considered that taking the lead in addressing crushing in crushing mills is our duty and responsibility.

[0006] The present inventors have noted this earlier on to address the crushing measure in crushing mills, and have also achieved great results. The representative technique is an improvement in roller crushing surface shapes, in particular, the development of a slit roller, described in Patent Documents 1 and 2. In the slit roller, slit grooves in the center line direction are formed at predetermined intervals in the perimeter direction on the outer circumference surface, as the crushing surface, of a grinding roller. With its use, in the field of vertical roller mills, as compared with the existing mills, the performance of biting substances to be ground has been improved to achieve increased crushing rate.

[0007] In other words, at present, in the coal crushing particle size in thermal power plants, fine particles pass 200 mesh, with an average percentage finer by weight of 75%, but if the crushing particle size is further reduced so that a larger amount of fine particles passing 200 mesh, with a percentage finer by weight over 75%, can be extracted than the conventional mills, the combustion efficiency in the boilers is improved, thereby leading to complete combustion for contributing to the reduction of the amount of carbon dioxide emissions.

[0008] In addition, the blast furnace of a steelmaking plant which produces pig iron generates and uses a large amount of coke reducing gas for reducing and dissolving iron ores, but the cokes which are produced from expensive caking coal are very expensive, so that to reduce the amount of use thereof, inexpensive pulverized coal is blasted from the blast furnace tuyere to reduce the amount of coke consumption, thereby reducing the pig iron production cost.

[0009] A large number of slit rollers developed by the present inventors are adopted for blast furnace pulverized coal blasting equipment, thereby greatly contributing to the cost reduction. It is said that the cost reduction effect in a certain steelmaking plant achieves as much as 600 million to 700 million yen annually. The production amount of fine particles including 200 mesh and under 200 mesh is increased by approximately 20% or more, as compared with the conventional mills, to increase the blast furnace combustion efficiency, thereby contributing to the further reduction of the amount of coke consumption. In other words, the reduction of the amount of coke consumption also leads to the reduction of carbon dioxide emitted at the time of coke production, and makes a significant contribution to the reduction.

[0010] As a coal crushing machine in an electric-power generating boiler, a vertical roller mill is used often. The vertical roller mill includes one driving table rotated horizontally, and a plurality of grinding rollers placed on the driving table so as to surround the rotation center line thereof, and conveys coal fed from the center of the mill onto the center portion of the table to the outside by centrifugal force to bite the coal between the rollers and the table, thereby subsequently crushing the coal. The crushed coal is airflow-conveyed upward by a conveying airflow so as to be classified by a

classifier, the coal having a necessary particle size is captured and conveyed to the later stage, and the coal having a larger particle size than that is returned to the inside of the mill again.

[0011] The vertical roller mill for crushing coal is divided broadly into a Loesche mill type in which grinding rollers are frusto-conical shaped and an annular crushing portion on the upper face of a rotary table has a horizontal plane and a tire type in which the outer circumference surfaces of grinding rollers are curved in the convex direction to the outer circumference side in a plane right-angled to the rotation direction and annular grooves of arcuate cross section into which the outer circumference surfaces of the grinding rollers are fitted are formed on the upper face of a rotary table. The tire type grinding roller is further divided into two: a convex-shaped tire in which the ratio between the largest diameter D and the radius of curvature R in a plane right-angled to the rotation direction of the tire crushing surface is 4.3 or more and a flat-shaped tire in which the ratio is less than 4.3. When the D/R of the commercially available tire type roller is examined by the present inventors, the average D/R of the convex-shaped tire of the former is in the range of 4.5 to 5.0 and the average D/R of the flat-shaped tire of the latter is in the range of 3.8 to 4.1, so that D/R = 4.3 is appropriate as a branching point between both.

[0012] Recently, the present inventors also have developed a vertical roller mill which has slit grooves provided on both the outer circumference surfaces of grinding rollers which are the crushing portions of the grinding rollers and an annular crushing portion formed on the upper face of the outer circumference portion of a rotary table (Patent Document 3). Although this vertical roller mill is very effective for crushing a raw material, like limestone, in which crushed fine particles are likely to adhere onto the surfaces of the rollers, in particular, for preventing vibration due to fine particle adherence in the crushing, it is not always effective for crushing coal or petroleum cokes.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0013]

Patent Document 1: Patent Nos. 1618574
Patent Document 2: Patent Nos. 2863768
Patent Document 3: Japanese Patent Application Laid-Open No. 2009-142809

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0014] An object of the present invention is to provide a vertical roller mill which is effective for making the crushing particle size in the crushing of coal or petroleum cokes finer.

MEANS FOR SOLVING THE PROBLEMS

[0015] To achieve the above object, the present inventors have examined a combination of the crushing surface shapes of the rotary table and the grinding roller in the vertical roller mill, and have studied appropriate combinations of both which can obtain finer particles than the conventional mills. In other words, considering the vertical roller mill again only in view of the crushing of coal or petroleum cokes, in the vertical roller mill described in JP-A No. 2009-142809, although described later in detail, in the combination of the annular crushing surface of the rotary table and the crushing surface of the grinding roller, the function is opposite, which may be effective for preventing fine particles from adhering onto the surfaces of the grinding rollers in the crushing of limestone, but cannot exhibit a sufficient effect for crushing coal or petroleum cokes, and in the vertical roller mill, the crushing principles are subtly different between the Loesche mill type, the convex-shaped tire type, and the flat-shaped tire type, so that the present inventors have noted that a design specific to each type is necessary for a combination of the crushing surfaces, and have examined again, for each mill, combinations of crushing surface shapes which can obtain a large amount of fine particles passing 200 mesh and under -235 mesh.

[0016] As a result, the present inventors have provided slit grooves in both the grinding roller and the rotary table to sufficiently grasp the respective characteristics of the crushing surfaces of the roller and the table, thereby effectively using the characteristics of the crushing surfaces of both, and have succeeded in achieving further crushing of coal or petroleum cokes, which has not been able to obtain. Its process will be described below.

[0017] The present inventors have conducted the following experiment as the first step for searching for combinations of crushing surface shapes for obtaining finer particles, which can extract a large amount of fine particles passing under 200 mesh and under -235 mesh in coal crushing and can contribute to the reduction of the amount of carbon dioxide

emissions.

[0018] For two combinations: a combination of the existing grinding roller having a smooth surface and a rotary table having a smooth surface and a combination of a right-angled slit roller in which slits right-angled to the rotation direction are formed at predetermined intervals in the rotation direction on the crushing surface thereof in order to improve the amount of crushing and a smooth surface table, a basic experiment is conducted about what influence the difference between three kinds of roller shapes of A), B), and C) below has on the performance of crushing, thereby examining the performance of crushing and characteristics that the respective crushing surfaces have. However, the table rotation speed is constant with respect to the three rollers, and the experiment is conducted at a rotation speed of 48 rpm. An experimenting machine will be described later. The experiment results are shown in Table 1. In addition, the position relation between the rotary tables and the grinding rollers and the respective shapes thereof are schematically shown in Figs. 1(a) to 1(c).

[0019]

A) Frusto-conical shaped grinding roller

B) Tire type grinding roller having D/R < 4.3 (flat-shaped)

C) Tire type grinding roller having D/R ≥ 4.3 (convex-shaped)

[0020]

[Table 1]

Roller shape		Coal layer thickness on the crushing surface	Amount of coal discharged to the outside of the table	Percentage finer by weight of fine particles of -235 mesh of coal discharged to the outside of the table	Percentage finer by weight of fine particles of 200 mesh of the total amount of crushing
A) Frusto -conical shaped roller	Smooth surface	3 mm	2105 g	27.8%	43.8%
	Right -angled slits	2 mm	2150 g	22.4%	51.4%
B) Tire type roller having D/R ≤ 4.3	Smooth surface	2 mm	2000 g	25.0%	38.0%
	Right -angled slits	2 mm	2000 g	25.7%	39.0%
C) Tire type roller having D/R ≥ 4.3	Smooth surface	1 mm	2125 g	26.8%	38.3%
	Right -angled slits	1 mm	2199 g	26.4%	43.7%

[0021]

A) As the characteristic of the frusto-conical shaped grinding roller, the crushing surface of the roller and the crushing surface of the rotary table are parallel to each other, are opposite to each other, and perform crushing, so that the surfaces are effectively used for the crushing operation. Therefore, the percentage finer by weight of fine particles passing 200 mesh and under 200 mesh is most excellent among the three roller crushing surface shapes. In more detail, the grinding roller is frusto-conical shaped, so that crushing is performed mainly on the large diameter side in which the circumference speed is high, but the circumference speeds of the circumference surface on the large diameter side and the circumference surface on the small diameter side are different, with the result that when rotated on the table, the grinding roller is likely to slip. This is intended originally, and crushing is performed according to a compression load and a shearing load caused by the slipping of the roller so as to be effectively performed by the synergistic effect of the surface loads of both. The roller surface pressure tends to be applied excessively so as not to frequently cause slipping, so that when the slit grooves are provided on this roller, the performance of biting is improved, the roller surface pressure applied excessively for preventing slipping is automatically converted to the crushing load of coal to increase the amount of crushing, and the percentage finer by weight of fine particles is also

increased.

[0022] This vertical roller mill is uneconomical because the grinding roller cannot be used reversely when it wears, but this vertical roller mill is excellent in performance as a coal crushing machine, and can be one of high-efficiency crushing machines.

[0023]

B) In the case of the flat-shaped roller which is the tire type grinding roller and has D/R < 4.3, the amount of coal discharged to the outside and the percentage finer by weight of fine particles are the smallest among the three. Determining from this, it is found that in the case of this vertical roller mill, coal fed from the center of the table is crushed immediately by the small diameter portion of the roller and is discharged to the large diameter portion, so that the crushing surface that the roller has cannot be effectively used for crushing.

[0024] This is because the tire has a large radius shape and is flat, the difference between the tire diameter below the main crushing portion and the tire diameter above the main crushing portion is small, and there is no large difference between the circumference speeds, so that the power discharging coal crushed by the main crushing portion in the tire outside direction is low and high-efficiency crushing is hard to perform. Therefore, only the circumference surface of the small diameter portion becomes the main crushing portion, and when passing through this, crushing on other crushing surfaces cannot be performed effectively. The main crushing portion of the real machine becomes the small diameter portion of the roller on the outer circumference side of the table, but, reversely, the main crushing portion of the experimenting machine becomes the small diameter portion on the inner circumference side of the table. It is assumed that this is because the crushing points are different due to the difference between the table rotation speeds. However, although the real machine and the experimenting machine have the main crushing portion in different positions, both of them perform crushing in the small diameter portion, so that the operation effect may be assumed to be the same.

[0025] In the characteristic of this roller, crushing is performed in the small diameter portion, so that when this roller wears on one side, it can be used reversely, which is economical. However, as compared with the convex-shaped tire roller of C), vibration is hard to occur.

[0026]

C) In the case of the convex-shaped roller which is the tire type grinding roller and has D/R ≥ 4.3, it is found that it is a roller which has the largest amount of coal discharged to the outside and provides a high production amount. As its evidence, the coal layer thickness on the crushing surface is 1 mm and small, and there is a stronger tendency to discharge coal to the outside than to store the coal in the crushing surface. As a result, coal fed from the center of the table is crushed on the center side in which the circumference speed of the roller is high. The difference between the tire diameter below the main crushing portion and the tire diameter above the main crushing portion is largely different, so that there is a large difference between the circumference speeds, and coal is scraped, is conveyed in the discharging direction, and is crushed at a high efficiency. The performance of crushing is improved as compared with the roller of B, but main crushing is performed on the center side of the large diameter, the main crushing region is smaller than B, and crushing is close to line crushing until wear is caused. With regard to the real machine, because of wear on the center side thereof, reverse use cannot be done, which is uneconomical. In addition, when electric power demand can be sufficient, the amount of coal fed is smaller than the rated operation, and it is said that vibration is likely to occur at the time of the low load operation. It is assumed that this is because due to high-efficiency crushing, coal bitten into a crushing chamber is discharged by the excellent performance of scraping, so that the coal layer thickness is smaller and slipping is likely to occur.

[0027] The following assumption is drawn from the above facts.

[0028] In the case of the frusto-conical shaped grinding roller of A, it is assumed that with regard to the production amount of fine particles, as compared with the combination of the existing flat crushing surfaces, the right-angled slit grooves right-angled to the rotation direction and the slit grooves having an inclination angle to 45° with respect to the rotation direction are optimum.

[0029] In the case of the flat-shaped roller which is the tire type grinding roller of B and has D/R < 4.3, with regard to the production amount of fine particles, as compared with the combination of the existing crushing surfaces, the effect of the right-angled slit grooves is not found. It is assumed that as its cause, since crushing is performed only on the small diameter side, the slit grooves are not effectively used for crushing. In the case of this roller, it is important to contrive a method for effectively using the crushing surface other than the small diameter portion, and for that, desirably, the direction of the slit grooves provided on the roller is directed in the direction scraping coal fed from the center of the table in the small diameter portion direction again, and it is assumed that the angle is effectively an angle to 45° with reference to the direction right-angled to the rotation direction (right-angled slits).

[0030] In the case of the convex-shaped roller which is the tire type grinding roller of C and has D/R ≥ 4.3, high-efficiency crushing is enabled by the circumference speed which is increased by performing main crushing toward the large diameter of the roller and the strong raw material scraping function by the outer diameter difference in the convex shape. The right-angled slits cross the main crushing line at a small width, but actively scrape coal to the outside of the roller, thereby increasing the percentage finer by weight of fine particles as compared with the existing smooth surface roller. It is assumed that when the slit grooves in the direction actively discharging coal to the outside of the table are provided on the annular crushing portion of the table, the performance of discharging that the roller originally has is further promoted to increase the percentage finer by weight of fine particles.

[0031] In addition, although it is found that in the grinding roller of A and the grinding roller of C, the right-angled slit grooves are very effective in the real machine and the experiment, but in the roller of B, the superiority of the slit grooves is not found in the experiment. However, with regard to the real machine, it has been already found that the direction scraping coal to the inside of the table by the 45°-oblique slit grooves is effective, so that with regard to the grinding roller, the direction scraping coal to the inside of the table by the right-angled slit grooves or the slit grooves inclined at 45° from the right angle is adopted. In the roller of B, crushing is performed on the small diameter side, so that the circumference speed is low to deteriorate the coal scraping function and that the width of the slit grooves crossing the main crushing line is small, which cannot exhibit the coal biting effect of the slit grooves. This cause may be affected by the low table rotation speed.

[0032] In addition, in the real machine, even when line crushing on the small diameter side is initially performed, wear is gradually caused to change line crushing to surface crushing for providing the biting effect of the slit grooves, but since the experimenting machine is not used to the extent wear is caused, line crushing is continued, so that it is considered that the biting effect of the slit grooves cannot be exhibited.

[0033] On the other hand, in the tire type crushing machine, when similar to the grinding roller, the right-angled slit grooves in the radius direction right-angled to the rotation direction are formed on the rotary table, the synergistic effect of the crushing surfaces of both makes the biting of coal excessive, with the result that the coal layer thickness in the crushing chamber formed between the roller and the table is increased, so that the roller surface pressure is insufficient, thereby obtaining no fine particles. When the roller surface pressure is increased, the percentage finer by weight of fine particles is recovered, but the axial electricity is increased and the roller wears immediately. Since in the case of the frusto-conical shaped roller, surface crushing is performed, so that it is assumed that even when the right-angled slits are provided on both, the effective crushing surfaces are large and the percentage finer by weight of fine particles is not lowered as compared with the tire type.

[0034] With regard to the slit grooves of the rotary table opposite the roller, as its operation effect, it suffices that the function of stably feeding coal fed from the center of the table into the main crushing point of the grinding roller is performed, and it is right to expect the scraping function. Therefore, the angle of the slit grooves provided on the table in the range of 0° to 45° in terms of an inclination angle with respect to the radius line right-angled to the rotation direction improves the performance of biting, so that it is determined that in view of providing the performance of coal movement and conveying, the angle is preferably above 45°, particularly preferably 50° to 85°.

[0035] In other words, from the function sharing between the roller and the table in which the right-angled slit grooves or the oblique slit grooves to 45° are provided on the grinding roller in the vertical roller mill in view of prioritizing the performance of biting and the slit grooves inclined above 45°, preferably 50° to 85° are provided on the rotary table in view of feeding the raw material into the main crushing portion, the extraction amount of fine particles having a particle size under -235 mesh is increased.

[0036] The vertical roller mill of the present invention has been completed based on such findings, and includes a rotary table driven to rotate, and a plurality of grinding rollers including free rollers placed at fixed positions on the rotary table so as to surround the rotation center line of the rotary table to bite and crush a raw material to be ground between the rotary table and the grinding rollers with the rotary driving of the rotary table, wherein a plurality of oblique slit grooves inclined in the table rotation direction or the reverse rotation direction thereof with respect to the table radius line are provided at predetermined intervals in the perimeter direction on an annular crushing portion on the upper face of the rotary table, each of the oblique slit grooves being present in a region of the angle exceeding 45° to the radius line.

[0037] In the vertical roller mill of the present invention, since the angle of the oblique slit grooves provided on the annular crushing portion of the rotary table with respect to the radius line is large, the biting and crushing function of the raw material to be ground is reduced on the table side, so that the performance of feed control of the raw material to be ground into the annular crushing portion is increased. In this state, the right-angled slit grooves right-angled to the rotation direction or the oblique slit grooves having a small inclination angle with respect to this are provided on the grinding rollers, thereby increasing the performance of biting and crushing on the grinding roller side, so that high-order management of both the performance of biting and crushing and the performance of feed control of the raw material is enabled, and this is performed under the conditions specific to the kinds of the grinding rollers in the vertical roller mills, so that a high crushing effect can be obtained in any of the vertical roller mills.

[0038] Particularly preferably, each of the oblique slit grooves on the rotary table is placed in an interior angle region

from a straight line inclined at 50° with respect to the table radius line (a straight line inclined at 40° with respect to the inner circle tangent line of the annular crushing portion) to the inner circle of the annular crushing portion.

[0039] As described above, as three kinds of grinding rollers in the vertical roller mill, there are the frusto-conical shaped roller, the flat-shaped roller which is the tire type roller and has D/R < 4.3, and the convex-shaped roller which is the tire type roller and has D/R ≥ 4.3.

[0040] In the so-called Loesche mill including, as the grinding roller, the frusto-conical shaped roller, the frusto-conical shaped roller having on the outer circumference surface thereof right-angled slit grooves parallel to a straight line right-angled to the roller rotation direction or oblique slit grooves inclined in the rotation direction or the reverse rotation direction at an angle of 22.5° or less with respect to the straight line, which is preferable in view of the crushing of coal or petroleum cokes.

[0041] In the vertical roller mill including, as the grinding roller, the flat-shaped tire roller in which the outer circumference surface thereof is curved in a plane right-angled to the rotation direction and the ratio D/R between the largest roller diameter D and the radius of curvature R of the curved outer circumference surface is less than 4.3, the flat-shaped tire roller having on the outer circumference surface thereof right-angled slit grooves parallel to a curving line right-angled to the roller rotation direction or oblique slit grooves inclined in the roller rotation direction (the raw material scraping direction) at an angle of 45° or less with respect to the curving line, and the inclination direction of oblique slit grooves on the upper face of the rotary table being directed in the table rotation direction(the raw material scraping direction), which is preferable in view of the crushing of coal or petroleum cokes.

[0042] In the vertical roller mill including, as the grinding roller, the convex-shaped tire roller in which the outer circumference surface thereof is curved in a plane right-angled to the rotation direction and the ratio D/R of the largest roller diameter D and the radius of curvature R of the curved outer circumference surface is 4.3 or more, the convex-shaped tire roller having on the outer circumference surface thereof right-angled slit grooves parallel to a curving line right-angled to the roller rotation direction or oblique slit grooves inclined in the reverse rotation direction (the raw material discharging direction) at an angle of 45° or less with respect to the curving line, and the inclination direction of oblique slit grooves on the upper face of the rotary table being directed in the reverse direction (the raw material discharging direction) of the table rotation direction, which is preferable in view of the crushing of coal or petroleum cokes.

[0043] In any of the grinding rollers, the slit grooves may be previously formed before the use of the mill is started or may be wear grooves formed with the use of the mill by arranging materials having a low wear resistance in portions corresponding to the respective grooves.

[0044] The oblique slit grooves formed on the annular crushing portion of the rotary table basically are straight line grooves from the inner circumference side of the annular crushing portion to the outer circumference side thereof, but may be arcuate grooves curved in the convex direction from the inner circumference side of the rotary table to the outer circumference side thereof.

[0045] In this connection, in the vertical roller mill described in JP-A No. 2009-142809, the slit grooves are provided on both the grinding rollers and the rotary table, but in view of preventing adherence, the slit grooves on the grinding rollers are so-called spiral grooves in which the angle thereof with respect to the direction right-angled to the rotation direction is close to 90°, and on the other hand, in view of ensuring the performance of biting and crushing lost on the grinding rollers, the slit grooves on the rotary table are close to the right-angled slit grooves in which the inclination angle thereof with respect to the radius line right-angled to the rotation direction is 45° or less, which is opposite the combination of inclinations of the slit grooves on the vertical roller mill of the present invention.

[0046] As a result, the vertical roller mill as described in JP-A No. 2009-142809 can be effective for preventing vibration due to fine particle adherence in the crushing of limestone, but is unsuitable for the crushing of coal or petroleum cokes. In other words, the vertical roller mill described in JP-A No. 2009-142809 is designed so as to prioritize the prevention of fine particles adherence onto the surfaces of the rollers over the crushing of the raw material to be ground.

EFFECT OF THE INVETION

[0047] In the vertical roller mill of the present invention, the slit grooves which are inclined at a large angle with respect to the table radius line are provided on the annular crushing portion of the rotary table, so that the raw material feed form which draws the best out of the performance of crushing which is the original performance of the mill can be selected for each mill form, thereby exhibiting a great effect for promoting the crushing of coal or petroleum cokes and contributing to the reduction of the amount of carbon dioxide emissions in an electric-power generating boiler.

BRIEF DESCRIPTIONS OF THE DRAWINGS

[0048]

Figs. 1(a) to (c) are schematic diagrams showing main crushing portions in grinding rollers of vertical roller mills

according to roller form.

Fig. 2 is a perspective view of the main portion of a small crushing machine for experiment used for confirming the effectiveness of the present invention.

Figs. 3 (a) to (d) are schematic diagrams showing the forms of slit grooves on the grinding rollers.

Figs. 4 (a) to (f) are schematic diagrams showing the forms (mainly, the inclination directions and the inclination angles) of slit grooves on the crushing portions of rotary tables.

Figs. 5(a) and (b) are schematic diagrams showing the forms (mainly, the shapes) of slit grooves on the crushing portions of the rotary tables.

BEST MODE FOR CARRYING OUT THE INVENTION

[0049] An embodiment of the present invention will be described below with reference to the drawings. In this embodiment, combinations of the crushing surface shapes of rollers and tables, which can extract a large amount of fine particles passing 200 mesh and under -235 mesh are examined by crushing experiments using a small crushing machine. The small crushing machine for experiment is shown in Fig. 2.

[0050] As shown in Fig. 2, in the crushing machine assuming a vertical roller mill, a grinding roller 2 is opposite the surface of the outer circumference portion of a horizontal rotary table 1 which is a base member. The grinding roller 2 is a frusto-conical shaped roller in Fig. 2, but can be replaced with a flat-shaped tire roller having D/R of less than 4.3 or a convex-shaped tire roller having D/R of 4.3 or more (see Fig. 1). The flat-shaped tire roller 2 is inclined and placed so that the large diameter side is directed to the outer circumference side, the small diameter side is directed to the center side, and the opposite surface of the table 1 is horizontal. Because of the experimenting machine, the number of rollers is one.

[0051] A plurality of slit grooves 7 are provided on the outer circumference surface of the grinding roller 2. The plurality of slit grooves 7 are right-angled grooves parallel to a straight line right-angled to the rotation direction in Fig. 2, and bite coal into a crushing chamber formed by the grinding roller 2 and the rotary table with rotation. As shown in Figs. 3 (a) to (d), as the slit grooves 7, there are the right-angled slit grooves, oblique slit grooves inclined at an angle of 45° in the roller rotation direction (the raw material scraping direction) with respect to a straight line right-angled to the rotation direction, and oblique slit grooves inclined at an angle of 45° in the reverse rotation direction (the raw material discharging direction) with respect to the straight line, and the grinding rollers [Figs. 3(b) to (d)] having those slit grooves, respectively, are prepared to the three grinding rollers 2, respectively. In addition, the smooth surface roller [Fig. 3(a)] without the slit grooves is also prepared to each of the three grinding rollers 2. In other words, four kinds of outer circumference surfaces are prepared to the three grinding rollers 2 [see Figs. 1(a) to (c)].

[0052] The outer circumference portion of the rotary table 1 opposite the grinding roller 2 becomes an annular crushing portion 3, and because of the experimenting machine, the annular crushing portion 3 is detachable from a table main body 4. The annular crushing portion 3 can be detachably replaced with a flat type combined with the frusto-conical shaped roller, a type with a shallow radius groove combined with the flat-shaped tire roller, or a type with a deep radius groove combined with the convex-shaped tire roller. And, as shown in Figs. 4 (a) to (f), six kinds of tables each having a smooth surface without slit grooves 6 [Fig. 4(a)], the right-angled slit grooves 6 in the table radius direction right-angled to the table rotation direction in the surface [Fig. 4(b)], the oblique slit grooves 6 inclined at 45° in the rotation direction (the raw material scraping direction) with respect to the radius line in the surface [Fig. 4(c)], the oblique slit grooves 6 inclined at 45° in the reverse rotation direction (the raw material discharging direction) in the surface [Fig. 4(d)], the oblique slit grooves 6 inclined at 65° in the rotation direction (the raw material scraping direction) with respect to the radius line in the surface [Fig. 4(e)], and the oblique slit grooves 6 inclined at 65° in the reverse rotation direction (the raw material discharging direction) in the surface [Fig. 4(f)] are prepared.

[0053] The grinding roller 2 of any of the types is attached so as to be rotatable and movable up and down with respect to a supporting mechanism 5 so that the clearance between the grinding roller 2 and the annular crushing portion 3 can be optionally adjusted. In addition, to apply predetermined pressing force to a raw material to be ground, the grinding roller 2 is biased in the direction in which it is pressed onto the annular crushing portion 3 by a spring.

[0054] By the rotation of the rotary table 1, the rotary table 1 and the grinding roller 2 perform a relative turning motion. In this experiment, to observe the performance of crushing of various combinations of the rotary tables and the grinding rollers, a classifier for crushed coal using air is not installed. Therefore, crushed coal as the raw material to be ground is discharged from the inside of the rotary table to the outside by the performance of discharging that the roller has and centrifugal force of the table rotation, so that a collecting case 8 which can completely collect discharged coal is installed outside of the rotary table 1.

[0055] In this way, the small crushing machine for experiment is designed so as to enable the experiment of all combinations of the rollers and the tables by one experimenting machine. The more detail of the experimenting machine is as follows.

Roller size:

[0056]

Frusto-conical shaped roller	Large diameter: 200 mm
	Small diameter: 170 mm
	Width: 57 mm
Flat-shaped tire roller having D/R = 4.0	
	Large diameter: 200 mm
	Tire radius: 50 mm
	Width: 74 mm
Convex-shaped tire roller having D/R = 5.0	
	Large diameter: 200 mm
	Tire radius: 40 mm
	Width: 66 mm

Table size:

[0057]

Frusto-conical shaped roller	Outer diameter: 410 mm
	Inner diameter: 280 mm
Flat-shaped tire roller having D/R = 4.0	
	Outer diameter: 420 mm
	Inner diameter: 220 mm
	Groove radius: 60 mm
Convex-shaped tire roller having D/R = 5.0	
	Outer diameter: 410 mm
	Inner diameter: 230 mm
	Groove radius: 50 mm

[0058]
Table circumference speed: 48 rpm (rotation in the left direction)
Roller pressing: Spring pressing
Clearance between the roller and the table: 0 mm
Experimenting time: 30 minutes
Coal feed amount: Approximately 2550 g/30 min
Coal feed method: Continuous feed screw feeder method
Coal used for experiment: Steelmaking caking coal
Initial particle size distribution

	over 20 mesh	40 g
	over 60 mesh	34 g
	over 120 mesh	3 g
	over 200 mesh	13 g
	over 235 mesh	2 g
	P	9 g
Moisture content:		5%

At the time of measuring the particle size, each sample is dried for 30 minutes and is measured.
The temperature is 25°C to 32°C, and the humidity is 51% to 87%.

[0059] By the small crushing machine for experiment, the amount of coal discharged to the outside of the table, the amount of coal remaining in the table, and the weight percentage of the occupation of fine particles passing 200 mesh and under -235 mesh in the total amount of crushing after crushing are examined. The most important matter in this

experiment is the particle size examination of coal discharged to the outside of the table by the grinding roller itself, and the weight of fine particles under -235 mesh is important for determining the production amount of fine particles. In this experiment, for convenience, crushing is performed only by one grinding roller, and in the real machine, two or three rollers are used and a classifier for collecting fine particles is installed, so that the experimenting machine shows the percentages finer by weight of fine particles which are quite different from those obtained by the real machine. In this experiment, the comparison of the percentages finer by weight of fine particles according to the difference between the crushing surfaces is examined in crushing under the same conditions.

[0060] In the particle size measurement, after the completion of the crushing experiment for 30 minutes, the total amount of coal discharged from the table into the collecting case 8 is accurately collected, and coal remaining in the table is accurately collected likewise. After the respective weights of the collected coal are measured, three samples are extracted for particle size measurement from any locations of the collected coal. As the particle size measurement result, the average value of the three samples is adopted for ensuring accuracy. Combinations of the crushing surfaces of the grinding rollers and the tables are as follows. In addition, the results are shown in Tables 2 to 4.

[0061]

A) Combinations in the case of the frusto-conical shaped grinding roller are as follows.

a) Smooth surface roller + smooth surface table
b) Right-angled slit grooves + smooth surface table
c) 45°-oblique slit grooves to the scraping side + smooth surface table
d) Right-angled slit grooves + right-angled slit grooves
e) Right-angled slit grooves + 65°-oblique slit grooves to the discharging side
f) Right-angled slit grooves + 45°-oblique slit grooves to the discharging side
g) Right-angled slit grooves + 65°-oblique slit grooves to the scraping side
h) 45°-oblique slit grooves to the scraping side + 65°-oblique slit grooves to the scraping side
i) 45°-oblique slit grooves to the discharging side + 65°-oblique slit grooves to the discharging side
j) 45°-oblique slit grooves to the scraping side + 65°-oblique slit grooves to the discharging side

[0062]

[Table 2]

Roller crushing surface shape	Table crushing surface shape	Percentage finer by weight of fine particles of -235 mesh contained in coal remaining in the table (%)	Percentage finer by weight of fine particles of -235 mesh contained in coal discharged to the outside of the table (%)	Percentage finer by weight of fine particles of -235 mesh contained in the total amount of crushing (%)
A) Smooth surface	Smooth surface	Remaining amount: 420 g 26.4%	Discharge amount: 2105 g 27.8%	T. G: 2526 g 27.6%
B) Right-angled slits	Smooth surface	400 g 25.1%	2150 g 22.4%	2550 g 22.8%
C) 45°-oblique slits to the scraping side	Smooth surface	400 g 28.7%	2190 g 39.2%	2590 g 37.6%
D) Right-angled slits	Right-angled slits	380 g 27.1%	2060 g 35.0%	2440 g 33.8%
E) Right-angled slits	65°-oblique slits to the discharging side	420 g 33.7%	1970 g 42.3%	2390 g 40.8%
F) Right-angled slits	45°-oblique slits to the discharging side	420 g 28.3%	1970 g 41.2%	2390 g 38.9%
G) Right-angled slits	65°-oblique slits to the scraping side	400 g 29.1%	2030 g 40.1%	2430 g 38.3%

(continued)

Roller crushing surface shape	Table crushing surface shape	Percentage finer by weight of fine particles of -235 mesh contained in coal remaining in the table (%)	Percentage finer by weight of fine particles of -235 mesh contained in coal discharged to the outside of the table (%)	Percentage finer by weight of fine particles of -235 mesh contained in the total amount of crushing (%)
H) 45°-oblique slit roller to the scraping side	65°-oblique slits to the scraping side	400 g 24.6%	2120 g 26.1%	2520 g 25.9%
I) 45°-oblique slit roller to the discharging side	65°-oblique slits to the discharging side	360 g 27.5%	2180 g 29.1%	2540 g 28.9%
J) 45°-oblique slit roller to the scraping side	65°-oblique slits to the discharging side	310 g 23.2%	2190 g 31.3%	2500 g 30.3%

[0063] Table 2 shows the results in the case of the frusto-conical shaped grinding roller, and the details are as follows.

[0064] The combinations e, f, and g of the frusto-conical shaped rollers with the right-angled slit grooves and the tables in which the oblique slit grooves whose angle is formed between the oblique slit grooves and the table radius line is from 65° to 45° are formed on the annular crushing portions show the result of the largest extraction amount of fine particles of -235 mesh. There are slightly more cases that the oblique slit grooves on the rotary tables are inclined to the discharging side, which is not largely different from the cases that the oblique slit grooves are inclined to the scraping side. Surface crushing is performed between the roller and the table, and when coal in the crushing chamber formed by both is moved between the surfaces to any of the scraping side and the discharging side, time required for crushing becomes longer according to that, so that the coal is easily crushed. Among these, the combination e shows the largest extraction amount of fine particles of -235 mesh, with a very slight difference. From this, as the angle of the oblique slits provided on the table, the angle formed between the oblique slits and the table radius line is preferably in the range of 50° to 85°, most preferably 60° to 70°.

[0065] Considering in theory the inclination of the slit grooves on the grinding roller, when the slit grooves are right-angled to the rotation direction, that is, when the slit grooves are not inclined, the performance of biting is most excellent, but the slit grooves are gradually inclined to 45° with respect to the direction right-angled to the rotation direction, the performance of biting is gradually decreased, and on the contrary, the performance of scraping is increased. In theory, at an angle of 45°, the performance of biting and the performance of scraping are 50%, and at an angle larger than that, the performance of scraping is increased and the performance of biting is decreased.

[0066] According to the small crushing experimenting machine, observing the crushing experiment results of h, i, and j, all the percentages finer by weight of fine particles of -235 mesh are extremely reduced as compared with the combinations of other crushing surfaces. It is assumed that this is because in the grinding roller with the 45°-oblique slit grooves, as described above, the performance of scraping coal is increased, and since the 65°-oblique slit grooves are provided on the table, the tendency to scrape coal becomes larger, so that the coal layer thickness is increased to make roller pressing force with respect to the layer thickness insufficient, thereby reducing the percentage finer by weight of fine particles. The percentages finer by weight of h, i, and j are different because the combinations of the slit grooves of the rollers and the tables are different, but totally, they show the overwhelmingly deteriorated numerical values as compared with the combinations of the crushing surfaces of e, f, and g.

[0067] It is assumed that the main cause is that the coal layer thickness is increased by the scraping effect of the slit grooves. That the coal layer thickness is the cause can be confirmed from the fact that when the crushing surface shapes of both the roller and the table of h, which scrape coal to the inside of the table are combined, the percentage finer by weight is lower than the combination of the smooth surfaces of a.

[0068] The angle of the slit grooves provided on the grinding roller is 22.5° or less because according to j in the crushing experiment, the combination of the 45°-oblique roller slit grooves to the direction scraping coal to the inside and the 65°-oblique table slits in the direction discharging coal to the outside can obtain a percentage finer by weight of fine particles under -235 mesh of 30.3%. The combination e of the right-angled slit grooves of the roller and the 65°-oblique slit grooves to the coal discharging direction of the table slit can obtain a percentage finer by weight of fine particles under -235 mesh of 40.8%, so that it is found that as the slit angle of the roller is close to 45°, the percentage finer by weight is decreased by 0.233% per degree. In other words, (40.8% - 30.3%) / 45° = 0.233% / deg.

[0069] According to the calculation, it is assumed that when the slit groove angle in the grinding roller is 22.5° which is half of 45°, the percentage finer by weight is increased by approximately 5. 24% so as to be approximately 35.6%. When the target value is 38% to 40%, the angle of the table slit grooves is gradually decreased from 85° which is the angle formed between the table slit grooves and the table radius line so as to be close to 40°, so that the performance of biting of the table is increased so as to be capable of achieving the target value, and therefore, with regard to the angle of the slit grooves on the grinding roller, 22.5° which is half of 45° is the limit value which can obtain a high percentage finer by weight.

[0070]

B) In the case of the flat-shaped tire roller having D/R = 4.0, combinations are as follows.

a) Smooth surface roller + Smooth surface table
b) Right-angled slit grooves + Smooth surface table
c) 45°-oblique slit grooves to the scraping side + Smooth surface table
d) Right-angled slit grooves + 45°-oblique slit grooves to the scraping side
e) 45°-oblique slit grooves to the scraping side + 65°-oblique slit grooves to the scraping side
f) Right-angled slit grooves + 65°-oblique slit grooves to the scraping side
g) Right-angled slit grooves + 65°-oblique slit grooves to the discharging side

[0071]

[Table 3]

Roller crushing surface shape	Table crushing surface shape	Percentage finer by weight of fine particles of -235 mesh contained in coal remaining in the table (%)	Percentage finer by weight of fine particles of -235 mesh contained in coal discharged to the outside of the table (%)	Percentage finer by weight of fine particles of -235 mesh contained in the total amount of crushing (%)
A) Smooth surface	Smooth surface	530 g 23.0%	2000 g 25.0%	2530 g 24.6%
B) Right-angled slits	Smooth surface	530 g 22.4%	2000 g 25.7%	2530 g 25.0%
C) 45°-oblique slits to the scraping side	Smooth surface	420 g 23.4%	2060 g 26.5%	2480 g 26.0%
D) Right-angled slits	45°-oblique slits to the scraping side	500 g 23.4%	2000 g 26.8%	2500 g 26.1%
E) 45°-oblique slits to the scraping side	65°-oblique slits to the scraping side	640 g 23.4%	1950 g 28.4%	2490 g 27.3%
F) Right-angled slits	65°-oblique slits to the scraping side	500 g 23.5%	1900 g 30.2%	2400 g 28.8%
G) Right-angled slits	65°-oblique slits to the discharging side	450 g 23.5%	1940 g 19.1%	2390 g 19.9%

[0072] Table 3 shows the results in the case of the flat-shaped tire roller, and the details are as follows.

[0073] In the case of the flat-shaped roller which is the tire type roller and has D/R = 4.0, in the combination of the grinding roller with the 45°-oblique (to the scraping side) slit grooves of e or the roller with the right-angled slit grooves of f and the table formed with the oblique slit grooves whose angle is formed between the oblique slit grooves and the table radius line is 65° (to the scraping side), the extraction amount of fine particles of -235 mesh is the largest. In the flat-shaped tire roller, main crushing is performed in the small diameter portion, so that the biting effect of the slit grooves is hard to occur, and due to that, the percentages finer by weight of fine particles are not different between the smooth surface roller of a and the roller with the right-angled slit grooves of b. On the contrary, in e and f, the highest percentage finer by weight of fine particles under -235 mesh is extracted, not by the performance of biting of the slit grooves, but by

the scraping effect of the slit grooves provided in the direction scraping coal to the inside of the table. In other words, by scraping coal which is crushed once to the small diameter side again, the coal is confined in the crushing surface for a long time, so that the sufficient crushing operation is received to increase the percentage finer by weight of fine particles. In the combination f of the crushing surfaces, since only the direction of the table slits is directed to the discharging side under the same conditions of g, the percentage finer by weight of fine particles of -235 mesh of g is much lower than that of f.

[0074] In the small crushing experimenting machine, as the operation effect of the slit grooves, a significant effect is observed in the coal scraping function, but somehow the biting function is not quite high. It is assumed that this is because the table rotation speed of 48 rpm is too low. It is considered that when the rotation speed is increased, the difference in the percentage of biting is clarified. However, in the real machine, the effect of the performance of biting of the slit grooves has also been already confirmed, and when the operation effects of both are overlapped, the percentage finer by weight of fine particles under -235 mesh is improved significantly, so that the shape disadvantage of the flat-shaped tire roller can be greatly improved. The experiment is performed by one roller, but three rollers are used in the real machine, so that the percentage finer by weight of fine particles is considered to be increased more largely.

[0075] The inclination angle of the slit grooves on the rotary table with respect to the table radius line is preferably in the range of 50° to 85°, most preferably in the range of 60° to 70°.

[0076]

C) In the case of the convex-shaped tire roller having D/R = 5.0, combinations are as follows.

a) Smooth surface roller + Smooth surface table
b) Right-angled slit grooves + Smooth surface table
c) Right-angled slit grooves + 70°-oblique slit grooves to the scraping side
d) Right-angled slit grooves + 70°-oblique slit grooves to the discharging side
e) 45°-oblique slit grooves to the discharging side + 70°-oblique slit grooves to the discharging side

[0077]

[Table 4]

Roller crushing surface shape	Table crushing surface shape	Percentage finer by weight of fine particles of -235 mesh contained in coal remaining in the table (%)	Percentage finer by weight of fine particles of -235 mesh contained in coal discharged to the outside of the table (%)	Percentage finer by weight of fine particles of -235 mesh contained in the total amount of crushing (%)
A. Smooth surface	Smooth surface	390 g 25.8%	2125 g 26.8%	2515 g 26.6%
B. Right-angled slits	Smooth surface	350 g 24.8%	2199 g 26.4%	2549 g 26.2%
C. Right-angled slits	70°-oblique slits to the scraping side	350 g 24.1%	2120 g 29.0%	2470 g 28.3%
D. Right-angled slits	70°-oblique slits to the discharging side	370 g 24.4%	2140 g 29.2%	2510 g 28.5%
E. 45°-oblique slits to the discharging side	70°-oblique slits to the discharging side	350 g 35.6%	2180 g 27.9%	2530 g 29.0%

[0078] Table 4 shows the results in the case of the convex-shaped tire roller, and the details are as follows.

[0079] In the case of the convex-shaped roller which is the tire type roller and has D/R = 5.0, as compared with the percentage finer by weight of fine particles of -235 mesh obtained by the existing smooth surfaces of a, the percentage finer by weight is found to be increased by approximately 6% to 8% in the combinations c, d, and e. With regard to the rotary table with the oblique slit grooves, the combinations of the roller with the right-angled slit grooves, the roller with the 45°-oblique (to the discharging side) slit grooves, and the table with the 70°-oblique slit grooves in the coal discharging direction and the coal scraping direction are effective for increasing the percentage finer by weight of fine particles. In particular, in the combination of the roller with the 45°-oblique (to the discharging side) slit grooves and the table with

the 70°-oblique (to the discharging side) slit grooves, the percentage finer by weight of fine particles of -235 mesh is 29% and is higher than other combinations, but the difference is within the error range and no data showing the superiority with regard to the directionality of the slit grooves can be obtained.

[0080] Accordingly, an additional experiment which examines how the directionality of the slit grooves of the convex-shaped tire roller itself having D/R = 5 makes the percentage finer by weight of fine particles different is conducted. The four roller crushing surface shapes each have the smooth surface, the right-angled slit grooves, the 45°-oblique slits to the scraping side, and the 45°-oblique slits to the discharging side. To examine the crushing surface shapes of these grinding rollers, the crushing experiment is conducted by combinations of these grinding rollers and the smooth surface tables to examine the difference between the percentages finer by weight of fine particles under -235 mesh. To observe the performance difference between the roller crushing surface shapes, the smooth surface table is used so as not to be subjected to the influence of the table. The results are shown in Table 5.

[0081]

[Table 5]

Roller crushing surface shape	Table crushing surface shape	Percentage finer by weight of fine particles of -235 mesh contained in coal remaining in the table (%)	Percentage finer by weight of fine particles of -235 mesh contained in coal discharged to the outside of the table (%)	Percentage finer by weight of fine particles of -235 mesh contained in the total amount of crushing (%)
A. Smooth surface	Smooth surface	240 g 22.8%	2290 g 10.7%	2530 g 11.85%
B. Right-angled slits	Smooth surface	200 g 24.6%	2330 g 16.5%	2530 g 17.1%
C. 45°-oblique slits to the scraping side	Smooth surface	200 g 12.4%	2330 g 18.3%	2530 g 17.8%
D. 45°-oblique slits to the discharging side	Smooth surface	200 g 17.8%	2330 g 19.6%	2530 g 19.5%

[0082] Although the kind and size of coal are different from those used in the above experiments, the table rotation speed is not 48 rpm and is increased to 60 rpm to easily make the performance difference between the crushing surfaces different. Although the experimenting conditions are slightly different from the above experiments, this crushing experiment determines the performance difference between the crushing surfaces, so that when the difference is determined, the performance itself of the roller crushing surface can be observed, and it is considered that this data can be adopted as an evidence.

[0083] By this experiment, the directionality of the slit grooves of the convex-shaped tire roller having D/R = 5 is observed clearly, and it is found that when the inclination direction of the roller slits is directed to the discharging side, the highest percentage finer by weight of fine particles under -235 mesh can be extracted. As compared with the smooth surface roller, the percentage finer by weight is increased by as high as approximately 39%.

[0084] In the case of the convex-shaped roller which is the tire type roller and has D/R = 5.0, since the circumference speed of the main crushing line located in the large diameter portion is high, the slit grooves provided on the roller greatly influence the coal scraping function to promote the increase of the percentage finer by weight of fine particles. However, in the real machine, when the use thereof is continued, the crushing portion wears to gradually change line crushing to surface crushing, so that it is considered that the directionality of the table slits can exhibit its effect more. Although the effect of the directionality is not clarified at the rotation speed at 46 rpm, the effect is clarified at 60 rpm, so that it is considered that the effect is subjected to the influence of the rotation speed.

[0085] The vertical roller mill including, as the grinding roller, the convex-shaped tire roller is a very high efficiency crushing machine, and has a high characteristic in which crushed coal is discharged to the outside of the table, so that the direction of the slit grooves in the roller and the table is desirably directed in the direction discharging coal to the outside. Thereby, the performance of crushing that this crushing machine has can be promoted more. The inclination angle of the table slit grooves is preferably a large angle from 50° to 85° with respect to the table radius line, and the direction is preferably directed in the direction discharging coal.

[0086]

[Table 6]

Mill type	Amount of coal remaining in the table	Amount of coal discharged to the outside of the table	Total amount of crushing	Under -235 mesh	Under 200 mesh
Frusto-conical shaped mill	391 g	2096.5 g	2487.5 g	32.5%	50.1%
Flat-shaped tire mill	495.7 g	1978.6 g	2474.3 g	25.4%	36.4%
Convex-shaped tire mill	362 g	2152.8 g	2514.8 g	27.7%	40.8%

[0087] Table 6 takes the average values of all the numerical values obtained by the crushing surface combination experiments of Tables 2, 3, and 4. It is considered that the average values including poor values and good values clearly show the ability of the rollers themselves. With this, in the frusto-conical shaped roller, the production amount of fine particles is the largest among the three roller shapes, but the crushing efficiency of the roller itself, that is, the discharge amount of coal, is smaller than that of the convex-shaped tire roller, and is larger than that of the flat-shaped tire roller. The vertical roller mill having the convex-shaped roller is the highest efficiency crushing mill, has the smallest amount of coal remaining in the table among the three, and has the largest discharge amount. With regard to the percentage finer by weight, the vertical roller mill having the convex-shaped roller is poorer than the vertical roller mill having the frusto-conical shaped roller, and is more excellent than the vertical roller mill having the flat-shaped tire roller. The flat-shaped tire mill tends to be the poorest among the three in terms of the amount of crushing and the performance of crushing.

[0088] In the above embodiment, the slit grooves 6 on the annular crushing portion 3 of the rotary table 2 have a straight line, but as shown in Figs. 5(a) and 5(b), may have a convex curving line from the inner circumference side to the outer circumference side. The point is that it suffices that the slit grooves inclined in the table rotation direction and the slit grooves inclined in the reverse rotation direction are placed in an interior angle region from a straight line inclined at 45° with respect to the table radius line (a straight line inclined at 45° with respect to the inner circle tangent line of the annular crushing portion) to the inner circle of the annular crushing portion (however, the straight line is excluded), and are preferably placed in an interior angle region from a straight line inclined at 50° with respect to the table radius line (a straight line inclined at 40° with respect to the inner circle tangent line of the annular crushing portion) to the inner circle of the annular crushing portion.

[0089] These curved (arcuate) slit grooves 6 do not inhibit the raw material discharging function and the raw material scraping function. The curved (arcuate) slit grooves curved in the reverse direction greatly inhibit these functions.

EXPLANATION OF REFERENCE NUMERALS

[0090]

1 Rotary table
2 Grinding roll
3 Annular crushing portion
4 Table main body
5 Supporting mechanism
6, 7 Slit groove
8 Collecting case

Claims

1. A vertical roller mill which includes a rotary table driven to rotate, and a plurality of grinding rollers including free rollers placed at fixed positions on the rotary table so as to surround the rotation center line of the rotary table to bite and crush a raw material to be ground between the rotary table and the grinding rollers with the rotary driving of the rotary table, wherein a plurality of oblique slit grooves inclined in the table rotation direction or the reverse

rotation direction thereof with respect to the table radius line are provided at predetermined intervals in the perimeter direction on an annular crushing portion on the upper face of the rotary table, each of the oblique slit grooves being present in a region of the angle exceeding 45° to the radius line.

2. The vertical roller mill according to claim 1, wherein each of the oblique slit grooves is placed in an interior angle region from a straight line inclined at 50° with respect to the table radius line (a straight line inclined at 40° with respect to the inner circle tangent line of the annular crushing portion) to the inner circle of the annular crushing portion.

3. The vertical roller mill according to claim 1 or 2, further comprising, as the grinding roller, a frusto-conical shaped roller, the frusto-conical shaped roller having on the outer circumference surface thereof right-angled slit grooves parallel to a straight line right-angled to the roller rotation direction or oblique slit grooves inclined in the rotation direction or the reverse rotation direction at an angle of 22.5° or less with respect to the straight line.

4. The vertical roller mill according to claim 1 or 2, further comprising, as the grinding roller, a flat-shaped tire roller in which the outer circumference surface thereof is curved in a plane right-angled to the rotation direction and the ratio D/R between the largest roller diameter D and the radius of curvature R of the curved outer circumference surface is less than 4.3, the flat-shaped tire roller having on the outer circumference surface thereof right-angled slit grooves parallel to a curving line right-angled to the roller rotation direction or oblique slit grooves inclined in the roller rotation direction (the raw material scraping direction) at an angle of 45° or less with respect to the curving line, and the inclination direction of oblique slit grooves on the upper face of the rotary table being directed in the table rotation direction (the raw material scraping direction).

5. The vertical roller mill according to claim 1 or 2, further comprising, as the grinding roller, a convex-shaped tire roller in which the outer circumference surface thereof is curved in a plane right-angled to the rotation direction and the ratio D/R of the largest roller diameter D and the radius of curvature R of the curved outer circumference surface is 4.3 or more, the convex-shaped tire roller having on the outer circumference surface thereof right-angled slit grooves parallel to a curving line right-angled to the roller rotation direction or oblique slit grooves inclined in the reverse rotation direction (the raw material discharging direction) at an angle of 45° or less with respect to the curving line, and the inclination direction of oblique slit grooves on the upper face of the rotary table being directed in the reverse direction (the raw material discharging direction) of the table rotation direction.

6. The vertical roller mill according to any one of claims 1 to 5, wherein the slit grooves are previously formed before the use of the mill is started.

7. The vertical roller mill according to any one of claims 1 to 5, wherein the slit grooves are wear grooves formed with the use of the mill by arranging materials having a low wear resistance in portions corresponding to the respective grooves.

8. The vertical roller mill according to any one of claims 1 to 7, wherein the oblique slit grooves formed on the rotary table are arcuate grooves curved in the convex direction from the inner circumference side of the rotary table to the outer circumference side thereof.

Fig. 1

1 MAIN CRUSHING PORTION

Fig. 5

1 ROTATION DIRECTION (SCRAPING DIRECTION)

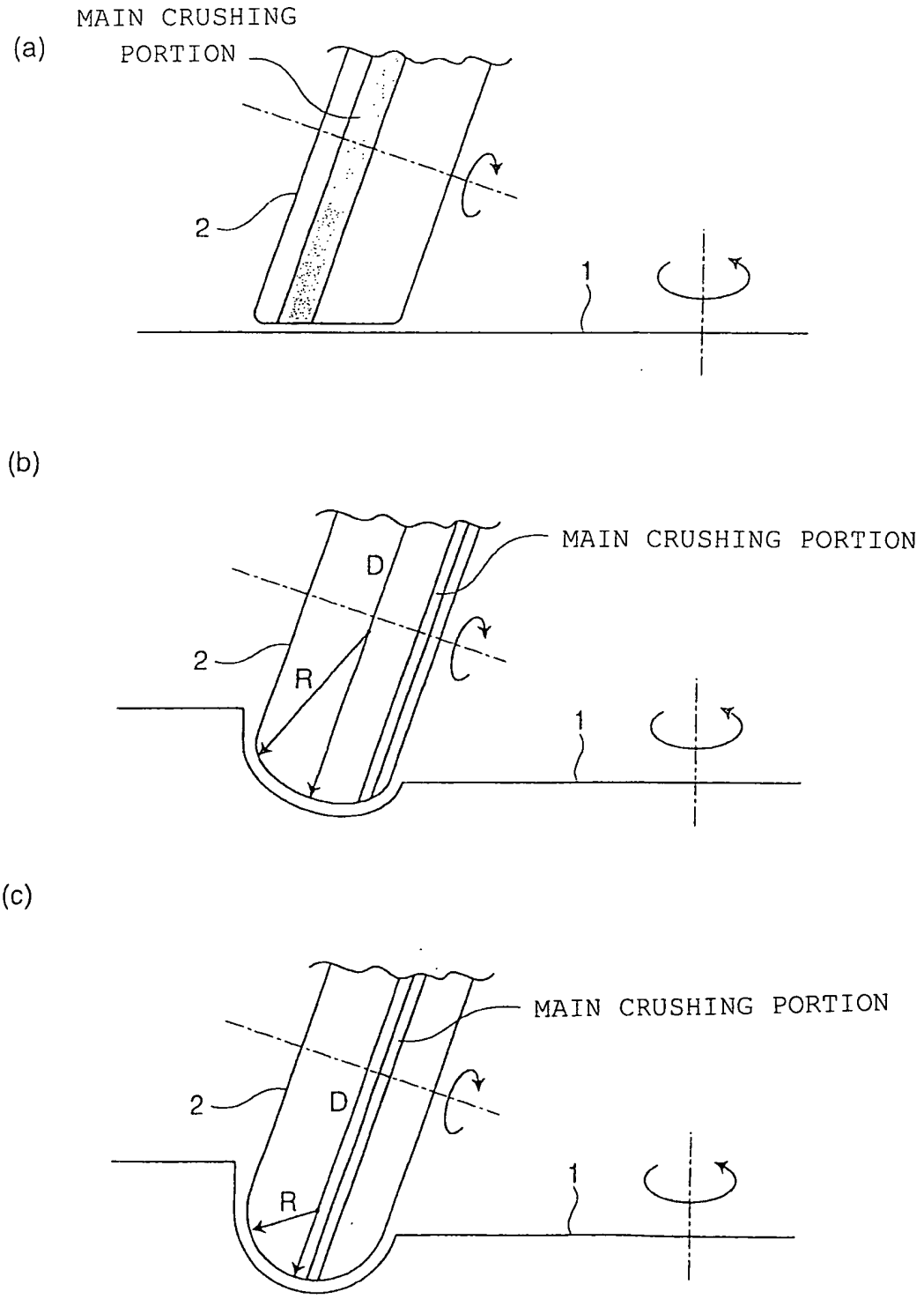
2 RADIUS LINE

3 INNER CIRCLE

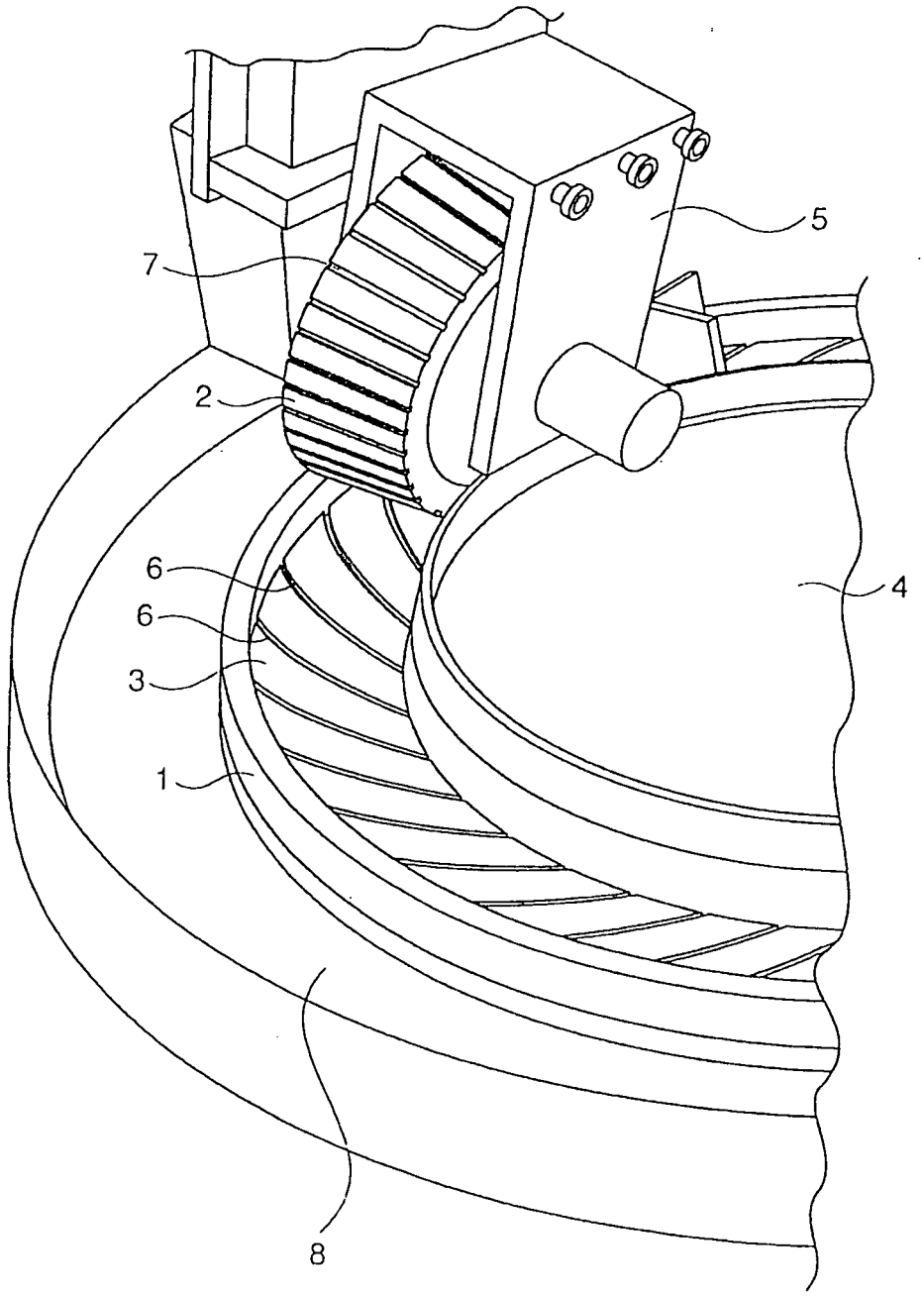
4 TANGENT LINE

5 DISCHARGING DIRECTION

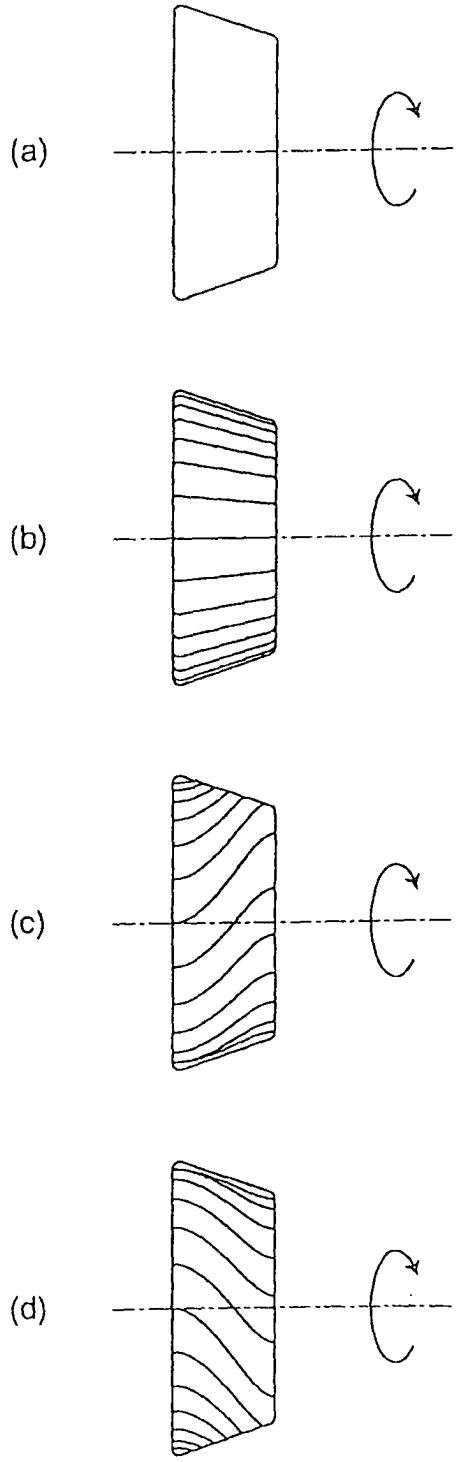
[FIG.1]


(a)
MAIN CRUSHING PORTION
2
1
(b)
MAIN CRUSHING PORTION
D
2
R
1
(c)
MAIN CRUSHING PORTION
2
D
R
1

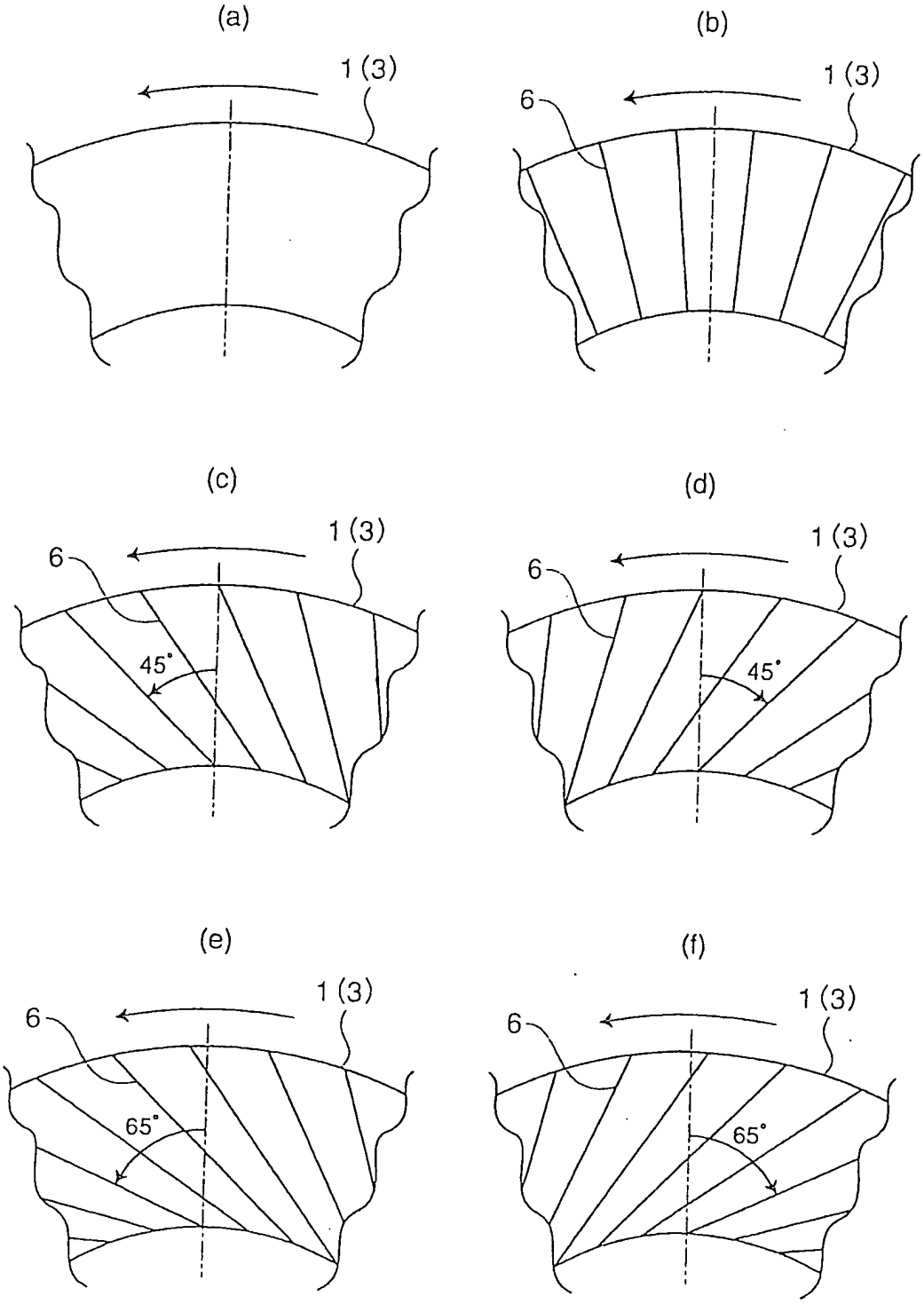
[FIG. 2]



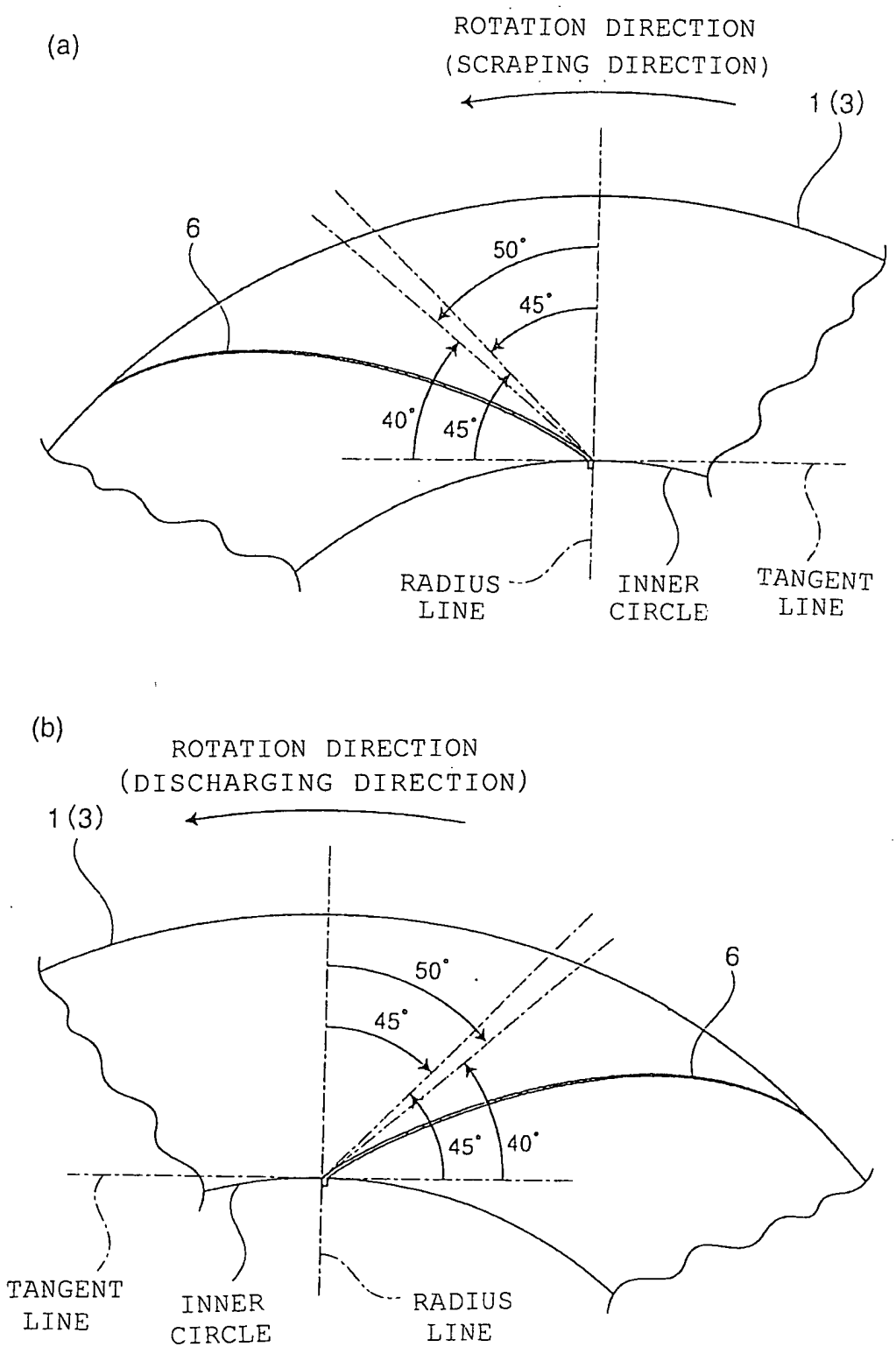
[FIG. 3]



[FIG. 4]



[FIG. 5]


(a)
ROTATION DIRECTION
(SCRAPING DIRECTION)
1 (3)
6
50°
45°
40°
45°
RADIUS LINE
INNER CIRCLE
TANGENT LINE
(b)
ROTATION DIRECTION
(DISCHARGING DIRECTION)
1 (3)
6
50°
45°
45°
40°
TANGENT LINE
INNER CIRCLE
RADIUS LINE

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/071663

A. CLASSIFICATION OF SUBJECT MATTER
B02C15/04(2006.01)i, *F23K1/00*(2006.01)n, *F23K3/02*(2006.01)n

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)
B02C15/04, F23K1/00, F23K3/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2009-142809 A (ING Shoji Co., Ltd.), 02 July 2009 (02.07.2009), paragraphs [0035] to [0040]; fig. 1 to 7 (Family: none)	1-8
Y	JP 60-106547 A (Asahimatsu Foods Co., Ltd.), 12 June 1985 (12.06.1985), specification, page 3, upper left column, line 17 to lower left column, line 14; fig. 5 to 11 (Family: none)	1-8
Y	JP 2007-111604 A (ING Shoji Co., Ltd.), 10 May 2007 (10.05.2007), paragraphs [0027], [0039]; fig. 2 (Family: none)	3-5

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search 08 March, 2010 (08.03.10)	Date of mailing of the international search report 16 March, 2010 (16.03.10)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/071663

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2005-034765 A (Kawasaki Heavy Industries, Ltd.), 10 February 2005 (10.02.2005), paragraph [0045]; fig. 3 & KR 10-2005-0009212 A & CN 1575852 A	4-5
Y	JP 63-143949 A (ING Shoji Co., Ltd.), 16 June 1988 (16.06.1988), specification, page 3, upper right column, lines 8 to 15; fig. 2 & US 4848683 A & EP 271336 A2 & DE 3787791 T & AU 7998487 A & KR 20-1993-0004835 Y	7
A	JP 05-293394 A (Kawasaki Heavy Industries, Ltd.), 09 November 1993 (09.11.1993), paragraphs [0010] to [0019]; fig. 1 to 8 (Family: none)	3

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 1618574 A **[0013]**
- JP 2863768 B **[0013]**
- JP 2009142809 A **[0013] [0015] [0045] [0046]**