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(54) Method for grinding roll.

(57) The known on-line roll grinding method is improved so as to avoid clogging of grinder, breaking of a grinder corner portion, complication of a grinder construction and buzzing vibration of a grinder. A plurality of grinder holders adapted to press grinders mounted to their tip end portions against a roll surface, are arrayed along the axial direction of the roll within a frame which can reciprocate along the roll axis. The grinders are mounted within the holders with their rotary axes inclined in the axial direction of the roll with respect to normal lines of the roll surface. The rotary axes of the grinders are displaced by a given offset amount H with respect to the rotary axis of the roll. The improvements reside in that an inner diameter d_G and an outer diameter D_G of the grinder and the offset amount H are chosen so as to fulfil the following formulae:

$0.1 \leqq H/D_G \leqq 0.4$, and

$0.1 \leqq d_G/D_G$.

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METHOD FOR GRINDING ROLL

BACKGROUND OF THE INVENTION:

Field of the Invention:

The present invention relates to a method for grinding a rotating roll, and more particularly to a method for remediably grinding a roll on an on-line basis in the event that the roll wears during a rolling work as is the case with a work roll in a rolling mill. In addition, the subject method is also applicable to on-line grinding of a pinch roll equipped in front of a downcoiler as well as grinding of work rolls and backup rolls in various kinds of rolling mills.

Description of the Prior Art:

Regarding a hot rolling mill or the like for rolling iron sheets, in order to achieve improvements in a production efficiency as well as improvements in quality of rolled sheet materials, development and practical use of an on-line grinding apparatus for grinding a roll surface into a desired profile while rolling with the grinding apparatus directly mounted to the rolling mill have been desired.

Fig. 8 shows one example of such on-line roll grinding system, in which a surface of a work roll 1 is ground into a desired profile by pressing an unrotating grinder 3 such as a grind stone against the surface of the work roll 1 while the work roll 1 is being rotated and also moving the grinder 3 in the axial direction of the roll, that is, in the direction perpendicular to the plane of the sheet of the figure. In addition, Fig. 9 shows another example, which is a method for grinding by pressing a revolving grinding belt 3′ against a rotating work roll 1 similarly to the preceding example and moving it in the axial direction of the roll.

In addition, Fig. 10 discloses another method, in which grinding of a roll 1 is made possible even if a forcive driving device for a grinder 3 is not present, by making a rotary axis O_G of the grinder 3 offset by H with respect to a rotary axis O_R of the roll 1.

In the above-described apparatus of the system shown in Fig. 8, although the structure is simple because of absence of a rotary driving device for the grinder 3, since the surface portion of the grinder 3 coming into contact with the work roll 1 is always the same surface portion, clogging would arise on the surface portion, and so, there is a shortcoming that a grinding performance is degraded. Furthermore, for the grinder 3 normally a rectangular block-shaped grind stone is used, and a grinding apparatus in which a plurality of such grind-stones are arrayed along the axial direction of the roll to enhance a grinding efficiency by a broadened grinding surface, has been used. However, in this case there is a shortcoming that a corner portion 3a of the grinder 3 is liable to be broken and damaged due to grinding resistance and the like.

On the other hand, in the apparatus of the system shown in Fig. 9, there is a merit that clogging on the surface of the grinder 3′ can be prevented and a grinding performance can be maintained because during grinding always a fresh grinding surface of the grinder 3′ comes into contact with the work roll 1 as the grinder 3′ is revolving. In addition, since normally a belt-shaped grind-stone is often used as the grinder 3′ in this case, the breaking damage of the corner portion as is the case with the above-mentioned rectangular block-shaped grind-stone can be also prevented. However, in this case although not shown, since a rotary driving device for rotating the grinder 3′ is necessitated, the structure becomes complicated, an installation expense is high, also as the installation place is narrow, maintenance and inspection of the installation becomes extremely difficult, and also, due to a large space occupied by the rotary driving device, a number of the grinder heads is reduced (normally reduced to only one head), so that a grinding capability in the case of grinding an entire roll is lowered.

A method proposed for resolving the above-mentioned problems is the non-drive type on-line grinding apparatus shown in Fig. 10. This method was characteristic in that since the grinder can achieve grinding while rotating in association with the roll even without a forcive driving device for the grinder, a stable grinding performance can be obtained. However, when a rolling mill roll was practically ground within an existing rolling mill installation according to this method, buzzing vibration was generated in the grinder, and the problem that a grinding performance became unstable and also an outer circumferential surface of the grinder was broken and damaged, arose.

SUMMARY OF THE INVENTION

It is therefore one object of the present invention to provide a novel reasonable method for grinding a rotating roll on an on-line basis, which is free from all the aforementioned disadvantages in the prior art.

A specific object of the present invention is to provide a method for grinding a rotating roll, in which clogging on a grinder does not occur and hence degradation of a grinding performance in use would not arise.

Another specific object of the present invention is to provide a method for grinding a rotating roll, in which breaking damage of a circumferential portion of a grinder would not occur.

Still another specific object of the present invention is to provide a method for grinding a rotating roll, in which neither buzzing vibration nor seizure of a grinder would occur.

Yet another specific object of the present invention is to provide a method for grinding a rotating roll, which does not necessitate to complicate a structure of a grinding apparatus nor to increase an installation expense of the apparatus.

According to one feature of the present invention, there is provided a method for grinding a roll, wherein the roll can be ground without forcibly driving grinders by arraying along the axial direction of the roll a plurality of grinder holders adapted to press grinders mounted to their tip end portions against the roll surface within a frame which can reciprocate along the roll axis, mounting the grinders within the holders with their rotary axes inclined in the axial direction of the roll with respect to normal lines of the roll surface, and also displacing the rotary axes of the grinders by a given offset amount H with respect to the rotary axis of the roll, which method is improved in that the relations between the offset amount H and dimensions D_G and d_G of the grinders are preset in the range defined by the following formulae:

$0.1 \leqq H/D_G \leqq 0.4$

$0.1 \leqq d_G/D_G$

where H represents an offset amount between a grinder rotary axis and a roll rotary axis, d_G represents an inner diameter of the grinder and D_G represents an outer diameter of the grinder.

According to the present invention, as a result of setting of the offset amount H given between the grinder rotary axis and the roll rotary axis at the above-specified values, the direction of a relative slip velocity V_S occurring at the contact portion between the grinder and the roll to be ground would become proper, so that vibration and breaking damage of the grinder can be prevented. In addition, by selecting the inner diameter of the grinder at the aforementioned values, the direction of a relative slip velocity would not coincide with a contact line, and so, seizure and clogging of the grinder can be precluded.

The above-mentioned and other objects, features and advantages of the present invention will become more apparent by reference to the following description of one preferred embodiment of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS:

In the accompanying drawings:

Fig. 1 is a plan view of a roll grinding apparatus according to one preferred embodiment of the present invention;

Fig. 2 is a cross-section view taken along line A-A in Fig. 1 as viewed in the direction of arrows;

Fig. 3 is a partial side view for explaining a principle of a roll grinding method according to the present invention;

Fig. 4 is a partial front view for explaining the principle of the same roll grinding method;

Fig. 5 is a diagram of grinding test results showing relations between grinding conditions and grinding performances;

Figs. 6(A), 6(B), 6(C), 6(D) and 6(E) are diagrams showing one example of a result of theoretical analysis of a contact condition and a relative slip velocity between a grind-stone and a roll according to the present invention;

Figs. 7(a), 7(b) and 7(c) are partial cross-section views and a diagram showing proper relations between a grind-stone offset H and grind-stone dimensions D_G and d_G as claimed in this patent application; and

Figs. 8, 9 and 10 are schematic partial cross- section views showing operation principles of some examples of a roll grinding apparatus in the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

In the following, the feature and advantage of the present invention will be described in greater detail on the basis of one preferred embodiment illustrated in the accompanying drawings. Fig. 1 is a plan view showing one example of a roll grinding apparatus embodying the grinding method according to the present invention as applied, by way of example, to a work roll in a four-stage rolling mill, and Fig. 2 is a cross-section view taken along line A-A in Fig. 1.

As shown in these figures, the rolling mill operates to roll a sheet material 15 to be rolled by means of a work roll 1, and the work roll 1 is reinforced by a back-up roll 2. Grinders 3 such as ring-shaped grind-stone arrayed in multiple along the axial direction of the work roll 1 are rotatably supported individually at tip end portions of grinder holders 6 respectively via shafts 4 and bearings 5. In the following description, the grinder 3 will be described as "grind-stone 3", and the grinder holder 6 will be described as "grind-stone holder 6".

Each grind-stone holder 6 forms a plunger, its rear portion is connected to a pressing device 8 consisting of a plunger 8a and a cylinder 8b, and it is fitted and mounted in a casing 9 so as to be able to advance and retreat in the direction of arrows X. Each pressing device 8 is mounted to the inside of a rear cover 9a of the casing 9, and it can press the grind-stone 3 against the surface of the work roll 1 by feeding working fluid into the cylinder 8b through a hole 10 via a hydraulic control valve not shown.

In addition, in the casing 9 is provided a fluid feed port 12 for feeding fluid into a pull-back cylinder chamber 11 for the grind-stone holder. The respective grind-stones 3 are mounted within the casing 9 with their rotary axes O_G inclined in the axial direction of the roll by an arbitrary set angle α with respect to normal lines N of the outer circumferential surface of the work roll 1 as shown in Fig. 1, and by moving the casing 9 vertically by means of an elevator device 13 it is possible to make the rotary axes O_G of the grind-stones 3 offset to the upper or lower side with respect to the work roll axis O_R. The illustrated example is the case where the rotary axes O_G are made to offset by a set value H to the upper side.

Fig. 3 is a partial side view showing a contact state between a grinder and a roll, and if the grind-stone rotary axis O_G is made to offset with respect to the work roll axis O_R, during grinding, a contact portion between a tip end surface of the grind-stone 3 and the work roll 1, that is, a grinding surface becomes line contact ℓ as shown in Fig. 4.

Under such a contact state, if the work roll 1 rotates at a circumferential velocity V_R, then the grind-stone 3 rotates at a circumferential velocity V_G, and at this time between the grind-stone 3 and the roll 1 is generated a relative slip velocity V_S. The surface of the roll 1 is ground due to this slip velocity V_S.

On the other hand, when a roll is ground, what is most important is that breaking damage or seizure of the grind-stone does not occur but a stable grinding performance can be maintained. It has become obvious in the step of trying a practical machine test that to that end the direction of the above-described slip velocity V_S is extremely important. More particularly, if the offset amount of the grind-stone becomes small, buzzing vibration and breaking damage of the grind-stone become liable to occur, and on the contrary, if it becomes too large, seizure of the grind-stone becomes liable to occur, and so, in either case normal grinding was impossible.

As a result of execution of a practical machine test and theoretical analysis in order to resolve these problems, it has been discovered that important relations exist between the offset amount H and the grind-stone sizes D_G (outer diameter) and d_G (inner diameter).

Fig. 5 shows data obtained by analyzing grinding performances when a roll was ground while the offset amount H (normalized by taking a proportion H/D_G relative to the grind-stone outer diameter) and the inner diameter of the grind-stone d_G (normalized by taking a proportion d_G/D_G relative to the grind-stone diameter). The grinding conditions at this time are as follows:

roll material: nickel grain cast iron
roll outer diameter: D_W = ∅600 mm
roll circumferential velocity: 800 m/min
grind-stone material: GC320K
grind-stone outer diameter: D_G = ∅240 mm

The ordinate of the diagram in Fig. 5 indicates a grinding ratio G which is defined by the following formula:

$$G = \frac{\text{ground volume of roll}}{\text{abraded volume of grind-stone}}$$

It is meant that as the grinding ratio G is larger, abrasion of a grind-stone is smaller and a life of the grind-stone is longer.

Accordingly it is desirable to grind under a condition having a high grinding ratio G, and if one observes Fig. 5 from such view point, it is seen that it is preferable to make d_G/D_G small and to make H/D_G large.

However, if d_G/D_G is made to be small, that is, if the inner diameter of the grind-stone is made to be small for a given outer diameter, seizure would be generated in the proximity of the inside of the grind stone, hence a grinding performance would become very unstable, and if it is reduced to $d_G/D_G \leq 0.1$, then seizure cannot be prevented for any value of the grind-stone offset amount (H/D_G).

On the other hand, in the case where the grind-stone offset amount (indicated by H/D_G in Fig. 5) is enlarged, also seizure would be generated, in this case also seizure is generated on the side of the inner circumference of the grind-stone, and in order to prevent seizure it is necessary to reduce the offset amount to $H/D_G < 0.4$.

Next, explanation will be made on the reasons and causes why such seizure of a grind-stone is liable to be generated on the side of the inner circumference of a grind-stone and why it is influenced by d_G and H. In Fig. 6 are shown results of vector analysis of the above-described slip velocities V_S under various grinding conditions.

In this figure, slip velocities V_S at any arbitrary points on the contact line ℓ between the grind-stone and the roll are displayed in terms of vectors, and it is seen that the direction of the slip velocity V_S is greatly varied depending upon the grind-stone offset. amount H and the grind-stone inner diameter d_G.

More particularly, in Figs. 6(A), 6(B) and 6(E) corresponding to a fixed value of d_G/D_G when the grind-stone offset amount H is increased in the sequence of (A) → (B) → (E), in the inside portion of the grind-stone, the direction of the slip velocity V_S would become to overlap on the contact line ℓ.

In the portion where the slip velocity V_S and the contact line coincides with each other as described above, seizure would be generated because heat generated by grinding would be accumulated in this portion.

Accordingly, in order to prevent seizure of the grind-stone, it is necessary to make the slip velocity V_S not coincide with the contact line ℓ, and as a measure for that purpose, setting of a proper grind-stone offset value becomes essentially necessary.

On the other hand, in the case of successively enlarging the inner diameter of the grind-stone, that is, successively increasing d_G/D_G while maintaining the offset amount H constant (Fig. 6(B) → Fig. 6(C) → Fig. 6(D)), comparing the respective data, while the directions of the slip velocities V_S would not vary largely, as a result of enlargement of the grind-stone inner diameter, the inside portion of the grind-stone where the slip velocities V_S coincide with the contact line ℓ disappears, and so, enlargement of the inner diameter of the grind-stone is advantageous for preventing seizure of the grind-stone.

As described above, from the viewpoint of preventing seizure, it is preferable to reduce the offset value H/D_G to minimum, but if it is reduced excessively, buzzing vibration of the grind-stone would be generated. In Fig. 5 is shown the relation between the buzzing vibration and the grinding conditions. That is, if the offset amount H/D_G becomes 0.1 or less, buzzing vibration becomes liable to occur, and if the offset amount H/D_G is further reduced, breaking damage of the grind-stone would be induced.

The cause of occurrence of such buzzing vibration as well as breaking damage of the grind-stone is also shown in Fig. 6. It can be explained as follows on the basis of a difference in the direction of the slip velocity V_S. The reason why buzzing vibration of the grind-stone is liable to occur when the offset amount H is small, is because the direction of the slip velocity V_S differs greatly between the inside portion and the outside portion of the grind-stone. More particularly, in the case of Fig. 6(A) where the offset amount H is small, the slip velocity V_S in the inside portion is directed downwards, but the slip velocity V_S in the outside portion is directed upwards, and thus the directions are greatly different. Whereas in the case of Fig. 6(B) or 6(E) where the offset amount H is large, the slip velocity V_S is directed downwards both in the inside portion and in the outside portion. As described above, when the offset amount is small, buzzing vibration would occur, because the direction of the slip velocity V_S would become reversed in the inside portion and the outside portion of the grind-stone, the direction of the external forces (grinding resistant forces) acting upon the rotary axis of the grind-stone would distribute over a broad range, and its deformation mode becomes complicated.

In addition, when the directions of the relative slip velocities V_S in the outer circumferential portion of the grind-stone are directed to the radially outward directions (the normal line directions), the grind-stone becomes liable to be broken and damaged. More particularly. at any arbitrary point on the contact line ℓ of the roll, grinding resistant forces in the direction of the slip velocites would act upon the grind-stone. In the inside portion of the contact line ℓ, they are resistant forces directed downwards, and so, they are not relevant to breaking damage of the grind-stone. Whereas, in the outer circumferential portion, a mechanical strength of the grind-stone is weak, and the grind-stone would be broken and damaged relatively easily even by small external forces. In this case, as the directions of the resistant forces exerted by the roll that is, the direction of the slip velocities are directed closer to the radially outward direction, breaking damage is liable to occur.

Accordingly, in order to prevent breaking damage of the grind-stone, it is necessary to prevent the direction of the slip velocity from being directed in the radially outward direction as much as possible, and as a countermeasure for that purpose, it is important to select a proper value of H/D_G.

Summarizing the above-mentioned relations between seizure, buzzing vibration and breaking damage of the grind-stone and an offset amount and an inner diameter of the grind-stone, and diagrammatically showing a range of proper values, it becomes as shown in Fig. 7. the proper range is, as best seen in Fig. 7(c), $0.1 \leq H/D_G \leq 0.4$ and $0.1 \leq d_G/D_G$.

With the grinding method according to the present invention, even without a forcive rotary driving device for a grinder, stable grinding can be achieved directly within an installation such as a rolling mill without causing breaking damage, buzzing vibration nor seizure of grind-stones, hence an efficiency of a rolling work is improved, and at the same time quality of the rolled products can be improved.

While a principle of the present invention has been described above in connection to one preferred embodiment of the invention, it is intended that all matter contained in the above-description and illustrated in the accompanying drawings shall be interpreted to be illustrative and not in a limiting sense.

Claims

1. A method for grinding a roll, wherein said roll can be ground without forcibly driving grinders by arraying along the axial direction of the roll a plurality of grinder holders adapted to press grinders mounted to their tip end portion against the roll surface within a frame which can reciprocate along the roll axis, mounting said grinders within said holders with their rotary axes inclined in the axial direction of the roll with respect to normal lines of the roll surface, and also displacing the rotary axes of the grinders by a given offset amount H with respect to the rotary axis of said roll; characterized in that the relations between said offset amount H and dimensions D_G and d_G of said grinders are preset in the range defined by the following formulae:

$0.1 \leq H/D_G \leq 0.4$

$0.1 \leq d_G/D_G$

where

H: an offset amount between a grinder rotary axis and a roll rotary axis,

d_G: an inner diameter of the grinder,

D_G: an outer diameter of the grinder.

Fig. 1

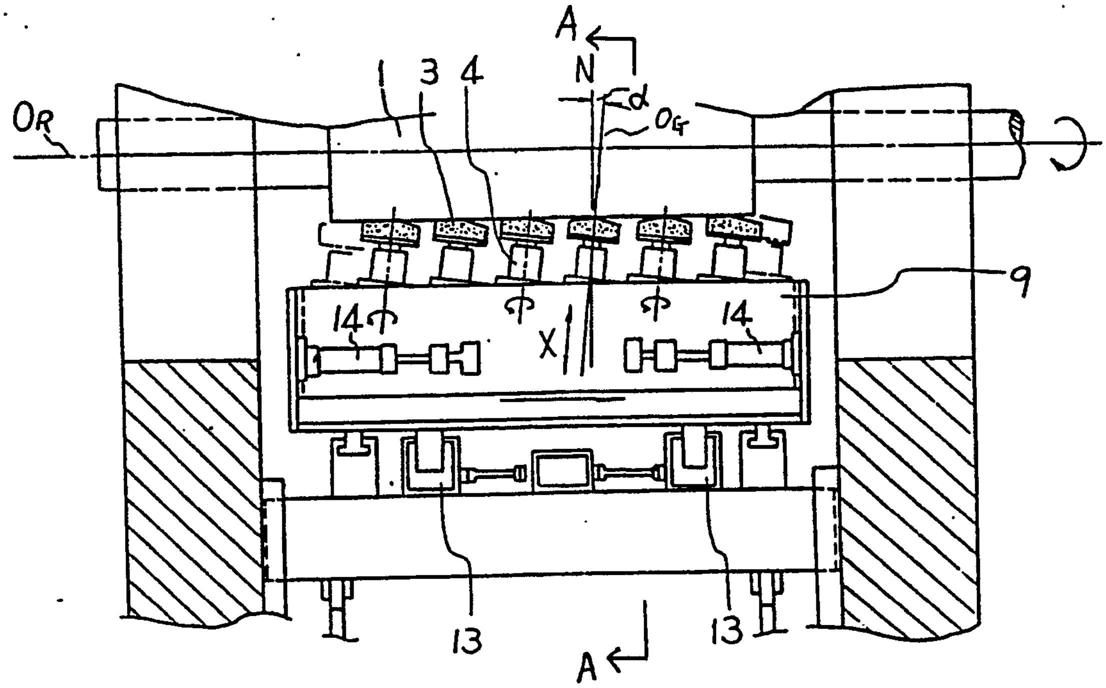


Fig. 2

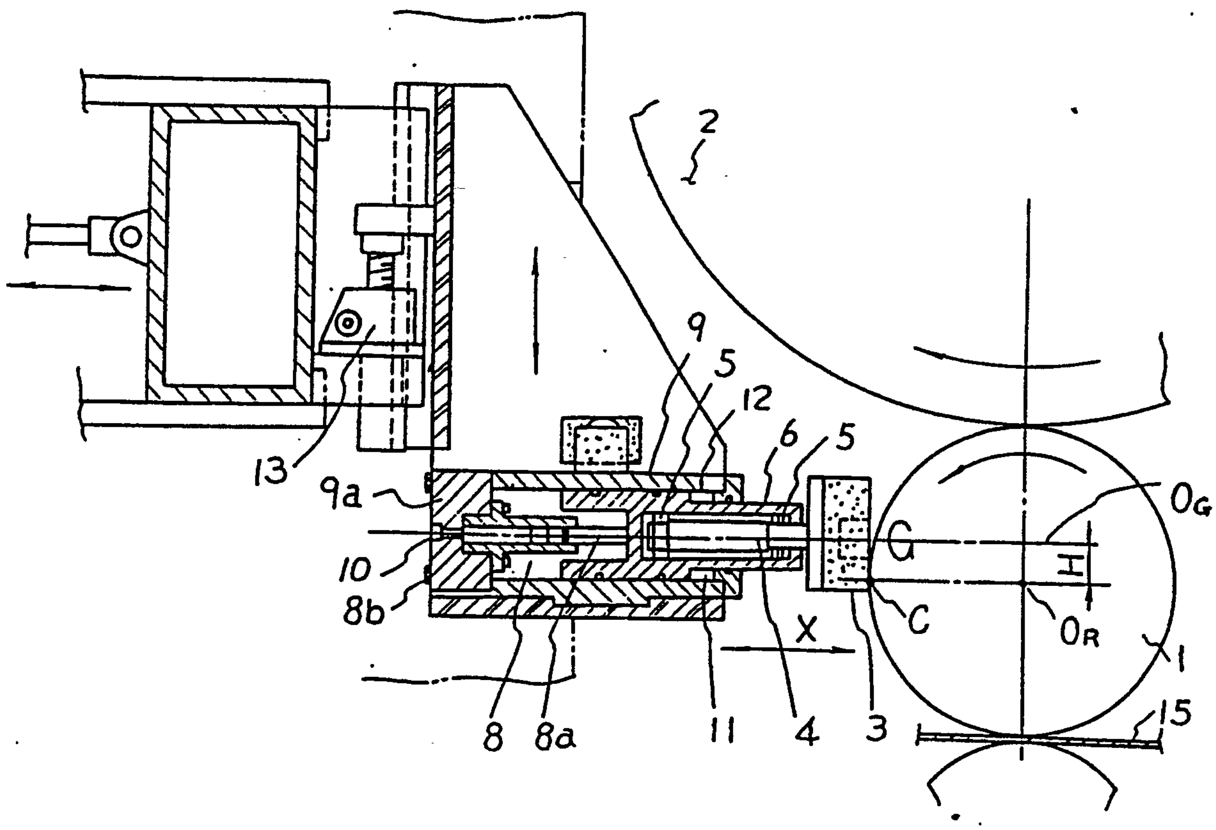


Fig. 3

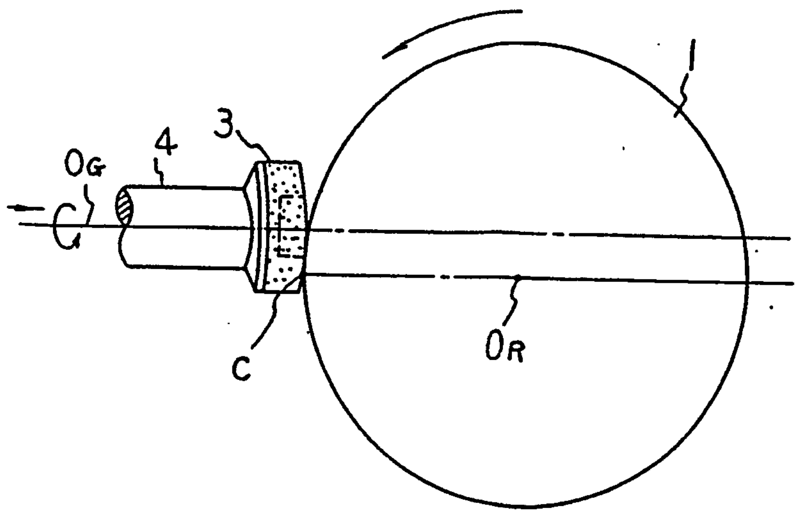


Fig. 4

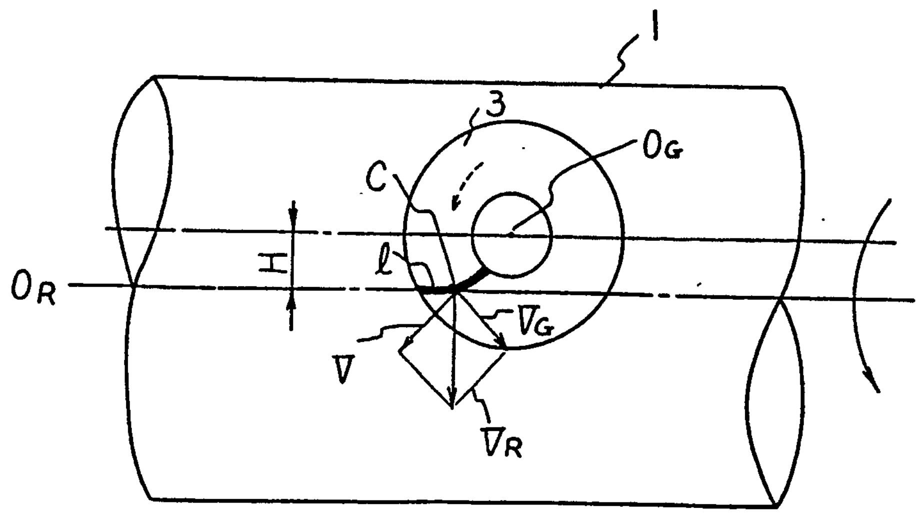


Fig. 5

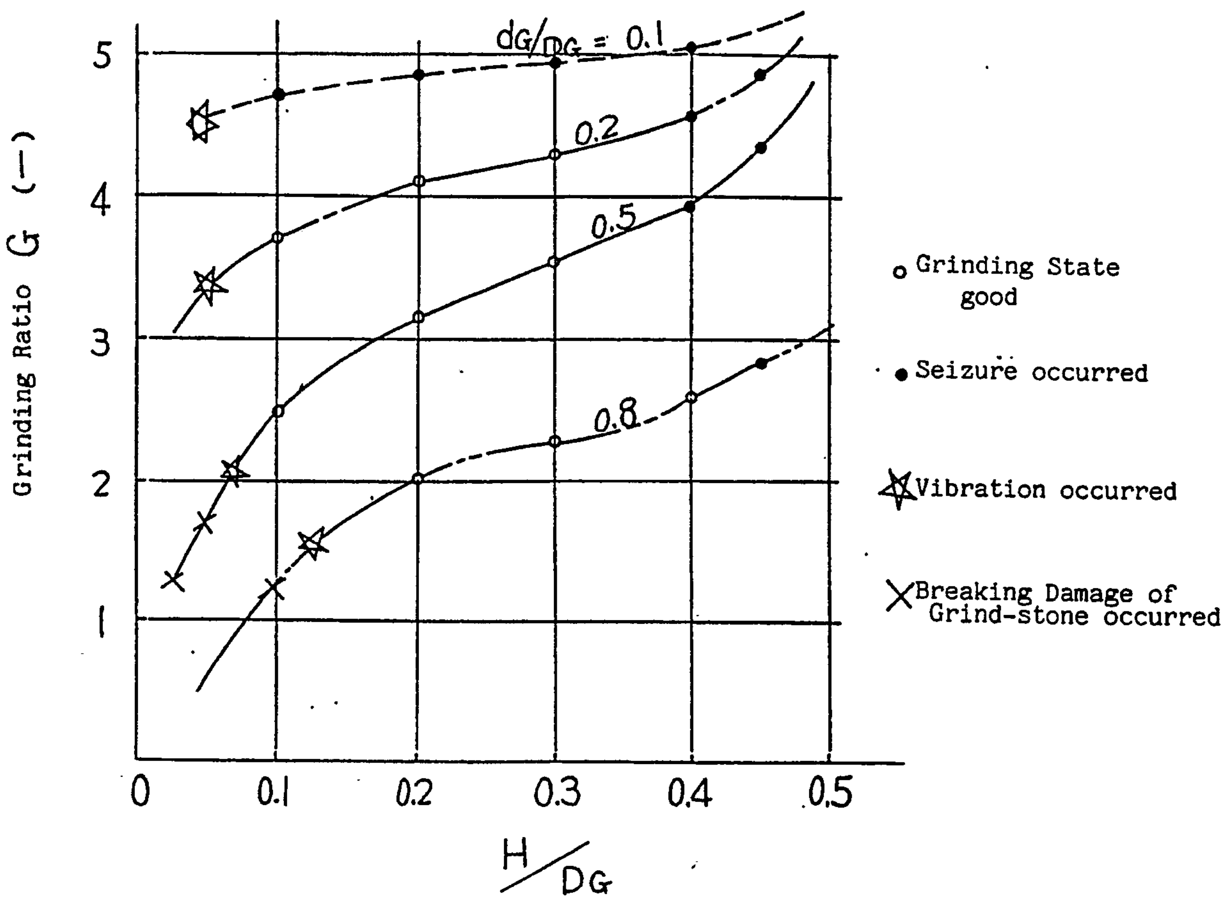

dG/DG = 0.1
0.2
0.5
0.8
Grinding Ratio G (—)
5
4
3
2
1
0
0.1
0.2
0.3
0.4
0.5
H/DG
o Grinding State good
● Seizure occurred
Vibration occurred
Breaking Damage of Grind-stone occurred

Fig. 6

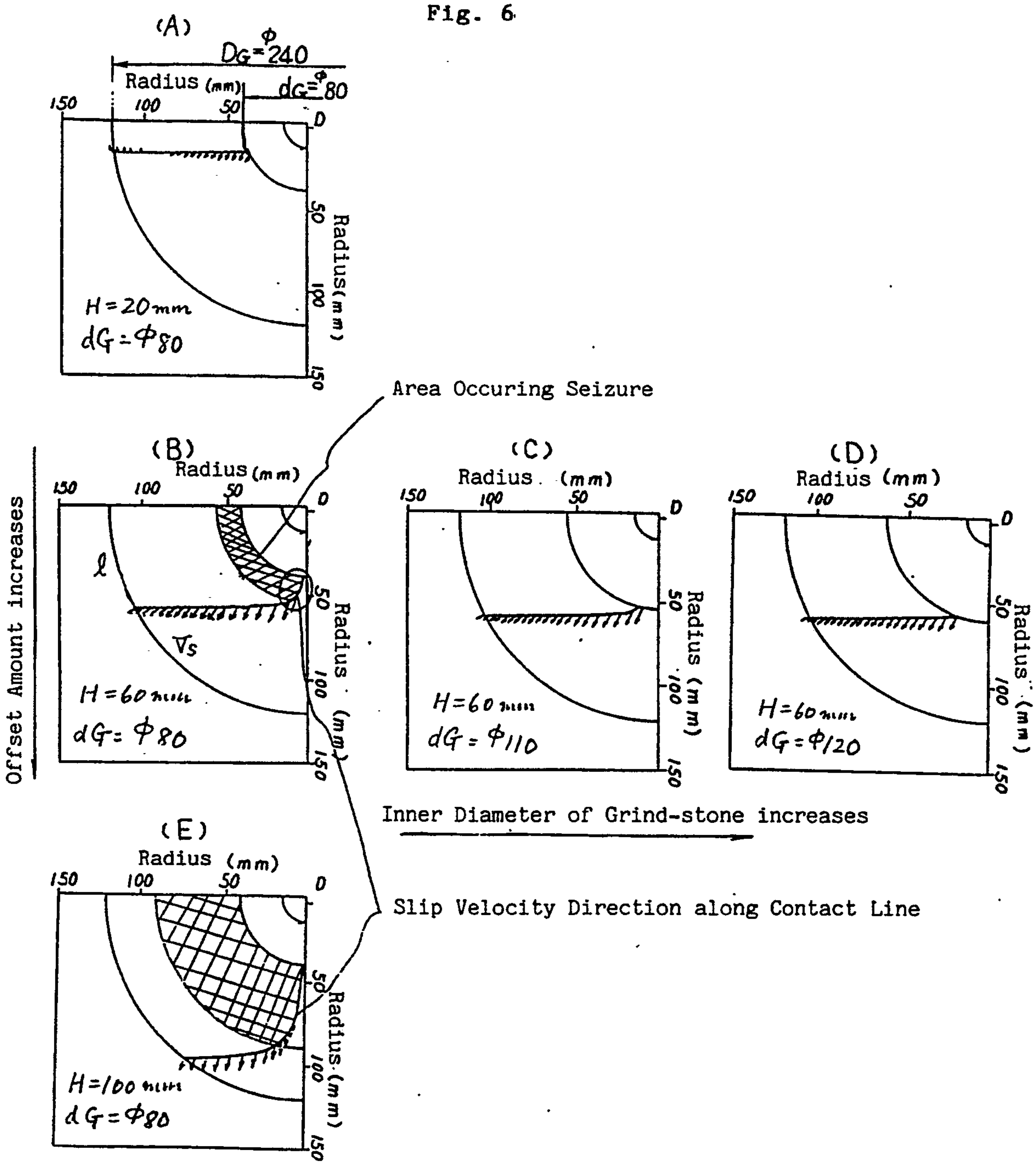
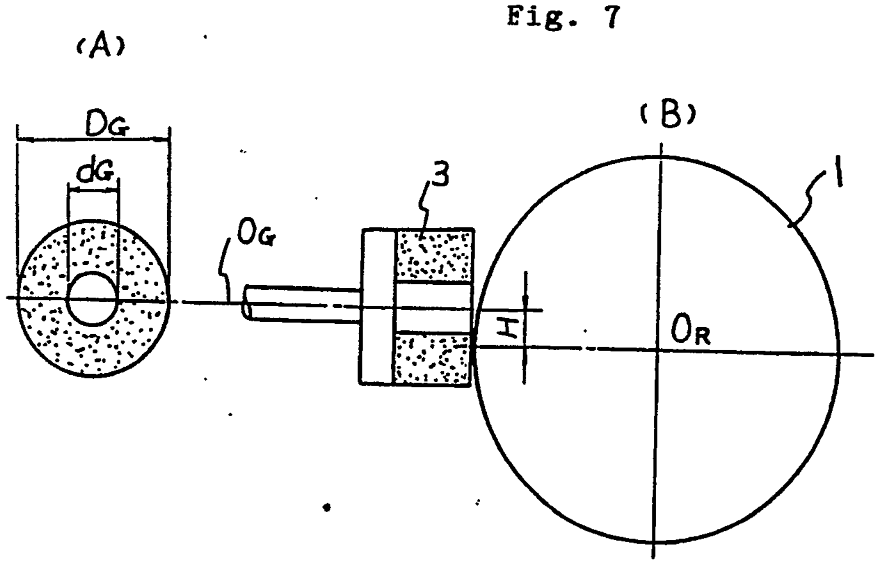

(A)
$D_G=\phi 240$
Radius (mm)
$d_G=\phi 80$
150
100
50
0
50
100
150
Radius (mm)
H=20mm
dG=Φ80
Area Occuring Seizure
(B)
Radius (mm)
150
100
50
0
ℓ
Vs
50
100
150
Radius (mm)
H=60mm
dG=Φ80
Offset Amount increases
(C)
Radius (mm)
150
100
50
0
50
100
150
Radius (mm)
H=60mm
dG=Φ110
(D)
Radius (mm)
150
100
50
0
50
100
150
Radius (mm)
H=60mm
dG=Φ120
Inner Diameter of Grind-stone increases
(E)
Radius (mm)
150
100
50
0
50
100
150
Radius (mm)
H=100mm
dG=Φ80
Slip Velocity Direction along Contact Line

Fig. 7


(A)
DG
dG
OG
3
(B)
1
H
OR

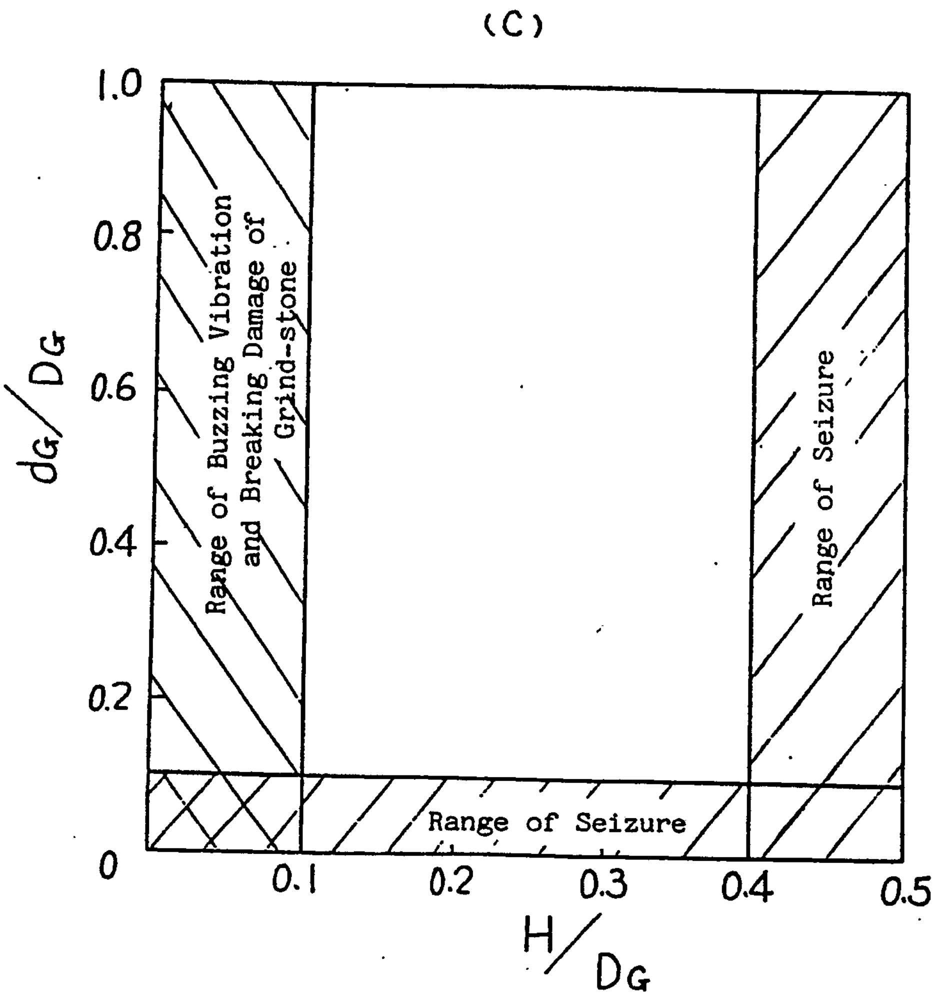

(C)
1.0
0.8
0.6
0.4
0.2
0
dG/DG
Range of Buzzing Vibration and Breaking Damage of Grind-stone
Range of Seizure
Range of Seizure
0.1
0.2
0.3
0.4
0.5
H/DG

Fig. 8 (Prior Art)

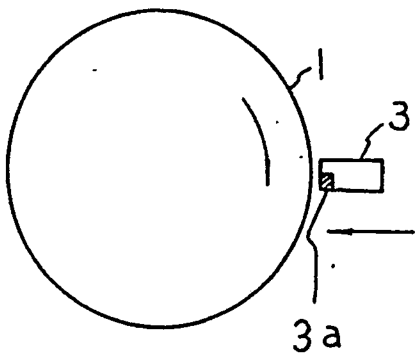


Fig. 9 (Prior Art)

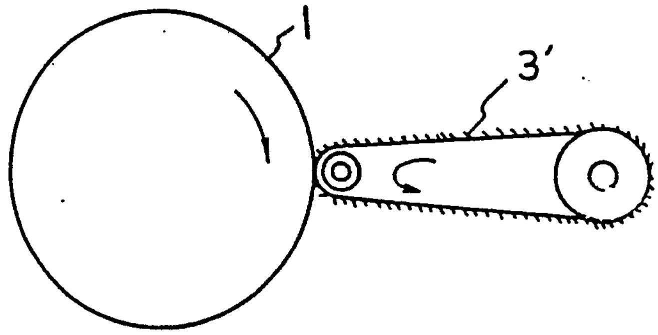


Fig. 10 (Prior Art)