



(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **93112229.5**

(51) Int. Cl.⁵: **B24B 53/007, B24C 1/02, B24C 11/00, B24B 55/04, B24B 55/06**

(22) Date of filing: **30.07.93**

(30) Priority: **31.07.92 JP 205798/92**
11.06.93 JP 141005/93

(43) Date of publication of application:
02.03.94 Bulletin 94/09

(84) Designated Contracting States:
BE DE FR GB

(71) Applicant: **NGK INSULATORS, LTD.**
2-56 Suda-cho,
Mizuho-ku
Nagoya 467(JP)

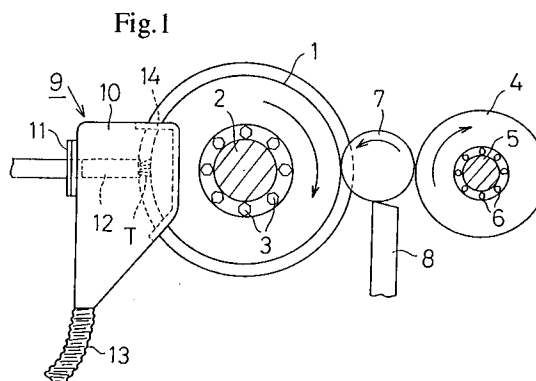
(72) Inventor: **Shimada, Hiromi**
34, Takemi-cho 1-chome,
Mizuho-ku
Nagoya-shi, Aichi-ken 467(JP)

Inventor: **Sato, Junji**
16, Aza-Gohura, Kawadagata,
Hagiwara-cho
Ichinomiya-shi, Aichi-ken 491-03(JP)
 Inventor: **Ono, Katsuhiro**
2-1, Asahi-cho
Yokkaichi-shi, Mie-ken 510(JP)
 Inventor: **Nishio, Akifumi**
Avenue, Charles, Michiels. 170 (Bte19)
B-1170, Bruxelles(BE)

(74) Representative: **Tiedtke, Harro, Dipl.-Ing. et al**
Patentanwaltsbüro
Tiedtke-Bühling-Kinne & Partner
Bavariaring 4
D-80336 München (DE)

(54) **A ground dust removing apparatus and method for grinding wheel.**

(57) An apparatus for removing ground dust from the surface of a grinding wheel (1,38,45,55) including a blasting apparatus (9,31,47,57) for application in a dry grinding process of ceramic work piece (7,39,52,60). The blasting apparatus (9,31,47,57) blasts abrasive grains against the surface of the grinding wheel (1,38,45,55). A circulating passage (13,33a,33b), both ends of which are connected with the blasting apparatus (9,31,47,57), receives the abrasive grains in the vicinity of the apparatus and returns them to the blasting apparatus (9,31,47,57). By such process, the grinding of the work piece (7,39,52,60) and ground dust removal from the surface of the grinding wheel (1,38,45,55) can be accomplished simultaneously, efficiently and speedily. Further, the blasted abrasive grains are recovered and recycled, enabling a reduction in grinding process costs.



The present invention generally relates to an apparatus and a method for removing ground dust from a grinding wheel that is used to grind ceramic components, such as β -alumina cylinders used as the solid electrolyte cylinders of sodium-sulfur batteries.

Generally, β -alumina cylinders and other ceramic components are ground to a predetermined shape through a dry grinding process which utilizes a grinding wheel. The dry grinding process does not require grinding fluid for grinding. The ceramic components have hygroscopic property, so that this method is suitable for grinding the ceramic components. In this case, specifically unsintered β -alumina is generally soft, and it is easily ground. Therefore, as shown in Fig. 20, ground dust of the β -alumina adheres to the peripheral surface of a rotating grinding wheel 70, giving rise to the tendency of teeth 71 to become clogged. In a known method for removing the adhering ground dust from grinding wheels, a stick 72 of white synthetic aluminum oxide abrasive sold under the trademark Alundum (hereinafter referred to as WA) is brought into contact with and held against the surface of the grinding wheel 70, as shown in Fig. 21. Another known dust removal method employs a brush in a similar manner.

However, these conventional methods have various inherent disadvantages. For instance, the WA stick 72 and brush are worn out very quickly, and requires frequent replacement. Furthermore, frequent replacing and discarding of the worn out WA sticks 72 results in increased manufacturing costs. Moreover, if an operator holds the WA stick 72 manually against the grinding wheel in order to remove the dust, the periphery of the grinding wheel may become inadvertently and unevenly deformed as a result of an operator's uneven application of WA stick 72 against the grinding wheel. As a work piece is ground according to the shape of the unevenly deformed peripheral surface of the grinding wheel, the quality of the processed work piece may be lowered. Further, during the removing operation, manually held stick 72 may break on the grinding wheel thereby creating a potential hazard to the operator in that pieces of stick 72 might ricochet off the grinding wheel striking the operator.

Accordingly, it is a primary objective of the present invention to provide an apparatus, which contributes to a secure operational condition, for removing ground dust from a grinding wheel without employing a stick or brush.

Further, another object of the present invention is to provide an apparatus for removing ground dust from a grinding wheel, the surface of which is deformed uniformly so as to contribute to ensure a high quality of processed work piece.

Yet, another object of the present invention is to provide a method for speedily and quickly removing the adhering ground dust from the surface of a grinding wheel.

To achieve the foregoing and other objects and in accordance with the purpose of the present invention, an apparatus for removing ground dust from the surface of the grinding wheel is used for applying a dry grinding process to ceramic components. The apparatus includes a blasting apparatus for removing ground dust from the surface of the grinding wheel by blasting abrasive grains against the peripheral surface of the grinding wheel, and a circulating passage being arranged to receive and supply the grains both from and to the blasting apparatus.

The invention and preferred objects and advantages thereof, may best be understood by reference to the following description of the certain exemplifying embodiments together with the accompanying drawings, in which:

Fig. 1 is a schematic front view of an apparatus for removing ground dust from the surface of a grinding wheel according to the first embodiment of the present invention;

Fig. 2 is a schematic side view of the apparatus for removing ground dust from the surface of the grinding wheel;

Fig. 3 is a schematic plan view of the apparatus for removing ground dust from the surface of the grinding wheel;

Fig. 4 is a schematic cross-sectional view of a gravity feed discharge unit for abrasive grains;

Fig. 5 is a schematic front view of a grinder according to the first embodiment;

Fig. 6a is a simplified explanatory drawing of a grinder equipped with a fixed nozzle, a grinding surface of which is formed around a circumferential surface of a grinding wheel;

Fig. 6b is a simplified explanatory drawing of a grinder equipped with a fixed nozzle, a grinding surface of which is formed on a side surface of a grinding wheel;

Fig. 6c is a simplified explanatory drawing of a grinder equipped with a fixed nozzle, grinding surfaces of which are formed on both side surfaces of a grinding wheel, respectively;

Fig. 7a is a simplified explanatory drawing of a grinder equipped with a movable nozzle, a grinding surface of which is formed on a circumferential surface of a grinding wheel;

Fig. 7b is a simplified explanatory drawing of a grinder equipped with a movable nozzle, a grinding surface of which is formed on a side surface of a grinding wheel;

Fig. 8 is a schematic front view of an apparatus for removing ground dust from a surface of a grinding wheel according to the second embodi-

ment of the present invention;

Fig. 9 is a schematic side view of the apparatus for removing ground dust from the surface of the grinding wheel as shown in Fig. 8;

Fig. 10 is a schematic side view of the apparatus for removing ground dust from the surface of the grinding wheel as shown in Fig. 8;

Fig. 11a is a simplified explanatory drawing which indicates a blasting angle of the nozzle with respect to the grinding surface formed around the circumference of the grinding wheel;

Fig. 11b is a simplified explanatory drawing which indicates a blasting angle of the nozzle with respect to the grinding surface formed on the side surface of the grinding wheel;

Fig. 12 is a simplified explanatory drawing which indicates the positions of a diffuser and the grinding wheel;

Fig. 13 is a graph showing correlation between the values K, K^* which represent the most preferable condition for removing the dust and the deformation of the grinding wheel after two hundred times of blasting;

Fig. 14 is a schematic front view of an apparatus for removing ground dust from a surface of a grinding wheel according to the third embodiment of the present invention;

Fig. 15 is a schematic side view of the apparatus for removing ground dust from the surface of the grinding wheel as shown in Fig. 14;

Fig. 16 is a schematic front view of the apparatus for removing ground dust from the surface of the grinding wheel as shown in Fig. 14;

Fig. 17 is a schematic front view of an apparatus for removing ground dust from a surface of a grinding wheel according to the fourth embodiment of the present invention;

Fig. 18 is a schematic side view of the apparatus for removing ground dust from the surface of the grinding wheel as shown in Fig. 17;

Fig. 19 is a schematic side view of the apparatus for removing ground dust from the surface of the grinding wheel shown in Fig. 17;

Fig. 20 is an enlarged cross-sectional view of the grinding wheel indicating the condition of the ground dust clogged between the teeth thereof; and

Fig. 21 is a perspective view showing a conventional method for removing ground dust from the surface of the grinding wheel.

A preferred embodiment according the present invention will now be described referring to the drawings.

Generally, grinders are classified into two types; the first type is a grinder equipped with a ground dust removing unit which has fixed nozzle, examples 62a, 62b and 62c of which are indicated in Figs. 6a through 6c, and the second type is a

grinder equipped with a ground dust removing unit which has a movable nozzle, examples 63a and 63b of which are indicated in figs. 7a and 7b, respectively. In the fixed nozzle type ground dust removing unit as shown in Fig. 6a, a grinding surface 65a is formed around the circumference of a grinding wheel and contains embedded teeth made of either diamond or cubic sodium boron (CBN). Width L of the grinding surface 65a is set narrower than the blasting width a, across which abrasive grains are blasted through blast nozzle 64. As shown in Fig. 6b, the grinding surface 65b is formed on the side surface of the grinding wheel, and width L of the grinding surface 65b is set narrower than blasting width a across which abrasive grains are blasted from the nozzle 64, in a similar manner shown in Fig. 6a. As shown in Fig. 6c, the grinding surfaces 65c are formed on the both sides of the grinding wheel, hence the nozzles 64 are provided at both sides, respectively. Further, width L of on both grinding surfaces of 65c is set narrower than the blasting width a across which abrasive grains are blasted from the nozzle 64.

Alternatively, the movable nozzle type unit shown in Fig. 7 can be further classified into two types. One type shown in Fig. 7a has a grinding surface 66a formed around the circumference of the grinding wheel, and the other type shown in Fig. 7b has a grinding surface 66b formed on the side surface of the grinding wheel.

First Embodiment

The first preferred embodiment of the invention, as shown in Figs. 1 through 3, illustrates a grinder includes a movable nozzle type unit for removing ground dust clogged between a multiplicity of teeth formed around the circumference of the grinding surface.

A grinding wheel 1 is fastened to a rotatable shaft 2 by means of a plurality of bolts 3, and rotated by a motor (not shown). regulating wheel 4 is located at a predetermined distance from the grinding wheel 1 and is rotatably fastened to a rotatable shaft 5 by means of a plurality of bolts 6. The regulating wheel 4 is made of polyurethane rubber having a hardness of 70 Shore.

An unsintered work piece 7 made of β -alumina as a ceramic component is supported on a supporting blade 8, such that the work piece 7 along with the regulating wheel 4 can be moved horizontally with respect to grinding wheel 1. However, in addition to β -alumina, α -alumina and other ceramic components can be used to form unsintered work piece 7. Work piece 7, according to the present invention is conceived to be, for example, a solid electrolyte tube of sodium-sulfur battery.

The upper surface of the blade 8 is slightly inclined to maintain work piece 7 in contact with the regulating wheel 4 at all times. While work piece 7 is rotated slowly by the rotational motion of regulating wheel 4, the surface of work piece 7 is ground by grinding wheel 1 rotating at a high speed with respect to work piece 7 and regulating wheel 4. This method is known by those familiar with the art of grinding as the centerless grinding method. Other conventional grinding method make use of clamping the axial center of work piece 7 relative to grinding wheel 1, thereby allowing work piece 7 to be supported during its grinding process. However, according to this embodiment, work piece 7 is not required to be clamped at its axial center, but rather is supported by means of supporting blade 8 and regulating wheel 4.

According to the present invention, regulating wheel 4 is preferably made of a synthetic rubber with a hardness from 50 to 90 Shore which does not contain abrasive grains. When a Shore hardness is too small, the grinding accuracy of the work piece 7 tends to be lowered. When a Shore hardness is too large, the work piece 7 may become damaged during the grinding process. Besides polyurethane rubber, other synthetic rubbers such as chloroprene rubber would be a suitable substitute for the material of the grinding wheel 4.

A blasting apparatus 9 is installed opposite to the work piece 7 with respect to the grinding wheel 1, and is provided with box-like housing 10 encompassing a portion of grinding wheel 1. A pair of slide doors 11 slidable in the left-and-right direction are provided in the rear surface of the housing 10. A blast nozzle 12 is inserted through the open space of the doors 11 into housing 10. From the blast nozzle 12, a stream of abrasive grains T are blasted against grinding wheel 1 in order to remove the ground dust adhering to the surface of the grinding wheel 1. The blast nozzle 12 is mounted on a table (not shown) that can be moved horizontally and vertically under numerical control. The position of the nozzle 12 with respect to the grinding wheel 1 for blasting is determined by this numerical control.

The tip of the blast nozzle 12 is positioned at an angle between 30° and 110°, preferably between 45° and 90°, relative to the surface of the grinding wheel 1. The ground dust is most effectively removed within the above range. If the cross section of the grinding surface 1 includes a round portion, the blast nozzle 12 is controlled to move along the arc of the surface of the grinding wheel 1 and to continuously locate on the radius of the arc at all the time under numerical control. This continuous repositioning of the nozzle 12 achieves the effective dust removal from the surface of the grinding wheel 1.

Housing 10 is so constructed as to receive the abrasive grains T blasted against the grinding wheel 1 through the blast nozzle 12. Bellowed return pipes 13 are connected to the lower part of the housing 10 for recovering and recycling the abrasive grains T. The peripheral edge of housing 10, encompassing grinding wheel 1, is further constructed with a lining of bristles 14 connected to the peripheral edge of housing 10 and which face toward grinding wheel 1. These bristles have their tips in contact with grinding wheel 1 to prevent abrasive grains T from scattering from the inside to the outside of housing 10. A thin flexible rubber plate or resin plate can be employed in place of the bristles 14. Housing 10, slide doors 11 and return pipes 13 form a recovery unit for recovering the abrasive grains T.

The blasting of the abrasive grains T through the blast nozzle 12 is achieved by means of a blaster 15, as illustrated in Fig. 4. Component parts of blaster 15 include a hopper 16, arranged to hold a supply of abrasive grains T, with its upper end open to atmosphere to allow the gravitational flow of the grains thorough a control valve 21 to an abrasive grain receiver 20. A cylindrical blaster barrel 17 has an air inlet 18 and pipes provided at the upper and bottom portions thereof, respectively. The air inlet 18 is connected to an air compressor (not shown) while the pipe is connected to the blast nozzle 12. A pipe 19 connects a abrasive grain receiver 20 disposed below the hopper 16 with blaster barrel 17 for delivering the abrasive grains T received at the abrasive grain receiver 20 to the blaster barrel 17. The abrasive grains T are delivered from the blaster barrel 17 to the blast nozzle 12 by the air blowing through the air inlet 18 to the blast nozzle 12. The amount of the abrasive grains T to be delivered to blast nozzle 12 depends both upon the pressure of the air delivered through air inlet 18 and to the incremental adjustments made to control valve 21.

The operation of the apparatus having the above-described structure according to this embodiment will now be described.

As shown in Fig. 5, the work piece 7 together with supporting blade 8 and regulation wheel 4 are moved toward grinding wheel 1 until work piece 7 contacts grinding wheel 1. While work piece 7 is in contact with grinding wheel 1, work piece 7 is at once rotated at a slow speed by the regulating wheel 4 while at the same time being ground by grinding wheel 1, which rotates at a high speed. This grinding condition is adjusted by changing the rotational speed of the regulation wheel 4 and/or the pressure with which the work piece 7 is urged against grinding wheel 1.

While the work piece 7 is being ground, the abrasive grains T are delivered from the hopper 10

and blasted through the blaster nozzle 12 toward the surface of the grinding wheel 1. In this way, ground dust adhering to the surface of the grinding wheel 1, formed during the grinding process of work piece 7, is removed by the blasted abrasive grains T. The blasted abrasive grains T fall down to be recovered in the housing 10, and are recycled through the return pipe 13. During the grinding process, bristles 14 lining the peripheral edge of housing 10 prevent the abrasive grains T from scattering outside of housing 10.

As clearly described above, the grinding of the work piece 7 and the ground dust removal from the surface of the grinding wheel 1 can be accomplished simultaneously, efficiently and speedily in this embodiment. Since the abrasive grains T blasted at the grinding wheel 1 can be recovered and recycled, WA sticks and brushes are not required. Therefore, by eliminating the need to replace WA sticks as required in conventional grinding method, the grinding method according to the above described invention results in a reduction of operating costs. Furthermore, since the regulation wheel 4 is made of polyurethane rubber having the predetermined hardness, the work piece 7 is much less likely to be damaged than conventional rubber regulation wheels containing abrasive grains.

This embodiment offers a further advantage that the vertical and horizontal traveling speed of the blast nozzle 12 can be adjusted so that ground dust is evenly removed from the surface of the grinding wheel 1. This, in turn, minimizes the deformation of the periphery of the grinding wheel 1 to the extent that no significant adverse effect on the quality of ground products is produced. Furthermore, since ground dust is automatically removed from the grinding wheel 1 in the housing 10, there is no danger involved to the operator of the grinder in removing ground dust. Moreover, since the abrasive grains T are prevented from scattering, other equipments disposed nearby are kept to be clean from the scattering abrasive grains T.

Although the ground dust removal unit is employed in a centerless grinding machine in this embodiment, this unit can be employed in a conventional cylindrical grinding machine. Further, this unit can be installed in an automatic grinding line assembly for processing work such as work piece 7. Instead of continuously and simultaneously carrying out both grinding and dust removal operations, the present invention also allows for both operations to be alternatively performed, or for the removal of ground dust after completion of the grinding operation.

Other embodiments according to the present invention will now be described referring to Figs. 8 through 19. The components and structures in

those drawings similar to the above embodiment are given similar numeric reference numbers so as to eliminate the explanation thereof.

5 Second Embodiment

10 Figs. 8 through 10 show a movable nozzle type ground dust removing unit, a grinding surface of which is formed around the circumference of a grinding wheel 38. Further, a circulation circuit for abrasive grains and the blasting condition will now be described in detail.

15 The circulation circuit for the abrasive grains T is composed of a blasting apparatus 31, a hopper 32 and connecting pipes 33a, 33b which are disposed between the blasting apparatus 31 and the hopper 32. A control device 34 for controlling the amount of abrasive grains is disposed at a discharge port 32a located at the bottom portion of the hopper 32. The connecting pipe 33a is extended from the control device 34, and connected to a blaster 36. The control device 34 controls the amount of abrasive grains transferred from the hopper 32 to the blaster 36. An air inlet 35 is disposed at the blaster 36, through which the compressed air is supplied. The blast abrasive grains T are blasted against the circumferential surface of the grinding wheel 38 with its embedded diamond teeth by means of the flow of compressed air through a blast nozzle 37 of the blaster 36.

30 In this occasion, the mesh number of the abrasive grains of the grinding wheel 38 is #140, the average diameter of which is 105 microns. On the other hand, the mesh number of the blasting abrasive grains T is #220, the average diameter of which is 63 microns. Since the blasting abrasive grains T are selected finer than those of the grinding wheel 38, the efficiency for removing the adhering ground dust is increased. The α -alumina used for the abrasive grains T is physically and chemically similar to the β -alumina forming work piece 39. Thus, should blast abrasive grains T penetrate the surface of the work piece 39, the work piece 39 is less likely to sustain damage during sintering were some other blasting material used in place of the α -alumina.

45 A diffuser 40 is fastened at the distal end of the blast nozzle 37. The diffuser 40 controls the area covered by blasting of the abrasive grains T. That is, even when the nozzle 37 is kept apart from grinding wheel 38, in order not to chip a bond portion of the grinding wheel 38 by blasting intensively, the excess scattering of the abrasive grains T can be prevented by diffuser 40. Diffuser 40 further prevents the scattering of abrasive grains T by the airflow generated by the high speed rotation of grinding wheel 38. As shown in Fig. 12, the distance l is defined as a length between the

diffuser 40 and the surface of the grinding wheel. In this case, the distance l is set less than 30 millimeters (mm) in relation to the most preferable blasting amount of grains T . Therefore, as the blasted area of the grains T is controlled by means of the diffuser, a high efficiency rate for removing ground dust from the surface is securely achieved.

As shown in Fig. 8, the abrasive grains T collide against adhering dust on the surface of the grinding wheel 38 so as to remove the dust. The blasted abrasive grains T and adhering dust fall into housing 44, and are transferred to the hopper 32 via the connecting pipe 33b. The hopper 32 includes two vertically stacked containers. The mixture of dust particles and abrasive grains transferred via pipe 33b are exhausted into the upper vertically stacked container. Due to their weight, the heavier abrasive grains T fall down into the lower vertically stacked container while the lighter weight dust particles are temporarily suspended in the upper container until exhausted through discharged port 32b. Thus, according to the invention, the abrasive grains are separated from the dust particles and recycled for reuse in the grinding operation. The recycled abrasive grains are supplemented by a source of new abrasive grains introduced to hopper 32 by a separate source not shown in Fig. 8.

As shown in Fig. 10, the blast nozzle 37 is mounted to a base 42 which is movably disposed along a rail 41, thus the nozzle 37 is horizontally (i.e., right-and-left direction in the drawing) movable with respect to the grinding wheel 38. The position of the nozzle 37 can be adjusted horizontally (i.e., front-and-back direction in the drawing) with respect to the grinding wheel 38 by adjusting the mounting position thereof to the base 42. An angle between the blast nozzle 12 and the surface of the grinding wheel for blasting can be likewise adjusted. That is, the angle can be adjusted to prevent the abrasive grains T which are blasted at the grinding wheel 38 from bounding away through sliding doors 43. Therefore, one distal end of the housing 44 is inclined and projectingly expanded to the side surface of the grinding wheel 38. Therefore, even when the inclined nozzle 37 is position at the distal end near the expanded housing 44 side, the abrasive grains T can be evenly blasted at the surface of the grinding wheel 38.

The most preferable blasting condition for removing the ground dust will now be described.

In the case where the movable nozzle type ground dust removing unit is employed and where the grinding surface is formed around the circumference of the grinding wheel 38, the most preferable condition for removing dust according to the embodiment is directed by the value of K_1^* where

$$K_1^* = (L / V) \cdot W / [(\pi DL) \cdot N]$$

and where $(L/a) > 1$. According to this equation, L (meter) indicates width of the grinding wheel 38, a (meter) indicates blasting width of the blast abrasive grains T blasted from the nozzle 37, N (1/second) indicates rotational speed of the grinding wheel 38, W (kilogram/second) indicates mass flow of the blast abrasive grains T , V (meter/second) indicates the moving speed of the nozzle, and D (meter) indicates the diameter of the grinding wheel 38.

Correlation between the value of K_1^* calculated through the above-described equation and the deformation of the grinding wheel after 200 times blasting is indicated by a graph in Fig. 13 based on experimental data. The axis of abscissa indicates the value of K_1^* , while the axis of ordinate indicates the maximum deformation of the periphery of the grinding machine. The maximum deformation of the periphery of the grinding wheel is calculated by comparing the contour of the work piece 39 before blasting with that of the work piece 39 after 200 times of blasting. This calculation results from a recognition that the shape of the grinding wheel 38 is transferred to the work piece 39 during the grinding process. The contour of the work piece 7 can be measured by a three-dimensional measuring machine (UPMC-550 made by CARL ZEISS) on an arbitrary line extending along the axis of the work piece 39.

Apparent from the graph, when the value of K_1^* exceeds 0.2, the maximum deformation of the contour is significantly increased. That indicates the grinding wheel itself is ground and deformed by blasting. Furthermore, not indicated in the graph, when the value of K_1^* is below 0.005, the removal of ground dust from the surface is not sufficient, because the amount of the abrasive grains T is too small.

Therefore, the value of K_1^* should generally be set within the range $0.005 \leq K_1^* [\text{kg} / (\text{m}^2\text{s})] \leq 0.2$. It is preferable to have K_1^* set within the range $0.01 \leq K_1^* [\text{kg} / (\text{m}^2\text{s})] \leq 0.05$, where $(L / V) \cdot W$ indicates the actual amount of the abrasive grains T blasted against the grinding wheel 38. $(\pi DL) \cdot N$ indicates the total area of grinding wheel 38 multiplied by the rotational speed of grinding wheel 38, in effect, the actual peripheral area of the grinding wheel per unit time. Therefore, K_1^* is an indication of the weight of the abrasive grains T blasted at a given area of the grinding wheel. In this case, the pressure of the compressed air is set within the range $1 \leq P [\text{kgf} / \text{cm}^2] \leq 4$.

Blasting abrasive grains T under these conditions, result in a grinding wheel 38 which is not ground and hence not deformed. Moreover, given the above described conditions, ground dust re-

moval is optimized.

As shown in Fig. 11 (a), a blasting angle θ is defined between the nozzle 37 and the tangent line of the peripheral surface of the grinding wheel with respect to the rotational direction. The angle θ can be set within the range between 30 degrees and 110 degrees, preferably between 45 degrees and 90 degrees. Within the above-described range, the efficiency for removing the adhering ground dust is improved, because the amount of the abrasive grains T blasted against the surface of the grinding wheel and collision energy are maximized. The blasting angle θ of the nozzle 37 in this embodiment is set to 70 degrees which achieves the highest efficiency for removing the adhering dust. Further, it is preferred that nozzle 37 be disposed opposite to work piece 39 with respect to the grinding wheel 38. The nozzle 37 can be disposed at either upper or lower side of the grinding wheel 38. However, when the nozzle 37 is disposed at the upper side, the efficiency to recover the abrasive grains T or adhering dust of the grinding wheel 38 is slightly lowered. When the nozzle 37 is disposed at the lower side, the abrasive grains T or ground dust are easily adhered to the nozzle 37 or the moving mechanism for the nozzle 37, which causes malfunction of those components.

According to this embodiment, the value of K_1^* would be calculated based on the numerical values indicated below: $L = 0.51$ (meter), $a = 0.05$ (meter), $N = 18$ (revolution per second), $W = 0.01$ (kilogram/second), $V = 0.025$ (meter/second), $D = 0.5$ (meter), $P = 2.8$ (kilogram force / square centimeter), $\theta = 70$ (degrees), $l = 8$ (millimeter), the value of K_1^* will be 0.0226 (kg/m²s).

Third Embodiment

Figs. 14 through 16 show a movable nozzle type ground dust removing unit, a grinding surface of which is formed on the side surface of the grinding wheel.

A grinding wheel 45 has a disc shape, and can be rotated at a high speed together with a shaft 46. A housing 48 of a blasting apparatus 47 covers at least part of grinding wheel 45 located at the one side of the grinding wheel 45. A blast nozzle 49 is inserted into the housing 48 through a sliding door 50, and is reciprocally movable between the shaft 46 and the edge of the circumference along a rail 51 in the radius direction. The end surface of a cylindrical work piece 52 perpendicular to the shaft is ground by the grinding surface which is arranged opposite to the blast nozzle 49.

The most preferable blast condition for removing ground dust, according to this embodiment, is determined by the value of K_2^* , which is similar to the above-described embodiment, where $(L/a) > 1$.

$$K_2^* = (L / V) \cdot W / [(\pi/4) \cdot \{D^2 - (D - 2L)^2\} \cdot N]$$

The value of K_2^* is similarly set within the range of $0.005 \leq K_2^* \text{ [kg/(m}^2\text{s)]} \leq 0.2$, and further it is preferable to be set within the range of $0.01 \leq K_2^* \text{ [kg/(m}^2\text{s)]} \leq 0.05$.

According to this embodiment, the value of K_2^* is calculated based on the numerical values given below:

Given values of $L = 0.1$ (meter), $a = 0.04$ (meter), $N = 33.3$ (revolution per second), $W = 0.015$ (kilogram/second), $V = 0.020$ (meter/second), $D = 0.4$ (meter), $P = 2.0$ (kilogram force/ square centimeter), $\theta = 90$ (degree) and $l = 10$ (millimeter), the value of K_2^* is calculated as 0.0239 (kg/m²s).

As shown in Fig. 11 (b), a blasting angle θ is defined as an angle of the nozzle 49 with respect to the grinding wheel. This angle θ can be set within the range of 30 through 110 degrees, similar to the above embodiment with blasting at the circumferential surface.

Fourth Embodiment

Figs. 17 through 19 show a fixed nozzle type ground dust removing unit, a grinding surface of which is formed around the circumference of the grinding wheel.

A grinding wheel 55 has a disc shape, and can be rotated at a high speed together with a shaft 56. A housing 58 of a blasting apparatus 57 covers at least part of grinding wheel 55 at the one side of the grinding wheel 55. A blast nozzle 59 is inserted into the housing 58, and secured. A generally small size work piece 60 is ground by the grinding surface which is formed at the side opposite to a nozzle 59.

The most preferable blast condition for removing ground dust according to this embodiment, is determined by the value of K_1 , where $0.7 \leq (L / a) \leq 1$.

$$K_1 = (L / a) \cdot W / [(\pi DL) \cdot N]$$

The value of K_1 is set within the range of $0.005 \leq K_1 \text{ [kg/(m}^2\text{s)]} \leq 0.05$, which is similar to the above embodiment. Further, it is preferable to set within the range of $0.01 \leq K_1 \text{ [kg/(m}^2\text{s)]} \leq 0.05$.

According to this embodiment, the value of K_1 is calculated based on the numerical values indicated below:

Given values of $L = 0.02$ (meter), $a = 0.022$ (meter), $N = 41.7$ (revolution per second), $W = 0.020$ (kilogram/second), $D = 0.2$ (meter), $P = 1.5$ (kilogram force/square centimeter), $\theta = 90$ (degree), and $l = 2$ (millimeter), the value of K_1 is calculated to 0.0347 (kg/m²s).

As clearly described by the preferred conditions of each of the aforementioned embodiments, ground dust in each case can most efficiently be removed using a minimal amount of abrasive grains during the grinding process. Further, since the grinding wheel will not be deformed by grinding itself, the quality of the ground products can be improved.

Although only four embodiments of the present invention have been described herein, it should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms.

Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive.

An apparatus for removing ground dust from the surface of a grinding wheel (1,38,45,55) including a blasting apparatus (9,31,47,57) for application in a dry grinding process of ceramic work piece (7,39,52,60). The blasting apparatus (9,31,47,57) blasts abrasive grains against the surface of the grinding wheel (1,38,45,55). A circulating passage (13,33a,33b), both ends of which are connected with the blasting apparatus (9,31,47,57), receives the abrasive grains in the vicinity of the apparatus and returns them to the

Claims

1. An apparatus for removing ground dust from a surface of a grinding wheel (1,38,45,55) for applying dry grinding process to ceramic components (7,39,52,60), the device comprising:
 - means (9,31,47,57) for blasting abrasive grains against the surface of the grinding wheel (1,38,45,55); and
 - means (16,32) for supplying said abrasive grains to said blasting means (9,31,47,57).
2. The apparatus according to claim 1, further including means (10,13,44,58) for recovering said abrasive grains blasted at the grinding wheel (1,38,45,55), and circulating said grains to said supplying means (16,32).
3. The apparatus according to claim 2, wherein said recovering means includes a housing (10,44,58) which accommodates at least a part of said blasting means (9,31,47,57).
4. The apparatus according to claim 3, wherein said recovering means further includes means (14) provided at the edge of said housing (10,44,58) and extending along the periphery of the grinding wheel (1,38,45,55) for preventing said grains from scattering from the inside to the outside of said housing (10,44,58).
5. The apparatus according to claim 4, wherein said recovering means further includes bristles (14).
6. The apparatus according to claim 1, wherein said abrasive grains are made of the same material as the ceramic components (7,39,52,60).
7. The apparatus according to claim 1, wherein said blasting means (9,31,47,57) blasts said grains against the grinding wheel (1,38,45,55) with a blasting angle selectable within the range between 45 degrees and 110 degrees.
8. The apparatus according to claim 1, wherein said blasting means (9,31,47,57) includes a nozzle (12,37,49,64) for blasting abrasive grains by means of compressed air under the condition that the grains blasted against a given area of the grinding wheel (K^*) weigh within the range $0.005 \leq K^* [\text{kg} / (\text{m}^2\text{s})] \leq 0.20$, under the pressure (P) of said compressed air within $1 \leq p [\text{kgf} / \text{cm}^2] \leq 4$.
9. The apparatus according to claim 7, wherein said blasting means (9,31,47,57) further includes a diffuser (40) fastened at a tip of said nozzle (12,37,49,64), said diffuser (40) being arranged to define the blasting area of the surface of the grinding wheel (1,38,45,55).
10. The apparatus according to claim 7, wherein said nozzle (12,37,49,64) is movable with respect to the grinding wheel (1,38,45,55).
11. A method for removing ground dust from a surface of a grinding wheel comprising the steps of:
 - applying the dry grinding process to ceramic components (7,39,52,60) by the grinding wheel (1,38,45,55); and
 - blasting abrasive grains against the grinding wheel (1,38,45,55) for removing the ground dust.
12. The method according to claim 11, further including a step of recovering said grains blasted against the grinding wheel (1,38,45,55).
13. The method according to claim 12, wherein said grains are blasted by blasting means (9,31,47,57), and said grains are recovered by recovering means (10,13,44,58).
14. The method according to claim 13, wherein said recovering means including a housing (13,44,58) which accommodates at least a part

of said blasting means (9,31,47,57).

15. The method according to claim 14, wherein said recovering means (10,13,44,58) further includes means (14) provided at the edge of said housing (13,44,58) and extending along the periphery of the grinding wheel (1,38,45,55) for preventing said grains from scattering from the inside to the outside of said housing (13,44,58).

5
10
16. The method according to claim 11, wherein said abrasive grains are made of the same material as the ceramic components (7,39,52,60).

15
17. The method according to claim 11, wherein said abrasive grains are blasted against the grinding wheel (1,38,45,55) with a blasting angle selectable within the range between 30 degrees and 110 degrees.

20
18. The method according to claim 11, wherein said abrasive grains are blasted by means of compressed air under the condition that said grains blasted against a given area of the grinding wheel (K^*) weigh within the range $0.005 \leq K^* \text{ [kg / (m}^2\text{s)]} \leq 0.20$, under the pressure (P) of said compressed air within $1 \leq P \text{ [kgf / cm}^2\text{]} \leq 4$.

25
30
19. The method according to claim 18, wherein the blasting area on the grinding wheel (1,38,45,55) is limited by a diffuser (40).

35
20. The method according to claim 11, wherein said dry grinding process is applied to said ceramic components (7,39,52,60) by the grinding wheel (1,38,45,55) when said abrasive grains are blasted against the grinding wheel (1,38,45,55) for removing the ground dust.

40

45

50

55

Fig.1

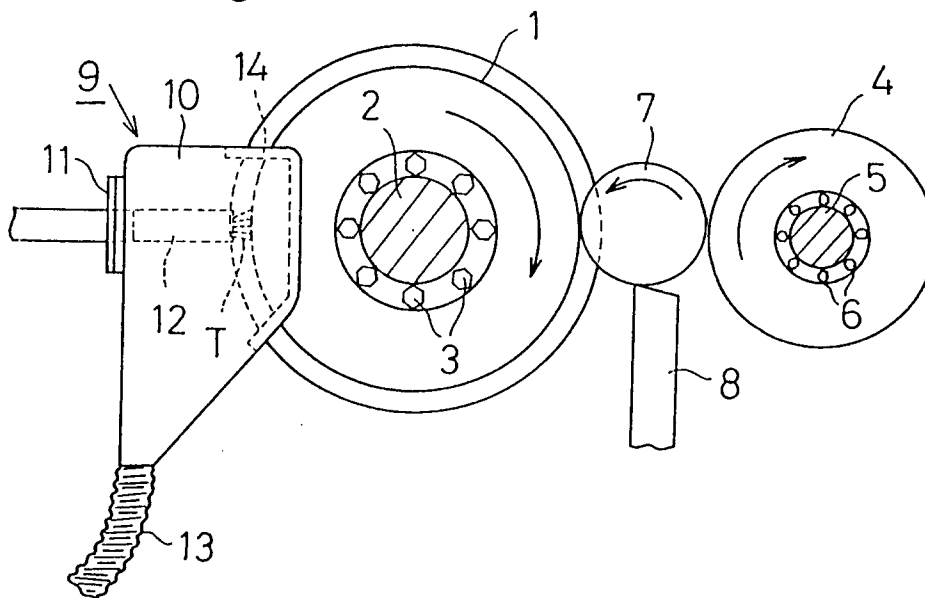


Fig.2

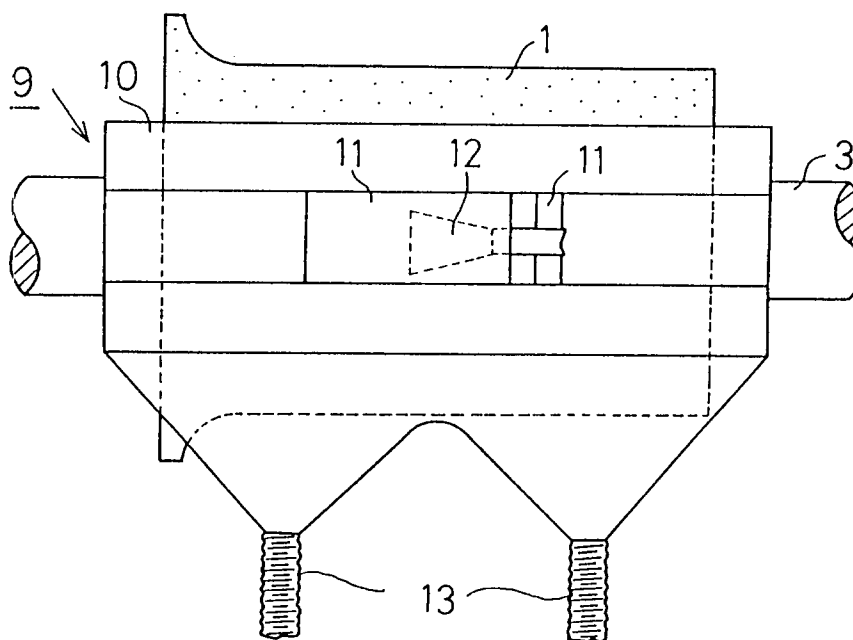


Fig.3

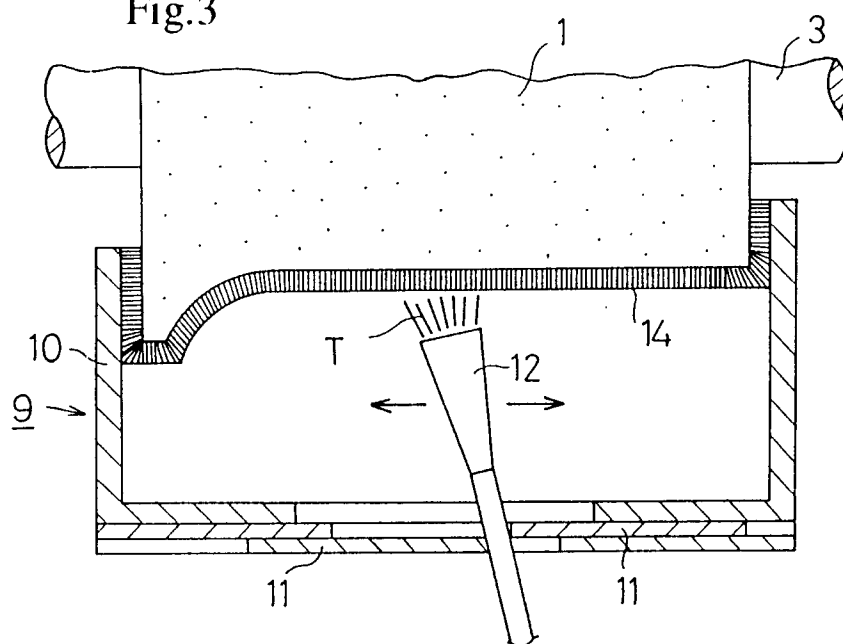


Fig.4

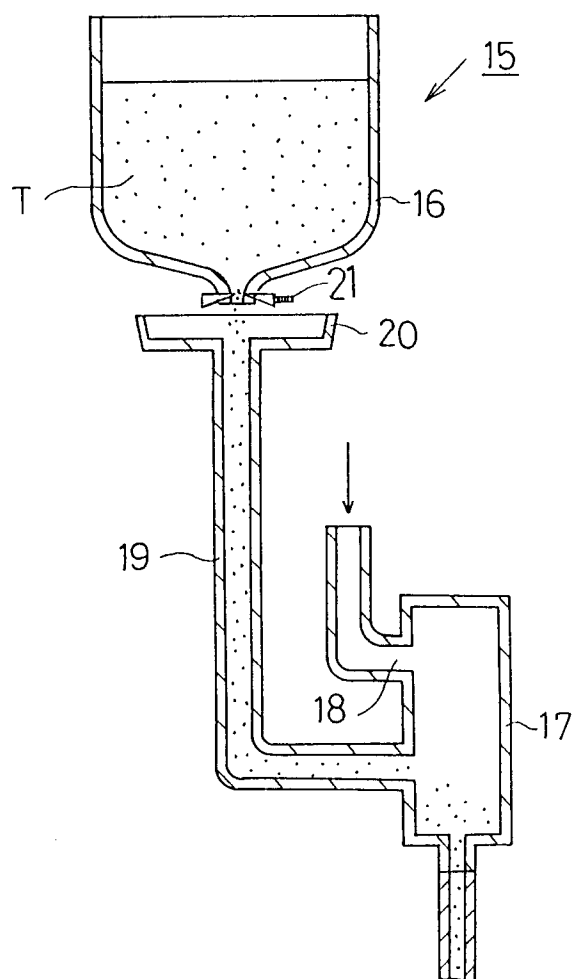


Fig.5

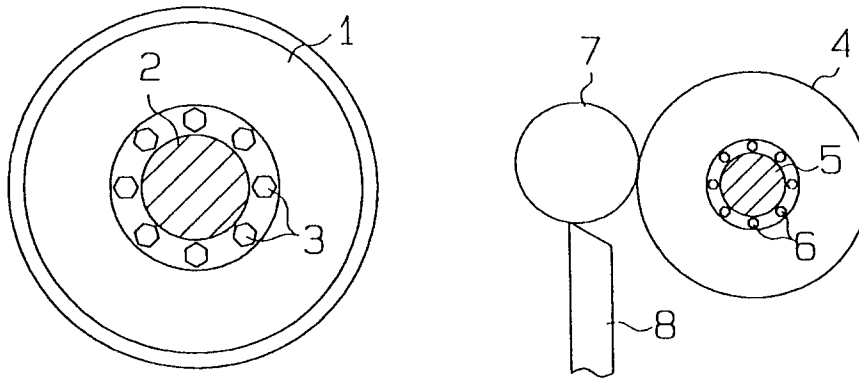


Fig.6a

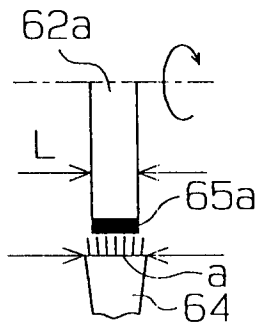


Fig.6b

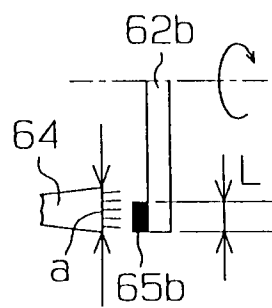


Fig.6c

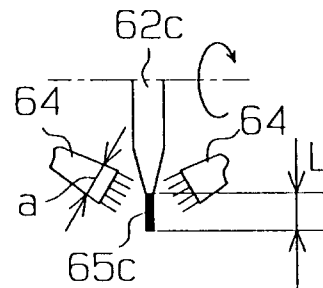


Fig.7a

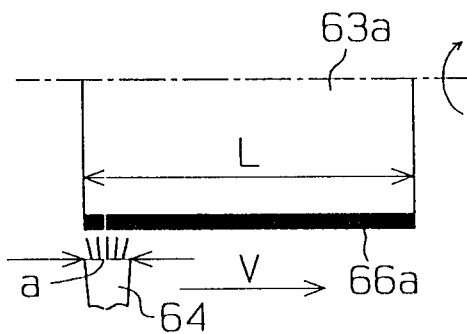


Fig.7b

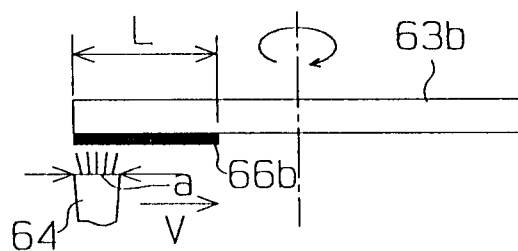


Fig.8

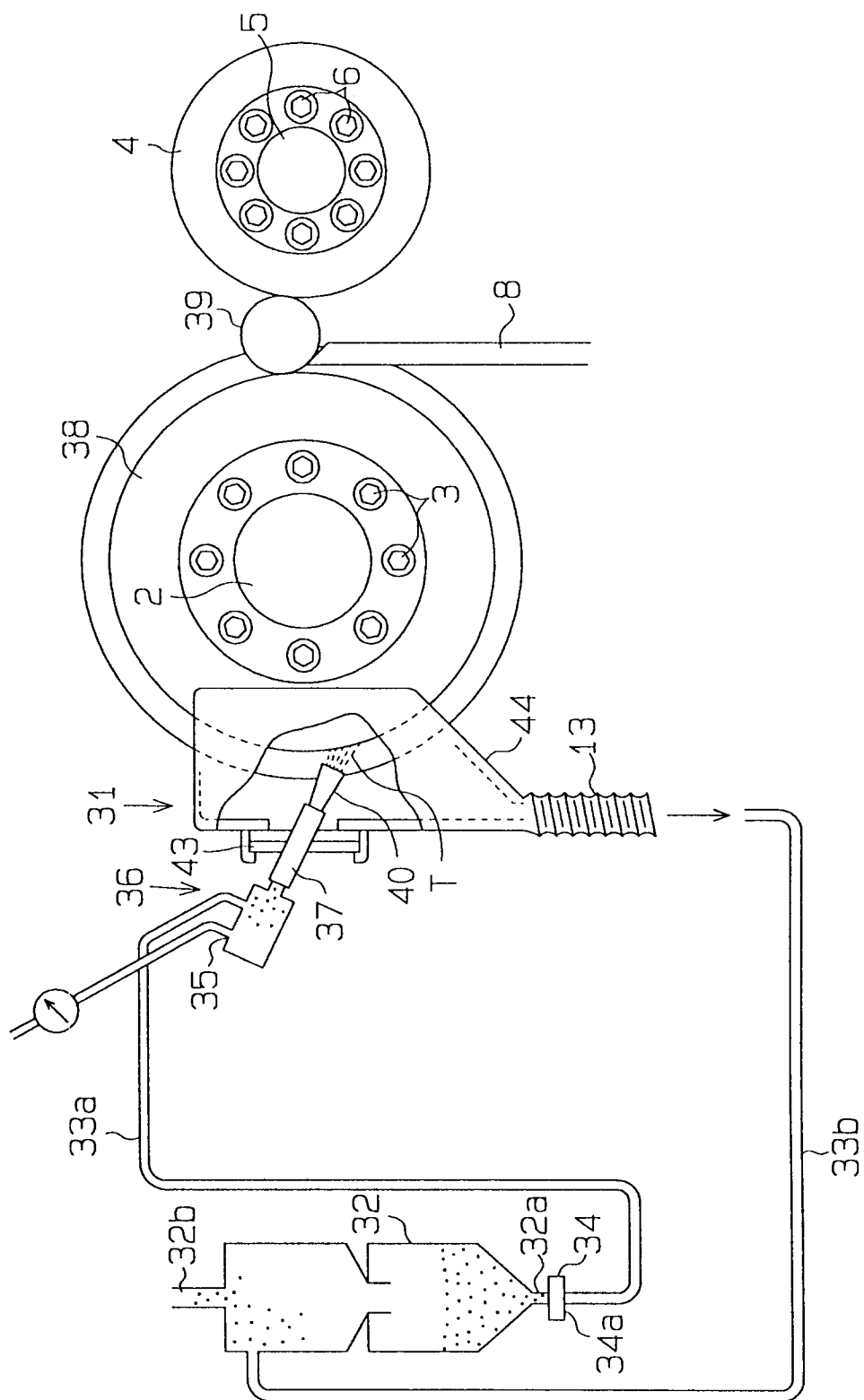


Fig.9

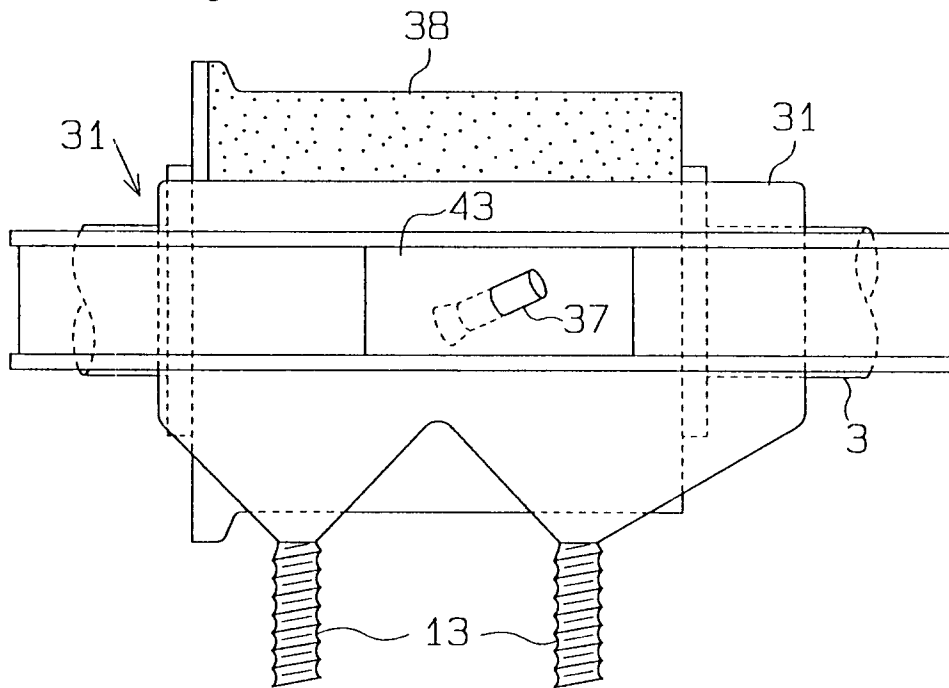


Fig.10

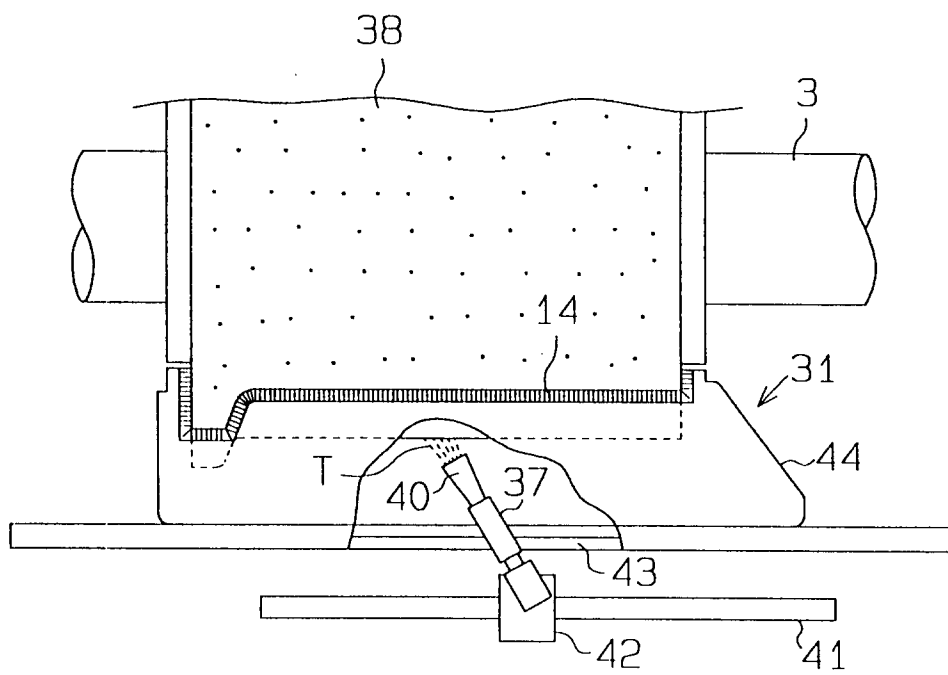


Fig.11a

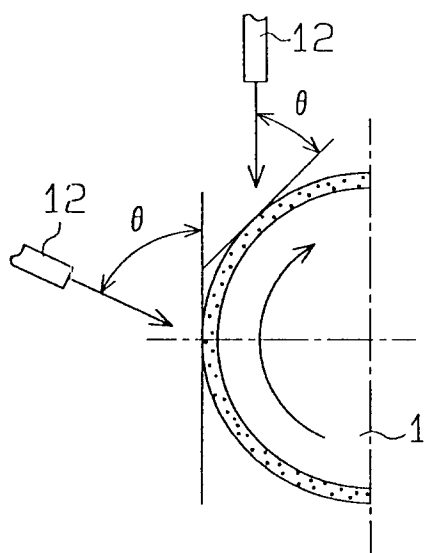


Fig.11b

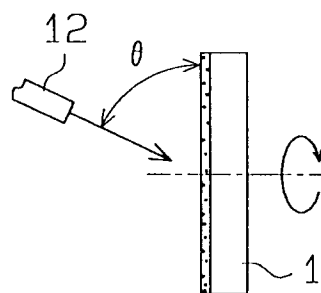


Fig.12

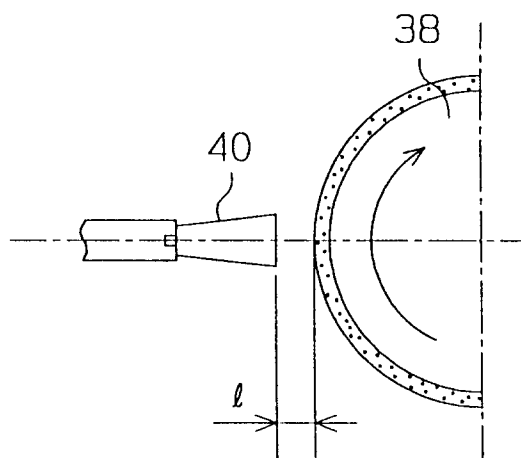


Fig.13

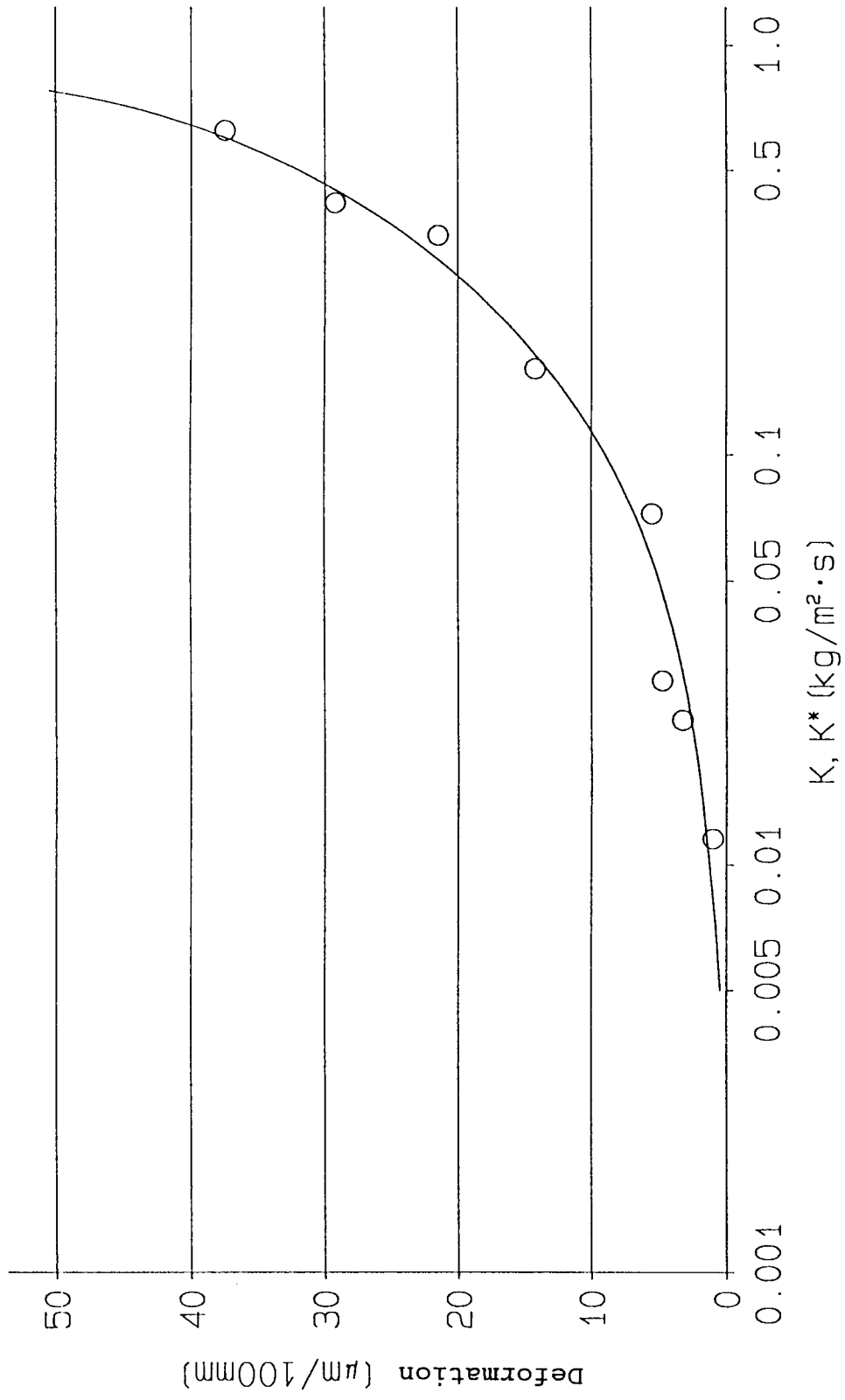


Fig.14

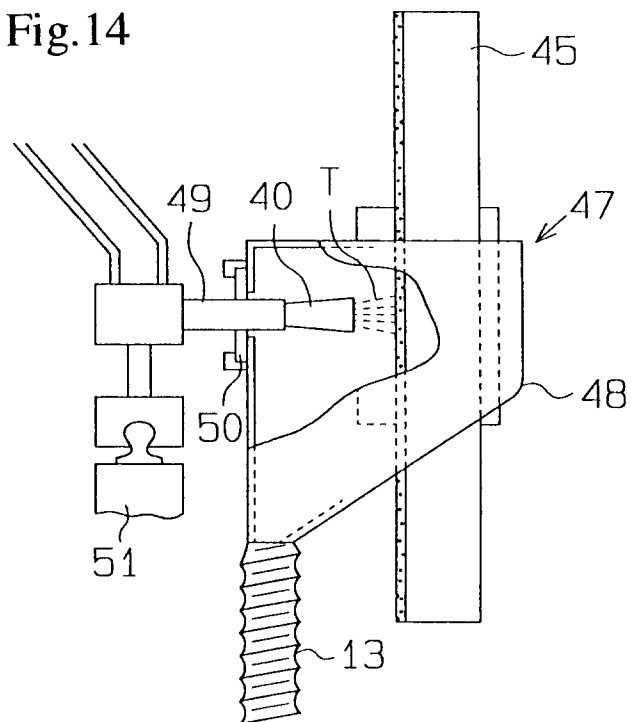


Fig.15

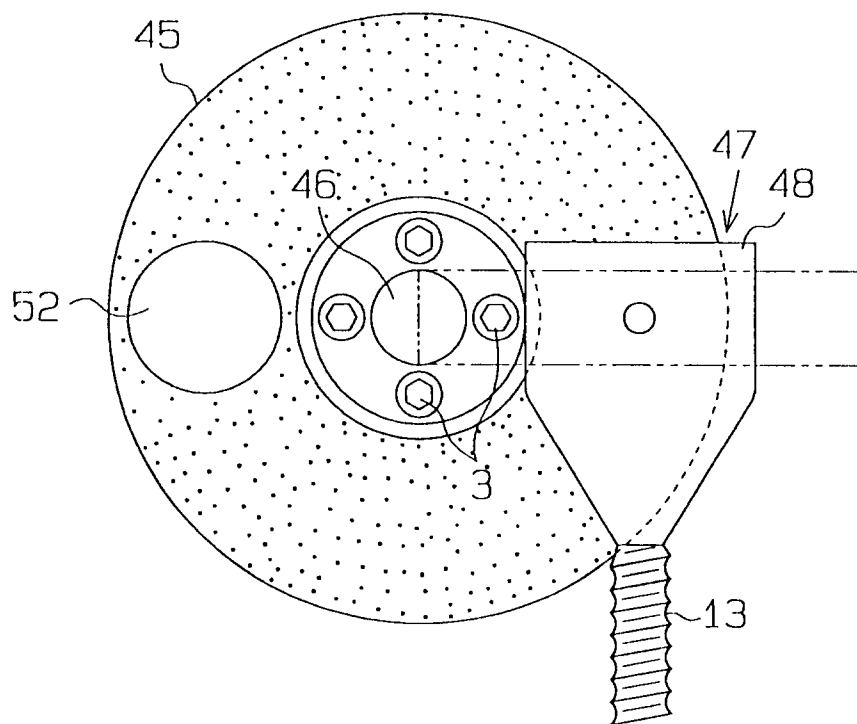


Fig.16

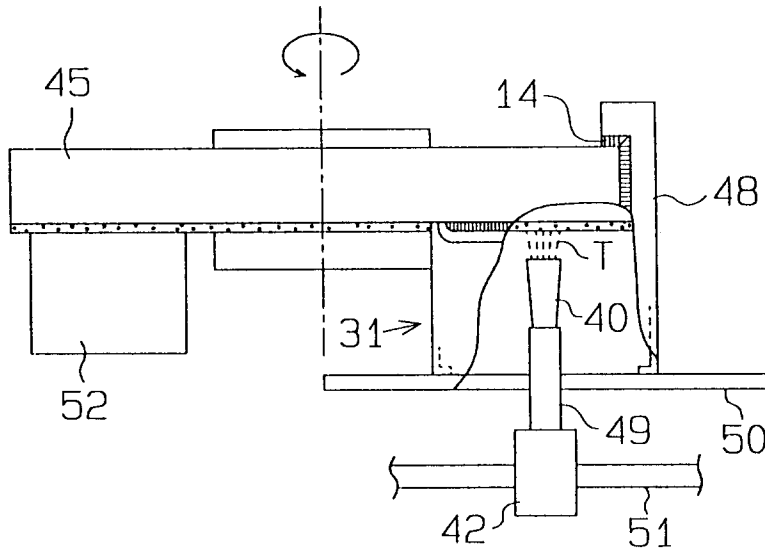


Fig.17

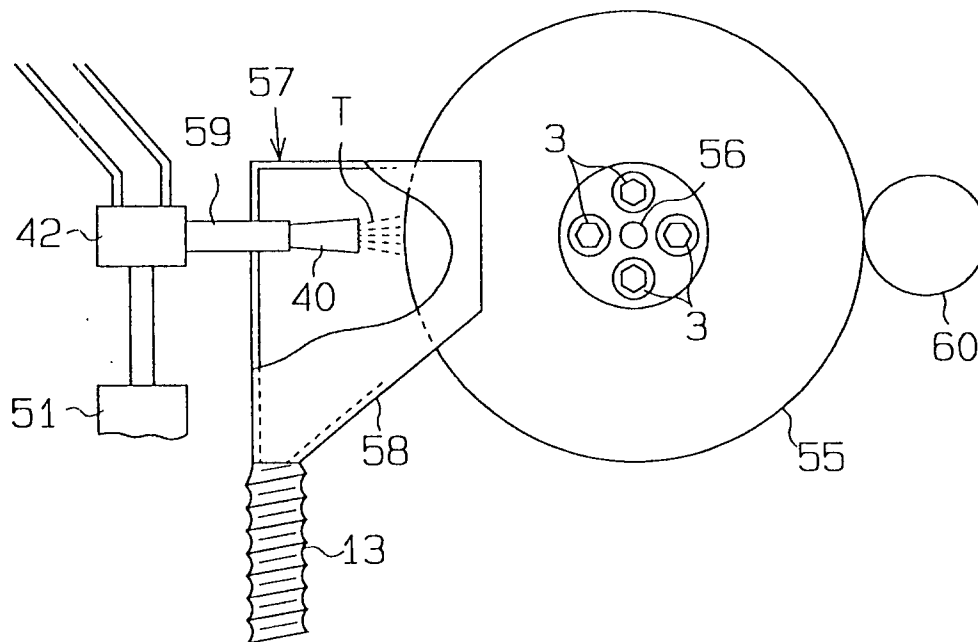


Fig.18

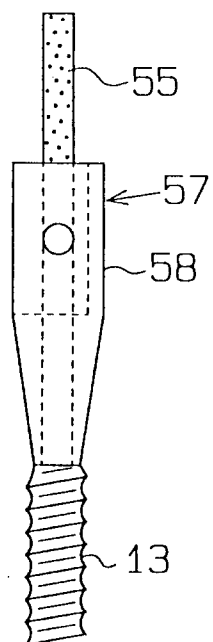


Fig.19

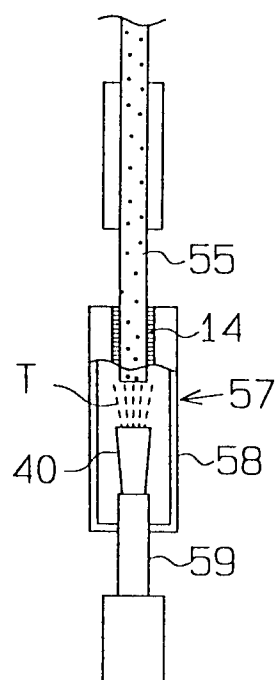


Fig.20

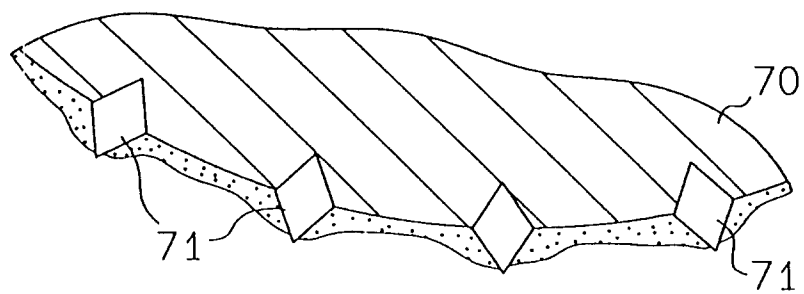
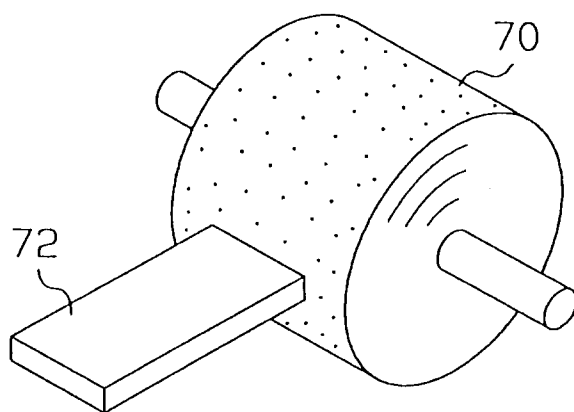


Fig.21





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 11 2229

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
Y	GB-A-2 143 755 (THE SECRETARY OF STATE FOR DEFENCE U.K.) * page 1, line 36 - line 98 * ---	1-3, 11-14, 20	B24B53/007 B24C1/02 B24C11/00 B24B55/04 B24B55/06
Y	DE-C-177 190 (BRUNO ZIMMERMANN) * the whole document * ---	1-3, 11-14, 20	
A	US-A-3 172 831 (L.A.WILLIAMS) * figures 2-4 * ---	4, 5, 15	
A	DATABASE WPI Week 8931, 27 July 1989 Derwent Publications Ltd., London, GB; AN 89-221491 & DE-A-38 02 042 (THERA GESE PATENTVE) * abstract * ---	6, 16	
A	FR-A-2 139 233 (CHRISTENSEN DIAMOND PRODUCTS CO.) * page 4, line 30 - line 37; figure 1 * ---	7, 10, 17	
A	GB-A-2 067 935 (THE HENDERSON DIAMOND TOOL CO. LTD) * figure 3 * ---	9, 19	TECHNICAL FIELDS SEARCHED (Int.Cl.5) B24B B24C
A	US-A-5 115 600 (KATAOKA ET AL.) * abstract * ---	8, 18	
A	V.D.I.-ZEITSCHRIFT vol. 125, no. 15, 1983, DÜSSELDORF, DE pages 621 - 623 ERNST SALJÉ 'Strahlverfahren für CBN- und Diamantschleifscheiben.' -----		
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 30 November 1993	Examiner Eschbach, D
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			