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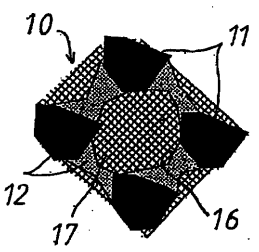
(54) VITRIFIED BOND GRINDING WHEEL AND PROCESS FOR PRODUCING THE SAME

(57) In a vitrified bonded grinding wheel having superabrasive grains 11 such as CBN, diamond or the like bonded with a vitrified bond 12, pores 16 of the vitrified bonded grinding wheel has impregnated thereinto a resin 17 consisting of any resin selected from, e.g., unsaturated polyester, vinyl ester and allyl ester which are in a liquid state at the normal temperature and which have a thermosetting property, and being capable of radical polymerization. Thus, any separation gas or the like is not generated when the impregnated resin is hardened, whereby the strength of the grinding wheel can be enhanced.

FIG. 2



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Description

TECHNOLOGICAL FIELD:

[0001] The present invention relates to a vitrified bonded grinding wheel with resign impregnated into pores thereof and a process for producing such a vitrified bonded grinding wheel.

BACKGROUND ART:

[0002] Vitrified bonded grinding wheels in which superabrasive grains such as CBN, diamond or the like are bonded with a vitrified bond are excellent in discharge capability of grinding chips and are sharp in grinding capability for the reason of numerous pores formed between the grains and hence, are advantageous in a respect that grinding can be performed with good surface roughness. In a vitrified bonded grinding wheel of this kind, the provision of much more volume of pore can enhance the sharpness of the grinding wheel, but gives rise to problems that the retaining force of abrasive grains is weakened to become liable to fall during a grinding operation and further that the grinding wheel becomes easy to reach its limit in bending strength.

[0003] Japanese unexamined, published patent application No. 2001-205566 describes a vitrified grinding wheel, in which with these problems taken into consideration, the retaining force of abrasive grains is increased to suppress the falling of abrasive grains by impregnating resin into pores of a vitrified grinding wheel. That is, the application describes that by impregnating liquid phenol resin into the matrix of a porous vitrified grinding wheel having numerous continuous pores and then, by drying the grinding wheel within a dryer to set the impregnated resin, apertures in the matrix of the vitrified grinding wheel are moderately occupied with the phenol resin.

[0004] However, it was verified as a result of applicant's experiences that one which has phenol resin impregnated into pores of a vitrified grinding wheel is not enhanced sufficiently in the grinding wheel strength (the bending strength of the grinding wheel). Through various studies, the cause was deemed to be due to the polymeric form in the setting reaction of phenol resin. That is, the polymeric form in the setting reaction of phenol resin is classified into polycondensation in consecutive polymerization, and there was acquired knowledge that in the polycondensation in consecutive polymerization, the polymerization reaction causes separation gases and steam to be generated during a setting period of the phenol resin impregnated into the pores and that the generation of such separation gases and steam impedes the impregnation action of the phenol resin, whereby cavities are formed inside the grinding wheel to decrease the strength of the same. For the reason, it is deemed that one having phenol resin impregnated into the pores of a vitrified grinding wheel is liable to have abrasive grains falling during a grinding operation, is easy to wear and is short in service life.

[0005] As a result of various studies based on the foregoing facts, it was found that the foregoing separation gases or the like are not generated during the setting reaction where unsaturated polyester resin capable of radical polymerization in chain polymerization which is opposite in polymeric form to the consecutive polymerization is impregnated into pores of a vitrified bonded grinding wheel.

[0006] Accordingly, the present invention is to provide a vitrified bonded grinding wheel and a production process therefor wherein the strength of the grinding wheel can be increased by impregnating a resin capable of radical polymerization which does not generate separation gases or the like during the setting of the impregnated resin.

DISCLOSURE OF THE INVENTION:

[0007] The first invention is a vitrified bonded grinding wheel having superabrasive grains such as CBN, diamond or the like bonded with a vitrified bond, characterized in that a resin capable of radical polymerization is impregnated into pores of the vitrified bonded grinding wheel.

[0008] According to the first invention, by impregnating the resin capable of radical polymerization into the pores of the vitrified bonded grinding wheel, any separation gases or steam is not generated, and thus, the impregnation of the resin can be performed appropriately thereby to contribute to an improvement in the bending strength of the grinding wheel. As a consequence, the falling of abrasive grains during a grinding operation can be suppressed, so that there can be attained an advantage that the wear amount of the grinding wheel can be reduced to elongate the service life of the grinding wheel.

[0009] The second invention resides in that in the vitrified bonded grinding wheel according to the first invention, the resin capable of radical polymerization consists of any resin selected from unsaturated polyester, vinyl ester and allyl ester which have a thermosetting property and which are in a liquid state at the normal temperature.

[0010] According to the second invention, since any resin selected from unsaturated polyester, vinyl ester and allyl ester having a thermosetting property and being in a liquid state at the normal temperature is employed as the resin capable of radical polymerization, there can be attained an advantage that any resin selected from unsaturated polyester, vinyl ester and allyl ester can easily be impregnated into the pores of the vitrified bonded grinding wheel at the normal

temperature.

[0011] The third invention resides in that in the vitrified bonded grinding wheel according to the first or second invention, the resin capable of radical polymerization consists of a resin which is within a range of 60-85 in hardness (Shore D).

[0012] According to the third invention, since the resin being within the range of 60-85 in hardness (Shore D) is employed as the resin capable of radical polymerization, the resin is softer in resin hardness than phenol resin, and hence, the heat generation is suppressed even upon the contact of a workpiece with the impregnated resin during a grinding operation, so that an advantage can be obtained in that it can be realized to prevent grinding burns on the workpiece, depositions on the grinding wheel and the like.

[0013] The fourth invention resides in a production process for a vitrified bonded grinding wheel having superabrasive grains such as CBN, diamond or the like bonded with a vitrified bond, wherein the process is characterized by filling a mold with material being a mixture of abrasive grains, bonding agent and the like; forming a grinding wheel substance through a press-forming and a burning; removing bubbles in a vacuum, with the grinding wheel substance being immersed in a fluid resin capable of radical polymerization, to impregnate the resin capable of radical polymerization into pores of the grinding wheel substance; and adhering the resin impregnated grinding wheel substance to a grinding wheel core after the setting of the resin.

[0014] According to the fourth invention, the grinding wheel substance is formed by filling the mold with the material being a mixture of abrasive grains, bonding agent and the like and then by performing the press forming and burning, the resin capable of radical polymerization is impregnated into the pores of the grinding wheel substance by removing bubbles in a vacuum, with the grinding wheel substance being immersed in the fluid resin capable of radical polymerization, and after the setting of the resin, the resin impregnated grinding wheel substance is adhered to the grinding wheel core. Therefore, it can be reliably and easily realized to impregnate the resin capable of radical polymerization into the pores of the grinding wheel substance. In addition, since no separation gases and steam is generated at the time of setting the impregnated resin, it does not occur that such separation gases or the like cause cavities to be formed in the resin impregnated pores of the grinding wheel substance, so that the resin can be impregnated uniformly into the pores of the grinding wheel substance. Accordingly, an advantage is attained in that there can be easily obtained a vitrified bonded grinding wheel which is capable of enhancing the bending strength of the grinding wheel, of suppressing the falling of abrasive grains during a grinding operation, and of reducing the wear amount of the grinding wheel.

BRIEF DESCRIPTION OF THE DRAWINGS:

[0015]

Figure 1 is a view showing a grinding wheel substance in an embodiment according to the present invention. Figure 2 is a view showing a section structure of the grinding wheel substance. Figure 3 is a chart showing production steps for the grinding wheel substance. Figure 4 is a graph representing the comparison in bending strength between grinding wheel substances. Figure 5 is a section showing a cup-shape vitrified bonded grinding wheel with the grinding wheel substance adhered thereto. Figure 6 is a view observed from the direction A in Figure 5. Figure 7 is a graph representing the comparison in hardness between resins. Figure 8 is a graph representing an effective range in hardness of the resins. Figure 9 is an external view of a vitrified bonded grinding wheel showing another embodiment according to the present invention.

PREFERRED EMBODIMENTS TO PRACTICE THE INVENTION:

[0016] Hereafter, embodiments according to the present invention will be described with reference to the drawings. Referring to Figures 1 and 2, numeral 10 denotes a ring-like grinding wheel substance having superabrasive grains 11 such as CBN, diamond or the like bonded with a vitrified bond 12. The grinding wheel substance 10 takes a two-layer structure in which an abrasive grain layer 13 having the superabrasive grains 11 bonded with the vitrified bond 12 and a foundation layer 14 not including such superabrasive grains are piled up and bonded bodily. The abrasive grain layer 13 is of the structure that the superabrasive grains 11 are bonded with the vitrified bond 12 to the depth of, e.g., 3 to 5 mm, wherein particles such as aluminum oxide (Al_2O_3) are mixed as aggregate in the vitrified bond 12 if necessary. Further, the foundation layer 14 is of the structure that foundation particles such as ceramics particles or the like are bonded with the vitrified bond to the depth of, e.g., 1 to 3 mm. Because the employment of the vitrified bond 12 enables numerous pores to be formed between the abrasives grains 11, the discharge capability of grinding chips becomes excellent to make the grinding capability sharp, so that it can be attained to perform a grinding operation for enhanced surface roughness at a little wear amount of the grinding wheel.

[0017] Next, a process for producing the ring-shape grinding wheel substance 10 will be described with reference to Figure 3. Table 1 shows the specification of the grinding wheel substance 10 employed in this process.

[Table 1]

Specification	
Kind of Abrasive Grains	CBN, Diamond
Abrasive Grain Size	#40-#800
Total Volume Percent of Abrasive Grains and Aggregate	10-60 %
Bonding Agent	Vitrified
Volume Percent of Bonding Agent	10-35%
Impregnated Resin	Polyester
Volume Percent of Resin	20-60%

[0018] First of all, at a material mixing step 21, the superabrasive grains 11 consisting of CBN or diamond of #40-#800 as the material for the grinding wheel substance 10, the bonding agent 12 consisting of a vitrified bond, and if necessary, the aggregate consisting of WA abrasive grains or the like are mixed at a predetermined mixing ratio. The superabrasive grains 11 and the bonding agent 12 (vitrified bond) are mixed so that after the burning of the grinding wheel substance 10, the total volume percent of the abrasive grains and the aggregate is in a range of 10-60% and the volume percent of the bonding agent is in a range of 10-35 %.

[0019] Then, a forming step 22 is reached, wherein respective materials for the abrasive grain layer 13 and the foundation layer 14 are filled in turn in a press mold and is placed under pressing, whereby a green material for the ring-like grinding wheel substance 10 taking a two-layer structure is formed. At a successive burning step 23, the green material of the grinding wheel substance 10 is burned at a temperature range of 800°C-1000°C, thereby producing a grinding wheel substance 10 which is ahead of resin impregnation and has numerous pores 16 between the superabrasive grains 11 bonded with the vitrified bond 12.

[0020] Then, at an impregnation step 24, there is used polyester resin in a liquid state contained in a container. The polyester resin in a liquid state is a mixture of unsaturated polyester, accelerator and hardener at a weight ratio of 100: 1:1. More specifically, product code XO-TP-03-38 (trade name: POLYLITE®), a product of DAINIPPON INK AND CHEMICALS, INCORPORATED, was used as the saturated polyester resin. Further, cobalt naphthenate is preferable as the accelerator, and methyl ethyl ketone peroxide or the like is preferable as the hardener. The grinding wheel substance 10 after the burning is immersed in the liquid polyester resin contained in the container, wherein bubbles are removed in a vacuum, whereby as shown in Figure 2, the liquid polyester resin 17 is impregnated into pores of the grinding wheel substance 10. It is preferable that the volume percent of the polyester resin 17 at this time is within a range of 25-60%.

[0021] The aforementioned unsaturated polyester is a thermosetting resin which is in a liquid form at the normal temperature, the polymeric form of which is classified into radical polymerization in chain polymerization, and has a property that the polymerization reaction does not generate any separation gas and steam when the resin (polyester resin) impregnated into the pores 16 is hardened.

[0022] Finally, at a setting step 25, the grinding wheel substance 10 is dried at a temperature of 60°C within a drier for three hours or longer, whereby the polyester resin 17 impregnated into the pores 16 of the grinding wheel substance 10 is hardened to complete the grinding wheel substance 10. Although the drying process by the drier is not necessarily required because the polyester resin 17 comes to be hardened in due time even at the normal temperature, the drying process by the drier is effective in preventing the incompleteness in setting. In this way, the pores 16 of the grinding wheel substance 10 are filled with the polyester resin 17 in dependence on the ratio of the polyester resin 17.

[0023] Figure 4 represents the comparison in bending strength between the grinding wheel substance 10 with the impregnated polyester resin 17 and another grinding wheel substance with impregnated phenol resin, and from the figure, it will be easily comprehended that the grinding wheel substance 10 with the impregnated polyester resin 17 is about twice as strong in bending as the grinding wheel substance with the impregnated phenol resin. Such an improvement in the bending strength of the grinding wheel substance 10 advantageously resulted in suppressing the falling of the abrasive grains during a grinding operation thereby to suppress the wear of the grinding wheel, whereby it became possible to increase the service life of the grinding wheel greatly.

[0024] Next, description will be made regarding an example that a face grinding on a workpiece is performed by the use of the aforementioned grinding wheel substance 10. Figures 5 and 6 show a cup-shape vitrified bonded grinding wheel 30, which takes a structure that a ring-like grinding wheel substance 10 produced as described above is adhered with, e.g., an epoxy adhesive to an end surface 31 a of a cup-shape grinding wheel core 31 which is made of a metal, such as iron, aluminum, titanium alloy or the like, a ceramics, a fiber-reinforced plastic or the like. A fitting hole 32 for enabling a wheel spindle (not shown) to fit therein is formed at a center part of the grinding wheel core 31.

[0025] The grinding wheel substance 10 adhered to the vitrified bonded grinding wheel 30 is not limited to the ring shape. Instead, a plurality of segmental grinding wheel substances, each of which takes a shape of arc or rectangular with its curvature center on the center of the grinding wheel core 31, may be arranged in an annular fashion.

[0026] Table 2 represents the comparison in grinding result between the vitrified bonded grinding wheel 30 (embodiment) adhering thereto the grinding wheel substance 10 with the impregnated polyester resin and another vitrified bonded grinding wheel (compared example) adhering thereto a grinding wheel substance with impregnated phenol resin.

[Table 2]

Specification	Embodiment	Compared Example
Kind of Abrasive Grains	CBN	CBN
Abrasive Grain Size	#40	#40
Volume Percent of Abrasive Grains and the like	30%	30%
Bonding Agent	Vitrified	Vitrified
Volume Percent of Bonding Agent	17%	17%
Impregnated Resin	Polyester	Phenol
Volume Percent of Resin	53%	53%
Resin Hardness (Shore D)	82-85	87-90
Grinding Result	Good	Bad

[0027] That is, the grinding wheel substance 10 with the impregnated polyester resin 17 shown as the embodiment uses CBN abrasive grains of #40 grain size as the abrasive grains to make the same occupy 30% in volume percent, uses vitrified as the bonding agent to make the same occupy 17% in volume percent, and uses a thermosetting polyester resin, which belongs to radical polymerization of chain polymerization in polymeric form, to make the resin occupy 53% in volume percent. Further, the polyester resin is a mixture of unsaturated polyester, accelerator and hardener at a weight ratio of about 100:1:1, is in a liquid state at the normal temperature and is in a range of 82-85 in the resin hardness (Shore D) after the setting. A measuring gauge, model GS-720G (trade name: Durometer) made by TECLOCK, was used to measure the resin hardness (Shore D).

[0028] On the other hand, except that as the resin to be impregnated, there was used phenol resin which was a thermosetting resin belonging to polycondensation of consecutive polymerization in polymeric form and the hardness (Shore D) of which was in a range of 87-90, the grinding wheel substance with the impregnated phenol resin shown as the compared example was set to have the same conditions in the kind of abrasive grains, grain size, volume percent of the abrasive grains or the like, bonding agent and volume percent of the same. However, the resin volume percent 53% in the compared example is the numerical value which includes that component for cavities generated with separation gas and steam in the polymerization reaction, wherein the actual resin volume percent becomes a numerical value reduced by the component for the cavities.

[0029] Regarding the drying process for hardening the resin after the filling of the same in the grinding wheel substance, the grinding wheel substance 10 with the impregnated polyester resin in the embodiment was dried for six hours at the temperature of 60°C, whereas the grinding wheel substance with the impregnated phenol resin in the compared example was dried for twenty-four hours at the temperature of 180°C because it could not be sufficiently hardened under the same hardening condition.

[0030] As a result of grinding workpieces with the vitrified bonded grinding wheel 30 adhering thereto the grinding wheel substance 10 with the impregnated polyester resin 17 and with the vitrified grinding wheel adhering thereto the grinding wheel substance with the impregnated phenol resin, it was verified that phenomena such as grinding burns on the workpiece and depositions on the grinding wheel did not occur in the use of the vitrified bonded grinding wheel 30 with the impregnated polyester resin 17.

[0031] The conditions for the grinding operations performed were that there were used the grinding wheels each taking the aforementioned cup-shape and that the grinding efficiency was set to 0.24mm^2/sec.

[0032] As a result, it was found that the vitrified bonded grinding wheel with the impregnated phenol resin could not obtain a satisfactory result in evaluation because the phenomena such as grinding burns on the workpiece and depositions on the grinding wheel were observed, whereas the vitrified bonded grinding wheel 30 with the impregnated polyester resin 17 was a little in the grinding wheel wear amount and was devoid of the phenomena such as grinding burns on the workpiece and depositions on the grinding wheel. Therefore, the tests were repeated with the grinding efficiency increased higher and higher, and it was verified that the vitrified bonded grinding wheel 30 with the impregnated polyester

resin 17 was capable of performing grinding operations without involving the grinding burns on the workpiece and depositions on the grinding wheel even when the grinding efficiency was increased by five times. From this fact, it was proved that the vitrified bonded grinding wheel 30 with the impregnated polyester resin 17 was very effective in suppressing the grinding wheel wear amount and further, in suppressing the phenomena such as grinding burns on the workpiece and depositions on the grinding wheel.

[0033] This is considered due to the fact that as shown in Figure 4, the grinding wheel strength is increased by employing unsaturated polyester resin which has a thermosetting property and which is capable of radical polymerization, because the polymerization reaction does not generate separation gas and steam at the setting time of the polyester resin 17 impregnated into the pores 16 of the grinding wheel substance 10 and hence, because the polyester resin 17 can be filled uniformly in the pores 16.

[0034] In addition, as shown in Figure 7, the resin hardness (82 to 85 at Shore D) after the setting of the unsaturated polyester impregnated into the pores 16 (in the case of product code XO-TP-03-38 made by DAINIPPON INK AND CHEMICALS, INCORPORATED) is softer than the resin hardness (87 to 90 at Shore D) after the setting of the phenol resin. From this fact, it is considered that in performing a grinding operation with the vitrified bonded grinding wheel 30 with the impregnated polyester resin 17, the generation of heat can be suppressed even upon contact of the impregnated resin with a workpiece during a grinding operation and that such suppression of the heat generation effectively works in suppressing the aforementioned phenomena such as grinding burns on the workpiece, depositions on the grinding wheel and the like.

[0035] To make sure this, there were selected polyester resins 17 which respectively take, as main ingredient, unsaturated polyester resins that are different in post-setting resin hardness from one (the unsaturated polyester resin within a range of 82-85 in resin hardness (Shore D)) in the aforementioned embodiment, that is, unsaturated polyester resins of three kinds that are respectively about 70, 60 and 50 in post-setting resin hardness (Shore D). The selected polyester resigns were impregnated respectively into grinding wheel substances 10, and the bending strengths of the same were measured for relation therebetween. As is clear from Figure 8, it was verified that in comparison with one shown as the aforementioned compared example and impregnating the phenol resin in a range of 87-90 in resin hardness (Shore D), the superiority in bending strength was not recognized on one which, of those impregnating the unsaturated polyester, was 50 or less in resin hardness (Shore D) because the resin was too soft and that those being 60 or higher in resin hardness (Shore D) were effective in bending strength. Accordingly, the resin hardness (Shore D) is suitable in a range of 60-85 and desirably, is optimum in the range of 82-85 demonstrated in the embodiment.

[0036] Figure 9 shows another embodiment according to the present invention. In this embodiment, a vitrified bond segmental grinding wheel 42 is constituted by impregnating and setting liquid polyester resin, in the same manner as aforementioned, in pores of segmental grinding wheel substances 40 each taking an arc shape and each having superabrasive grains such as CBN, diamond or the like bonded with a vitrified bond and then by adhering the grinding wheel substances 40 on an outer circumferential surface of a disc-like grinding wheel core 41 which is made of a metal such as iron, aluminum, titanium alloy or the like, a ceramics, a fiber-reinforced plastic or the like.

[0037] Table 3 exemplifies the specification of the grinding wheel substances 40 for the vitrified bonded grinding wheel 42 which is used in performing a face grinding operation on a workpiece.

[Table 3]

Specification	
Kind of Abrasive Grains	CBN
Abrasive Grain Size	#120
Volume Percent of Abrasive Grains and the like	38%
Bonding Agent	Vitrified
Volume Percent of Bonding Agent	24%
Impregnated Resin	Polyester
Volume Percent of Resin	38%

[0038] That is, the segmental grinding wheel substances 40 in this embodiment used superabrasive grains being CBN of #120 grain size, and the volume percent of the abrasive gains or the like was set to 38%. Further, vitrified was used as the bonding agent, and the volume percent of the bonding agent was set to 24%. In the same manner as the foregoing embodiment, there was used a mixture of the unsaturated polyester (product code: XO-TP-03-38) made by DAINIPPON INK AND CHEMICALS, INCORPORATED, accelerator and hardener at the weight ratio of about 100:1:1, and the polyester was impregnated into pores of the grinding wheel substances 40 to set the resin volume percent to 38%.

[0039] By performing a face grinding operation on a workpiece with the grinding wheel 42 in which as shown in Figure 9, a plurality of the grinding wheel substances 40 of the structure mentioned above had been adhered to the outer circumference of the disc-like grinding wheel core 41, it was able to realize a high efficiency grinding operation which is capable of suppressing phenomena such as grinding burns on the workpiece, depositions on the grinding wheel and the like.

[0040] The foregoing embodiments have been described taking examples that unsaturated polyester resin is impregnated into the pores of the vitrified bonded grinding wheels. However, as the impregnated resin, vinyl ester and allyl ester which have a thermosetting property and are capable of radical polymerization are also effective in increasing the bending strength of the grinding wheel.

[0041] Further, the present invention is not limited to the resins of the aforementioned unsaturated polyester, vinyl ester and allyl ester. The present invention does not exclude other resins which are capable of radical polymerization contributing to an improvement in the bending strength of grinding wheel and which have a thermosetting property and thermoplasticity.

[0042] Further, although in the foregoing embodiment, the grinding wheel substance 10 has been described as one having the two-layer structure in which the abrasive grain layer 13 having the superabrasive grains 11 bonded with the vitrified bond 12 is piled up and bodily bonded on the foundation layer 14 not including the superabrasive grains, the same advantages can be expected even in a vitrified bonded grinding wheel constituted only by a single layer of the abrasive grain layer.

[0043] The specifications or the like for the grinding wheel substances 10, 40 described in the foregoing embodiments are presented as examples suitable to the present invention and are not intended to limit the present invention thereto. It is needless to say that the present invention may be altered within an extent which does not deviate from the gist thereof.

INDUSTRIAL APPLICABILITY:

[0044] The vitrified bonded grinding wheel and the production process therefor according to the present invention are suitable for use in a grinding machine for grinding workpieces.

Claims

1. A vitrified bonded grinding wheel having superabrasive grains such as CBN, diamond or the like bonded with a vitrified bond, **characterized in that** a resin capable of radical polymerization is impregnated into pores of the vitrified bonded grinding wheel.

2. The vitrified bonded grinding wheel according to Claim 1, wherein the resin capable of radical polymerization consists of any resin selected from unsaturated polyester, vinyl ester and allyl ester which have a thermosetting property and which are in a liquid state at the normal temperature.

3. The vitrified bonded grinding wheel according to Claim 1 or 2, wherein the resin capable of radical polymerization consists of a resin which is in a range of 60-85 in hardness (Shore D).

4. A production process for a vitrified bonded grinding wheel having superabrasive grains such as CBN, diamond or the like bonded with a vitrified bond, wherein the process is **characterized by** filling a mold with material being a mixture of abrasive grains, bonding agent and the like; forming a grinding wheel substance through a press-forming and a burning; removing bubbles in a vacuum, with the grinding wheel substance immersed in a fluid resin capable of radical polymerization, to impregnate the resin capable of radical polymerization into pores of the grinding wheel substance; and after setting of the resin, adhering the resin impregnated grinding wheel substance to a grinding wheel core.

FIG. 1

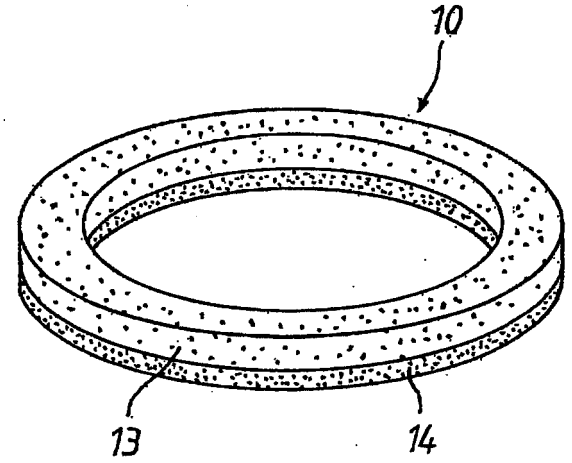


FIG. 2

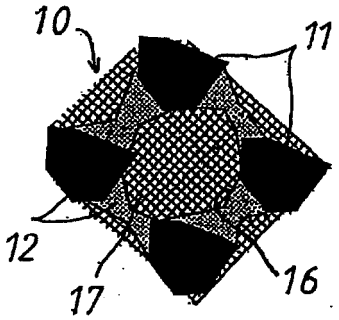


FIG. 3

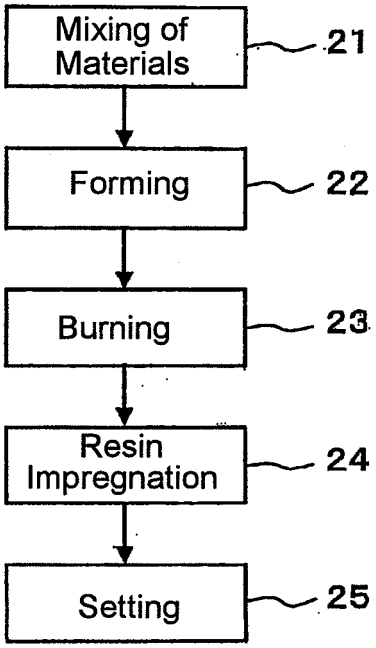

Mixing of Materials
21
Forming
22
Burning
23
Resin Impregnation
24
Setting
25

FIG. 4

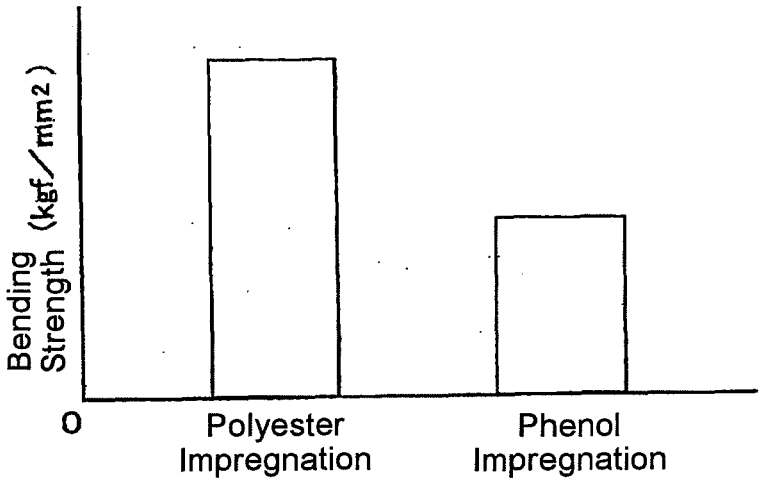

Bending Strength (kgf/mm2)
0
Polyester Impregnation
Phenol Impregnation

FIG. 5

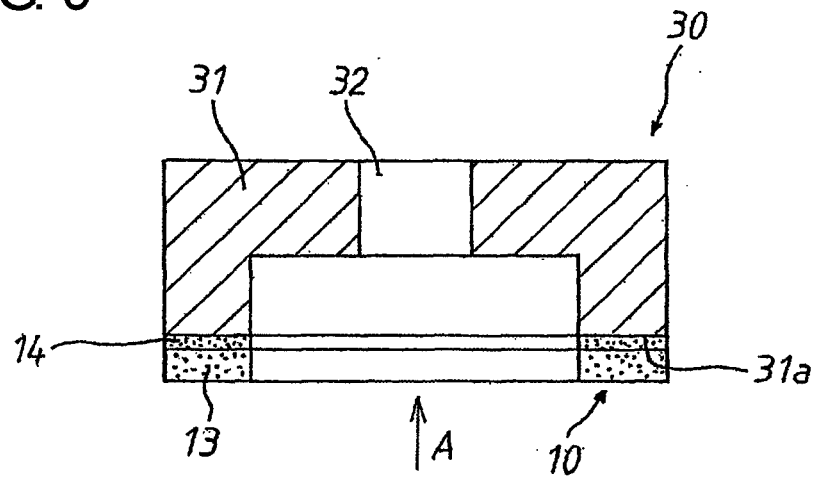
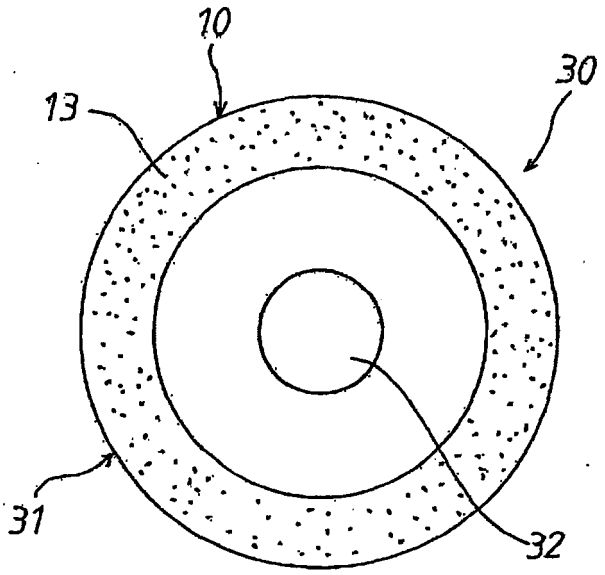

30
31
32
14
31a
13
A
10

FIG. 6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13
30
31
32

FIG. 7

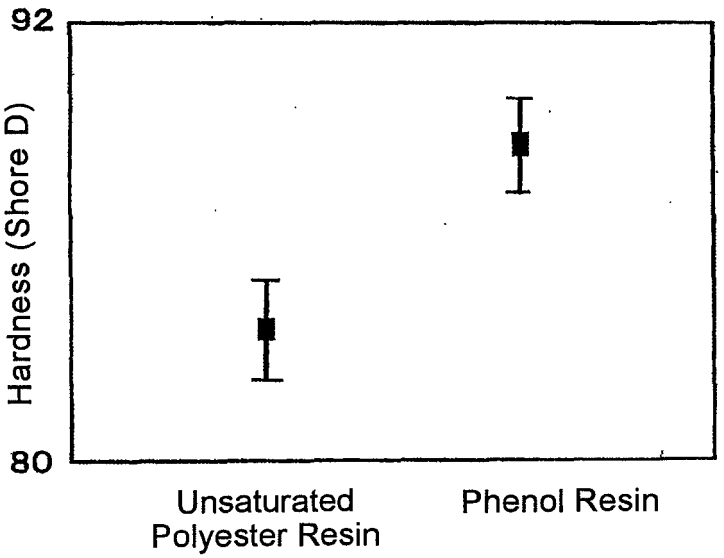

92
80
Hardness (Shore D)
Unsaturated Polyester Resin
Phenol Resin

FIG. 8

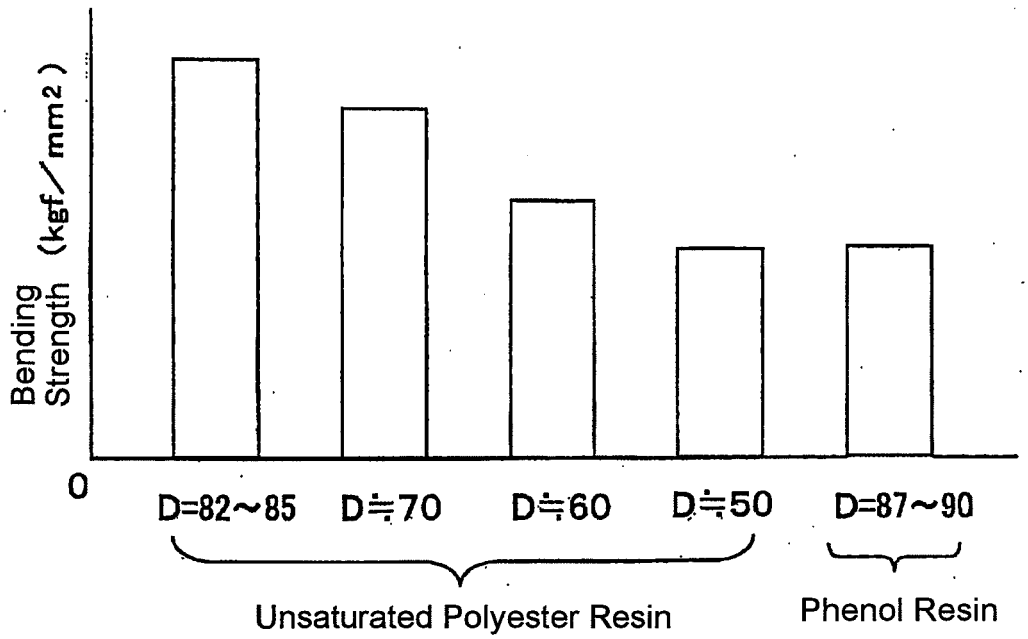
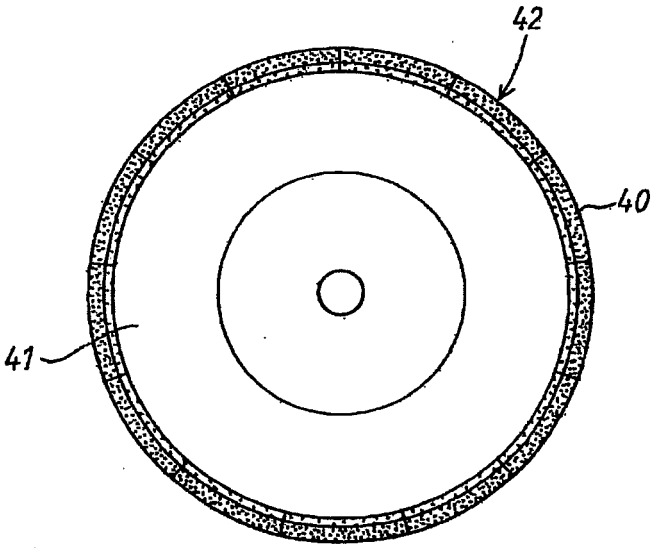

Bending Strength (kgf/mm2)
0
D=82~85
D≒70
D≒60
D≒50
D=87~90
Unsaturated Polyester Resin
Phenol Resin

FIG. 9


42
40
41

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/024222

A. CLASSIFICATION OF SUBJECT MATTER
B24D3/14(2006.01), ***B24D3/00***(2006.01), ***B24D3/02***(2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B24D3/14, B24D3/00, B24D3/02

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 1996-2006
Kokai Jitsuyo Shinan Koho 1971-2006 Toroku Jitsuyo Shinan Koho 1994-2006

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.
A	JP 48-11558 B1 (Norton Company), 13 April, 1973 (13.04.73), Full text; drawings & US 3535832 A & GB 1194110 A & DE 1803233 A & FR 1599786 A & CS 149646 B	1-4
A	JP 5-59259 A (Noritake Co., Ltd.), 09 March, 1993 (09.03.93), Par. No. [0013] (Family: none)	1-4
A	JP 2001-205566 A (Noritake Co., Ltd.), 31 July, 2001 (31.07.01), Claims & US 2001/0018324 A1 & EP 1120197 A3	1-4

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

* Special categories of cited documents:
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 March, 2006 (31.03.06)	11 April, 2006 (11.04.06)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/024222

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 61-159375 A (Tsuneo MASUDA), 19 July, 1986 (19.07.86), Claims & US 4743508 A & US 4765801 A & GB 2168988 A & DE 3529196 A & FR 2575460 A & MX 168099 B & CA 1286509 A & CN 85106817 A	1-4
A	JP 2003-55421 A (Nippon Yupika Kabushiki Kaisha), 26 February, 2003 (26.02.03), Claims (Family: none)	1-4

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2001205566 A **[0003]**