**ABSTRACT**

A grinding wheel includes: a plurality of abrasive grains arranged so as not to contact with one another; interval adjustment materials interposed between the abrasive grains, arranged in contact with the abrasive grains, and having a grain size that allows a distance between the abrasive grains to be equal to a minimum separation distance; a binder that binds each of the abrasive grains to the interval adjustment materials; and pores formed between the abrasive grains.
GRINDING WHEEL AND METHOD FOR MANUFACTURING THE SAME

INCORPORATION BY REFERENCE


BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention
[0003] The invention relates to a grinding wheel and a method for manufacturing the grinding wheel.
[0004] 2. Description of Related Art
[0005] To prevent thermal damage such as grinding burn and grinding cracks and to achieve high machining accuracy, a grinding wheel with small grinding resistance is used even for efficient grinding. In this case, for example, a low-concentration grinding wheel disclosed in Japanese Patent Application Publication No. H6-155307 (JP H6-155307 A) and having a reduced abrasive-grain content (abrasive-grain concentration) per unit volume is effectively used to reduce the grinding resistance. In the technique disclosed in JP H6-155307 A, abrasive grains, an aggregate, and a binder are mixed together, and the mixture is molded and sintered to form the low-concentration grinding wheel. JP H6-155307 A discloses that, in this case, the grinding wheel is formed as follows. Surfaces of the abrasive grains are coated with an organic binder. A mixture of binder powder and aggregate grains with a grain size of 30% or less of the grain size of the abrasive grains is added to the abrasive grains. The mixture and the abrasive grains are mixed together and stirred to form, on the surface of each abrasive grain, an attachment layer containing the binder and the aggregate. The resultant abrasive grains are finally sintered. JP H6-155307 A discloses that the above-described process results in a vitrified grinding wheel that has a concentration of less than 200 and in which the abrasive grains and the aggregate and pores formed in the binder are substantially uniformly dispersed.

[0006] However, in the technique disclosed in JP H6-155307 A, the abrasive grains and the aggregate are significantly different in specific gravity from the binder. Consequently, when abrasive grains, binder powder, and aggregate grains are mixed and stirred, uniformly arranging the abrasive grains and the aggregate grains is difficult. Thus, the technique disclosed in JP H6-155307 A may result in non-uniform distances between the abrasive grains, making the grinding resistance non-uniform depending on an area of the grinding wheel used.

SUMMARY OF THE INVENTION

[0007] It is an object of the present embodiment to provide a grinding wheel that enables the distances between abrasive grains to be uniformly set, and a method for manufacturing the grinding wheel.
[0008] According to a first aspect of the invention, a grinding wheel includes:
[0009] a plurality of abrasive grains arranged so as not to contact with one another,
[0010] interval adjustment materials interposed between the abrasive grains, arranged in contact with the abrasive grains, and having a grain size that allows a distance between the abrasive grains to be equal to a predetermined minimum separation distance;
[0011] a binder that binds each of the abrasive grains to the interval adjustment materials; and
[0012] pores formed between the abrasive grains.
[0013] According to the aspect, since the interval adjustment materials are arranged between the abrasive grains, the abrasive grains are reliably arranged at a distance from one another; the distance is equal to the grain size of the interval adjustment materials, or a minimum separation distance. Thus, since the minimum separation distance is maintained between the abrasive grains, it is possible to produce a grinding wheel in which the intervals between the abrasive grains are uniform, and which has a small variation in grinding resistance all over the circumference of the grinding wheel.

[0014] According to a second aspect, a method for manufacturing a grinding wheel includes the steps of:
[0015] (a) generating intermediate materials each including an abrasive grain, interval adjustment materials, and an attachment agent that is generated by mixing a binder and an attachment agent, covers a surface of the abrasive grain, and that allows the interval adjustment materials to be attached to the surface such that the interval adjustment materials are exposed from the attachment agent;
[0016] (b) feeding the intermediate materials into a molding die and pressuring an interior of the molding die to adjust a distance between the abrasive grains such that the distance is equal to a minimum separation distance between the abrasive grains determined by a grain size of the interval adjustment materials; and
[0017] (c) heating a molding generated in step (b) to generate the grinding wheel.
[0018] A grinding wheel similar to the above-described grinding wheel can be manufactured by the manufacturing method according to the second aspect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The foregoing and further features and advantages of the invention will become apparent from the following description of example embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:
[0020] FIG. 1 is a diagram of a whole vitrified bond grinding wheel depicting an embodiment of the present invention;
[0021] FIG. 2 is an enlarged diagram depicting a tissue near a grinding wheel surface of a grinding wheel layer of the vitrified bond grinding wheel;
[0022] FIG. 3 is an enlarged diagram of an intermediate material (tertiary intermediate material) forming the grinding wheel layer;
[0023] FIG. 4 is a flowchart of a method for manufacturing a grinding wheel layer;
[0024] FIG. 5A is an enlarged view of a primary intermediate material;
[0025] FIG. 5B is an enlarged view of a secondary intermediate material; and
[0026] FIG. 6 is a diagram illustrating the state of a molding during a pressuring step.

DETAILED DESCRIPTION OF EMBODIMENTS

[0027] An embodiment of the invention will be described below with reference to the attached drawings.
As depicted in FIG. 1, a grinding wheel 10 is a grinding wheel shaped like a disc. The grinding wheel 10 includes a disc-shaped core 21 and a ring-shaped grinding wheel layer 22. The core 21 is formed of a metal material such as steel, aluminum, or titanium, a fiber reinforced plastic (FRP) material, or ceramics. The grinding wheel layer 22 is formed by burning a material into a ring shape and securing the ring-shaped material to an outer periphery of the core 21 with an adhesive or by sintering. Alternatively, the grinding wheel layer 22 may be formed by attaching a plurality of grinding wheel segments to the outer periphery of the core 21 so as to form a ring.

A center hole 23 is formed in the center of the core 21 so as to penetrate the core 21. The center hole 23 is filled over a centering boss protruding from a shaft end of a wheel spindle of a wheel spindle stock not depicted in the drawings. A plurality of bolt holes 24 is formed around the center hole 23. Through the bolt holes, bolts are inserted which are screwed into screw holes formed at the shaft end of the wheel spindle. The bolts are inserted through the bolt holes 24 and threaded into the screw holes to secure the grinding wheel 10 to the wheel spindle.

As depicted in an enlarged view in FIG. 2, the grinding wheel layer 22 includes abrasive grains 12 (in the description, super abrasive grains of diamond or CBN), interval adjustment materials 14, a binder 16 (in the description, a vitrified bond), and pores 18. As described below in detail, the grinding wheel layer 22 is generated by pressurizing and heating a plurality of tertiary intermediate materials 22a3 (intermediate materials 22a). As depicted in FIG. 3, each of the tertiary intermediate materials 22a3 includes, before heating, one super abrasive grain 12, an attachment agent 15, and a plurality of the interval adjustment materials 14. The attachment agent 15 includes a vitrified bond 16 and is attached to the entire surface of one super abrasive grain 12. In this case, the interval adjustment materials 14 are held on the surface of the super abrasive grain 12 via the attachment agent 15 so as to be exposed from the attachment agent 15 instead of being entirely covered with the attachment agent 15. In the tertiary intermediate material 22a3 of FIG. 3, the interval adjustment materials 14 are held on the super abrasive grain 12 at a portion facing the viewer and at a portion facing away from the viewer. However, for convenience of description, the illustration of the interval adjustment materials 14 held on the super abrasive grains 12 at the portions facing the viewer and facing away from the viewer is omitted.

As described above, the super abrasive grains 12 are formed of, for example, cubic boron nitride (CBN) abrasive grains or diamond abrasive grains. In the present embodiment, the average grain size to (see FIG. 3) of the super abrasive grains 12 is, for example, approximately 125. As depicted in FIG. 2, in the grinding wheel layer 22, the super abrasive grains 12 are arranged so as not to contact one another.

The interval adjustment materials 14 are formed of, for example, alumina (Al2O3), which is fine ceramics. However, the present invention is not limited to this aspect, the interval adjustment materials 14 may be formed of another type of ceramics. The interval adjustment materials 14 may be formed of a member used as an aggregate. In the present embodiment, the average grain size ΦB (see FIG. 3) of the interval adjustment materials 14 is about 25 μm to 40 μm. In other words, the ratio of the average grain size ΦB of the interval adjustment materials 14 to the average grain size ΦA of the super abrasive grains 12 is approximately one-third to one-fifth. The average grain size (DB) of the interval adjustment materials 14 is adjusted as needed according to the type and concentration of the grinding wheel.

As depicted in FIG. 2, the interval adjustment materials 14 are discretely interposed between the super abrasive grains 12 and arranged in contact with the super abrasive grains 12. Thus, each of the interval adjustment materials 14 allows two super abrasive grains 12 to be arranged so as to be separated from each other by a distance approximately equal to the average grain size ΦB of the interval adjustment materials 14 to determine a minimum separation distance α (ΦB) between the super abrasive grains 12. In the present embodiment, the separation distance (corresponding to the distance in the invention) between the two abrasive grains 12 is equal to or larger than the average grain size ΦB of the interval adjustment materials 14 and is twice or less as large as the average grain size ΦB (1×ΦB≤2×ΦB). When one interval adjustment material 14 is interposed between two super abrasive grains 12, the separation distance is equal to the minimum separation distance α and is approximately equal to the average grain size ΦB. When two interval adjustment materials 14 are interposed between two super abrasive grains 12, the separation distance is up to approximately twice as large as the average grain size ΦB.

The vitrified bond 16, which is well known, bridges the super abrasive grain 12 and the interval adjustment material 14 that are adjacent to each other to form a bridging portion 20 (see FIG. 2). Before the tertiary intermediate material 22a3 depicted in FIG. 3 is heated, the vitrified bond 16 (binder) is mixed with an attachment agent 17 not depicted in the drawings and which is effective for allowing adhesion of the interval adjustment materials 14. The vitrified bond 16 forms the above-described attachment agent 15 along with the attachment agent 17. The attachment agent 17 is evaporated and lost due to heat when heated in a heating step 814. For example, a material for the attachment agent 17 is a polyacrylic acid. As depicted in FIG. 3, before the tertiary intermediate material 22a3 is heated, the attachment agent 15 attached to the entire surface of the super abrasive grain 12 by coating holds the interval adjustment materials 14 such that the interval adjustment materials 14 are partly buried in the attachment agent 15.

In the heating step 814, the tertiary intermediate material 22a3 is heated to cause the attachment agent 17, which is a polyacrylic acid, to be lost. The vitrified bond 16 (binder) is melted and flows from the surface of the super abrasive grain 12 to surfaces of the interval adjustment materials 14 that contact the super abrasive grain 12. The vitrified bond 16 is then cooled and solidified with the surface of the super abrasive grain 12 and the surfaces of the interval adjustment materials 14 bridged. As described above, the interval adjustment materials 14 are arranged at predetermined intervals on the surface of the super abrasive grain 12. Thus, in the grinding wheel layer 22, spaces are formed between the super abrasive grains 12 to form pores 18 as depicted in FIG. 2. In other words, the pores 18 are formed at portions other than the super abrasive grains 12, the interval adjustment materials 14, and the vitrified bond 16.

Now, a method for manufacturing the grinding wheel layer 22 using CBN abrasive grains will be described. The method for manufacturing the grinding wheel layer 22
includes an intermediate material generation step S10, a pressuring step S12, and a heating step S14 as illustrated in a flowchart in FIG. 4.

[0037] The intermediate material generation step S10 is a step of generating the tertiary intermediate material 22a3 depicted in FIG. 3 using the super abrasive grain 12, the interval adjustment materials 14, and the attachment agent 15 as materials. The intermediate material generation step S10 includes an attachment agent coating step S101 serving as a step of generating a primary intermediate material 22a1 using the above materials and an interval adjustment material attachment step S102 of generating the tertiary intermediate material 22a3 depicted in FIG. 3 using the primary intermediate material 22a1. In the attachment agent coating step S101, the attachment agent 15 containing the vitrified bond 16 is attached to the entire surface of each super abrasive grain 12 to generate the primary intermediate material 22a1 as depicted in FIG. 5A.

[0038] In the attachment agent coating step S101, each of the super abrasive grains 12 is coated with the attachment agent 15 all along the outer periphery of the super abrasive grain 12 such that the attachment agent 15 has a thickness t smaller than the average grain size \( \Phi \beta \) of the interval adjustment materials 14 (for example, 25 \( \mu \)m to 40 \( \mu \)m). Any coating method may be used. For example, each of the super abrasive grains 12 may be coated with the attachment agent 15. Alternatively, the super abrasive grains 12 may be fed into a barrel along with the attachment agent 15, and the barrel may be rotated to simultaneously coat the entire outer peripheries of the super abrasive grains 12 with the attachment agent 15.

[0039] As described above, the attachment agent 15 is powder that is a mixture of the vitrified bond 16 and the polyacrylic acid (not depicted in the drawings) as the attachment adhesive 17. Specifically, the attachment agent 15 is soft powder and exhibits characteristics similar to the characteristics of soft clay. Thus, when the super abrasive grain 12 is coated with the attachment agent 15 all along the outer periphery of the super abrasive grain 12, the attachment agent 15 is attached to the entire outer periphery. At this time, as described above, the thickness t of the coating of the attachment agent 15 on each super abrasive grain 12 is preferably smaller than the average grain size of the interval adjustment materials 14.

[0040] As illustrated in FIG. 4, the interval adjustment material attachment step S102 in the intermediate material generation step S10 includes a first attachment step S102A serving as a step of generating a secondary intermediate material 22a2 using the primary intermediate material 22a1 and a second attachment step of generating the tertiary intermediate material 22a3 using the secondary intermediate material 22a2. In the first attachment step S102A, the interval adjustment materials 14 are partly buried in the surface of the primary intermediate material 22a1 generated in the attachment agent coating step S101, so that the secondary intermediate material 22a2 is generated in which the interval adjustment materials 14 are in contact with the super abrasive grain 12 as illustrated in FIG. 5B. Specifically, the primary intermediate materials 22a1 and the interval adjustment materials 14 are mixed together using a mixer such that the interval adjustment materials 14 surround each primary intermediate material 22a1.

[0041] In this case, in terms of volume ratio, the total volume of the interval adjustment materials 14 supplied is preferably approximately five times or more as large as the total volume of the super abrasive grains 12. Thus, a large amount of interval adjustment material 14 can be uniformly attached to the surface of each super abrasive grain 12, that is, the surface of the attachment agent 15. A mixture of the primary intermediate materials 22a1 and the interval adjustment materials 14 is fed into a molding die for buried pressuring in which the interval adjustment materials 14 are buried in the primary intermediate materials 22a1. The inner side of the molding die for buried pressing is pressurized at a predetermined pressure. Thus, a molding is generated in which the interval adjustment materials 14 are partly buried in the attachment agent 15 as depicted in FIG. 5B. In the secondary intermediate material 22a2 of FIG. 5B, the interval adjustment materials 14 are held on the super abrasive grain 12 at a portion facing the viewer and at a portion facing away from the viewer. However, for convenience of description, the illustration of the interval adjustment materials 14 held on the super abrasive grains 12 at the portions facing the viewer and facing away from the viewer is omitted.

[0042] In the second attachment step S102B, some of the interval adjustment materials 14 attached to the secondary intermediate material 22a2 generated in the first attachment step S102A are removed to generate the tertiary intermediate material 22a3 in which the interval adjustment materials 14 are discretely arranged on the super abrasive grain 12 as depicted in FIG. 3. Specifically, the secondary intermediate materials 22a2 may be sequentially shifted through different scribe lines in order of increasing fineness so that large secondary intermediate materials 22a2 with a large number of interval adjustment materials 14 attached therto are sequentially removed in order of decreasing grain size. This allows removal of those of the secondary intermediate materials 22a2 which have large external dimensions as a result of a large number of interval adjustment materials 14 attached to the secondary intermediate materials 22a2. Consequently, the tertiary intermediate materials 22a3 are sorted out which have small external dimensions and in which the interval adjustment materials 14 are discretely arranged on the surface of each super abrasive grain 12.

[0043] In the pressuring step S12, the sorted-out tertiary intermediate materials 22a3 are fed into a molding die for interval adjustment pressuring that allows the intervals between the super abrasive grains 12 to be adjusted. The interior of the mold is pressurized at a predetermined pressure. Thus, as depicted in FIG. 3, the tertiary intermediate material 22a3, and the interval adjustment materials 14 and super abrasive grain 12 of the tertiary intermediate material 22a3 are moved by the pressure for the pressuring. The mixture is then adjusted such that two or more interval adjustment materials 14 are not arranged between the super abrasive grains 12 in a direction from one of the super abrasive grains 12 to the other. There is a slight possibility that two interval adjustment materials 14 may be arranged in contact with each other. Even in this case, the separation distance is twice or less as large as the grain size of the interval adjustment materials 14. Normally, the super abrasive grains 12 are arranged so as to be separated from each other by a distance equal to the grain size of the interval adjustment materials 14. A molding shaped in the pressuring step S12 is a structure in which the tertiary intermediate materials 22a3 are integrally molded by a pressuring force. In the present embodiment, the molding is shaped like a ring corresponding to the grinding wheel layer 22.
The thickness $t$ of the coating of the attachment agent $15$ on each super abrasive grain $12$ is smaller than the average grain size of the interval adjustment materials $14$. When a predetermined pressure is applied to the interior of the molding die to bring the interval adjustment materials $14$ into contact with the attachment agent $15$ on the adjacent super abrasive grains $12$ and the interval adjustment materials $14$ are then buried in the attachment agent $15$, exposed portions of the interval adjustment materials $14$ are easily buried in the attachment agent $15$ without being hindered by the coating thickness $t$ of the attachment agent $15$. Thus, the interval adjustment materials $14$ can come into direct contact with the adjacent super abrasive grains $12$.

Now, in the heating step $S14$, the molding generated in the pressing step $S12$ is heated to generate the grinding wheel layer $22$ depicted in FIG. 1. In the heating step $S14$, after the pressing step $S12$, the pressed ring-like molding is extracted from a mold frame and heated at an appropriate sintering temperature for the vitrified bond $16$ (for example, approximately $1,000^\circ$ C.). Consequently, the polyacrylic acid, which is the attachment agent $17$ forming the attachment agent $15$, is lost. The vitrified bond $16$ forming the attachment agent $15$ is melted and then solidified to bond the adjacent super abrasive grains $12$ and the interval adjustment materials $14$ together. Thus, the super abrasive grains $12$ are firmly bonded to the interval adjustment materials $14$ arranged between the super abrasive grains $12$.

In other words, the vitrified bond $16$ forming the attachment agent $15$ flows from the surfaces of the super abrasive grains $12$ to the surfaces of the interval adjustment materials $14$ to bridge the surfaces of two super abrasive grains $12$ that contact each of the interval adjustment materials $14$ and thus the bridging portions $20$ are formed. In this manner, the ring-like grinding wheel layer $22$ is manufactured. Subsequently, the sintered grinding wheel layer $22$ is secured to the outer periphery of the core $21$ using an adhesive to complete the vitrified bond grinding wheel $10$.

A tissue of the grinding wheel layer $22$ manufactured as described above was observed with a microscope. In the grinding wheel layer $22$, one or two interval adjustment materials $14$ were arranged between each pair of super abrasive grains $12$ (see FIG. 2). The super abrasive grains $12$ were arranged at a distance from one another; the distance was approximately equal to the average grain size $\Phi 3$ of the interval adjustment materials $14$. That is, in a plurality of the tertiary intermediate materials $22a3$ forming the molding, the movement of each super abrasive grain $12$ was regulated by the action of the interval adjustment materials $14$ each arranged between the super abrasive grains, and the minimum separation distance $\alpha$ that was equal to the average grain size $\Phi 3$ of the interval adjustment materials $14$ was maintained between the super abrasive grains $12$. Thus, the vitrified bond grinding wheel $10$ was obtained which had the grinding wheel layer $22$ with a low concentration and in which the super abrasive grains $12$ were uniformly distributed. In the grinding wheel layer $22$ according to the invention, it was found possible to produce not only vitrified bond grinding wheels having a concentration of 200 but those having a lower concentration of down to 100.

In the above-described embodiment, the entire surfaces of the super abrasive grains $12$ were coated with the attachment agent $15$, and the interval adjustment materials $14$ were attached to the attachment agent $15$ on the entire surfaces. Next, unwanted interval adjustment materials $14$ were removed, and the remaining structure was heated. However, the invention is not limited to this aspect. The super abrasive grains $12$ may be coated with the attachment agent $15$ such that only portions of outer peripheral surfaces of the super abrasive grains $12$ where the interval adjustment materials $14$ need to be attached are coated with the agent. This is expected to produce similar effects.

In the above-described embodiment, the surfaces of the super abrasive grains $12$ are coated with the attachment agent $15$ such that the thickness $t$ of the attachment agent $15$ is equal to or smaller than the grain size of the interval adjustment materials $14$. However, the invention is not limited to this aspect. The thickness $t$ may be larger than the grain size of the interval adjustment materials $14$. In this case, the pressuring pressure applied to the molding die for buried pressuring is elevated to allow formation of the grinding wheel layer $22$ which is similar to the grinding wheel layer $22$ in the above-described embodiment and in which the adjacent super abrasive grains $12$ and the interval adjustment materials $14$ are in contact with each other.

In the above-described embodiment, in the first attachment step $S102A$, the interval adjustment materials $14$ are buried in the surface of each primary intermediate material $22a1$ generated in the attachment agent coating step $S101$ to generate the secondary intermediate material $22a2$, and the total volume of the interval adjustment materials $14$ supplied is, in terms of the volume ratio, approximately five times or more as large as the total volume of super abrasive grains $12$. However, the invention is not limited to this aspect. The volume ratio may have any value. This also produces reasonable effects. However, the total volume approximately five times or more as large as the total volume of super abrasive grains $12$ allows the interval adjustment materials $14$ to be attached in a desired amount.

In the above-described embodiment, in the second attachment step $S102B$, the secondary intermediate materials $22a2$ are sintered so that some of the attached interval adjustment materials $14$ are removed. However, the invention is not limited to this aspect, and the second attachment step $S102B$ may be omitted. This also produces reasonable effects. However, provision of the second attachment step $S102B$ allows desired states of the bonding force of the vitrified bond $16$ and the rate of the pores $18$.

In the above-described embodiment, the grinding wheel layer $22$ in the grinding wheel $10$ includes the super abrasive grains $12$ arranged so as not to contact one another, the interval adjustment materials $14$ each interposed between the super abrasive grains $12$ and arranged in contact with the super abrasive grains $12$ and having a grain size that determines the minimum separation distance $\alpha$ between the super abrasive grains $12$, the vitrified bond $16$ that is a binder binding each of the super abrasive grains $12$ to the interval adjustment materials $14$, and the pores $18$ each formed between the super abrasive grains $12$.

Thus, the super abrasive grains $12$ are arranged so as to be reliably separated from each other by a distance equal to the average grain size $\Phi 3$ of the interval adjustment materials $14$, in other words, the minimum separation distance $\alpha$. Since the minimum separation distance $\alpha$ is maintained between the super abrasive grains $12$, it is possible to produce a grinding wheel in which the intervals between the super abrasive grains $12$ are uniform and which has a small variation in grinding resistance along the circumference of the grinding wheel layer $22$. 
In the above-described embodiment, the separation distance between the super abrasive grains 12 is twice or less as large as the grain size of the interval adjustment materials 14 and equal to or longer than the grain size of the interval adjustment materials 14. Thus, a grinding wheel 10 is obtained which has a stable composition and a small variation in grinding resistance.

In the above-described embodiment, the grinding wheel layer 22 is formed of the plurality of intermediate materials 22a. Each intermediate material 22a includes the super abrasive grain 12, the interval adjustment materials 14, and the vitrified bond 16 serving as a binder. Each intermediate material 22a further includes the attachment agent 15 that covers the surface of the super abrasive grain 12 (abrasive grain) and that allows the interval adjustment materials 14 to be attached to the surface of the super abrasive grain 12 such that the interval adjustment materials 14 are exposed from the attachment agent 15.

Thus, when the intermediate material 22a is adjacent to other intermediate materials 22a, each interval adjustment material 14 and the adjacent super abrasive grains 12 are very likely to come into direct contact with each other. Consequently, the interval adjustment materials 14 each are sandwiched between the super abrasive grains 12 that are adjacent to each other so as to be in contact with the interval adjustment material 14. Therefore, the distances between the adjacent super abrasive grains 12 are determined by the grain size of the interval adjustment materials 14 and can be a uniform value.

In the above-described embodiment, the attachment agent is generated by mixing the vitrified bond 16 with the attachment adhesive 17 such as the polyacrylic acid. The intermediate materials 22a (tertiary intermediate materials 22a,3) are heated to cause the attachment adhesive 17 to be evaporated and lost, and to cause the binder to be melted and flow from the surfaces of the super abrasive grains 12 to the surfaces of the interval adjustment materials 14. Consequently, the surfaces of two super abrasive grains 12 that contact each of the interval adjustment materials 14 are bridged.

As described above, when the super abrasive grains 12 are fixed by the vitrified bond 16, the interval adjustment materials 14 are arranged at predetermined intervals on the surfaces of the super abrasive grains 12. Consequently, the pores 18 can be appropriately arranged between the super abrasive grains 12 and between the interval adjustment materials 14.

In the above-described embodiment, in the intermediate materials 22a (secondary intermediate materials 22a,2), the attachment agent 15 holds the interval adjustment materials 14 so as to partly bury each of the interval adjustment materials 14 in the attachment agent 15. This prevents the interval adjustment materials 14 from being separated from the attachment agent 15 and keeps the remaining part of each of the interval adjustment materials 14 exposed from the attachment agent 15.

In the above-described embodiment, in the intermediate materials 22a (primary intermediate materials 22a,1), the entire surfaces of the super abrasive grains 12 are coated with the attachment agent 15. Thus, the interval adjustment materials 14 are more easily attached to the entire surfaces and can be easily arranged between the adjacent super abrasive grains 12, which provides a predetermined interval between the super abrasive grains 12 at a high probability. Consequently, the minimum separation distance α can be appropriately maintained between the super abrasive grains 12.

In the above-described embodiment, in each of the intermediate materials 22a, the thickness t of the attachment agent 15 is smaller than the grain size of the interval adjustment materials 14. Consequently, even when the interval adjustment materials 14 are partly buried in the attachment agent 15, the remaining parts are inevitably exposed. Thus, even when the exposed remaining parts of the interval adjustment materials 14 are buried in the attachment agent 15 on the adjacent super abrasive grains 12, the interval adjustment materials 14 and the adjacent super abrasive grains 12 are very likely to directly contact each other. This allows the minimum separation distance α to be appropriately maintained between the super abrasive grains 12.

In the above-described embodiment, in the intermediate materials 22a (tertiary intermediate materials 22a,3), the interval adjustment materials 14 are discretely arranged on the surface of each super abrasive grain 12. Thus, the pores 18 can be appropriately arranged at positions other than the positions of the interval adjustment materials 14.

In the above-described embodiment, the grain size (average grain size) of the interval adjustment materials 14 is one-fifth to one-third of the grain size (average grain size) of the super abrasive grains 12 (abrasive grains). Thus, the interval adjustment materials 14 with a large grain size determine the interval between the super abrasive grains 12. Thus, a grinding wheel with a desired low concentration can be formed.

In the above-described embodiment, the interval adjustment materials 14 are ceramics or alumina. The use of such a highly versatile material is economical.

The method for manufacturing the grinding wheel 10 in the above-described embodiment includes: the intermediate material generation step S10 of generating the intermediate materials 22a; the interval adjustment materials 14, and the attachment agent 15 that is generated by mixing the vitrified bond 16 and the polyacrylic acid 17 together, covers the surface of the super abrasive grain 12, and that allows the interval adjustment materials 14 to be attached to the surface of the super abrasive grain 12 such that the interval adjustment materials 14 are exposed from the attachment agent 15; the pressurizing step S12 of feeding the intermediate materials 22a into the molding die and pressurizing the interior of the molding die to adjust the distance between the super abrasive grains 12 such that the distance is equal to the minimum separation distance α between the super abrasive grains 12, which is determined by the grain size of the interval adjustment materials 14; and the heating step S14 of heating the molding generated in the pressurizing step S12 to generate the grinding wheel 10. The grinding wheel 10 can be formed by this manufacturing method.

According to the method for manufacturing the grinding wheel 10 in the above-described embodiment, in the heating step S14, the attachment agent 15 is heated to cause the polyacrylic acid 17 to be evaporated and lost, and to cause the vitrified bond 16 serving as a binder to be melted and flow from the surface of the super abrasive grain 12 to the surfaces of the interval adjustment materials 14. Consequently, the surfaces of two super abrasive grains 12 that contact each of the interval adjustment materials 14 are bridged.
pores 18 can be appropriately formed at portions other than the super abrasive grains 12, the interval adjustment materials 14, and the vitrified bond 16.

[0067] According to the method for manufacturing the grinding wheel 10 in the above-described embodiment, the intermediate material generation step S10 includes: the attachment agent coating step S101 of coating the surfaces of the super abrasive grains 12 with the attachment agent 15 to generate the primary intermediate materials 22a1, and the interval adjustment material attachment step S102 of attaching the interval adjustment materials 14 to the primary intermediate materials 22a1 generated in the attachment agent coating step S101 to generate the intermediate materials 22a. Thus, the interval adjustment materials 14 can be reliably arranged between the super abrasive grains 12.

[0068] According to the method for manufacturing the grinding wheel 10 in the above-described embodiment, in the attachment agent coating step S101, the primary intermediate materials 22a1 are generated in which the entire surfaces of the super abrasive grains 12 are coated with the attachment agent 15. The interval adjustment material attachment step S102 includes: the first attachment step S102A of generating the secondary intermediate materials 22a2 in which the interval adjustment materials 14 are attached to the entire surfaces of the primary intermediate materials 22a1 generated in the attachment agent coating step S101; and the second attachment step S102B of removing some of the interval adjustment materials 14 attached to the secondary intermediate materials 22a2 generated in the first attachment step S102A to generate the tertiary intermediate materials 22a3 that each have the interval adjustment materials 14 discretely arranged on the surface of the super abrasive grain 12. Since no extra interval adjustment materials 14 are attached to the super abrasive grains 12, the pores 18 can be appropriately formed at portions other than the super abrasive grains 12, the interval adjustment materials 14, and the vitrified bond 16.

[0069] According to the method for manufacturing the grinding wheel 10 in the above-described embodiment, in the first attachment step S102A, the interval adjustment materials 14 are fed to the outer peripheral surfaces of the primary intermediate materials 22a1 such that the total volume of the interval adjustment materials 14 is five times or more as large as the total volume of the super abrasive grains 12. The interval adjustment materials 14 thus attached to the outer peripheral surface of each of the super abrasive grains 12 at positions including the optimum positions, and then the interval adjustment materials 14 attached to unwanted positions are removed. Consequently, in the state of the intermediate materials 22a, the interval adjustment materials 14 are attached to the optimum positions.

[0070] Unlike normal aggregates, the interval adjustment materials 14 may be arranged between the abrasive grains and held such that the abrasive grain interval has a predetermined value. Furthermore, two or more interval adjustment materials 14 may be arranged in a direction in which the abrasive grains are not separated from one another.

[0071] In the above-described embodiment, the attachment agent forming the attachment agent 15 is the polysacrylic agent. However, the invention is not limited to this. Any attachment agent may be used so long as the attachment agent is lost when heated and is mixed with the vitrified bond such that the mixture is attached to the surface of each super abrasive grain 12 to hold the interval adjustment materials 14 so that the intermediate material 22a can be formed. In the above-described embodiment, the grinding wheel 10 is the vitrified bond grinding wheel containing the vitrified bond as a binder. However, the invention is not limited to this aspect. In another aspect, the grinding wheel may be a metal bond grinding wheel formed using a binder containing metal as a main component. The grinding wheel may be a resinoid bond grinding wheel formed using a binder containing resin as a main component. The temperature in the heating step may be adjusted according to the binder or an attachment agent that can be lost at low temperature may be used. In the above-described embodiment, the abrasive grains of the grinding wheel are the super abrasive grains. However, the invention is not limited to this. The abrasive grains may be abrasive grains containing alumina or silicon carbide.

[0073] In the above-described embodiment, the pressure in the buried pressuring in the interval adjustment material attachment step S102 is lower than the pressuring force in the pressuring step but may be changed according to the binder or the type of abrasive grains.

What is claimed is:

1. A grinding wheel comprising:
   a plurality of abrasive grains arranged so as not to contact with one another;
   interval adjustment materials interposed between the abrasive grains, arranged in contact with the abrasive grains, and having a grain size that allows a distance between the abrasive grains to be equal to a predetermined minimum separation distance;
   a binder that binds each of the abrasive grains to the interval adjustment materials; and
   pores formed between the abrasive grains.

2. The grinding wheel according to claim 1, wherein
   a distance between the abrasive grains is twice or less as large as the grain size of the interval adjustment materials and equal to or larger than the grain size of the interval adjustment materials.

3. The grinding wheel according to claim 1, wherein
   the grinding wheel includes a plurality of intermediate materials each containing the abrasive grain, the interval adjustment materials, and the binder, and
   each of the intermediate materials further comprises an attachment agent that cover a surface of the abrasive grain and that allows the interval adjustment materials to be attached to the surface such that the interval adjustment materials are exposed from the attachment agent.

4. The grinding wheel according to claim 3, wherein
   the binder and an attachment adjuvant are mixed together to generate the attachment agent, the intermediate materials are heated to cause the attachment adjuvant to be evaporated and lost, and to cause the binder to be melted and flow from the surfaces of the abrasive grains to surfaces of the interval adjustment materials, thereby surfaces of two abrasive grains that contact each of the interval adjustment materials are bridged.

5. The grinding wheel according to claim 3, wherein
   in each of the intermediate materials, the attachment agent holds each of the interval adjustment materials partly buried in the attachment agent.

6. The grinding wheel according to claim 3, wherein
   in each of the intermediate materials, the entire surface of the abrasive grain is coated with the attachment agent.
7. The grinding wheel according to claim 3, wherein in each of the intermediate materials, a thickness of the attachment agent is smaller than the grain size of the interval adjustment materials.

8. The grinding wheel according to claim 3, wherein in each of the intermediate materials, the interval adjustment materials are discretely arranged on the surface of the abrasive grain.

9. The grinding wheel according to claim 1, wherein the grain size of the interval adjustment materials is one-fifth to one-third of a grain size of the abrasive grains.

10. The grinding wheel according to claim 1, wherein the interval adjustment materials are ceramics or alumina.

11. A method for manufacturing a grinding wheel, the method comprising the steps of:
   (a) generating intermediate materials each including:
       an abrasive grain,
       an interval adjustment materials,
       an attachment agent that is generated by mixing a binder and an attachment adjuvant, covers a surface of the abrasive grain and that allows the interval adjustment materials to be attached to the surface such that the interval adjustment materials are exposed from the attachment agent;
       feeding the intermediate materials into a molding die and pressuring an interior of the molding die to adjust a distance between the abrasive grains such that the distance is equal to a minimum separation distance between the abrasive grains determined by a grain size of the interval adjustment materials; and
   (c) heating a molding generated in step (b) to generate the grinding wheel.

12. The method for manufacturing a grinding wheel according to claim 11, wherein in step (c), the attachment agent is heated to cause the attachment adjuvant to be evaporated and lost, and to cause the binder to be melted and flow from the surfaces of the abrasive grains to surfaces of the interval adjustment materials, thereby the surfaces of two abrasive grains that contact with each of the interval adjustment materials are bridged.

13. The method for manufacturing a grinding wheel according to claim 11, wherein step (a) comprises the steps of:
   (d) coating the surfaces of the abrasive grains with the attachment agent to generate primary intermediate materials; and
   (e) attaching the interval adjustment materials to the primary intermediate materials generated in step (d) to generate the intermediate materials.

14. The method for manufacturing a grinding wheel according to claim 13, wherein in step (d), the primary intermediate materials are generated in which the entire surfaces of the abrasive grains are coated with the attachment agent, step (e) comprises the steps of:
   (f) generating secondary intermediate materials in which the interval adjustment materials are attached to the entire surfaces of the primary intermediate materials generated in step (d);
   (g) removing some of the interval adjustment materials attached to the secondary intermediate materials generated in step (f) to generate tertiary intermediate materials that each have the interval adjustment materials discretely arranged on the surface of the abrasive grain and that each serve as the interval material.

15. The method for manufacturing a grinding wheel according to claim 14, wherein in step (f), the interval adjustment materials are fed to outer peripheral surfaces of the primary intermediate materials such that a total volume of the interval adjustment materials is five times or more as large as a total volume of the abrasive grains.

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