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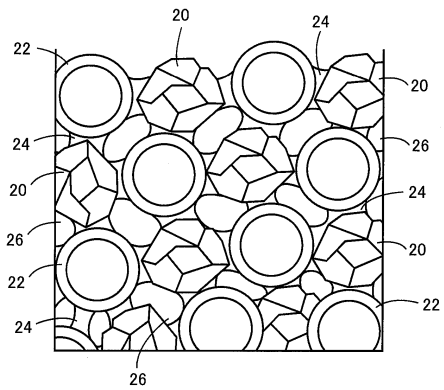
(54) **VITRIFIED GRINDSTONE HAVING ROUGH-TEXTURED HOMOGENEOUS STRUCTURE**

(57) Provided is a vitrified grindstone having a rough-textured (porous) homogeneous structure, the vitrified grindstone being capable of grinding even hard-to-cut materials without generating a burn and while retaining shape-maintenance properties. According to to this vitrified grindstone having a rough-textured homogeneous structure, abrasive grains fill the vitrified grindstone at a proportion of 23-35 vol% together with an inorganic hollow filler, the abrasive grains being homogeneous so as to have a standard deviation σ of 8.7 or less in a frequency distribution map of abrasive grain area, which is a proportion of solids including the abrasive grains per unit area at a plurality of locations in a cross-section of the vitrified grindstone. This results in high homogeneity in a grindstone structure and maintains shape-maintenance properties (reduction in the amount of wear of the grindstone) even with respect to a rough texture having a low volume ratio of abrasive grains, and therefore the generation of burns in a to-be-cut material is suppressed while properties are mainteined even with respect to hard-to-cut materials.

FIG.4



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Description

Technical Field

[0001] The present invention relates to a vitrified grinding stone having an open and homogeneous structure having a low volume fraction of abrasive grains and being porous, which is suitably applied to a field where grinding load is high and grinding burn is likely to occur on a workpiece.

Background Art

[0002] In general, a high-porosity vitrified grinding stone is known as a grinding stone suitably applied to the field where grinding load is high and grinding burn is likely to occur on a workpiece, such as internal grinding and angular grinding. For example, a high-porosity CBN vitrified grinding stone described in Patent Document 1 is such a type. According to such a high-porosity vitrified grinding stone, pores are artificially formed by a pore forming material to have a high porosity, and as a result, the grinding heat is easily released in grinding under a grinding fluid, and grinding burn on the workpiece is suitably suppressed.

[0003] Meanwhile, in the case of a grinding process in which dulling due to grinding stone shaping and dressing is likely to occur, such as grinding of turbine blades and bearing grooves, and in the case of a grinding process in which the thermal conductivity of a workpiece is low and heat during the process is difficult to escape, there still remains a problem of early burning and shape wear even in the foregoing conventional high-porosity vitrified grinding stone.

[0004] Further, when aiming to reduce processing resistance by lowering the percentage of abrasive grains, an open-structured vitrified grinding stone which forms large pores is formed as a result in order to maintain a wide spacing between the abrasive grains. The foregoing conventional art has a drawback that the structure of the grinding stone is likely to be heterogeneous due to formation of large pores. Further, there is also a drawback that agglomeration of the abrasive grains is likely to occur when the abrasive grains are rearranged due to firing shrinkage if an organic pore forming material which burns out during firing of the grinding stone is used for forming the pores.

Citation List

Patent Documents

[0005]

Patent Document 1: Publication of Japanese Patent No. 3987719
Patent Document 2: Publication of Japanese Patent No. 6013133

Summary of Invention

Technical Problem

[0006] On the other hand, in Patent Document 2, a vitrified grinding stone having a porous and homogeneous structure with a low percentage of abrasive grains in which the contact ratio between abrasive grains is increased to lower the volume fraction of abrasive grains to a certain degree is constituted by forming pores using an alumina balloon to obtain a homogeneous grinding stone structure. As a result, the agglomeration of the abrasive grains when the abrasive grains are rearranged due to firing shrinkage is suppressed, and the occurrences of grinding burn and shape wear are suppressed.

[0007] However, even in the foregoing vitrified grinding stone described in Patent Document 2, there is a case in which reduction in shape retention property (grinding stone wear amount) and grinding burn cannot be sufficiently eliminated depending on grinding conditions, such as the case of grinding a hard-to-cut material such as Inconel (registered trademark), Hastelloy (registered trademark) of Haynes International, Inc., stainless steel, and titanium alloy, and a problem of grinding quality and grinding stone life remains.

[0008] The present invention has been made in view of the foregoing circumstances, and the object thereof is to provide a vitrified grinding stone having an open (porous) and homogeneous structure capable of grinding even a hard-to-cut material without causing burning while maintaining the shape retention property.

[0009] In view of the foregoing circumstances, the present inventors carried out various studies on the volume fraction of abrasive grains and the homogeneity of the grinding stone structure regarding the suppression in work material burn without reducing the shape retention property of a vitrified grinding stone having a porous and open structure whose volume fraction of abrasive grains falls below, for example, 40% by volume, and as a result, found the unexpected fact that even if an inorganic hollow filler is used to obtain a low volume fraction of abrasive grains, which has been conventionally considered not to be able to obtain the shape retention property, the shape retention property (reduction in grinding stone wear amount) is maintained and the effect of suppressing grinding burn can be obtained even for the hard-to-cut material if the homogeneity of the grinding stone structure is increased. The present invention has been made based on this finding. It is presumed that when the dispersion of the inorganic hollow filler having been filled at a ratio in a predetermined range with respect to the volume fraction of abrasive grains is accelerated by lowering the volume fraction of abrasive grains, a homogeneous structure in which abrasive grains and the inorganic hollow filler are close to each other is obtained, whereby the work material burn is suitably suppressed while the shape retention property is maintained.

Solution to Problem

[0010] According to a first aspect of the invention, there is provided a vitrified grinding stone having an open and homogeneous structure in which an abrasive grain and an inorganic hollow filler are bonded by an inorganic bonding agent, wherein the abrasive grain is filled at a proportion by volume fraction of 23 to 35 vol%, and have homogeneity with a standard deviation of 10 or less in a frequency distribution chart of an area ratio of an abrasive grain, which is a distribution chart of proportions of a solid matter including the abrasive grain per unit area at a plurality of locations in a cross section of the vitrified grinding stone.

[0011] According to a second aspect of the invention, in the vitrified grinding stone having the open and homogeneous structure according to the first aspect of the invention, the inorganic hollow filler has an average particle diameter of 1.6 times or less with respect to the abrasive grain.

[0012] According to a third aspect of the invention, in the vitrified grinding stone having the open and homogeneous structure according to the first or second aspect of the invention, the inorganic hollow filler is included 0.2 times to 1.7 times with respect to the volume fraction of the abrasive grain in a volume fraction.

[0013] According to a fourth aspect of the invention, in the vitrified grinding stone having the open and homogeneous structure according to any one of the first to third aspects of the invention, the inorganic bonding agent is included within 10 to 15 vol% in a volume fraction.

[0014] According to a fifth aspect of the invention, in the vitrified grinding stone having the open and homogeneous structure according to any one of the first to fourth aspects of the invention, homogeneity with a standard deviation of 6.5 to 8.7 in the frequency distribution chart of the area ratio of an abrasive grain is provided.

[0015] According to a sixth aspect of the invention, in the vitrified grinding stone having the open and homogeneous structure according to any one of the first to fifth aspects of the invention, the inorganic hollow filler is included within 4 to 45 vol% in a volume fraction.

[0016] According to a seventh aspect of the invention, in the vitrified grinding stone having the open and homogeneous structure according to any one of the first to sixth aspects of the invention, the inorganic hollow filler has an average particle diameter of 0.6 to 1.6 times with respect to the abrasive grain.

[0017] According to an eighth aspect of the invention, in the vitrified grinding stone having the open and homogeneous structure according to any one of the first to seventh aspects of the invention, the inorganic hollow filler has a volume fraction of 0.2 to 1.67 times with respect to the volume fraction of the abrasive grain.

[0018] According to a ninth aspect of the invention, in the vitrified grinding stone having the open and homogeneous structure according to any one of the first to seventh aspects of the invention, the abrasive grain is an alumina abrasive or a silicon carbide abrasive, and the abrasive grain has a grain size of F80 to F120. Advantageous Effects of Invention

[0019] In the vitrified grinding stone according to the first aspect of the invention, the abrasive grain is filled at a proportion of 23 to 35 vol%, and has homogeneity with a standard deviation of 8.5 or less in a frequency distribution chart of an area ratio of an abrasive grain, which is a distribution chart of proportions of a solid matter including the abrasive grain per unit area at a plurality of locations in a cross section of the vitrified grinding stone. As a result, the homogeneity of the grinding stone structure is high and the shape retention property (reduction in the grinding stone wear amount) is maintained even with the low volume fraction of an abrasive grain. Thus, even for the hard-to-cut material, the occurrence of burning on the work material can be suppressed while the shape retention property is maintained.

[0020] In the vitrified grinding stone according to the second aspect of the invention, the inorganic hollow filler has an average particle diameter of 1.6 times or less with respect to the abrasive grain. Therefore, a vitrified grinding stone having a high-porosity, open, and homogeneous structure, provided with a highly homogeneous grinding stone structure can be obtained.

[0021] In the vitrified grinding stone according to the third aspect of the invention, the inorganic hollow filler is included 0.2 times to 1.7 times with respect to the volume fraction of the abrasive grain in a volume fraction. Therefore, a vitrified grinding stone having a high-porosity, open, and homogeneous structure, provided with a highly homogeneous grinding stone structure can be obtained.

[0022] In the vitrified grinding stone according to the fourth aspect of the invention, the inorganic bonding agent is included within 10 to 15 vol% in a volume fraction. From this, a vitrified grinding stone having a high-porosity, open, and homogeneous structure can be obtained.

[0023] In the vitrified grinding stone according to the fifth aspect of the invention, homogeneity with a standard deviation of 6.5 to 8.7 in the frequency distribution chart of the area ratio of an abrasive grain is provided. As a result, even with the low volume fraction of abrasive grain, the homogeneity of the grinding stone structure is high and the shape retention property (reduction in the grinding stone wear amount) is maintained.

[0024] In the vitrified grinding stone according to the sixth aspect of the invention, the inorganic hollow filler is included within 4 to 45 vol% in a volume fraction. Therefore, a vitrified grinding stone having an open and homogeneous structure having a low volume fraction of an abrasive grain and a high porosity can be obtained.

[0025] In the vitrified grinding stone according to the seventh aspect of the invention, the inorganic hollow filler has an average particle diameter of 0.6 to 1.6 times with respect to the abrasive grain. Therefore, a vitrified grinding stone having an open and homogeneous structure having a low volume fraction of an abrasive grain and a high porosity can be obtained.

[0026] In the vitrified grinding stone according to the eighth aspect of the invention, the inorganic hollow filler has a volume fraction of 0.2 to 1.67 times with respect to the volume fraction of the abrasive grain. Therefore, a vitrified grinding stone having an open and homogeneous structure having a low volume fraction of an abrasive grain and a high porosity can be obtained.

[0027] According to a ninth aspect of the invention, in the vitrified grinding stone having the open and homogeneous structure according to any one of the first to seventh aspects of the invention, the abrasive grain is an alumina abrasive or a silicon carbide abrasive, and the abrasive grain has a grain size of F80 to F120. As a result, even if the work material is a hard-to-cut material, it becomes possible to grind the hard-to-cut material using a general abrasive grain without causing the grinding burn.

Brief Description of the Drawings

[0028]

Fig. 1 is a front view showing a vitrified grinding stone having a porous and homogeneous structure according to an embodiment of the present embodiment.

Fig. 2 is a drawing for explaining a grinding example by a grinding device using the vitrified grinding stone of Fig. 1.

Fig. 3 is a process chart for explaining a main part of a method for manufacturing the vitrified grinding stone of Fig. 1.

Fig. 4 is a schematic diagram for explaining an open structure of the vitrified grinding stone of Fig. 1 in an enlarged manner.

Fig. 5 is a chart showing compositions and standard deviations indicating the homogeneity of the grinding stone constitution of a plurality of kinds of test pieces (Example products 1 to 4 and Comparative Example products 1 to 3) in which the composition of the vitrified grinding stone of Fig. 1 is changed in order to confirm the relationship between the volume fraction of abrasive grains and the homogeneity of the grinding stone structure.

Fig. 6 is a graph showing test results of Fig. 5 in a two-dimensional coordinate system having a horizontal axis indicating the volume fraction of abrasive grains and a vertical axis indicating the standard deviation for indicating the homogeneity of the grinding stone constitution.

Fig. 7 is a chart showing compositions and standard deviations indicating the homogeneity of the grinding stone constitution of a plurality of kinds of test pieces (Example products 2 and 5 to 10) in which the composition of the vitrified grinding stone of Fig. 1 is changed in order to show the relationship between the particle/grain size ratio of the inorganic hollow filler to the abrasive grains and the homogeneity of the grinding stone constitution.

Fig. 8 is a graph showing test results of Fig. 7 in a two-dimensional coordinate system having a horizontal axis indicating the particle/grain size ratio of the inorganic hollow filler to the abrasive grains and a vertical axis indicating the standard deviation for indicating the homogeneity of the grinding stone constitution.

Fig. 9 is a chart showing compositions and standard deviations indicating the homogeneity of the grinding stone constitution of a plurality of kinds of test pieces (Example products 1 to 3 and 11 to 21) in which the composition of the vitrified grinding stone of Fig. 1 is changed in order to confirm the relationship between the volume ratio of the inorganic hollow filler to the abrasive grains and the homogeneity of the grinding stone structure.

Fig. 10 is a graph showing test results of Fig. 9 in a two-dimensional coordinate system having a horizontal axis indicating the volume ratio of the inorganic hollow filler to the abrasive grains and a vertical axis indicating the standard deviation for indicating the homogeneity of the grinding stone constitution.

Fig. 11 is a chart showing volume fractions of abrasive grains and homogeneity (standard deviations) in Comparative Example products 4 to 6 and Example product 22, which are grinding stone test pieces prepared for evaluating the grinding stone wear amount corresponding to the shape retention property.

Fig. 12 is a graph showing grinding stone wear amounts in comparison, which are results of grinding stone grinding tests of Comparative Example product 4 and Example product 22 having a large difference in the volume fraction of abrasive grains in Fig. 11.

Fig. 13 is a graph showing grinding stone wear amounts in comparison, which are results of grinding stone grinding tests of Comparative Example products 5 and 6 and Example product 22 having a large difference in the homogeneity in Fig. 11.

Fig. 14 is a photograph showing a burned state of a work material in the grinding test according to Comparative Example product 4 of Fig. 11.

Fig. 15 is a photograph showing a burned state of a work material in the grinding test according to Comparative Example product 5 of Fig. 11.

Fig. 16 is a photograph showing a burned state of a work material in the grinding test according to Comparative Example product 6 of Fig. 11.

Fig. 17 is a photograph showing a burned state of a work material in the grinding test according to Example product 22 of Fig. 11.

Description of Embodiments

[0029] In a mode for carrying out the present invention, for example, a shirasu balloon, an alumina balloon, a mullite balloon, a glass balloon, etc., is preferably used for the inorganic hollow filler.

Embodiment

[0030] Hereinafter, an embodiment of the present invention will be described in detail with reference to the drawings. The drawings are simplified or conceptualized as appropriate in the following embodiment, and the dimensional ratios and shapes of each portion are not necessarily drawn accurately.

[0031] Fig. 1 shows an example of a vitrified grinding stone 10 which is a high-porosity vitrified grinding stone having a porous and homogeneous structure according to one embodiment of the present invention. The vitrified grinding stone 10 is formed in a disc shape as a whole and is rotationally driven around an axis C in a state of being attached to a main shaft of a grinder by using a mounting hole formed in a central portion of the vitrified grinding stone 10. A work material 16 is ground by slidingly contacting the work material 16 with a tapered outer circumferential grinding surface 14 of the vitrified grinding stone 10.

[0032] Fig. 2 shows a case of grinding a corner 18 of a rectangular parallelepiped work material 16 made of a heat-resistant alloy such as Inconel (registered trademark). While the outer circumferential grinding surface 14 is pressed against the corner of the rectangular parallelepiped work material 16 with the vitrified grinding stone 10 rotating, the work material 16 is fed in a longitudinal direction thereof, that is, a direction perpendicular to the sheet of Fig. 2. As a result, the corner 18 of the work material 16 is ground.

[0033] Fig. 4 is a schematic diagram for explaining a structure of the vitrified grinding stone 10 in an enlarged manner. In Fig. 4, abrasive grains 20 composed of general abrasive grains such as an alumina abrasive or a silicon carbide abrasive, and an inorganic hollow filler 22 composed of, for example, a shirasu balloon, an alumina balloon, a mullite balloon, or a glass balloon are mutually bonded by melting of a vitrified bond 24, which is a vitreous inorganic bonding agent. Pores 26 naturally formed due to the absence of a binding agent (molding aid) in a manufacturing process are formed among the abrasive grains 20, the inorganic hollow filler 22, and the vitrified bond 24.

[0034] The abrasive grains 20 are filled at a volume fraction of abrasive grains of 23 to 35 vol%, and have homogeneity with a standard deviation of 8.5 or less in a frequency distribution chart of an area ratio of abrasive grains, which is a proportion of a solid matter including the abrasive grains 20 per unit area at a plurality of locations in a cross section of the vitrified grinding stone 10. As described above, the vitrified grinding stone 10 is a vitrified grinding stone having a porous and homogeneous structure having an extremely low volume fraction of abrasive grains and nevertheless having the grinding stone shape retention property maintained by the homogeneity of the grinding stone structure.

[0035] In the vitrified grinding stone 10, the inorganic hollow filler 22 is included at a volume fraction of filler of 0.2 to 1.7 times with respect to the volume fraction of abrasive grains. Further, the inorganic hollow filler 22 is included at a proportion of 4 to 45 vol%. Further, the inorganic hollow filler 22 has an average particle diameter of 1.6 times or less with respect to the average grain diameter of the abrasive grains 20, preferably has an average particle diameter in a range of 0.6 to 1.4 times. Further, the inorganic hollow filler 22 has a volume ratio of 0.2 to 1.67 times, and preferably 0.43 to 1.4 times with respect to the volume of the abrasive grains 20 in the vitrified grinding stone 10.

[0036] The vitrified bond (inorganic bonding agent) 24 is included at a volume fraction of 10 to 15 vol% in the vitrified grinding stone 10.

[0037] With such a composition, the vitrified grinding stone 10 is provided with homogeneity having a standard deviation of 10 or less, and preferably 6.5 to 8.5 in the frequency distribution chart of the area ratio of abrasive grains, which is the proportion of the solid matter including the abrasive grains 20 per unit area at a plurality of locations in the cross section of the grinding stone.

[0038] The vitrified grinding stone 10 is manufactured according to a process chart shown in Fig. 3, for example. That is, first, in an abrasive grain bond coating process P1, abrasive grains 20 and a powder vitrified bond 24 which is a glass powder fritted after melting and being excellent in high impact resistance and heat resistance and has an average particle diameter of, for example, 1/10 or less of the abrasive grains 20 are mixed together with a well-known binding agent (molding aid) such as a synthetic adhesive paste represented by dextrin. As a result, a coating composed of the vitrified bond (inorganic bonding agent) 24 and the binding agent is formed on an outer surface of the abrasive grain 20 in a layered form and is dried according to need, whereby further fluidity is given. Also, in a filling agent particle bond coating process P2, the inorganic hollow filler 22 composed of, for example, a mullite balloon is mixed together with the same vitrified bond 24 as described above and a well-known binding agent such as dextrin. As a result, a coating composed of the vitrified bond 24 and the binding agent is formed on an outer circumferential surface of the inorganic hollow filler 22 in a layered form and is dried according to need, whereby further fluidity is given.

[0039] The vitrified bond 24 is a glass powder excellent in high impact resistance and heat resistance, and is composed of, for example, glass frit having an oxide composition of 50 to 80% by weight of SiO_2, 10 to 20% by weight of B_2O_3, 5 to 15% by weight of Al_2O_3, 8 to 15% by weight of a total of metal oxides selected from CaO, MgO, K_2O, and Na_2O, or glass frit having an oxide composition of 70 to 90% by weight of SiO_2, 10 to 20% by weight of B_2O_3, 1 to 5% by weight of Al_2O_3, and 1 to 5% by weight of Na_2O_3, that is, powder glass fritted after melting. The vitrified bond 24 may be such that gairome clay, etc., is added to the above powder glass. The vitrified bond 24 is preferably rounded-off particles obtained by wet milling, and has 55 vol% or more of single volume fraction when a molding pressure of 300 kg/mm^2 is applied, and has 1.2 or more of apparent density (bulk specific gravity) according to measurement based on a standard of ASTM D2840.

[0040] The abrasive grains 20 have a grain size in a range of, for example, F80 to F120, and have a grain diameter, for example, whose average grain diameter is in a range of about 180 μm to 106 μm, and is filled at a proportion of 23 to 35 vol%.

[0041] The inorganic hollow filler 22 is closed type hollow particles, for example, having an apparent density of 0.5 to 1.0 g/cm^3, a bulk density of 0.25 to 0.45 g/cm^3, a compression strength of 70 N/mm^2, a melting point of 1200°C or higher, and a water absorption of almost zero.

[0042] The inorganic hollow filler 22 is prepared so as to have a volume fraction of filler of 0.4 to 1.7 times with respect to the volume fraction of abrasive grains of the abrasive grains 20, a volume proportion of 15 to 45 vol%, and a volume ratio of 0.43 to 1.67 times with respect to the volume of the abrasive grains 20.

[0043] Next, in a mixing process P3, the abrasive grains 20 and the inorganic hollow filler 22 to which the foregoing corresponding coatings are applied are put into a mixer together with a well-known binding agent such as dextrin, and mixed uniformly there. Next, in a molding process P4, the foregoing mixed material is filled into a predetermined press die for forming a cylindrical molding space, and pressurized by a pressing machine to be molded. In a firing process P5, a molded article having undergone the molding process P4 is sintered under a firing condition that a temperature of, for example, about 900°C is maintained for 0.5 hours in a predetermined firing furnace. This sintering burns off the binding agent and melts the vitrified bond 24 to form a molten glass body. Thus, as shown in the diagram of the structure of the vitrified grinding stone of Fig. 4, the abrasive grains 20 and the inorganic hollow filler 22 are mutually bonded via the melted vitrified bond 24 to form the vitrified grinding stone 10. Next, in a finishing process P6, the vitrified grinding stone 10 is manufactured by being ground or mechanically finished using a grinding tool so that outside dimensions such as the outer circumferential surface and the end surface meet a predetermined product specification. The vitrified grinding stone 10 is shipped through an inspection process P7.

[0044] According to the vitrified grinding stone 10 provided with the grinding stone structure as shown in Fig. 4 by being manufactured as described above, the vitrified grinding stone structure in which the abrasive grains 20 contribute relatively greatly to grinding performance and the inorganic hollow filler 22 constituting the grinding stone structure together with the abrasive grains 20 are bonded by the vitrified bond 24 while being homogeneously filled in a predetermined space is formed. The abrasive grains 20 and the inorganic hollow filler 22 are made homogeneous by the foregoing blending, and a relatively homogeneous distance is formed between the abrasive grains 20 via the inorganic hollow filler 22, so that the occurrence of grinding burn is small and a long grinding stone life can be obtained. Since the abrasive grains 20 and the inorganic hollow filler 22 are homogeneously dispersed and bonded by the vitrified bond 24 while being in contact with or close to each other, the shape retention property is enhanced.

[0045] The present inventors performed homogeneity evaluation test 1, homogeneity evaluation test 2, and homogeneity evaluation test 3 shown below in order to evaluate the dispersibility of the abrasive grains 20 with respect to changes in the volume fraction of abrasive grains and the material quality of the pore forming material, changes in the grain size of the abrasive grains, changes in the volume fraction of the inorganic hollow filler in the grinding stone structure of the vitrified grinding stone 10. In these tests, the vitrified grinding stones were prepared using different compositions and using the same processes as those shown in Fig. 3, and their cross-sectional images were captured with a digital microscope. In each of a plurality of divided (unit) areas in which binarized black-and-while cross-sectional images obtained from the cross-sectional images were divided, the area ratio of a solid matter in the white part was calculated, and a frequency distribution chart with a horizontal axis representing the size of the area ratio and a vertical axis of the cumulative number of the divided areas was created. The standard deviation σ of the frequency distribution chart was calculated as a value indicating the dispersion state, and the homogeneity evaluation test was performed using the standard deviation σ. One side x of the divided area is, for example, a function of an average grain diameter D of the abrasive grains and an abrasive grain deposition rate Vg ($x = (500\ nD^2/4Vg)^{0.5}$). It is indicated that the smaller the standard deviation σ, the higher the homogeneity of the grinding stone structure of the vitrified grinding stone 10.

(Homogeneity Evaluation Test 1)

[0046] In order to evaluate the homogeneity of the vitrified grinding stone when the volume fraction of abrasive grains and the material quality of the inorganic hollow filler were changed, Example product 1 to Example product 4 and Comparative Example product 1 to Comparative Example product 3, which were test pieces of vitrified grinding stones prepared by mixing abrasive grains having a grain size of F100 of Alundum (registered trademark), which is typical alumina-based abrasive grains, with a pore forming material at volume fractions of abrasive grains of 23%, 27%, 31%, and 35% (lowpercentages of abrasive grains corresponding to structure numbers 20, 18, 16, and 14, that is, open structures) and using the same processes as those of Fig. 3 were manufactured, and standard deviations σ were measured from cross-sectional images of the test pieces as described above. Fig. 5 shows compositions and standard deviations σ of the test pieces, and Fig. 6 shows evaluation results thereof in the form of a graph. Amullite balloon (inorganic hollow filler) having an average particle diameter of 125 μm was used as the pore forming material in Example product 1 to Example product 4. On the other hand, an organic pore forming material having an average particle diameter of 250 μm was used as the pore forming material in Comparative Example product 1 to Comparative Example product 3. When an organic pore forming material having an average particle diameter of 125 μm is used in Comparative Example product 1 to Comparative Example product 3, contact points between the abrasive grains are small, so that shrinkage during firing is large, and cracks, etc., which become an origin of grinding stone failure are generated. Therefore, in order to avoid this, the organic pore forming material having the average particle diameter of 250 μm was used. Although not shown in Fig. 5, a vitrified bond at a mutually fixed ratio in a range of 10 to 15 vol% was filled. As shown in Fig. 5 and Fig. 6, in the low volume fraction of abrasive grains of 27 to 35 vol%, firing shrinkage was relatively large and uniform and the standard deviations σ were 10 or more in Comparative Example product 1 to Comparative Example product 3 in which the organic pore forming material was used, whereas firing shrinkage was relatively small and the spacing between the abrasive grains was able to be maintained and the standard deviations σ were sufficiently below 10 and were 7.6 to 8.4 in Example product 1 to Example product 4 in which the inorganic hollow filler was used.

(Homogeneity Evaluation Test 2)

[0047] Vitrified grinding stone test pieces (Example product 2, Example product 5 to Example product 10) having a structure number 16 (volume fraction of abrasive grains of 31%) corresponding to the lower volume fraction of abrasive grains (open structure) in the range of the grain size of F80 to F120 of Alundum (registered trademark), which is typical alumina-based abrasive grains, used for grinding and grooving of a hard-to-cut material were prepared using the same processes as those of Fig. 3. Standard deviations σ were measured from cross-sectional images of the test pieces as described above in order to evaluate the homogeneity. Fig. 7 shows compositions and standard deviations σ of the test pieces, and Fig. 8 shows evaluation results thereof in the form of a graph. As shown in Fig. 7 and Fig. 8, the standard deviations σ were 10 or less, specifically, 6.8 to 9.4 in the particle/grain diameter ratio of the pore forming material to the abrasive grain (= pore forming material / particle/grain diameter) of 0.6 to 1.6 times. In Fig. 8, a tendency is shown that the standard deviations σ are reduced as the particle/grain diameter ratio of the inorganic hollow filler (mullite balloon) to the abrasive grain (= pore forming material / particle/grain diameter) is smaller regardless of the grain size of the abrasive grains.

(Homogeneity Evaluation Test 3)

[0048] Example products 1 to 3 and Example products 11 to 21 in which the volume fraction of the inorganic hollow filler was changed as shown in Fig. 9 in structure numbers 14, 16, 18, and 19 (volume fractions of abrasive grains of 35%, 31%, 27%, and 26%) corresponding to the low volume fraction of abrasive grains (open structure) using a grain size of F100 of Alundum, which is typical alumina-based abrasive grains, used for grinding and grooving of a hard-to-cut material were prepared using the processes shown in Fig. 3. Standard deviations σ were measured from cross-sectional images of the test pieces as described above in order to evaluate the homogeneity. Fig. 9 shows compositions and standard deviations σ of the test pieces, and Fig. 10 shows evaluation results thereof in the form of a graph. As shown in Fig. 9 and Fig. 10, in any of the volume fractions of abrasive grains of 35%, 31%, 27%, and 26%, the volume ratio of the inorganic hollow filler (mullite balloon) to the abrasive grains was in the range of 0.43 to 1.67 and the standard deviation σ was 8.5 or less. In Fig. 10, a hyperbolic tendency characteristic is shown that the standard deviations σ increase as the volume ratio of the inorganic hollow filler to the abrasive grains is lowered regardless of the volume fraction of abrasive grains in the low volume fraction of abrasive grains (volume fractions of abrasive grains of 35%, 31%, 27%, and 26%). The standard deviation σ of 10 or less is obtained in the linear tendency characteristic even if the volume ratio of the inorganic hollow filler to the abrasive grains is 0.35.

[0049] Next, the present inventors manufactured, using the processes shown in Fig. 3, Comparative Example 4 having a structure number 12 (volume fraction of abrasive grains of 39%) and Comparative Example products 5, 6 and Example product 22 having a structure number 14 (volume fraction of abrasive grains of 35%) using a grain size of F80 of abrasive grains which were Alundum (registered trademark), and measured σ from cross-sectional images of the test pieces as described above in order to evaluate the homogeneity. Comparative Example products 5, 6 and Example product 22 have different standard deviations σ due to changes in the volume proportion of the vitrified bond. Fig. 11 shows compositions and standard deviations σ of the test pieces. The standard deviations σ of Comparative Example products 4, 5, and 6 were 8.8, 11.3, and 10.6, whereas the standard deviation σ of Example product 22 was not more than 10 and was 9.8.

[0050] Next, the present inventors used the test pieces shown in Fig. 11 (Comparative Example product 4, Comparative Example product 5, Comparative Example product 6, and Example product 22) to perform a grinding test, for example, shown in Fig. 2, under the following conditions.

(Grinding Test Conditions)

[0051]

Grinder: Surface grinder
Grinding method: Wet speed stroke
Work material: Inconel (registered trademark of Special Metals Corporation)
Table feed speed: Average 20 m/min
Depth of cut: 5.5 mm/min
Grinding stone size: 255 × 19 × 76.2 (mm)
Grinding fluid: Water-soluble grinding fluid
Grinding stone peripheral speed: 45 m/sec

[0052] Fig. 12 is a graph showing grinding stone wear volume ratios (%) when Comparative Example product 4 is set to 100%, which are grinding results of Comparative Example product 4 and Example product 22. The grinding stone wear volume represents the shape retention property of the vitrified grinding stone. As obvious from Fig. 12, Example product 22 is superior in the shape retention property to Comparative Example product 4 having the same homogeneity (standard deviation of not more than 10) due to the difference in the structure of the grinding stone.

[0053] Fig. 13 is a graph showing grinding stone wear volume ratios (%) when Comparative Example product 5 is set to 100%, which are grinding results of Comparative Example products 5 and 6 and Example product 22. The grinding stone wear volume represents the shape retention property of the vitrified grinding stone. As obvious from Fig. 13, Example product 22 is superior in the shape retention property to Comparative Example product 4 having the same structure (volume fraction of abrasive grains) due to the homogeneity of the grinding stone.

[0054] Fig. 14, Fig. 15, Fig. 16, and Fig. 17 show photographs showing burned states of work materials after the grinding test according to Comparative Example product 4, Comparative Example product 5, Comparative Example product 6, and Example product 22, respectively. In each photograph, a white part indicates burning. As shown in Fig. 14, Fig. 15, Fig. 16, and Fig. 17, the grinding burn of Example product 22 is the least, and Comparative Example product 6 and Comparative Example product 5 have increases in burning in order. This indicates that burning is made larger as the homogeneity of the grinding stone is reduced and the standard deviation is increased even if the structure (volume fraction of abrasive grains) is the same. Further, the grinding burn of Example product 22 is less than that of Comparative Example product 4. This indicates that even with the equal homogeneity that the standard deviation is not more than 10, burning is made less due to the difference in the structure, that is, as the volume fraction of abrasive grains is smaller.

[0055] As described above, according to the vitrified grinding stone 10 having the open and homogeneous structure of the present embodiment, the abrasive grain 20 is filled at a proportion of 23 to 35 vol% and have homogeneity with a standard deviation σ of 8.5 or less in the frequency distribution chart of the area ratio of an abrasive grain, which is the distribution chart of proportions of the solid matter including the abrasive grain per unit area at a plurality of locations in the cross section of the vitrified grinding stone 10. As a result, the homogeneity of the grinding stone structure is high and the shape retention property (reduction in the grinding stone wear amount) is maintained even with the open structure with the low volume fraction of an abrasive grain. Thus, even for the hard-to-cut material, the occurrence of burning on the work material can be suppressed while the shape retention property is maintained.

[0056] Further, according to the vitrified grinding stone 10 having the open and homogeneous structure of the present embodiment, the inorganic hollow filler 22 has an average particle diameter of 1. 6 times or less with respect to the abrasive grain 20. Therefore, a vitrified grinding stone 10 having a high-porosity, open, and homogeneous structure, provided with a highly homogeneous grinding stone structure can be obtained.

[0057] According to the vitrified grinding stone 10 having the open and homogeneous structure of the present embodiment, the inorganic hollow filler 22 is included 0.4 times to 1.7 times with respect to the volume fraction of an abrasive grain in a volume fraction. Therefore, a vitrified grinding stone 10 having a high-porosity, open, and homogeneous structure, provided with a highly homogeneous grinding stone structure can be obtained.

[0058] According to the vitrified grinding stone 10 having the open and homogeneous structure of the present embodiment, the vitrified bond (inorganic bonding agent) 24 is included within 10 to 15 vol% in a volume fraction. From this, a vitrified grinding stone 10 having a high-porosity, open, and homogeneous structure can be obtained.

[0059] According to the vitrified grinding stone 10 having the open and homogeneous structure of the present embodiment, the homogeneity having a standard deviation of 6. 5 to 8. 5 in the foregoing frequency distribution chart of the area ratio of an abrasive grain is provided. As a result, even with the low volume fraction of an abrasive grain, the homogeneity of the grinding stone structure is high and the shape retention property (reduction in the grinding stone wear amount) is maintained.

[0060] According to the vitrified grinding stone 10 having the open and homogeneous structure of the present embodiment, the inorganic hollow filler 22 is included within 15 to 45 vol% in a volume fraction. Therefore, a vitrified grinding stone having an open and homogeneous structure having a low volume fraction of an abrasive grain and a high porosity can be obtained.

[0061] According to the vitrified grinding stone 10 having the open and homogeneous structure of the present embodiment, the inorganic hollow filler 22 has an average particle diameter of 0.6 to 1.6 times with respect to the abrasive grain 20. Therefore, a vitrified grinding stone having an open and homogeneous structure having a low volume fraction of an abrasive grain and a high porosity can be obtained.

[0062] According to the vitrified grinding stone 10 having the open and homogeneous structure of the present embodiment, the inorganic hollow filler 22 has a volume fraction of 0.43 to 1.67 times with respect to the volume fraction of the abrasive grain 20. Therefore, a vitrified grinding stone having an open and homogeneous structure having a low volume fraction of an abrasive grain and a high porosity can be obtained.

[0063] According to the vitrified grinding stone 10 having the open and homogeneous structure of the present embodiment, the abrasive grain 20 is the alumina abrasive or the silicon carbide abrasive, and the grain size of the abrasive grain 20 is F80 to F120. As a result, even if the work material is a hard-to-cut material, it becomes possible to grind the hard-to-cut material using a general abrasive grain without causing the grinding burn.

[0064] Although one embodiment of the present invention is described above with reference to the drawings, the present invention can also be applied to other aspects of the present invention.

[0065] For example, the vitrified grinding stone 10 of the foregoing embodiment has a disc shape as shown in Fig. 1, for example, but may have another shape such as a cup shape or a block shape.

[0066] It should be noted that what has been described above is only an embodiment, and although other examples are not exemplified, the present invention can be practiced in a mode in which various modifications and improvements are added based on the knowledge of those skilled in the art without departing from the gist of the present invention.

Reference Signs List

[0067]

10: vitrified grinding stone
20: abrasive grain
22: inorganic hollow filler
24: vitrified bond (inorganic bonding agent)

Claims

1. A vitrified grinding stone having an open and homogeneous structure in which an abrasive grain and an inorganic hollow filler are bonded by an inorganic bonding agent, wherein
the abrasive grain is filled at a proportion by volume fraction of 23 to 35 vol%, and has homogeneity with a standard deviation of 10 or less in a frequency distribution chart of an area ratio of an abrasive grain, which is a distribution chart of proportions of a solid matter including the abrasive grain per unit area at a plurality of locations in a cross section of the vitrified grinding stone.

2. The vitrified grinding stone having the open and homogeneous structure according to claim 1, wherein the inorganic hollow filler has an average particle diameter of 1.6 times or less with respect to the abrasive grain.

3. The vitrified grinding stone having the open and homogeneous structure according to claim 1 or 2, wherein the inorganic hollow filler is included 0.2 times to 1.7 times with respect to the volume fraction of the abrasive grain in a volume fraction.

4. The vitrified grinding stone having the open and homogeneous structure according to any one of claims 1 to 3, wherein the inorganic bonding agent is included within 10 to 15 vol% in a volume fraction.

5. The vitrified grinding stone having the open and homogeneous structure according to any one of claims 1 to 4, wherein homogeneity with a standard deviation of 6.5 to 8.7 in the frequency distribution chart of the area ratio of an abrasive grain is provided.

6. The vitrified grinding stone having the open and homogeneous structure according to any one of claims 1 to 5, wherein the inorganic hollow filler is included within 4 to 45 vol% in a volume fraction.

7. The vitrified grinding stone having the open and homogeneous structure according to any one of claims 1 to 6, wherein the inorganic hollow filler has an average particle diameter of 0.6 to 1.6 times with respect to the abrasive grain.

8. The vitrified grinding stone having the open and homogeneous structure according to any one of claims 1 to 7, wherein the inorganic hollow filler has a volume fraction of 0.2 to 1.67 times with respect to the volume fraction of the abrasive grain.

9. The vitrified grinding stone having the open and homogeneous structure according to any one of claims 1 to 8, wherein the abrasive grain is an alumina abrasive or a silicon carbide abrasive, and the abrasive grain has a grain size of F80 to F120.

FIG.1

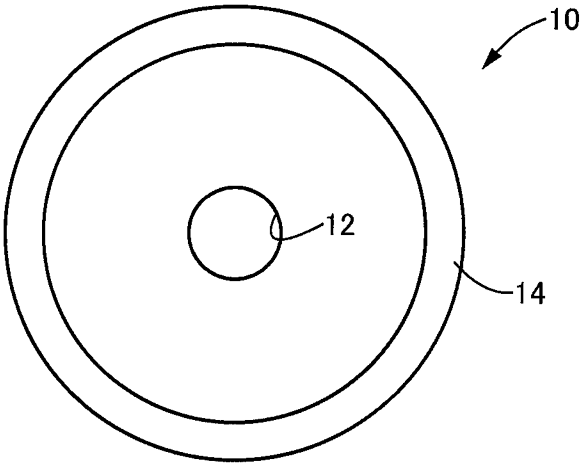


FIG.2

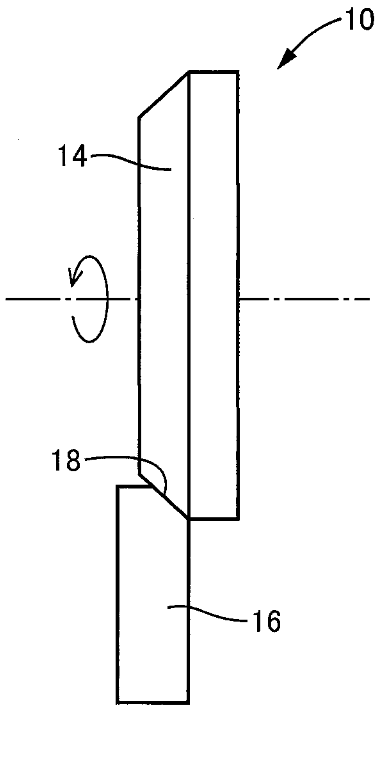


FIG.3

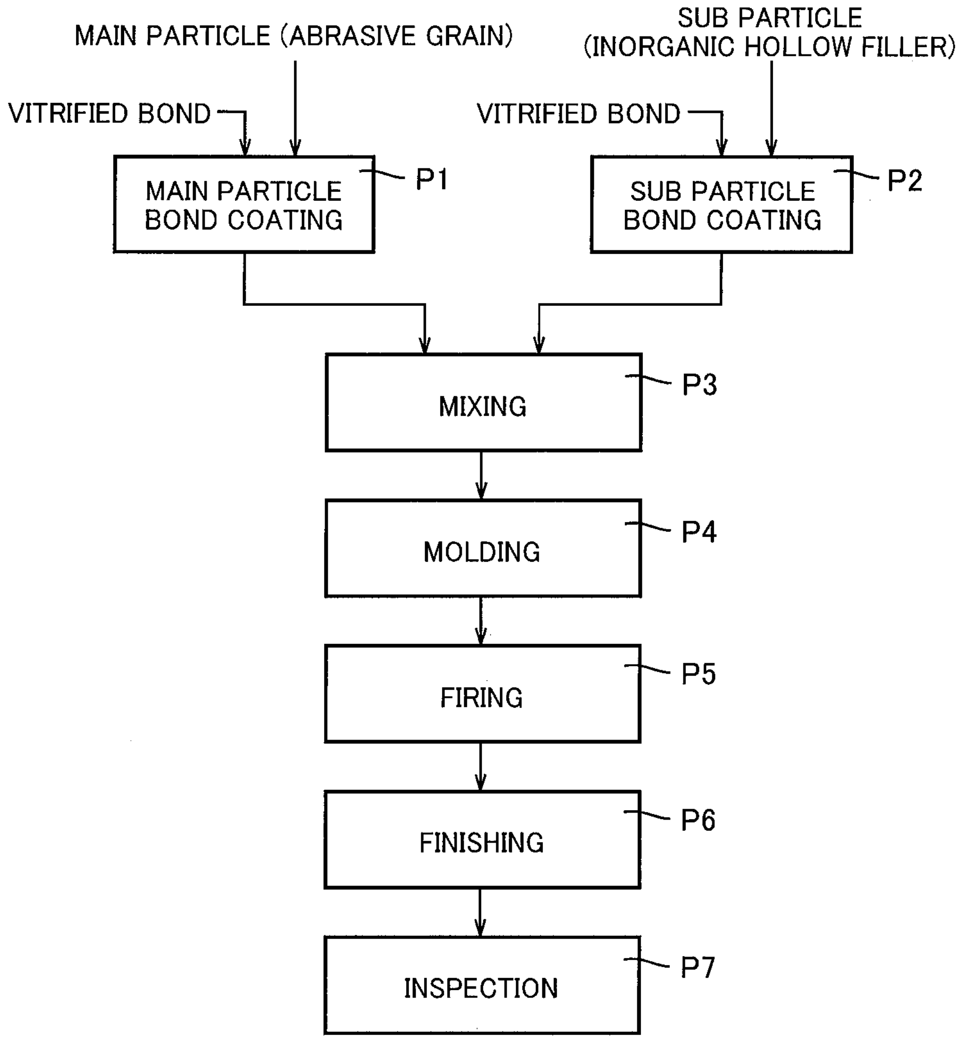

MAIN PARTICLE (ABRASIVE GRAIN)
SUB PARTICLE
(INORGANIC HOLLOW FILLER)
VITRIFIED BOND
VITRIFIED BOND
MAIN PARTICLE
BOND COATING
P1
SUB PARTICLE
BOND COATING
P2
MIXING
P3
MOLDING
P4
FIRING
P5
FINISHING
P6
INSPECTION
P7

FIG.4

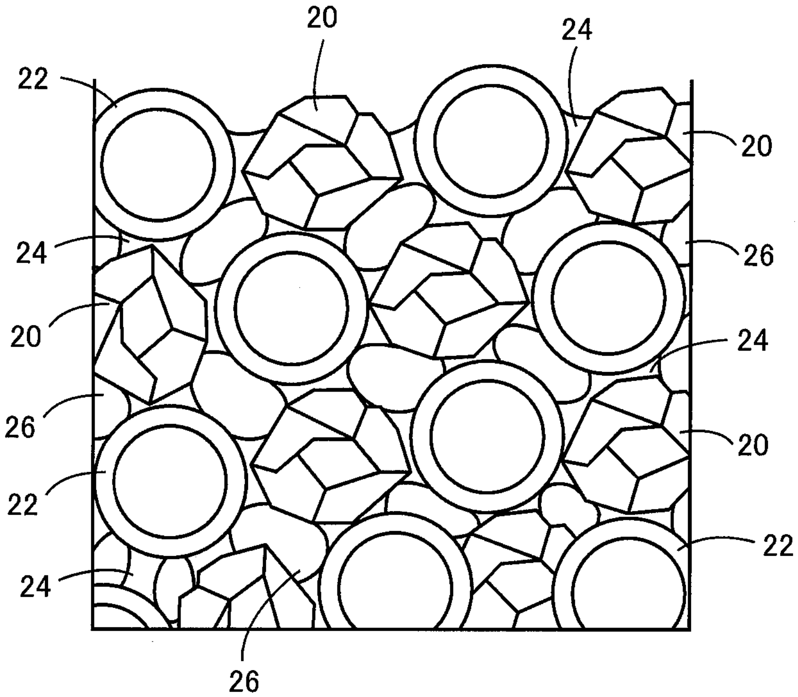
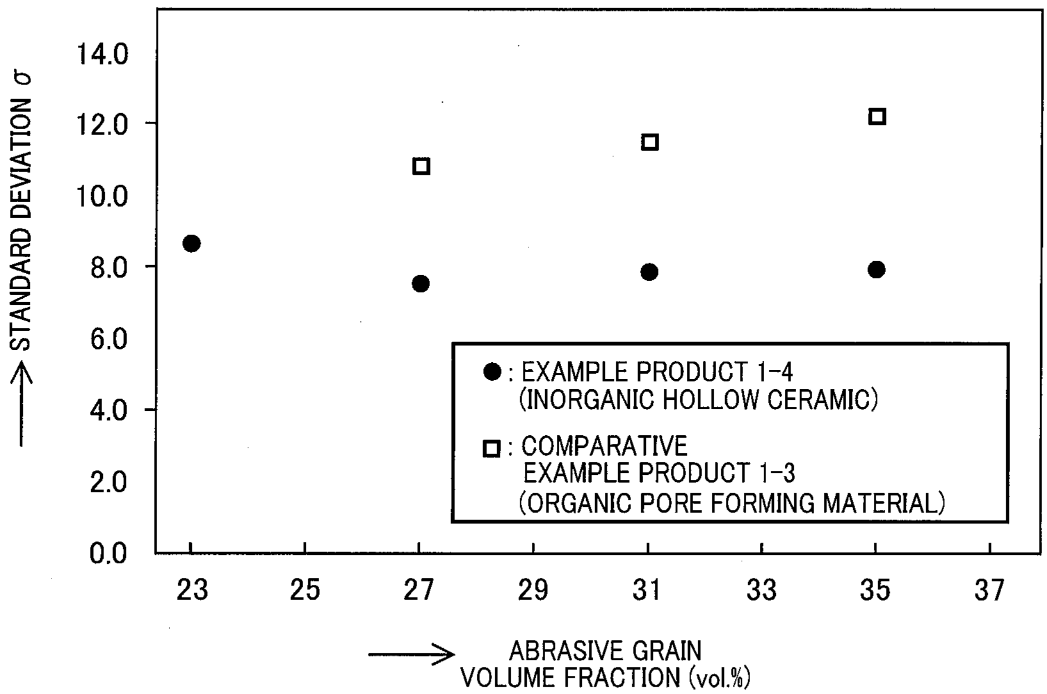


FIG.5

TEST PIECE NO.	ABRASIVE MATERIAL GRAIN SIZE	STRUCTURE	ABRASIVE GRAIN VOLUME FRACTION vol.%	PORE FORMING MATERIAL	ABRASIVE MATERIAL AVERAGE GRAIN DIAMETER μm	PORE FORMING MATERIAL AVERAGE PARTICLE DIAMETER μm	PARTICLE/GRAIN DIAMETER RATIO (PORE FORMING MATERIAL/ ABRASIVE GRAIN)	PORE FORMING MATERIAL VOLUME FRACTION vol.%	VOLUME RATIO (PORE FORMING MATERIAL/ ABRASIVE GRAIN)	STANDARD DEVIATION σ
EXAMPLE PRODUCT 1	F100	14	35	INORGANIC HOLLOW FILLER	125	125	1.0	25	0.71	7.9
EXAMPLE PRODUCT 2	F100	16	31	INORGANIC HOLLOW FILLER	125	125	1.0	25	0.81	7.8
EXAMPLE PRODUCT 3	F100	18	27	INORGANIC HOLLOW FILLER	125	125	1.0	25	0.93	7.6
EXAMPLE PRODUCT 4	F100	20	23	INORGANIC HOLLOW FILLER	125	125	1.0	23	1.00	8.4
COMPARATIVE EXAMPLE PRODUCT 1	F100	14	35	ORGANIC PORE FORMING MATERIAL	125	250	2.0	25	0.71	12.1
COMPARATIVE EXAMPLE PRODUCT 2	F100	16	31	ORGANIC PORE FORMING MATERIAL	125	250	2.0	25	0.81	11.4
COMPARATIVE EXAMPLE PRODUCT 3	F100	18	27	ORGANIC PORE FORMING MATERIAL	125	250	2.0	25	0.93	10.8

FIG.6



STANDARD DEVIATION σ
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
23
25
27
29
31
33
35
37
ABRASIVE GRAIN VOLUME FRACTION (vol.%)
●: EXAMPLE PRODUCT 1-4 (INORGANIC HOLLOW CERAMIC)
□: COMPARATIVE EXAMPLE PRODUCT 1-3 (ORGANIC PORE FORMING MATERIAL)

FIG.7

TEST PIECE NO.	ABRASIVE MATERIAL GRAIN SIZE	STRUCTURE	ABRASIVE GRAIN VOLUME FRACTION vol.%	PORE FORMING MATERIAL	ABRASIVE MATERIAL AVERAGE GRAIN DIAMETER μm	PORE FORMING MATERIAL AVERAGE PARTICLE DIAMETER μm	PARTICLE/GRAIN DIAMETER RATIO (PORE FORMING MATERIAL/ ABRASIVE GRAIN)	PORE FORMING MATERIAL VOLUME FRACTION vol.%	VOLUME RATIO (PORE FORMING MATERIAL/ ABRASIVE GRAIN)	STANDARD DEVIATION σ
EXAMPLE PRODUCT 5	F80	16	31	INORGANIC HOLLOW FILLER	180	200	1.1	25	0.81	7.9
EXAMPLE PRODUCT 6	F80	16	31	INORGANIC HOLLOW FILLER	180	125	0.7	25	0.81	7
EXAMPLE PRODUCT 7	F100	16	31	INORGANIC HOLLOW FILLER	125	200	1.6	25	0.81	9.4
EXAMPLE PRODUCT 2	F100	16	31	INORGANIC HOLLOW FILLER	125	125	1.0	25	0.81	7.8
EXAMPLE PRODUCT 8	F100	16	31	INORGANIC HOLLOW FILLER	125	75	0.6	25	0.81	7.4
EXAMPLE PRODUCT 9	F120	16	31	INORGANIC HOLLOW FILLER	106	125	1.2	25	0.81	8.3
EXAMPLE PRODUCT 10	F120	16	31	INORGANIC HOLLOW FILLER	106	75	0.7	25	0.81	6.8

FIG.8

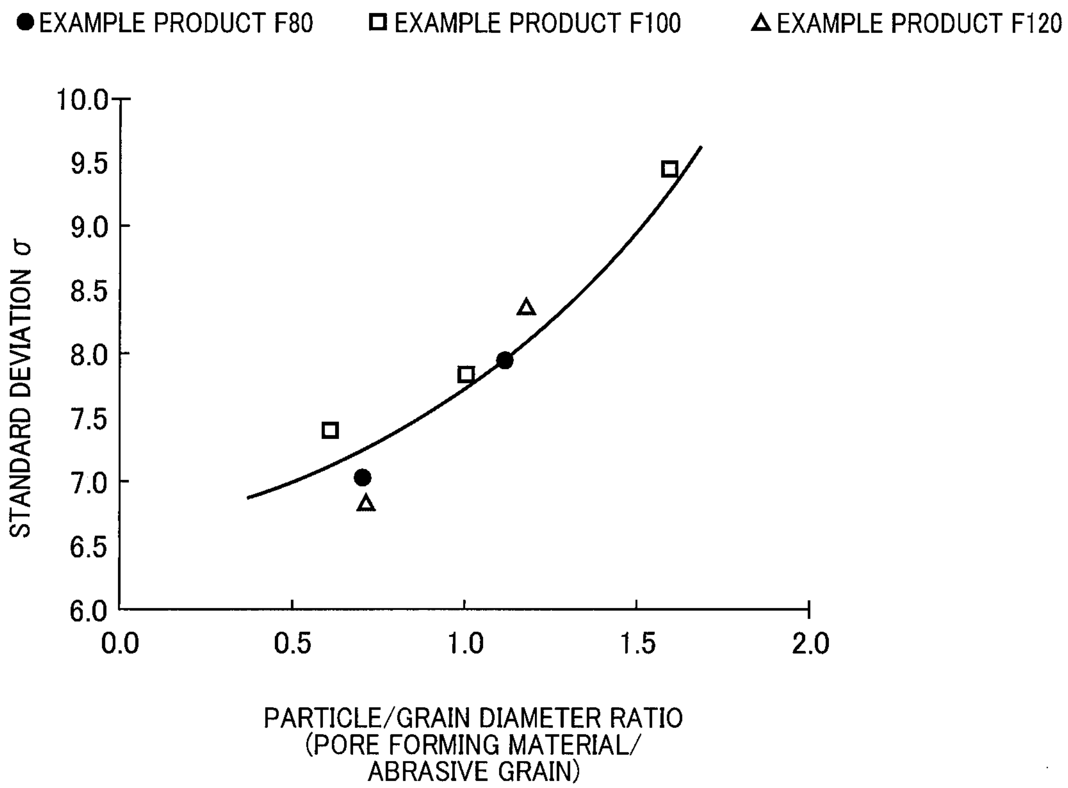
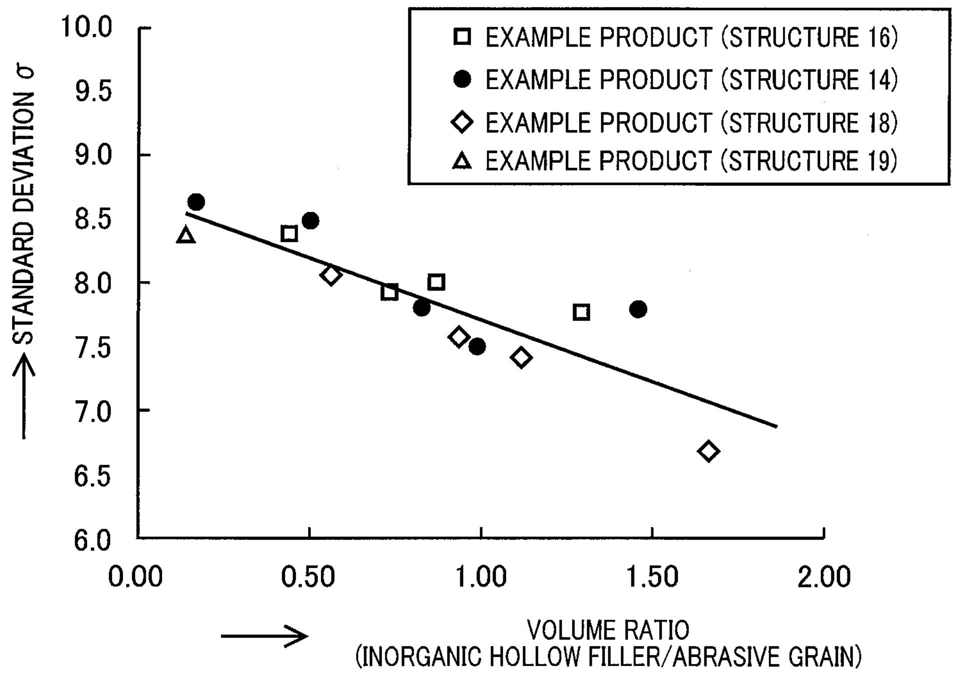

●EXAMPLE PRODUCT F80
□EXAMPLE PRODUCT F100
△EXAMPLE PRODUCT F120
STANDARD DEVIATION σ
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
0.0
0.5
1.0
1.5
2.0
PARTICLE/GRAIN DIAMETER RATIO
(PORE FORMING MATERIAL/
ABRASIVE GRAIN)

FIG.9

TEST PIECE NO.	ABRASIVE MATERIAL GRAIN SIZE	STRUCTURE	ABRASIVE GRAIN VOLUME FRACTION vol.%	PORE FORMING MATERIAL	ABRASIVE MATERIAL AVERAGE GRAIN DIAMETER μm	PORE FORMING MATERIAL AVERAGE PARTICLE DIAMETER μm	PARTICLE/GRAIN DIAMETER RATIO (PORE FORMING MATERIAL/ ABRASIVE GRAIN)	INORGANIC HOLLOW FILLER VOLUME FRACTION vol.%	VOLUME RATIO (INORGANIC HOLLOW FILLER/ ABRASIVE GRAIN)	STANDARD DEVIATION σ
EXAMPLE PRODUCT 11	F100	16	31	INORGANIC HOLLOW FILLER	125	125	1.0	15	0.48	8.5
EXAMPLE PRODUCT 2	F100	16	31	INORGANIC HOLLOW FILLER	125	125	1.0	25	0.81	7.8
EXAMPLE PRODUCT 12	F100	16	31	INORGANIC HOLLOW FILLER	125	125	1.0	30	0.97	7.5
EXAMPLE PRODUCT 13	F100	16	31	INORGANIC HOLLOW FILLER	125	125	1.0	45	1.45	7.8
EXAMPLE PRODUCT 14	F100	14	35	INORGANIC HOLLOW FILLER	125	125	1.0	15	0.43	8.4
EXAMPLE PRODUCT 1	F100	14	35	INORGANIC HOLLOW FILLER	125	125	1.0	25	0.71	7.9
EXAMPLE PRODUCT 15	F100	14	35	INORGANIC HOLLOW FILLER	125	125	1.0	30	0.86	8
EXAMPLE PRODUCT 16	F100	14	35	INORGANIC HOLLOW FILLER	125	125	1.0	45	1.29	7.8
EXAMPLE PRODUCT 17	F100	18	27	INORGANIC HOLLOW FILLER	125	125	1.0	15	0.56	8.1
EXAMPLE PRODUCT 3	F100	18	27	INORGANIC HOLLOW FILLER	125	125	1.0	25	0.93	7.6
EXAMPLE PRODUCT 18	F100	18	27	INORGANIC HOLLOW FILLER	125	125	1.0	30	1.11	7.4
EXAMPLE PRODUCT 19	F100	18	27	INORGANIC HOLLOW FILLER	125	125	1.0	45	1.67	6.7
EXAMPLE PRODUCT 20	F100	16	31	INORGANIC HOLLOW FILLER + ORGANIC PORE FORMING MATERIAL	125	INORGANIC HOLLOW 200 / ORGANIC 140	INORGANIC HOLLOW 1.6 / ORGANIC 1.12	6.0	0.19	8.7
EXAMPLE PRODUCT 21	F100	19	26	INORGANIC HOLLOW FILLER + ORGANIC PORE FORMING MATERIAL	125	INORGANIC HOLLOW 200 / ORGANIC 140	INORGANIC HOLLOW 1.6 / ORGANIC 1.12	4.0	0.15	8.4

FIG.10



STANDARD DEVIATION σ
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
0.00
0.50
1.00
1.50
2.00
VOLUME RATIO
(INORGANIC HOLLOW FILLER/ABRASIVE GRAIN)
EXAMPLE PRODUCT (STRUCTURE 16)
EXAMPLE PRODUCT (STRUCTURE 14)
EXAMPLE PRODUCT (STRUCTURE 18)
EXAMPLE PRODUCT (STRUCTURE 19)

FIG.11

TEST GRINDING STONE	GRAIN SIZE OF ABRASIVE GRAIN	ABRASIVE GRAIN FRACTION vol.%	VITRIFIED BOND vol.%	STANDARD DEVIATION
COMPARATIVE EXAMPLE PRODUCT 4	F80	39	10.9	8.8
COMPARATIVE EXAMPLE PRODUCT 5	F80	35	10.7	11.3
COMPARATIVE EXAMPLE PRODUCT 6	F80	35	10.8	10.6
EXAMPLE PRODUCT 22	F80	35	11.0	9.8

FIG.12

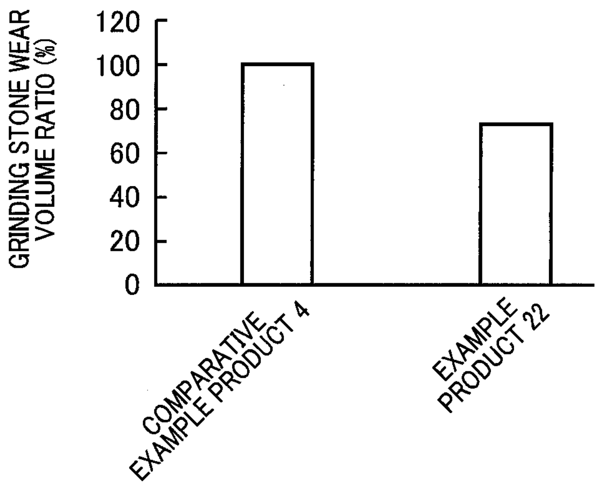


FIG.13

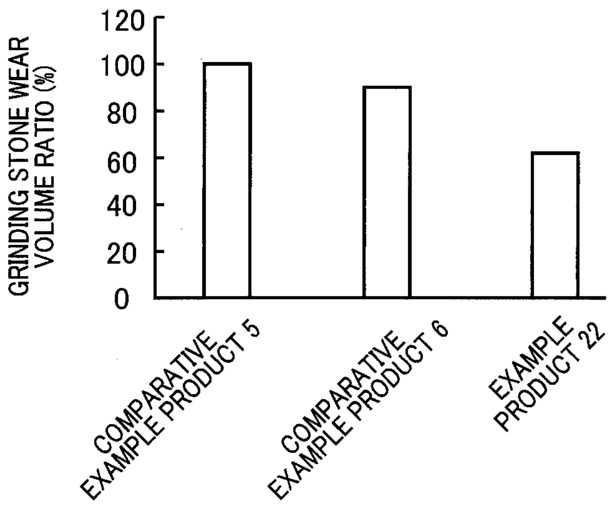


FIG.14

TEST GRINDING STONE 1
STANDARD DEVIATION 8.8

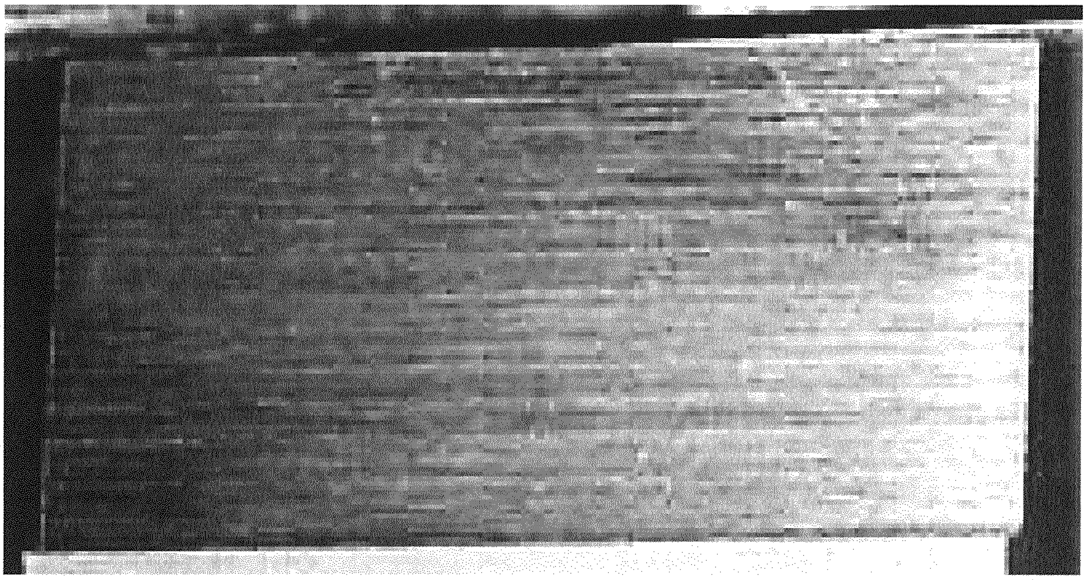


FIG.15

TEST GRINDING STONE 2
STANDARD DEVIATION 11.3

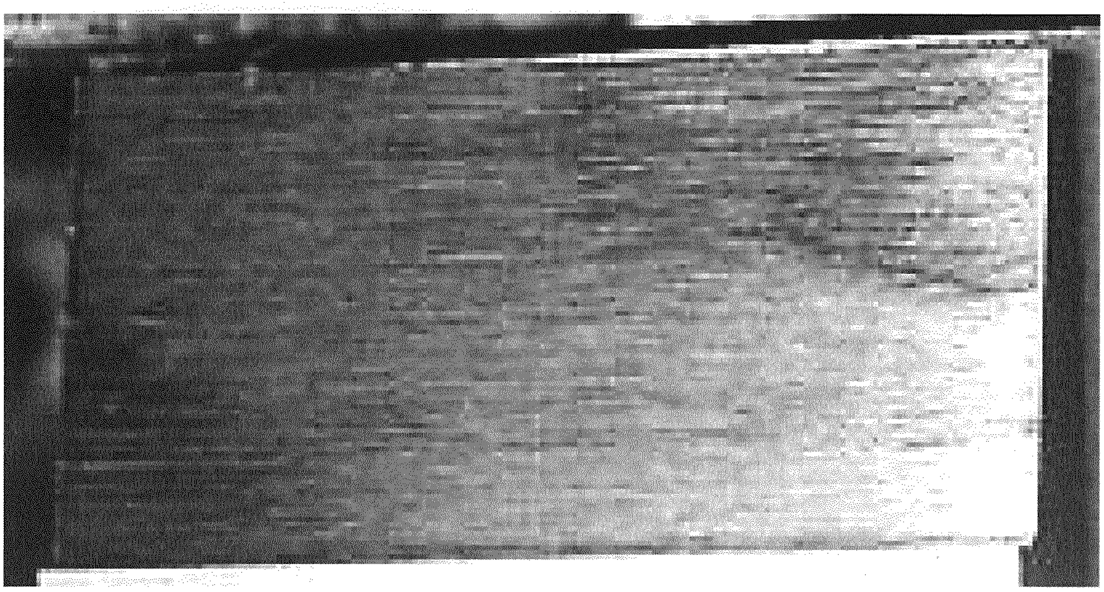


FIG.16

TEST GRINDING STONE 3
STANDARD DEVIATION 10.6

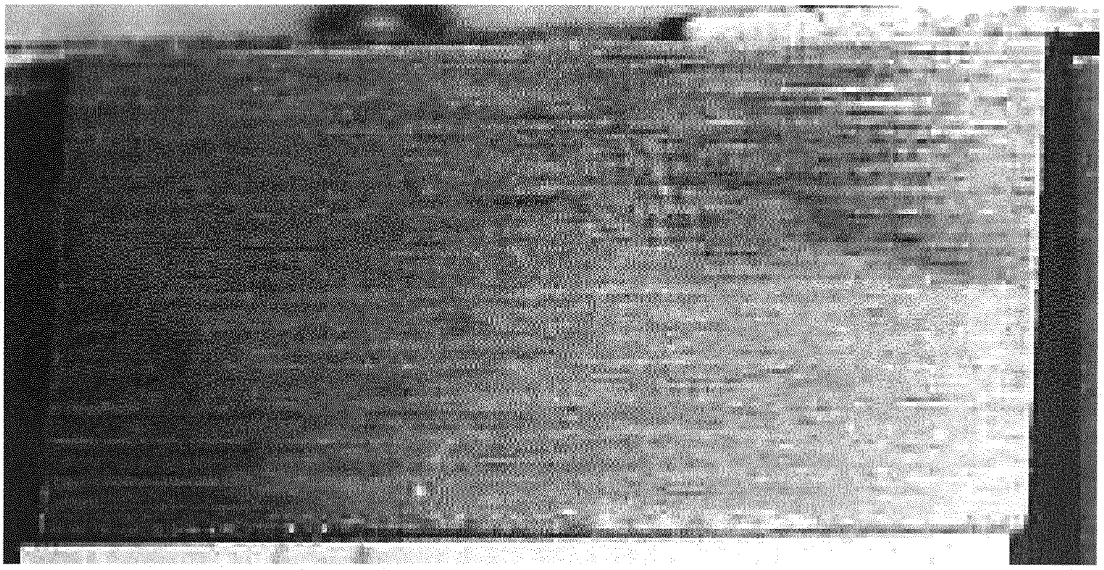
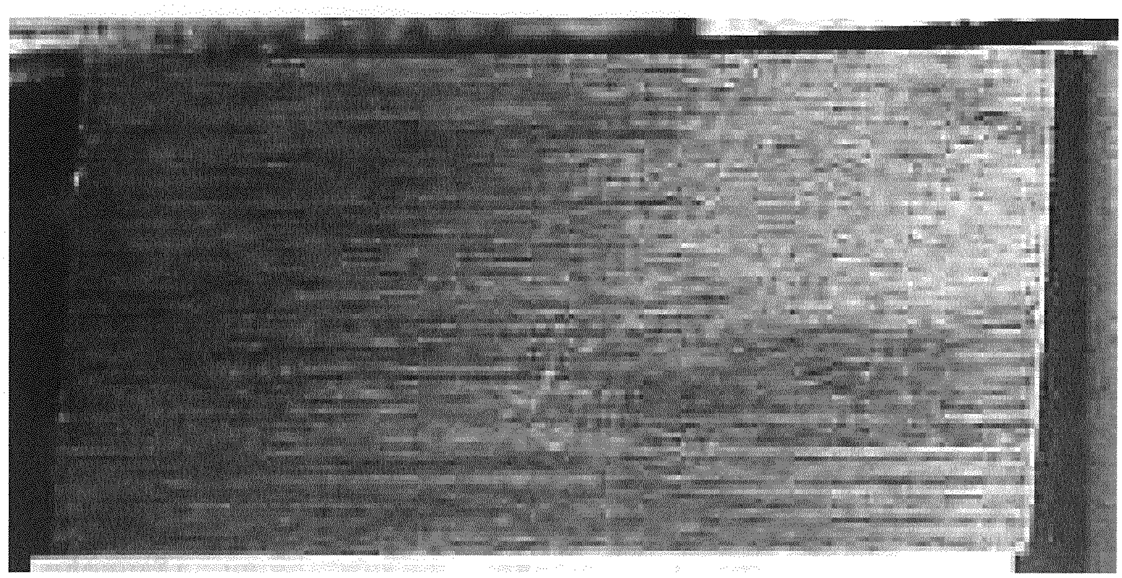


FIG.17

TEST GRINDING STONE 4
STANDARD DEVIATION 9.8



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/008220

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. B24D3/18(2006.01)i, B24D3/00(2006.01)i, B24D3/02(2006.01)i

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)
Int. Cl. B24D3/18, B24D3/00, B24D3/02

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2019
Registered utility model specifications of Japan 1996-2019
Published registered utility model applications of Japan 1994-2019

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.
X Y	JP 2009-72835 A (NORITAKE CO., LTD.) 09 April 2009, paragraphs [0002]-[0007], [0027]-[0050], fig. 3 (Family: none)	1-8 1-9
Y	JP 2014-83621 A (NORITAKE CO., LTD.) 12 May 2014, paragraphs [0011], [0012], fig. 7 (Family: none)	1-9
A	JP 3-184771 A (KURE-NORTON CO., LTD.) 12 August 1991 (Family: none)	1
A	JP 2011-67947 A (SAINT GOBAIN ABRASIVES INC.) 07 April 2011, & US 2003/0045221 A1 & GB 2395200 A & WO 2003/018261 A2	1

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"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
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16.04.2019	07.05.2019

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 3987719 B **[0005]**
- JP 6013133 B **[0005]**