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(54) A GRINDING TOOL FOR MACHINING BRITTLE MATERIALS AND A METHOD OF MAKING A GRINDING TOOL

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Description

FIELD OF THE INVENTION

[0001] The invention relates to a grinding tool, in particular a grinding tool for grinding hard and/or brittle materials such as tungsten carbide. The grinding tool may in particular be a grinding wheel. The invention also relates to a method of making such a grinding tool.

BACKGROUND OF THE INVENTION

[0002] Grinding tools such as grinding wheels are used for machining of brittle materials. One area where such grinding tools are used is machining of tools that are made of hard metal (tungsten carbide). For example, grinding tools may be used for machining operations in which drills or milling tools are shaped by grinding. If the work piece which is to be shaped is made of a hard material such as tungsten carbide, the abrasive tool must have abrasive particles of a very hard material. In practice, this normally means that the abrasive particles are diamond particles or grains of cubic boron nitride. Diamonds or cubic boron nitride grains for this purpose are commercially available and can be considered as standard components. Diamonds for this purpose may typically have an average or mean particle size of 50μm (the size of the particles is of course varying) and have a plurality of sharp edges that can cut hard materials such as tungsten carbide. EP 1 144 160 A1 discloses an abrasive wheel for abrading very hard materials.

[0003] A known type of grinding tool for this purpose is a grinding wheel with a core which may be made of, for example, a metallic material such as steel or aluminum. The core may also be made of a non-metallic material such as a polymeric material. The core can be shaped as a disc which can be mounted on a tool spindle for rotation about the axis of the disc-shaped metal core. An abrasive rim surrounds the core and is joined to the core. The abrasive rim may comprise abrasive particles embedded in a matrix with one or more bonding agents. The material used in the abrasive rim is normally more expensive than the material of the core. For this reason, the abrasive rim has a smaller extension in the radial direction than the core (i.e. the abrasive rim is normally a smaller part of the grinding wheel since it is more expensive).

[0004] During grinding, the abrasive rim is gradually worn down until it is consumed and the grinding wheel can no longer be used.

[0005] Known bonding agents for abrasive rims of grinding wheels include polymeric bonding agents such as, for example, Bakelite. Alternatively, the bonding agent may be a ceramic bonding agent. It is also known to use metallic bonding agents, in particular bonding agents of bronze that have been made by sintering. In such sintering operations, metal powder containing copper and tin is sintered together with abrasive particles such as diamond particles or grains of cubic boron nitride. Sometimes, silver can be added such that the bronze contains copper (Cu), tin (Sn) and silver (Ag). In the past, practical experience has showed that Cu/Sn/Ag alloys function well as bonding agents for abrasives and that such bonding agents function well during grinding. Although the precise reason for this is not entirely understood, it is believed by the inventors that improved thermal conductivity caused by the addition of silver may explain why bronze alloys comprising silver function well as bonding agents for abrasives. However, since silver is expensive, other bronze alloys may be used in order to reduce the cost and the present invention is applicable also to bronze alloys without silver.

[0006] Other known bronze compositions for this purpose include copper/tin/cobalt (Cu/Sn/Co) and copper/tin/nickel (Cu/Sn/Ni). It has also been suggested that bronze compositions for this purpose may include copper/tin/titanium (Cu/Sn/Ti).

[0007] Yet another known system includes hybrids of polymeric and metallic bonding agents in which metallic powder is sintered together with polymeric material such that a matrix is formed in which the polymeric bonding agent and the metallic bonding agent (typically a bronze alloy as described above) are closely intertwined with each other on a microscopic level. In such hybrids, the metal bonding agent and the polymeric bonding agent each forms a network and the respective networks of the bonding agents penetrate each other. Such a hybrid matrix that comprises both a metal bonding agent and a polymeric bonding agent is disclosed in for example US patent No. 6063148.

[0008] In addition to metallic and polymeric bonding agents, such hybrids normally include one or several fillers. One such filler may be graphite which is used for its lubricating properties.

[0009] The abrasive particles used may have different properties. For example, the brittleness of diamonds may vary depending on the purpose for which the grinding tool is to be used. The properties of different diamonds may be matched to meet the properties of different bonding agents (or hybrids of bonding agents).

[0010] In a good grinding tool, the abrasive particles should be bonded in its matrix in such a way that the grinding tool functions as desired. It is desirable that the grinding tool have a good resistance to wear such that it can be used over an extended period. However, good wear resistance is not the only desired property and the grinding tool with the highest resistance to wear is not necessarily the best choice. Other desirable properties include low energy consumption (i.e. that the power required to drive the grinding tool is not excessively high) and constant or at least predictable performance properties. If the grinding effect of the abrasive rim varies too much over time, this causes problems. This is especially the case if the performance of the grinding tool varies in a way that is unpredictable.

[0011] The extent of wear of the grinding tool under given circumstances depends to a very high degree on the properties of the matrix in which the abrasive particles are embedded. Therefore, the composition of the matrix is important.

[0012] When a grinding tool is used for machining a work piece, sharp corners and edges on the abrasive particles act on the work piece. Thereby, force is exerted on abrasive particles embedded in the matrix. During the grinding, the abrasive particles are damaged. Gradually, small pieces break loose from the abrasive particles such that the abrasive particles are gradually worn down. When the abrasive particles in one area of the abrasive rim have been completely worn down, the work piece meets the matrix directly. The matrix as such is less hard than the work piece and it is quickly worn down. As a result, fresh abrasive particles come to the surface of the abrasive rim and can start to act on the work piece.

[0013] However, if the matrix that holds the abrasive particles is too weak, abrasive particles may be torn away from the matrix before they have been worn down. When this happens in part of the surface of the abrasive rim, the work piece will come into direct contact with the relatively brittle matrix and wear down the matrix prematurely. When this happens, power consumption drops momentarily until so much of the matrix has been worn down that fresh abrasive particles come to the surface. As a result, the abrasive rim of the grinding tool is worn out faster than it would otherwise have been. If the operation of the grinding tool has been programmed in advance, the consequence thereof may be that the grinding operation does not function properly since the grinding tool is set to operate based on an assumption of tool diameter that is now incorrect. This problem becomes more serious if the abrasive rim is worn out in a way that is difficult to predict, for example if wear occurs in sudden steps that come in irregular intervals.

[0014] It is also desirable that the required power for the grinding operation can be kept low such that the energy consumption during grinding can be minimized.

[0015] Another desirable property of grinding tools is a high G-ratio. The G-ratio expresses the ratio between the volume of the material removed by the grinding tool from a work piece and the volume lost by the grinding tool (the wear on the tool). A good grinding tool has a high G-ratio.

[0016] Therefore, it is an object of the present invention to provide a grinding tool that has a good resistance to wear. Further objects of the invention are to provide a tool that is worn out in a regular and predictable way, which has a low power requirement and a high G-ratio. These objects are achieved by means of the present invention as will be explained in the following.

SUMMARY OF THE INVENTION

[0017] The invention relates to a grinding tool as defined in claim 1. Preferred embodiments are defined in the dependent claims.

[0018] In embodiments of the invention, the matrix may further optionally comprise a polymeric bonding agent that has been sintered together with the metallic bonding agent such that the polymeric bonding agent and the metallic bonding agent form a connected network.

[0019] In embodiments, the silicon nitride constitutes 0.3 % - 5.0 % by volume of the metallic bonding agent. For example, it may constitute 0.5 % - 5.0 % by volume of the metallic bonding agent, 1.0 % - 5.0 % by volume of the metallic bonding agent, or 0.5 % - 3.0 % by volume or 0.5 % - 2.0 % by volume.

[0020] The silicon nitride may be present in the shape of grains having an average grain size which is preferably less than 10μm but also preferably above 0.1μm. Such particles may be 1250 Tyler mesh particles. The particles may thus include particles up to 10μm even though average grain size is smaller.

[0021] When a polymeric bonding agent is part of the matrix, the polymeric bonding agent may comprise polyimide or be made entirely or almost entirely of polyimide.

[0022] The matrix may optionally additionally comprise filler materials such as graphite.

[0023] Graphite has lubricating properties which may be desirable during grinding.

[0024] The metallic bonding agent is preferably a bronze alloy that comprises copper, tin and silver.

[0025] The abrasive particles may be, for example, diamond particles or cubic boron nitride particles. For both diamonds and cubic boron nitride, the abrasive particles may have a mean particle size in the range of 4μm - 181μm. In many realistic embodiments, the abrasive particles may have a size in the range of 46μm - 91μm. In embodiments of the invention, the abrasive particles may have a coating of copper or nickel.

[0026] The invention also relates to a method of making the inventive grinding tool, as defined in claim 11.

[0027] In embodiments of the inventive method, the metallic powder may additionally comprise silver.

[0028] When reference is made to the relative proportion of silicon nitride in the metal bonding agent, it should be understood that this refers to the volume proportion of the powder used in the manufacturing process. In other words, the method of manufacturing is such that, in the powder added before sintering, silicon nitride will constitute 0.02 % - 2.0% by volume of the metallic bonding agent (the silicon nitride being counted as part of the metal bonding agent). It is assumed that the silicon carbide particles will retain the same relative proportion of total volume also after sintering.

[0029] Optionally, a polymer is added to the metallic powder before sintering, preferably in the form of polyimide powder, such that also a polymeric bonding agent is formed which is a part of the matrix.

[0030] The method may be carried out in such a way that the powder material for the bonding agents of the matrix is mixed with the abrasive particles to form a mixture. The mixture is then compacted in a cold press. The compacted mixture is then cured in a kiln at a temperature in the range of 380°C - 520°C, preferably 400°C - 500°C, for a period of 120 - 150 minutes. Thereafter, the compacted and cured mixture is placed in a press and subjected to a pressure of 1500 - 2000 kg/cm^2. The pressure is then held until the mixture has reached a temperature below 300°C.

[0031] Optionally, filler material is added to the mixture of metallic powder and abrasive particles before the sintering operation. The filler material may optionally comprise graphite.

[0032] The matrix of the inventive grinding tool may advantageously be a matrix which is a hybrid, i.e. a matrix having both a metal bonding agent and a polymeric bonding agent. Hybrid bonding solutions can combine the best properties of metal bonding agents with the best properties of polymeric bonding agents. If re-sharpening by a sharpening tool is needed, a grinding tool with a hybrid matrix can be re-sharpened easier than a pure metal matrix. At the same time, a grinding tool with a hybrid matrix has better resistance to wear than a matrix using only a polymeric bonding agent.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033]

Figure 1	is a schematic representation of a grinding tool.
Figure 2	is a schematic cross sectional representation of abrasive particles embedded in the abrasive rim of a grinding tool.
Figure 3	is a schematic cross sectional representation of a grinding tool that acts on a work piece.
Figure 4	is a diagram that represents the power consumption for two different grinding tools.
Figure 5	is a schematic cross sectional representation of a first embodiment of the inventive grinding tool.
Figure 6	is a schematic cross sectional representation of a second embodiment of the inventive grinding tool.
Figure 7	is a diagram that shows wear of a grinding tool as a function of silicon nitride content.
Figure 8	is a diagram that shows the G-ration of a grinding tool as a function of silicon nitride content.

DETAILED DESCRIPTION OF THE INVENTION

[0034] With reference to Figure 1, a grinding tool 1 is shown. The grinding tool may in particular be a grinding wheel which is intended for machining hard and/or brittle materials such as tungsten carbide. Such materials may be present in work pieces for tools such as for example drills or milling tools and the grinding tool 1 of the present invention may be a grinding wheel that is used for shaping such tools. The grinding tool 1 comprises a core 2 and an abrasive rim 4. The core 2 may be made of a less expensive material such as steel or some other metal. Alternatively, the core could be made of, for example, a polymeric material. The core could also comprise more than one material. For example, it could be made partially by metal such as steel or aluminum and partially be a polymeric material. The core 2 may be provided with a through-hole or cavity 3 such that the grinding tool 1 may be mounted on a spindle (not shown) for rotary movement. With reference to Figure 2, the abrasive rim 4 comprises abrasive particles 5 embedded in a matrix 6. The matrix 6 in turn comprises a metallic bonding agent which is a sintered bronze alloy. The metallic bonding agent constitutes 50 % - 100 % by volume of the matrix 6 and embodiments are thus conceivable in which the entire matrix 6 is made up of the metallic bonding agent. However, the matrix 6 normally comprises at least some other component. For example, it may comprise filler such as graphite that has lubricating properties. In most embodiments, the matrix 6 would also comprise a polymeric bonding agent that may be formed by polyimide.

[0035] If the matrix 6 holds the abrasive particles 5 well, the abrasive particles 5 will emit small fragments and be worn down gradually. As a result, the wear on the abrasive rim 4 will be relatively slow such that the diameter of the grinding tool 1 can be kept substantially constant during a longer period. Moreover, wear on the abrasive rim 4 will be kept at an even pace and the power during operation will not vary so much.

[0036] If the matrix 6 is instead incapable of holding the abrasive particles 5 firmly, it may happen that abrasive particles come loose well before they have been fragmented. As a consequence, they will be lost before their entire abrasive potential has been used. The abrasive tool 1 will be worn out faster and the diameter of the grinding tool (such as a grinding wheel) will decrease faster. A smaller diameter of the grinding tool 1 may result in a less accurate machining of the work pieces.

[0037] With reference to Figure 3, a grinding tool 1 acts on a work piece 7. The work piece 7 may be, for example, a work piece that shall be shaped to a drill. The grinding tool 1 is rotated by means of a power source acting through for example a spindle (not shown). Thereby, the abrasive rim 4 of the grinding tool acts on the work piece 7 to cut a groove in the work piece. In Figure 3, the work piece has a core diameter CD which is determined by the action of the grinding tool 1. If the grinding tool 1 is worn down such that its diameter decreases, the core diameter CD will grow unless the wear is compensated (for example by repositioning of the grinding tool 1 in relation to the work piece 7). It is therefore very desirable that the wear can be kept low and that the wear that does take place does not come in sudden unpredictable leaps.

[0038] It can be added that, when the abrasive particles 5 are properly fragmented piece by piece, this is good for the free-cutting properties of the grinding tool 1, i.e. the ability of the grinding tool to re-sharpen itself. When the abrasive particles 5 become fragmented step by step, the wear on the matrix 6 can occur smoothly and the surface of the abrasive rim 4 does not become clogged so easily. If abrasive particles are instead torn away suddenly before they have been properly fragmented, this tends to lead to increased clogging of the surface; the surface of the abrasive rim 4 may become clogged to a greater extent by small particles 5 from the work piece 7. This may necessitate temporary removal of the grinding tool 1 from operation such that the grinding tool 1 may be re-sharpened. If the abrasive particles 5 are gradually fragmented, the risk of such clogging is smaller. When abrasive particles have been completely worn out, new abrasive particles 5 may come to surface in a smoother process which in itself contributes to re-sharpening of the grinding tool (or rather the abrasive rim 4 of the grinding tool 1).

[0039] When abrasive particles are torn away from the abrasive rim before they have been completely fragmented, this tends to show itself in the power consumption of the grinding tool; the power suddenly drops and then starts to rise again after a while. If the abrasive particles are held properly by the matrix so that they are allowed to fragment as they should, also this can be seen on the power consumption. In such a case, the power tends to remain relatively constant over time (it should be noted, however, that there is normally always a gradual increase in the power requirement from the first work pieces such that less power is required for the very first work pieces).

[0040] It has been suggested in an article by E. D. Kizikov and P. Kebko ("Microadditions to alloys of the system Cu-Sn-Ti", Institute of Superhard Materials, Academy of Science of the Ukrainian SSR, Kiev, in translation from Metallovedenie I Termicheskaya Obrabotka Metallov, No. 1, pp 50 - 53, January 1987) that an alloy of Cu/Sn/Ti which is to be used as binder for diamond-abrasive tools be reinforced with 0.01% silicon nitride (Si_3N_4). According to the authors of that article, this addition resulted in improved yield strength.

[0041] The inventors of the present invention have considered what steps can be taken to improve the ability of the matrix to hold the abrasive particles. Without wishing to be bound by theory, the inventors believe that one reason that metal bonding agents release the abrasive particles embedded therein may be that dislocations inside the metal bonding agent weaken the metallic bonding agent. Assuming this theory to be correct, the inventors first speculated that it should be possible to improve the matrix by reinforcing it with particles blocking dislocations in the metal bonding agent. Consequently, the inventors tried different additions to the metal powder that was used for sintering the metal bonding agent. One additive that was tried was aluminum oxide which was added to an extent corresponding to 1.0 % by volume of the metal bonding agent. This resulted in a certain improvement but the improvement was not as good as the inventors had hoped. The inventors also tried addition of 0.01 % by volume of silicon nitride. The improvement of that addition was even less than the improvement achieved by the aluminum oxide.

[0042] The inventors then investigated whether increased amounts of silicon nitride would produce better results. This was confirmed in testes carried out by the inventors. When silicon nitride was added in quantities significantly larger than 0.01 % by volume of the metal bonding agent, it was discovered that a very substantial improvement was obtained.

[0043] For example, the inventors tested a composition in which the metal bonding agent contained 1.0 % by volume of silicon nitride (Si_3N_4). A grinding tool with this composition was then compared to a standard grinding tool using a hybrid matrix and which did not contain silicon nitride (Si_3N_4). The grinding tools were both grinding wheels in which the abrasive rim 4 was shaped as a ring surrounding the core 2. Under comparable conditions, the diameter of the standard tool was worn down by 136μm while the diameter of the grinding tool with the experimental composition was worn down by only 58μm. The G-ratio for the tool with 1.0 % silicon nitride was 2335. By comparison, a tool using 0.01 % by volume of silicon nitride was worn down 94μm while a tool using 1.0 % by volume aluminum oxide was worn down 84μm.

[0044] A test was made with a composition where silicon nitride constituted 5 % by volume of the metal bonding agent. The resistance to wear was still good but not quite as good as for the grinding tool with 1.0% by volume silicon nitride. Moreover, the tool with 5.0 % silicon nitride had higher power consumption. The G-ratio was good but not quite as good as for the tools with 1.0% and 0.1 % by volume.

[0045] The inventors have also tested a grinding wheel which had a shape and a composition similar to the other tools tested but in which the silicon nitride constituted 0.1 % by volume of the metal bonding agent. It was found that, under the same test conditions as the other tools that were tested, the wear of the tool with 0.1 % by volume silicon nitride was 62μm and the G-ration was 2084. While this was inferior to the results obtained at 1 % by volume, it was still a very substantial improvement compared to the standard grinding tool.

[0046] The inventors have also tested a grinding wheel which had a silicon nitride content of 0.02 % by volume of the metal bonding agent but which was otherwise similar to the other grinding wheels tested. Under similar test conditions, the grinding wheel with 0.02 % by volume of silicon nitride has a wear (diameter reduction) of 58μm and a G-ratio of 2283. The results were thus slightly better than the results obtained at a ratio of 0.1 % by volume.

[0047] The results lead to the conclusion that significantly better results are obtained in the range of 0.02 % - 5.0 % by volume silicon nitride (Si_3N_4). In this range, both G-ratio and resistance to wear has been found to be significantly better than at 0% or 0.01 %.

[0048] Tests of resistance to wear and test of G-ratio have been carried out at 0 % by volume, 0.01 % by volume, 0.02 % by volume, 1.0 % by volume and 5.0 % by volume silicon nitride.

[0049] The tools that were tested were grinding wheels of substantially the kind shown in Figure 5, i.e. grinding tools with an abrasive rim 4 that surrounds a core 2 and where the grinding tool 1 rotates about the axis A during operation. Resistance to wear as a function of silicon nitride content can be seen in Figure 7. The resistance to wear is expressed in Figure 7 as diameter reduction. As can be seen in Figure 7, resistance to wear increased significantly when the content of silicon nitride was increased from 0.01 % to 0.02 %. The wear resistance continued to be high up to a silicon nitride content of 5.0 % by volume of the metallic bonding agent. However, at 5.0 % by volume silicon nitride, the resistance to wear was somewhat lower compared to the resistance observed at a content of 0.02 % - 1.0 %. The inventors have therefore concluded that the best wear resistance is obtained in the range of 0.02 % - 5.0 % by volume.

[0050] The G-ratio as a function of silicon nitride content can be seen in Figure 8. As can be seen in the figure, the best values are obtained at a silicon nitride content in the range of 0.02 % - 5.0%. From Figure 8, it can also be derived that the G-ratio is sinking towards the right in the figure even though the G-ratio at 5.0% by volume is still good.

[0051] Therefore, the inventors have concluded that the metallic bonding agent may contain silicon nitride in an amount that constitutes 0.02 % - 5.0 % by volume of the metallic bonding agent. Since power consumption was higher at 5.0 % by volume, the inventors have concluded that values lower than 5.0% will have good resistance to wear but lower power consumption compared to tools with a silicon nitride content of 5% by volume. Therefore, a preferred range may be 0.02 % by volume to 3.0% by volume, 0.5 % - 3.0 % by volume, 0.5 % - 2.0 % by volume or 1.0 % - 2.0 % by volume of the metallic bonding agent.

[0052] At 0.1 % by volume, power consumption was generally lower than at 0.02 % by volume. At a silicon nitride of 5.0 % by volume, power consumption was higher than at a content of 0.02 % but the power consumption at 5.0 % by volume was more even, the power consumption was more predictable than at 0.02 % by volume.

[0053] The silicon nitride particles should preferably have a size up to 10μm (1250 Tyler mesh). For sieved particles, this will normally mean that average grain size is less than 10μm. The average particle size (D50) of the silicon nitride particles may then be about 2μm - 3μm (depending on how average particle size is measured). The specific surface area of the silicon nitride particles may advantageously be in the range of 5 m^2/g - 6 m^2/g. If the particles used are too small, this may result in clogging and difficulties during manufacturing. Moreover, for giving optimized strength to the metal bonding agent, it is believed by the inventors that particles up to 10μm should preferably be included.

[0054] Normally, the matrix 6 should further comprise a polymeric bonding agent that has been sintered together with the metallic bonding agent such that the polymeric bonding agent and the metallic bonding agent form a connected network (even though such a polymeric bonding agent is optional). The use of a polymeric agent makes it possible to fine tune the properties of the matrix and adapt it to different kinds of abrasive particles. The polymeric bonding agent may suitably be polyimide or comprise polyimide. The reason for this is that polyimide is heat resistant and can withstand the high temperatures during sintering. If a polymeric bonding agent is used, the polymeric bonding agent may be present in an amount of up to 50% by volume of the matrix (i.e. the amount of polymeric bonding agent is in the range of 0% - 50% by volume of the matrix). For example, the polymeric bonding agent may represent 10 % - 40 % or 10% - 30% by volume of the matrix.

[0055] Possibly, the polymeric bonding agent could be formed by some other polymeric material. For example, it could be formed by polyamide-imide which is also capable of withstanding high temperatures. However, polyimide is preferred since it has better grinding properties than polyamide-imide.

[0056] The metallic bonding agent is a preferably a bronze alloy that comprises copper, tin and silver. Silver improves the desirable properties of the metal bonding agent.

[0057] The abrasive particles 5 may be either diamond particles or cubic boron nitride particles. Diamonds are harder and have better abrasive properties but cubic boron nitride is more temperature resistant. Moreover, diamonds may react chemically with certain materials.

[0058] The abrasive particles 5 may be are diamond particles or particles of cubic boron nitride. The particles may be in the range of 4μm - 181μm even though particles outside this range may be considered depending on the requirements in each specific case. In many realistic embodiments, the abrasive particles 5 may have a mean particle size in the range of 46μm - 91μm which is a range that is suitable for many grinding operations.

[0059] The abrasive particles 5 may optionally have a coating of copper or nickel. A coating of copper or nickel can improve the bond between the abrasive particles 5 and the matrix 6. However, the abrasive properties of the particles 5 will be somewhat reduced if the particles have such a coating.

[0060] The relative proportion of abrasive particles 5 in relation to the bonding agents and fillers in the matrix 6 may vary depending on the requirements in each case. In many realistic embodiments, the amount of abrasive particles may represent a 10 % - 50 % of the total volume of the abrasive rim (i.e. the total volume of the abrasive particles and the matrix). If the relative proportion of abrasive particles is higher than 50 %, there is a substantial danger that the matrix will no longer be able to hold the abrasive particles. If the relative proportion of abrasive particles is less than 10 %, the grinding effect may become too small. The relative proportion of abrasive particles may preferably be in the range of 15 % - 30 % and a suitable value may be 25 %.

[0061] Preferably, the silicon nitride is present in the shape of grains having an average grain size which is equal to or less than 10μm but above 0.1μm. For example, they may have a mean size in the range of 1μm - 10μm or 2μm - 9μm . It is believed by the inventors that silicon nitride particles smaller than 0.1μm may result in clogging of the silicon nitride particles which reduces their reinforcing effect.

[0062] The silicon nitride particles may have three different crystallographic structures designated as α, β and γ phases (also known as trigonal phase, hexagonal phase and cubic phase). The α and β phases are the most common. The γ phase can only be synthesized under high pressure and high temperature. Any of these phases can be used. Preferably, the phase used is the α phase. The silicon nitride particles added may also be a mixture of particles of different phases.

[0063] With reference to Figure 4, a grinding tool according to the invention is compared with a standard grinding tool. The vertical axis represents power consumption while the horizontal axis represents number of work pieces upon which the respective grinding tool has acted. In Figure 4, B5 represents a grinding tool according to the invention while EZ represents a standard grinding tool. As can be seen in Figure 4, the tool represented as B5 has a power consumption that first rises steeply and thereafter remains substantially constant. The conventional tool as represented by EZ has a power consumption that rises steeply and then suddenly drops before it rises again. This indicates that the abrasive particles of the B5 tool are slowly fragmented while EZ represents a grinding tool where the abrasive particles are suddenly torn away. The wear on the tool will therefore be faster.

[0064] It can be added that B5 represents a tool with both a metal bonding agent and a polymeric bonding agent. The metal bonding agent is a bronze that has copper, tin and silver. It has been sintered using a metal powder that contains 45 % by volume copper, 45 % by volume tin and 10 % by volume silver. In the tool according to B5, the polymeric bonding agent constitutes 1.0 % by volume of the total amount of bonding agent.

[0065] The grinding tool of Figure 1 may have a cross section as shown in Figure 5. In such an embodiment, the abrasive rim 4 is placed radially outside the core 2 such that the rim 4 completely surrounds the core 2. The tests explained with reference to Figure 4, Figure 7 and Figure 8 have been carried out on such a grinding tool. However, the invention is not limited to such an embodiment. With reference to Figure 6, it should be understood that the core 2 may extend at least as much in the radial direction as the abrasive rim 4. In Figure 6, the grinding tool has an abrasive rim 4 that does not extend beyond the core 2 in the radial direction. Instead, the abrasive rim 4 has an extension in the axial direction that is different from that of the core 2 (the axial direction being the axis of rotation A of the grinding tool 1 when it is driven by a spindle, see Figure 5 and Figure 6). It should also be understood that the grinding tool 1 is not necessarily designed for rotation. Instead, it could act on work pieces in a reciprocating movement. In the context of the claims, the term "core" should thus be understood broadly as any kind of carrier body for the abrasive rim. Likewise, the term "rim" should also be understood broadly as any kind of layer secured to the core 2 such that abrasive particles can act on a work piece.

[0066] The invention further comprises a method of making the inventive grinding tool. The method comprises sintering abrasive particles together with metallic powder that comprises copper and tin such that the sintering results in a matrix in which the abrasive particles 5 are embedded. The matrix comprises a metallic bonding agent which is a sintered bronze alloy. According to the invention, silicon nitride in the form of a powder is added to the metallic powder before sintering to such an extent that the silicon nitride will constitute 0.1% - 5.0% by volume of the metallic bonding agent.

[0067] The metal powder used is preferably metal powder with particles that are smaller than 44μm but they should preferably be larger than the silicon nitride particles. Preferably they should be at least twice as large. An average size in the range of 15μm - 44μm may be suitable.

[0068] The metallic powder may optionally also comprise silver.

[0069] The metal powder may come in the shape of pre-alloyed particles or as particles of pure copper, pure tin, pure silver etc.

[0070] A polymer may be added to the metallic powder before sintering, preferably in the form of polyimide powder, such that also a polymeric bonding agent is formed which is a part of the matrix 6.

[0071] The sintering method may be carried out such that the powder material for the bonding agents of the matrix 6 is mixed with the abrasive particles 5. The mixture is compacted in a cold press. Thereafter the compacted is mixture is cured in a kiln at a temperature in the range of 380°C - 520°C, preferably 400°C - 500°C or 440°C - 460°C, for a period of 120 - 150 minutes. The time required depends on size. In a larger press form, more time is required. Thereafter (preferably immediately thereafter) the compacted and cured mixture is placed in a press and subjected to a pressure of 1500 - 2000 kg/cm^2. The pressure is then maintained until the mixture has reached a temperature below 300°C.

[0072] For example, the inventors have made grinding tools according to this method in a process where the temperature in the kiln was 450°C.

[0073] The abrasive rim 4 may also be manufactured by means of spark plasma sintering (SPS). By this technique, the abrasive rim 4 may be manufactured very fast.

[0074] The rim with the matrix containing abrasive particles may be sintered separately and subsequently fastened (e.g. glued) onto the core 2. Alternatively, the abrasive rim 5 may be sintered directly onto the core 2 such that it is bonded to the core as it is formed. Before sintering, the core 2 may be electrolytically plated with copper on at least one surface of the core which will meet the abrasive rim 4. The abrasive rim 4 can then be sintered onto the copper-plated surface such that a seam is formed.

[0075] Filler material may optionally be added to the mixture of metallic powder and abrasive particles 5 before the sintering operation. As previously explained, the filler material may comprise graphite. Other possible filler materials may include, for example, spheres of aluminum oxide.

[0076] Preferably, the bronze used in the metal bonding agent is selected from the group including copper - tin (Cu/Sn), copper - tin - cobalt (Cu/Sn/Co), copper - tin - nickel (Cu/Sn/Ni) or copper - tin - silver (Cu/Sn/Ag). Even more preferred, the bronze is a copper - tin - silver bronze. Other bronze alloys can also be considered.

[0077] The inventive grinding tool can be used for machining hard and/or brittle materials. This does not exclude the possibility that the grinding tool can be used also for other materials.

[0078] In embodiments of the invention, the matrix 6 may optionally also comprise at least one ceramic component in the shape of ceramic particles. The ceramic component may be, for example, frit and contain SiO_2. Ceramic particles for the matrix may be frit in the shape of spherical particles having a particle size of 50μm - 500μm depending on the size of the abrasive particles. For larger abrasive particles, larger ceramic particles will be used. The abrasive particles may be embedded in the ceramic particles while the ceramic particles are embedded in a hybrid matrix with a metallic bonding agent and a polymeric bonding agent. The ceramic particles may be held stronger by the matrix than the abrasive particles would be held. The free-cutting properties of the abrasive rim are thus improved. The ceramic component does not have such a good resistance to wear as the metallic bonding agent. By combining ceramics, metal and polymeric bonding agents, it is possible to combine the best properties of these bonding agents.

Claims

1. A grinding tool (1) for machining hard and/or brittle materials which grinding tool (1) comprises a core (2) and an abrasive rim (4), the abrasive rim (4) comprising abrasive particles (5) embedded in a matrix (6), the matrix (6) comprising a metallic bonding agent which is a sintered bronze alloy, the metallic bonding agent constituting 50 % - 100 % by volume of the matrix, the metallic bonding agent containing silicon nitride in an amount that constitutes 0.02 % - 2.0 % by volume of the metallic bonding agent wherein the silicon nitride is present in the shape of grains having an average grain size which is less than 10μm and above 0.1μm.

2. A grinding tool (1) according to claim 1, wherein the matrix (6) further comprises a polymeric bonding agent that has been sintered together with the metallic bonding agent such that the polymeric bonding agent and the metallic bonding agent form a connected network.

3. A grinding tool (1) according to claim 1 or claim 2, wherein the silicon nitride constitutes 0.3 % - 2.0 % by volume of the metallic bonding agent.

4. A grinding tool (1) according to claim 1 or claim 2, wherein the silicon nitride constitutes 0.5 % - 2 % by volume of the metallic bonding agent.

5. A grinding tool according to claim 2, wherein the polymeric bonding agent comprises polyimide.

6. A grinding tool according to claim 1 or claim 2, wherein the matrix additionally comprises filler materials such as graphite.

7. A grinding tool according to any of claims 1 - 6, wherein the metallic bonding agent is a bronze alloy that comprises copper, tin and silver.

8. A grinding tool according to any of claims 1 - 7, wherein the abrasive particles (5) are diamond particles or cubic boron nitride particles.

9. A grinding tool according to claim 8, wherein the abrasive particles (5) have a mean particle size in the range of 4μm - 181 μm and preferably in the range of 46μm - 91μm.

10. A grinding tool according to claim 9, wherein the abrasive particles (5) have a coating of copper or nickel.

11. A method of making a grinding tool (1) which method comprises sintering abrasive particles together with metallic powder that comprises copper and tin such that the sintering results in a matrix (6) in which the abrasive particles (6) are embedded, the matrix comprising a metallic bonding agent which is a sintered bronze alloy, wherein silicon nitride in the form of a powder is added to the metallic powder before sintering and to such an extent that the silicon nitride will constitute 0.02 % - 2.0% by volume of the metallic bonding agent and wherein the silicon nitride which is added is in the shape of grains having an average grain size which is less than 10μm and above 0.1μm.

12. A method according to claim 11, wherein the metallic powder additionally comprises silver.

13. A method according to claim 11 or claim 12, wherein a polymer is added to the metallic powder before sintering, preferably in the form of polyimide powder, such that also a polymeric bonding agent is formed which is a part of the matrix (6).

14. A method according to any of claims 11 - 13, wherein the method comprises; mixing the powder material for the bonding agents of the matrix (6) with the abrasive particles (5); compacting the mixture in a cold press; curing the compacted mixture in a kiln at a temperature in the range of 380°C - 520°C, preferably 400°C - 500°C, for a period of 120 - 150 minutes; thereafter placing the compacted and cured mixture in a press and subjecting it to a pressure of 1500 - 2000 kg/cm2; and holding the pressure until the mixture has reached a temperature below 300°C.

15. A method according to any of claims 11 - 14, wherein filler material is added to the mixture of metallic powder and abrasive particles (5) before the sintering operation and wherein the filler material comprises graphite.

Patentansprüche

1. Ein Schleifwerkzeug (1) zum Bearbeiten von harten und/oder spröden Materialien, wobei das Schleifwerkzeug (1) einen Kern (2) und einen Schleifrand (4) aufweist, wobei der Schleifrand (4) Schleifteilchen (5) aufweist, die in einer Matrix (6) eingebettet sind, wobei die Matrix (6) ein metallisches Bindemittel aufweist, das eine gesinterte Bronzelegierung ist, wobei das metallische Bindemittel 50 bis 100 Vol.-% der Matrix ausmacht, wobei das metallische Bindemittel Siliziumnitrid in einer Menge enthält, die 0,02 bis 2,0 Vol.-% des metallischen Bindemittels ausmacht, wobei das Siliziumnitrid in Form von Körnern mit einer durchschnittlichen Korngröße, die weniger als 10 μm und mehr als 0,1 μm beträgt, vorliegt.

2. Ein Schleifwerkzeug (1) nach Anspruch 1, wobei die Matrix (6) ferner ein polymeres Bindemittel aufweist, das zusammen mit dem metallischen Bindemittel derart gesintert wurde, dass das polymere Bindemittel und das metallische Bindemittel ein verbundenes Netzwerk bilden.

3. Ein Schleifwerkzeug (1) nach Anspruch 1 oder Anspruch 2, wobei das Siliziumnitrid 0,3 bis 2,0 Vol.-% des metallischen Bindemittels ausmacht.

4. Ein Schleifwerkzeug (1) nach Anspruch 1 oder Anspruch 2, wobei das Siliziumnitrid 0,5 bis 2 Vol.-% des metallischen Bindemittels ausmacht.

5. Ein Schleifwerkzeug nach Anspruch 2, wobei das polymere Bindemittel Polyimid aufweist.

6. Ein Schleifwerkzeug nach Anspruch 1 oder Anspruch 2, wobei die Matrix zusätzlich Füllmaterialien wie Graphit aufweist.

7. Ein Schleifwerkzeug nach einem der Ansprüche 1 bis 6, wobei das metallische Bindemittel eine Bronzelegierung ist, die Kupfer, Zinn und Silber aufweist.

8. Ein Schleifwerkzeug nach einem der Ansprüche 1 bis 7, wobei die Schleifteilchen (5) Diamantteilchen oder kubische Bornitrid-Teilchen sind.

9. Ein Schleifwerkzeug nach Anspruch 8, wobei die Schleifteilchen (5) eine mittlere Teilchengröße im Bereich von 4 μm bis 181 μm und vorzugsweise im Bereich von 46 μm bis 91 μm aufweisen.

10. Ein Schleifwerkzeug nach Anspruch 9, wobei die Schleifteilchen (5) eine Beschichtung aus Kupfer oder Nickel aufweisen.

11. Ein Verfahren zum Herstellen eines Schleifwerkzeugs (1), wobei das Verfahren das Sintern von Schleifteilchen zusammen mit Metallpulver aufweist, das Kupfer und Zinn aufweist, sodass das Sintern in einer Matrix (6) resultiert, in der die Schleifteilchen (6) eingebettet sind, wobei die Matrix ein metallisches Bindemittel aufweist, das eine gesinterte Bronzelegierung ist, wobei Siliziumnitrid in Form eines Pulvers vor dem Sintern und in einem solchen Ausmaß zu dem metallischen Pulver zugegeben wird, dass das Siliziumnitrid 0,02 bis 2,0 Vol.-% des metallischen Bindemittels ausmacht, und wobei das zugegebene Siliziumnitrid in Form von Körnern mit einer durchschnittlichen Korngröße, die weniger als 10 μm und mehr als 0,1 μm beträgt, vorliegt.

12. Ein Verfahren nach Anspruch 11, wobei das Metallpulver zusätzlich Silber aufweist.

13. Ein Verfahren nach Anspruch 11 oder Anspruch 12, wobei dem Metallpulver vor dem Sintern ein Polymer, vorzugsweise in Form von Polyimidpulver, zugegeben wird, sodass auch ein polymeres Bindemittel gebildet wird, das Teil der Matrix (6) ist.

14. Ein Verfahren nach einem der Ansprüche 11 bis 13, wobei das Verfahren Folgendes umfasst; Mischen des Pulvermaterials für die Bindemittel der Matrix (6) mit den Schleifteilchen (5); Verdichten der Mischung in einer Kaltpresse; Härten der verdichteten Mischung in einem Ofen bei einer Temperatur im Bereich von 380 °C bis 520 °C, vorzugsweise 400 °C bis 500 °C, für einen Zeitraum von 120 bis 150 Minuten; danach Platzieren der verdichteten und gehärteten Mischung in einer Presse und Aussetzen derselben einem Druck von 1.500 bis 2.000 kg/cm^2; und Halten des Drucks, bis die Mischung eine Temperatur unterhalb von 300 °C erreicht hat.

15. Ein Verfahren nach einem der Ansprüche 11 bis 14, wobei das Füllmaterial vor dem Sintervorgang zu der Mischung aus Metallpulver und Schleifteilchen (5) zugegeben wird und wobei das Füllmaterial Graphit aufweist.

Revendications

1. Outil de meulage (1) pour usiner des matériaux durs et/ou cassants, lequel outil de meulage (1) comprend un cœur (2) et un rebord abrasif (4), le rebord abrasif (4) comprenant des particules abrasives (5) intégrées dans une matrice (6), la matrice (6) comprenant un agent de liaison métallique qui est un alliage de bronze fritté, l'agent de liaison métallique constituant 50 % à 100 % en volume de la matrice, l'agent de liaison métallique contenant du nitrure de silicium en une quantité qui constitue 0,02 % à 2,0 % en volume de l'agent de liaison métallique dans lequel le nitrure de silicium est présent sous la forme de grains ayant une taille moyenne de grain qui est inférieure à 10 μm et supérieure à 0,1 μm.

2. Outil de meulage (1) selon la revendication 1, dans lequel la matrice (6) comprend en outre un agent de liaison polymère qui a été fritté conjointement avec l'agent de liaison métallique de telle sorte que l'agent de liaison polymère et l'agent de liaison métallique forment un réseau connecté.

3. Outil de meulage (1) selon la revendication 1 ou la revendication 2, dans lequel le nitrure de silicium constitue 0,3 % à 2,0 % par volume de l'agent de liaison métallique.

4. Outil de meulage (1) selon la revendication 1 ou la revendication 2, dans lequel le nitrure de silicium constitue 0,5 % à 2 % par volume de l'agent de liaison métallique.

5. Outil de meulage selon la revendication 2, dans lequel l'agent de liaison polymère comprend du polyimide.

6. Outil de meulage selon la revendication 1 ou la revendication 2, dans lequel la matrice comprend en outre des matériaux de remplissage tels que du graphite.

7. Outil de meulage selon l'une quelconque des revendications 1 à 6, dans lequel l'agent de liaison métallique est un alliage de bronze qui comprend du cuivre, de l'étain et de l'argent.

8. Outil de meulage selon l'une quelconque des revendications 1 à 7, dans lequel les particules abrasives (5) sont des particules de diamant ou des particules de nitrure de bore cubiques.

9. Outil de meulage selon la revendication 8, dans lequel les particules abrasives (5) ont une taille moyenne de particule dans la plage de 4 μm à 181 μm et de préférence dans la plage de 46 μm à 91 μm.

10. Outil de meulage selon la revendication 9, dans lequel les particules abrasives (5) ont un revêtement de cuivre ou de nickel.

11. Procédé de fabrication d'un outil de meulage (1) lequel procédé comprend le frittage de particules abrasives conjointement avec de la poudre métallique qui comprend du cuivre et de l'étain de telle sorte que le frittage donne une matrice (6) dans laquelle les particules abrasives (6) sont intégrées, la matrice comprenant un agent de liaison métallique qui est un alliage de bronze fritté, dans lequel du nitrure de silicium sous la forme d'une poudre est ajouté à la poudre métallique avant le frittage et dans une telle mesure que le nitrure de silicium constitue 0,02 % à 2,0 % par volume de l'agent de liaison métallique et dans lequel le nitrure de silicium qui est ajouté est sous la forme de grains ayant une taille moyenne de grain qui est inférieure à 10 μm et supérieure à 0,1 μm.

12. Procédé selon la revendication 11 dans lequel la poudre métallique comprend en outre de l'argent.

13. Procédé selon la revendication 11 ou la revendication 12, dans lequel un polymère est ajouté à la poudre métallique avant le frittage, de préférence sous la forme de poudre de polyimide, de telle sorte que également un agent de liaison polymère est formé qui est une partie de la matrice (6).

14. Procédé selon l'une quelconque des revendications 11 à 13, dans lequel le procédé comprend ; mélanger le matériau en poudre pour les agents de liaison de la matrice (6) avec les particules abrasives (5) ; compacter le mélange dans une presse à froid ; durcir le mélange compacté dans un four à une température dans la plage de 380 °C à 520 °C, de préférence de 400 °C à 500 °C, pendant une période de 120 à 150 minutes ; ensuite placer le mélange compacté et durci dans une presse et le soumettre à une pression de 1500 à 2000 kg/cm2 ; et maintenir la pression jusqu'à ce que le mélange ait atteint une température inférieure à 300 °C.

15. Procédé selon l'une quelconque des revendications 11 à 14, dans lequel un matériau de remplissage est ajouté au mélange de poudre métallique et de particules abrasives (5) avant l'opération de frittage et dans lequel le matériau de remplissage comprend du graphite.

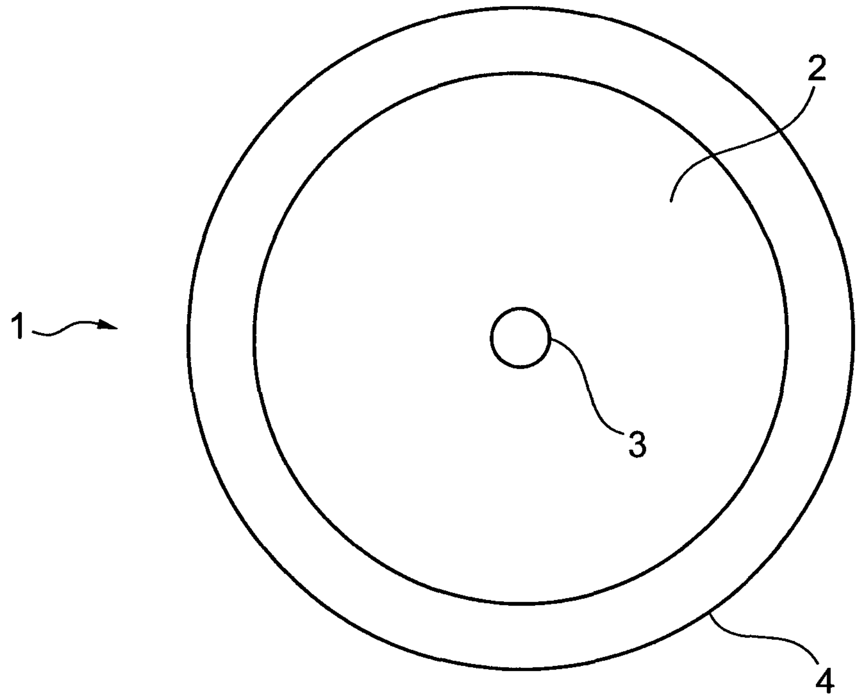


Fig. 1

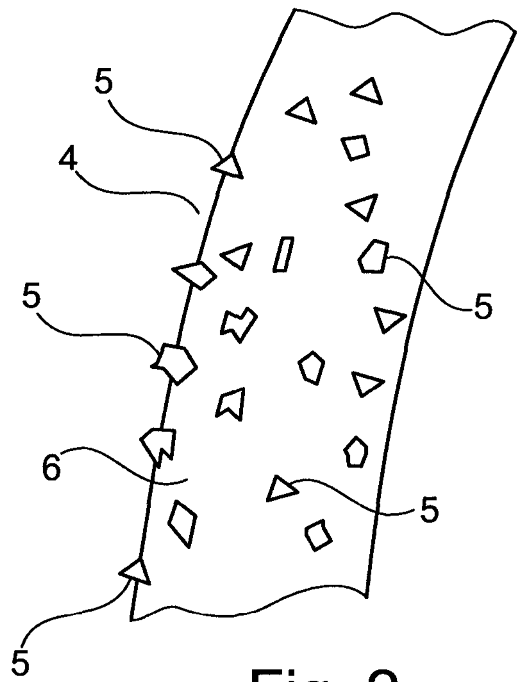


Fig. 2

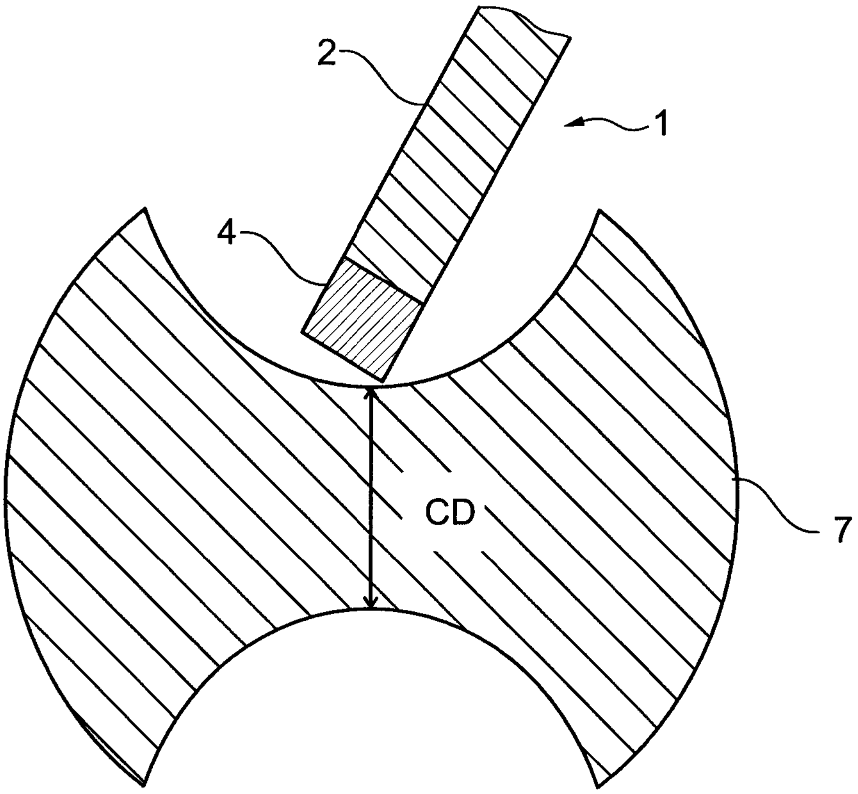


Fig. 3

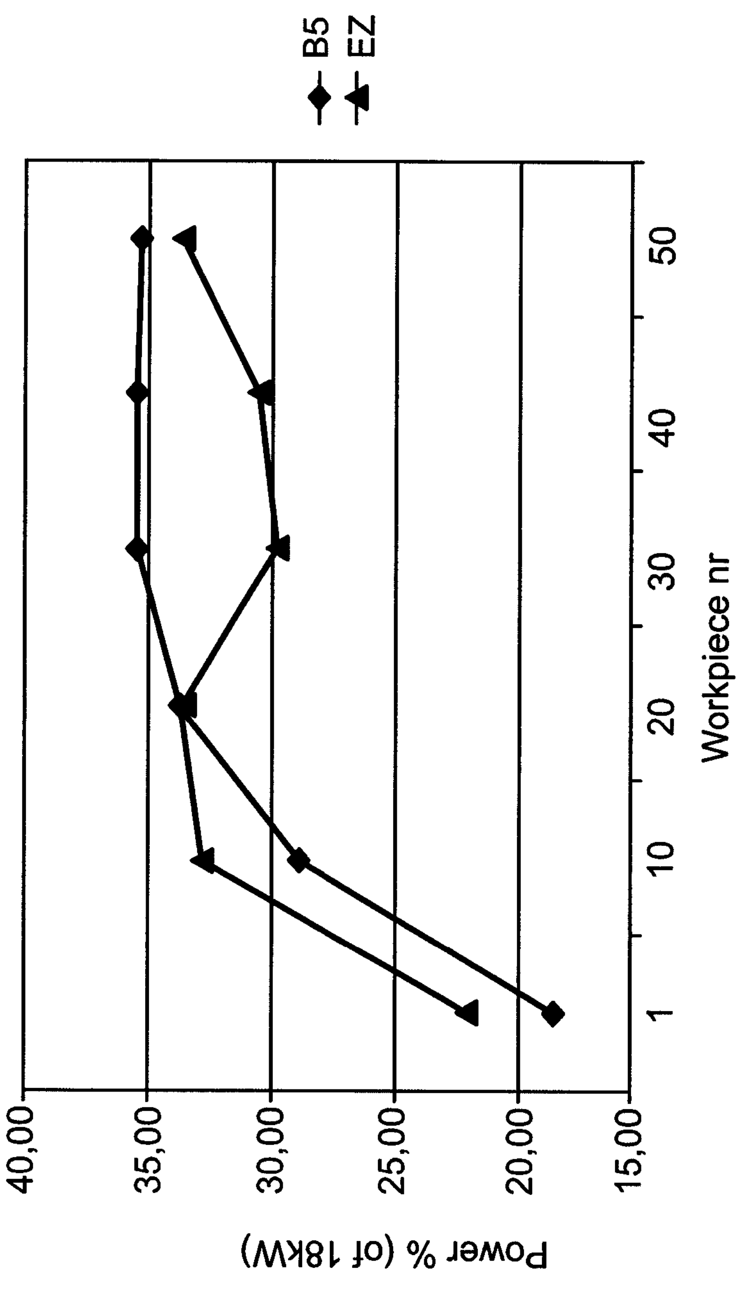

B5
EZ
40,00
35,00
30,00
25,00
20,00
15,00
Power % (of 18kW)
1
10
20
30
40
50
Workpiece nr

Fig. 4

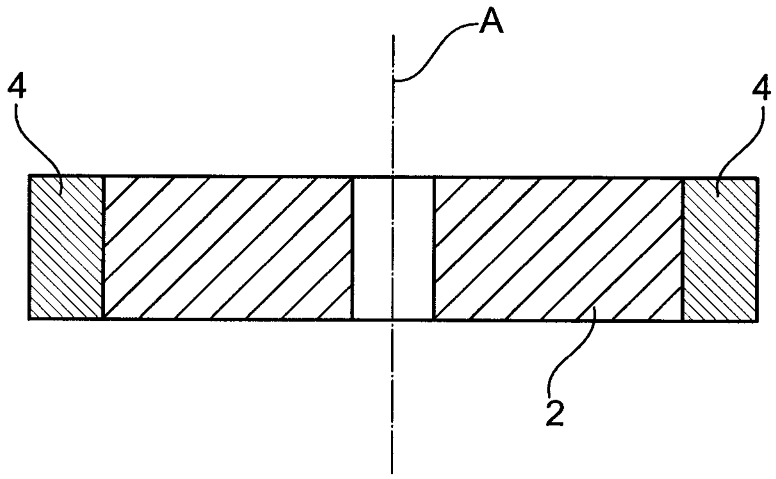


Fig. 5

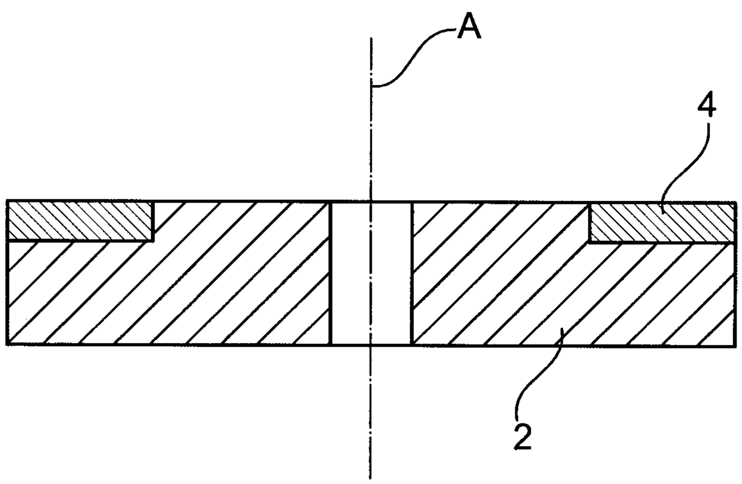
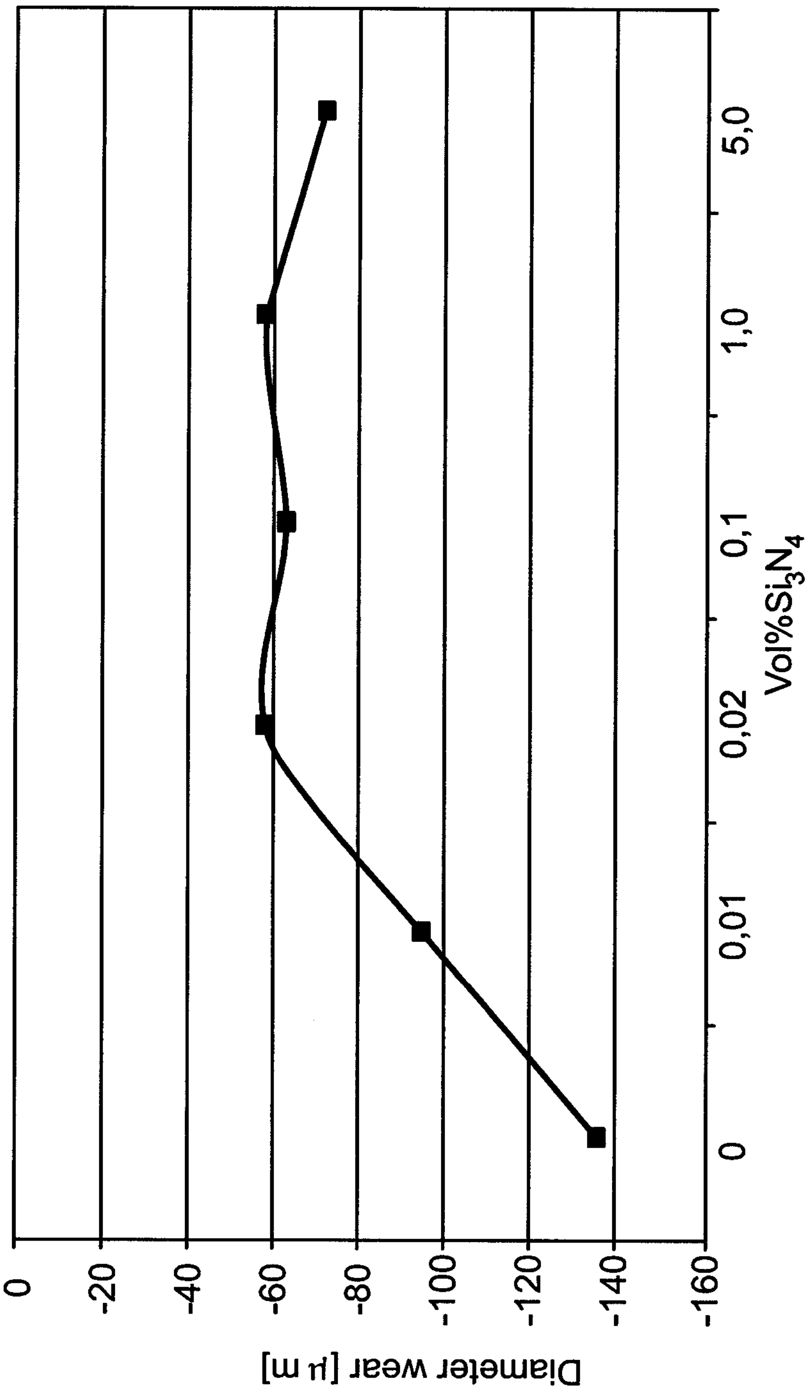


Fig. 6


0
-20
-40
-60
-80
-100
-120
-140
-160
Diameter wear [μ m]
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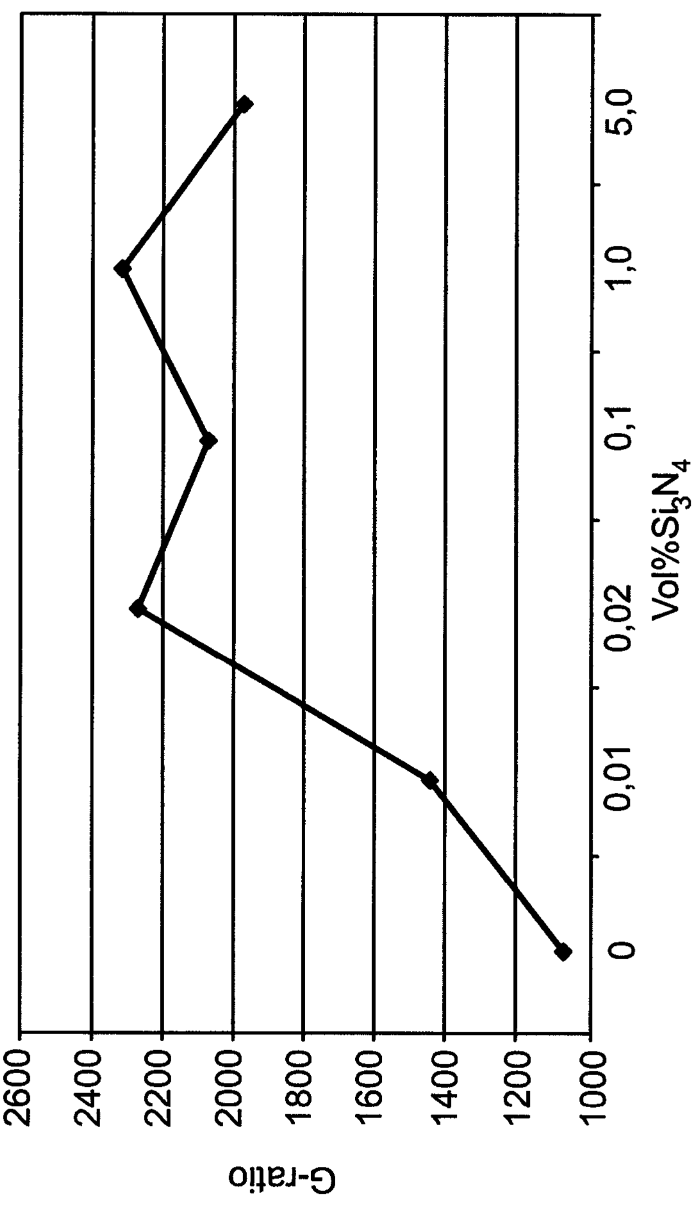
0,01
0,02
0,1
1,0
5,0
Vol%Si_3N_4

Fig. 7


G-ratio
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2400
2200
2000
1800
1600
1400
1200
1000
0
0,01
0,02
0,1
1,0
5,0
Vol%Si3N4

Fig. 8

REFERENCES CITED IN THE DESCRIPTION

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