METHOD OF MAKING A METAL IMPREGNATED GRINDING TOOL

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References Cited

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Date</th>
<th>Inventor(s)</th>
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<tr>
<td>2,162,600</td>
<td>6/1939</td>
<td>Ball</td>
<td>51/298</td>
</tr>
<tr>
<td>2,216,728</td>
<td>10/1940</td>
<td>Benner et al.</td>
<td>51/295</td>
</tr>
<tr>
<td>2,367,404</td>
<td>1/1945</td>
<td>Kott</td>
<td>51/309</td>
</tr>
<tr>
<td>2,578,167</td>
<td>12/1951</td>
<td>Bjorklund et al.</td>
<td>51/309</td>
</tr>
<tr>
<td>3,128,165</td>
<td>4/1964</td>
<td>Bridwell et al.</td>
<td>51/309</td>
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ABSTRACT

Metal bonded abrasive tools are manufactured in which the abrasive grits are uniformly spaced and distributed throughout the tool, by encapsulating one or several abrasive grits in a porous layer of powdered metallic material and preferably sintering the layer, thereby forming individual abrasive grit containing particles which are then placed in a mold and the spaces between the particles filled with a conventional metallic bonding agent. Heat, and in some instances heat and pressure, is applied which permanently binds the mixture together in the desired form. The process is particularly well suited for the fabrication of metal bonded diamond wheels where the metal-bond to diamond-grit volume ratio is relatively high.

1 Claim, 4 Drawing Figures
METHOD OF MAKING A METAL IMPREGNATED GRINDING TOOL

BACKGROUND OF THE INVENTION

The invention relates to the field of metal bonded abrasive tools. More particularly it relates to a method for fabricating abrasive shapes wherein the abrasive particles are relatively widely spaced from each other.

Prior to the instant invention, metal bonded abrasive tools have been manufactured by several processes. Among such methods the "cold press and sinter" technique is probably the most widely used primarily because of economic factors. Simply, this method consists of coating abrasive particles with a pick-up agent, or temporary binder as it is called, followed by addition of a powdered metallic bond. The temporary binder serves to cause a quantity of the powdered metallic binder to adhere to or be picked up on the abrasive particles. This mixture is then placed in a mold of the desired configuration and pressed at for example 35 tons per square inch. The pressed tool is then fired in a furnace for a time and at a temperature sufficient to cause sintering of the particles of the metal bond; the firing is preferably done in an inert or nonoxidizing atmosphere. Such a process and the resulting product are amply described in U.S. Pat. No. 2,737,454 to J. C. Danec.

Another technique for fabricating such abrasive articles is that of hot pressing. In this method a mixture of abrasive particles such as diamonds grits, are mixed with a temporary binder and a metallic bonding agent in the same manner as for the method described above. The mixture is then placed in a mold which is capable of withstanding high temperatures and pressures; these are preferably thick walled graphite molds. The abrasive-metal bond containing mold is then placed in a heating press and pressed at a pressure and temperature sufficient to densify the mix to almost theoretical density and to cause the metallic bonding agent to sint. When the mold and its contents have cooled, an abrasive tool with a permanent configuration results. The use of this process is not as wide spread as the cold press-sinter technique primarily due to the higher cost of hot pressing particularly with respect to equipment cost. The higher cost of the hot process is justified by its capability of producing somewhat more intricate shaped grinding tools than is possible with the aforesaid cold press-sinter process. However, even with hot pressing the degree of complexity of the grinding tool is somewhat limited.

A major contribution to the art of manufacturing metal bonded abrasive tools was described, more recently, in U.S. Pat. No. 3,316,073 to J. G. Kelso. The Kelso invention was a major stride in overcoming one of the most serious shortcomings of both the cold press-sinter and the hot press processes, namely, the difficulty of uniformly distributing abrasive grits throughout the metal bond when the volume ratio of the latter to the former is relatively high, that is about 1:1 or greater. Kelso discovered that if he carefully tumbled abrasive grits in the presence of a finely divided powdered metal bonding agent, e.g., WC/Co, while simultaneously spraying controlled amounts of a dampening agent or a so-called temporary binder such as water, or a solution of shellac, dextrin, phenol-formaldehyde resin, or the like, each abrasive grit became singularly coated with a spherical jacket of powdered WC/Co. The thickness of the jacket or coating can be built up to any dimension desired, depending on the intended spacing or distribution of the abrasive grits in the final product. These jacketed abrasive grits, or pellets as they are called in the Kelso patent, are then placed in a mold and either cold pressed and sintered, or hot pressed in an inert atmosphere. Thus, the extreme difficulty of uniformly mixing relatively coarse abrasive grits with finely divided metal powders was essentially overcome by mechanically attaching all of said metal powder to the abrasive grits prior to placing of the mix in the mold for pressing. The resultant abrasive tool is then vastly improved with respect to uniformity of distribution of the abrasive grits. Although processes based on the combination of the Kelso invention with cold pressing and sintering, or hot pressing constitute a major advancement in the art, such methods do have shortcomings. Among these the most serious are, the abrasive grit size in the Kelso patent of about 60 grit or coarser, and the fact that although more complex abrasive tools can be fabricated by hot pressing, the degree of complexity is limited.

SUMMARY OF THE INVENTION

Essentially the invention is a process for making abrasive tools wherein abrasive grits, such as diamond, silicon carbide, boron carbide, boron nitride, aluminum oxide, alumina-zirconia, zirconia-spinel, and the like, are first encapsulated or jacketed in a porous layer of a powdered metallic material, which is initially attached to the abrasive grits with the aid of a temporary binder. The encapsulating layer may literally be built up to any thickness ranging from a single grain coating of the powdered metal material which can be as thin as one micron or even less if the powdered metallic material has a grain size finer than 1 micron, to a thickness of one-eighth inch or greater if the abrasive grit size, grinding tool dimensions, and desired spacing of abrasive grits warrants such a thick coating. The encapsulated abrasive grit particles are then preferably heated to decompose and/or vaporize the temporary binder and sinter the grains of the powdered metallic material making up the encapsulating layer. If the abrasive grit being used is about 60 grit or coarser, the preferable method of affixing to the grits the porous encapsulating layer of powdered metallic material is that described in the Kelso patent. On the other hand, if the abrasive grit size is finer than 60 grit, especially if it is as fine as 200 grit and finer, the preferred method is that of mixing the fine grits with sufficient temporary binder and powdered metallic material to provide a mix ranging in consistency from damp to pasty, thereby facilitating the uniform distribution of the grits in the powdered metallic material; otherwise, if the mix is the conventional relatively dry type, the grits tend to separate from the grains of the powdered metallic material. The mix is then screened through for example, a 60 grit screen forming discrete particles which may contain one or several abrasive grits, followed by sintering of this screened particulate mixture and finally, gently breaking up the sintered agglomerate of particles. The screening step, however, is not absolutely essential. The damp mix may be sintered, without prior screening, followed by breaking up of the sintered mass which is then screened.
The particles, whether they be the spherical particles of the Kelso invention or the irregular shaped particles formed as described above, are placed in a mold of the desired configuration and the interstices between the particles are filled with a metallic bonding agent. Basically, this may be accomplished in two ways. Preferably, a casting mold is constructed, which consists of the mold chamber proper which is connected by a channel or runner to a reservoir. With the mold cavity filled with abrasive grit containing particles, the reservoir is filled with a metallic bonding agent and the entire mold is assembled and placed in a furnace heated to a temperature above the melting point of the metallic bonding agent. The metallic bonding agent becomes fluid and, because the reservoir is located higher than the mold cavity proper, the gravitational force of the heat of molten metallic bonding agent causes the liquid to flow through the runners into the mold cavity and up through the particles filling the interstices between them. Of course one need not rely on the gravitational force of the molten metal; an external force may be applied to the liquid e.g. in the manner of injection molding.

In an alternate method, either type of abrasive grit containing particles are placed in a conventional mold, for example, one made of graphite, along with a sufficient quantity of powdered metallic bonding agent to fill the interstices between the particles. This mixture then may be cold pressed and heat treated to sinter or melt the metallic materials in the conventional manner, or it may be hot pressed applying sufficient heat and pressure simultaneously, to bring about sintering or melting of the metallic bonding agent and in the case where the encapsulating layer about the abrasive grits is the same material as the bonding agent it, too, will sinter or melt.

Although it is not a strict requirement the heating phases of the process should preferably be carried out in an inert or nonoxidizing atmosphere such as an atmosphere of nitrogen, hydrogen, argon or the like, to prevent oxidation of the metallic materials used to form the encapsulating layer and the principal bond. Further, an inert atmosphere is especially desirable when the abrasive grit is diamond in order to prevent oxidative decomposition of the diamond at elevated temperatures.

Increasingly wider spacing between the abrasive grits can be accomplished by building up very thick encapsulating layers of grains of powdered metallic material on the grits, but as a manufacturing expedience the same end may be accomplished by applying a moderately thick encapsulating layer and increasing the spacing between these by mixing them with particles made up of only sintered grains of powdered metallic material sans abrasive grit or even containing a secondary abrasive or filler such as grits of boron nitride, silicon carbide, tungsten carbide, aluminum oxide, boron carbide, alumina-zirconia, zirconia-spinel, or mixtures of these. This is a device which produces a harder, stronger, bond than when such secondary abrasives or fillers are omitted.

The embodiment of the invention wherein a molten metallic bonding agent is cast into a formed bed of particles is of particular value and utility when the metallic bonding agent is one of the commonly used bronzes or silver solders. Because such bonds do not wet diamond, ordinary manufacturing techniques result in poorly bonded diamond grits. When, however, the grits are first encapsulated in a porous powdered metallic material and a molten metallic bonding agent is cast into the interstices between such encapsulated grits, the molten metal actually impregnates the encapsulating layer thereby permanently uniting the particles.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a side elevation of a lens beveling grinding wheel showing the complex face of the grinding portion 14.

FIG. 2 is a sectional view of a graphite mold for fabricating complexly shaped abrasive tools such as that of FIG. 1, by the method of casting a molten metallic bonding agent into and around encapsulated abrasive grits.

FIG. 3 is a section through the irregular shaped encapsulated abrasive grit particle produced by the screening technique described above.

FIG. 4 is a sectional view of a graphite mold for simultaneously fabricating the core or abrasive supporting section and the abrasive containing section of an abrasive tool.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention is concerned with abrasive tools containing about 1 percent or more abrasive by volume; with reference to the diamond abrasive tool segment of the art, this would be known as "4 concentration" or more.

For the successful practice of the instant invention certain restrictions should be observed with respect to what powdered metallic encapsulating material is combined with which metallic bonding agent; they may be the same metallic composition or they must be different, depending on which particular embodiment of the invention is used.

When the cold-press and sinter approach is used, then the encapsulating material and the bonding agent may be the same, for example, tungsten carbide, or they may be different, for example, bronze and tungsten carbide respectively, as long as both are sinterable at an attainable processing temperature.

When the approach is used that incorporates the simultaneous application of heat and pressure, the two materials may be the same or may differ. If they are the same in composition the only requirement is that the material selected is fusible or sinterable at the available hot pressing temperatures. On the other hand, if the two materials are different, the metallic bonding agent should desirably sinter or melt at a temperature below the melting temperature of the encapsulating material.

Using the third and preferable embodiment, the choice of materials for the encapsulating layer and the bond is more limited. An important part of this approach is that the porous encapsulating layer about the abrasive grits becomes impregnated with the metal bonding agent. In order for this to occur the metallic bonding agent must become molten or fluid significantly below the softening temperature of the encapsulating material. With the interstices between the particles filled with the relatively low melting bonding agent, as well as the pores within the encapsulating layer itself, a strong, dense, high quality abrasive tool results. This method provides a means of inexpensively and reliably manufacturing wheels with grinding faces.
of any degree of complexity, such as those used in form grinding of carbide cutting tools; any abrasive wheel or tool configuration can now be made that one can make a mold for. For example, a grinding wheel with a configuration that is difficult to make by conventional means is the beveling wheel shown in FIG. 1. This wheel has a solid core 10 with an arbore hole 12 in its center and the grinding section 14 containing the abrasive is attached to the periphery of the core 10. A simple mold design for casting wheels of complex configuration such as that of FIG. 1, is shown in section in FIG. 2. The cavity of the mold is defined by the graphite cup 16 split at 18 and containing the depression 17, the bottom of the cylindrical graphite sleeve 20, and the graphite reservoir 22. The reservoir 22 is constructed in a manner to provide a nodule 24 which serves as a means of centering the reservoir 22 within the graphite cup 16 when the nodule 24 is mated with the depression 17 in the center of the graphite cup 16. Passing through the bottom of the reservoir 22 and concentrically adjacent to the nodule 24 is a series of holes 26 to allow passage of the molten metallic material 40 to pass into the channel 28 and finally into the forming or mold cavity 30. The reservoir forms the inside wall of the mold cavity 30 and with the inside bottom face of the cup 16, forms the channel 28.

To use such a mold, the parts 16' and 16'' of the cup 16 are fastened together, e.g., by a steel strap, and the reservoir 22 is centered therein by mating the nodule 24 with the depression 17 in the cup 16. A precalculated volume of encapsulated abrasive grits 32 is poured down into the mold cavity 30 thereby filling the cavity. The sleeve 20 is then put in place, the reservoir 22 filled with metallic bonding agent and the entire assembly heated to a temperature above the melting point of the bonding agent. The force exerted by the head of molten metallic bonding agent 40 forces the liquid into the mold cavity 30 where it fills the interstices 38 between the encapsulated particles 32 and impregnates the pores of the encapsulating layer 36 about the grits 34. The complete mold setup is allowed to cool, readily disassembled and the formed abrasive ring easily removed.

A further advantage of the casting embodiment of the invention is that the core or abrasive section supporting member can be made simultaneously with the grit containing section of the wheel. This produces a complete wheel in one operation, thereby eliminating the step of brazing or otherwise attaching the grit containing section to a core. To accomplish this, a mold assembly such as that shown in FIG. 4, may be used. This mold assembly is similar to that in FIG. 3 in that the graphite mold cup 16, split at 18, is the same, being made up of parts 16' and 16'' and, containing part of the abrasive section forming cavity 30 and the depression 17 in the inner bottom surface of the cup. The remainder of this type of mold is made up of a plug 46 containing therein the T shaped channel 48 connecting with the abrasive section supporting member portion of the mold cavity 50 and the lower portion of the reservoir 52. The reservoir 52 is shaped so as to fit snugly into the cup 16 and to mate by way of a hole 54, with the plug 46 thus forming the complete mold cavity made up of that portion 50 for forming the abrasive section supporting member and that portion 30 of the cavity forming the abrasive section.

To simultaneously cast the core and abrasive section, the two parts 16' and 16'' of the cup 16 are strapped together and the plug 46 inserted in the depression 17. A thin walled shallow cylinder shown as 56 is then centered in the mold and the proper volume of encapsulated grits 32 are poured between the cylinder 56 and the abrasive section portion 30 of the mold cavity. Porous metallic particles 58, which may or may not contain secondary abrasive or filler, are then placed in the core portion 50 of the mold cavity. The thin walled cylinder 56 is then removed. The reservoir 52 is put in place completing the formation of the mold cavity. The reservoir is then filled with solid metallic bonding agent and the entire assembly heated to the melting point of the metallic bonding agent 40 causing it to liquify and pass through the channel 48 and into the mold cavity thereby filling the interstices between the particles contained in both portions 50 and 30, of the mold cavity. The mold assembly is cooled, disassembled and the complete wheel, core and abrasive section, is removed.

If the tool being fabricated is of relatively simple configuration, the abrasive or grit containing portion and the core of the tool can be made by filling the interstices between the particles with powdered metallic bonding agent, followed by cold-pressing and sintering, or hot-pressing as described above.

The encapsulated spherical particles 32 shown in FIG. 2 could be substituted for by the irregular shaped particles formed by the method described above and shown in FIG. 3. In such particles as these the porous encapsulating coating 42 has an irregular shape and contains one or several abrasive grits 44. This particular configuration becomes almost essential when the abrasive grit size is much finer than 60 grit.

The abrasive products made by this process are distinguishable from those made by prior art processes, in that under microscopic examination of a section through a product of the instant invention, the encapsulated particles are discernible because they can be seen contrasted against the metallic bonding agent. This is conspicuously so when the casting approach is employed. It is also true when the cold press-sinter or the hot press techniques are used if the encapsulating metal material differs in particle size or chemical composition from the metallic bonding agent. When the two metallic materials are the same with respect to particle size and chemical composition the encapsulated particles are not as easily discernable from the metallic bonding agent.

The following examples will further elucidate the novel concept of this invention.

EXAMPLE I

A metal bonded diamond grit section of cylindrical shape, to be attached to a driving means thereby forming what is known as a core drill, was made by first calculating the volume of the diamond section and then the amount of diamond needed in that volume to result in a diamond concentration of 100 (25 volume percent; they were respectively 10 cubic centimeters and 2.5 cubic centimeters (8.775 grams). The 8.775 grams of 46 grit diamond was encapsulated in a layer of powder made up of 90 weight percent of tungsten carbide and 10 weight percent of cobalt following the teachings of the Kelso patent; the WC/Co layer built up to such a thickness as to result in a volume of WC/C approximately equal in Volume to the abrasive grit. The encaps-
sulated abrasive grits then had a true volume of 5 cc. A quantity, 20 cc, of abrasive grit free WC/Co particles of approximately the same size as the grit containing particles, was prepared in the same manner. A sufficient amount of these particles was mixed with the diamond grit containing particles to provide a total loose packed volume of 10 cc. There were then heat treated at 350°C for 30 minutes in nitrogen to remove the temporary binder, followed by heating at 950°C in nitrogen causing the powdered WC/Co to sinter. Some minor amount of sintering between the particles themselves occurred but the agglomerations were easily broken up with the fingers. A mold basically like that of FIG. 2, except that the mold cavity was a simple straight walled cylinder instead of the complex cavity of FIG. 2, was partially assembled and the 10 cc mold cavity was filled with the 10 cc loose packed volume of encapsulated diamond grit and WC/Co particles, and the mold assembling completed. The reservoir was filled with a bronze powder made up of 20 percent tin and 80 percent copper by weight. The entire assembly was placed in a furnace and heated at 1,050°C in a hydrogen atmosphere for 30 minutes. During the heating step the bronze powder melted and because it was located higher than the cavity it flowed into the mold cavity filling the interstices between the particles and impregnating the porous encapsulating layer of WC/Co around the diamond grits and the WC/Co particles. The mold set-up was removed from the furnace, cooled, disassembled and the diamond section removed. The latter was then brazed, by means of a silver solder and flux, to a suitable steel tube fitted with an adapter, forming a core drill attachable to a driving means.

Although WC/Co were used other carbides are equally suitable such as W2C, B4C, or the like or any of the many iron-nickel-carbon alloys; it is only necessary that the metallic material used to encapsulate the grits and to form the grit free particles, have a melting point above that of the metallic bonding agent. By the same token, a bronze was used as the bonding agent but other metallic materials such as silver solder, brass, and the like can be, and in fact, have been used.

EXAMPLE II

A diamond edge beveling wheel was made in the same manner as described in Example I except that in this case the abrasive was 100 grit diamond, the shape of the diamond bearing section was that of 14 in FIG. 1, and the method of producing the WC/Co encapsulated grit containing particles and the grit free WC/Co particles was that of the mixing and screening described above. The diamond containing particles were prepared by thorough mixing together equal parts by true volume of diamond grit and the powdered WC/Co with about 5 percent by weight of a 10 weight percent solution of paraffin in 1,1,1-trichloroethane. This made a damp mix which was then screened through a 60 mesh screen creating a small mass of discrete, irregular shaped particles, such as that shown in FIG. 3. The particles were heat treated as in Example I and the agglomerate was gently broken up. A quantity of grit free WC/Co particles were made in the same manner as the encapsulated diamond grit particles. All of diamond containing particles was mixed with a sufficient quantity of grit free particles to bring the total apparent volume to 10 cc, and the mixture placed in a mold like that of FIG. 2. The remainder of the process was the same as in Example I. The intricately shaped diamond section was silver soldered to an appropriately sized steel disc forming a wheel like that shown in FIG. 1 which was then used to grind the edges of ceramic plates and other artifacts.

EXAMPLE III

A diamond core drill bonded entirely with WC/Co but with the configuration of the core drill of Example I is made by first preparing diamond containing and diamond free particles in the exact quantities and in the manner of Example I. Instead of placing the total 10 cc of grit and non-grit containing particles in a casting mold, the particles are mixed with about 14 grams of a powdered 75:25 weight percent WC/Co mixture and placed in a graphite mold of conventional configuration. The mold assembly is then hot-pressed at 1,200°C under a pressure of 3 tons per square inch for about 15 minutes.

In this case the 14 grams of sintered powdered WC/Co fills the interstices between the particles, instead of the molten bronze in Examples I and II.

EXAMPLE IV

A diamond core drill with the configuration and composition of that in Example I is made by encapsulating the diamond grits in WC/Co and preparing non-grit containing particles in the manner described in Example II, mixing the 10 cc of grit containing and non-grit containing particles with 8.6 grams of an 80:20 weight percent mixture of Cu/Sn, placing this mixture in a steel mold of conventional design, pressing the mix under 35 tons per square inch, and finally sintering the cold pressed diamond section by heating it at 900°C for 30 minutes.

In this modification of the invention, the 8.6 grams of sintered bronze powder fills the interstices between the particles instead of the sintered WC/Co of Example III. What is claimed is:

1. A method of fabricating metal bonded grinding tools comprising the steps of:
   a. affixing to abrasive grits, a porous encapsulating layer of powdered metallic material by mixing the abrasive grits and powdered metallic material with sufficient temporary binder to dampen the mix, pushing the damp mix through a screen with openings larger than the abrasive grits thereby forming a plurality of irregular shaped abrasive grit containing composite particles, and heat treating the plurality of said particles to devoid them of temporary binder and to sinter the powdered metallic material;
   b. placing said abrasive grit containing particles in a mold cavity of appropriate configuration;
   c. filling the interstices between said particles with a metallic bonding agent; and
   d. permanently uniting said particles and said metallic bonding agent by the application of heat and pressure.

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