Earth boring drills such as are useful in oil well drilling or other drilling operations and methods of producing such drills in which metal-encapsulated primary abrasive particles such as diamonds and metal-encapsulated secondary particles are bonded together and to a metallic shank by means of a metal matrix.

24 Claims, 5 Drawing Figures
DRILL BITS AND METHOD OF PRODUCING DRILL BITS

This application is a continuation in part of applications, Ser. No. 219,973; 220,351; 220,352, Jan. 24, 1972.

This invention is an improvement on diamond drills in which diamonds are incorporated in the body of or positioned on the surface of an abraded structure in the form of a drill, for example, as may be used for earth boring.

In one form of earth-boring drill, a plurality of different abrasive particles are employed. In addition to particles of high hardness values, for example, diamonds which act on the primary abrasive, there is positioned in the continuous phase of a metal matrix binder a secondary abrasive of lower hardness value.

The purpose of this secondary abrasive particle is to wear away preferentially thus exposing new abrasive faces of the primary abrasive particle.

The abraded structures thus formed are deemed self-sharpening. That is, the matrix including the secondary abrasive wears away preferentially and uniformly exposing new primary abrasive cutting surfaces. This, however, tends to reduce the area of the interfacial surfaces between the bonding metal of the matrix and the primary and secondary abrasive particles. Where the bond is weak, the particles are torn out of the metal matrix, causing excessive wear.

In such a structure, it is conventional to form the abraded body of tungsten carbide to act as the secondary abrasive particle. The diamonds and tungsten carbide are bonded by means of a metal matrix which is formed by percolating molten metal to infiltrate the body of discrete tungsten carbide in a suitable mold to bond the tungsten carbide; if diamonds are also distributed throughout this metal matrix, the mixture of diamonds and tungsten carbide form the mass which is infiltrated by the molten metal. In another form, the diamonds are positioned in spaced configuration on the external grinding surface of the drill. These are termed surface set diamond drills.

There are a number of difficulties in forming such drills arising from the nature of the tungsten carbide and the diamonds which add to the disadvantage of the high cost of these abrasives. Where diamonds are employed because of their peculiar properties, this cost must be borne.

It is a purpose of this invention to avoid the problems arising from the chemical nature of the tungsten carbide by substituting a different abrasive particle having suitable and improved chemical characteristics. The substitution has also improved the economics of the manufacture.

One of the problems arising when using tungsten carbide in such structures is the restriction which it places on the metal which may be used as a metal matrix bond.

The metal chosen should be fluid at the temperature at which it is desired to employ the molten metal in forming the composite drill structure, for example, below 2,000° F. and desirably should have, when solid, ductility as measured in the terms of microhardness of below about 400 kg/mm². Desirably, also, it should have a compressive strength above about 90,000 p.s.i. and an impact strength above about 5 foot pounds.

For this purpose, we may use copper-based alloys such as brass and bronze alloys and copper-based alloys, for example,

<table>
<thead>
<tr>
<th>TABLE 1</th>
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<td></td>
</tr>
</tbody>
</table>

|          | 3.5  | 1.5   | 8000*  |
| Aluminum Oxide (A1₂O₃) | 2060 | 3.5-4 | 4.4 |
| Cast Eutectic Tungsten Carbide | 4800 | 15 |
| Tungsten Monocarbide (WC) | 4800 | 15.8 | 2.7 |
| Ditungsten Carbide (W₂C) | 4800 | 17.3 | 1950-2400 |
| Boron Nitride (Cubic) | >1700 | 3.48 | ~20 |
| Tetrachromium Carbide (Cr₇C₃) | 1500 | 6.99 | 3 |
| Trichromium Carbide (Cr₄C) | 1910 | 6.68 | 2.4 |
| Titanium Diboride (TiB₂) | 2870 | 4.52 | 4.2 |
| Hafnium Diboride (HfB₂) | 3250 | 11.20 | 4.2 |
| Zirconium Diboride (ZrB₂) | 3100 | 6.09 | 4.6 |
| Calcium Hexaboride (CaB₆) | 4050 | 2.46 | 3.6 |
| Barium Hexaboride (BaB₆) | 4100 | 4.32 | 3.8 |
| Tantalum Carbide (Ta₃C) | >1000 | 3.21 | 2.4 |
| Silicon Carbide | 2200-2900 |

Copper-based alloys containing various amounts of nickel, cobalt, tin, zinc, manganese, iron and silver, cast iron, iron-based alloys, nickel-based alloys, for example, nickel-copper-alumina-silicon alloy melting below 2,000° C.

However, tungsten carbide is attacked by iron-based or nickel-based alloys. The W₂C tungsten carbide is attacked or dissolved in the binder, and on freezing precipitates a new phase called Eta. This phase is an M₄C type carbide, and in the case of nickel binders will have the composition Ni₃W₂C. Eta phase is more brittle than the original particle. The particle is said to be "hard."] The "harded" portion of particle will have a hardness only of about 1,500 kilograms per square millimeter, compared, for example, to 1,950 to 2,100 kilograms per square millimeter (Knoop) for the core of the particle.

Tungsten carbide has been used in the past because among other properties it has a high specific gravity, hardness, and high melting point.

By encapsulating the tungsten carbide with a metal envelope, the tungsten carbide is prevented from attack by such metals and also obtains the additional benefit of encapsulation as described above.

We have found that we may use alumina, silicon carbide, boron nitride, and other abrasives as listed in Table 1 in place of tungsten carbide. The most practical both from point of view of economy and functional suitability are aluminum oxide, boron nitride, and silicon carbide. However, these materials may not be employed when a metal matrix is to be used as a bonding agent. The particles are not sufficiently wetted by the molten metal. When the metal solidifies, it pulls away from the abrasive particle. The result is an excessive loss of abrasive particles as the abraded surface exposes the loosely held particles.
We have solved this problem by encapsulating the secondary particles with a metal envelope. The encapsulated particle is more easily wetted by the molten metal than the non-metallic substrate. The improved interfacial tension between the metal envelope and the metal matrix used to bind the particles, increases the grip of the metal matrix on the encapsulated particle and thus helps to prevent the loss of the particle in case fragmentation of the particle does occur.

Another problem in structure of the prior art arises from the fact that the abrasive action places the abrasive particle in tension and the resultant excessive fragmentation of the abrasive particles may thereby result in loss of the particle from the matrix.

We have solved this problem referred to above by producing a novel metal-encapsulated abrasive particle and novel abrader structures by first encapsulating an abrasive particle with a metallic envelope.

When metal is used as a matrix to bind the abrasive particles, both in the case of the primary as well as in the case of the secondary abrasive particles in the abrader structure, encapsulation of the abrasive particles increases the grip of the metal matrix on the abrasive particle.

In selecting the metal for the envelope when the encapsulated particle is to be used with metal matrix acting as a bonding agent, it is desirable that the metal in the envelope have a suitably higher melting point than the metal matrix.

The further advantage of the encapsulated abrasive particle of our invention when used together with a metal matrix resides in the increased rate of heat transfer from the abrasive particle resulting from the more intimate contact at the surfaces between the envelope and the substrate particle and the envelope and the metal matrix. Heat generated at the abrading surfaces, if not readily transmitted to and absorbed in the metal matrix, acting as a heat mass, will cause a local rise in temperature which may have a deleterious effect upon the life of the abrasive particle.

In order to obtain the increased bond between the abrasive particles and the metal matrix, any convenient method for deposit of the metal envelope on the particle substrate may be employed. Thus electrochemical or electrolytic methods which have been previously employed in coating abrasive particles for use in abrader structure will, when used together with a metal bonding agent in our novel abrader structure, result in an improved bond between the metal matrix and the coated particle due to the improved wetting by the molten metal. In this respect, the use of the coated particle in a composite structure employing a metal matrix is an improvement over the use of an abrasive particle coated by an electrochemical or electrolytic process when used with a resin binder. It is similarly an improvement over the use of uncoated abrasive particles with resin or metal binders acting as a matrix for the abrasive particles.

Abrasive particles coated by such procedures result in deposits which are contaminated by intergranular inclusions of impurities from their aqueous environment. Furthermore, the deposits particularly in the case of electroplated deposits have intergranular planes of weakness and the coating has a relatively low tensile and bending strength. They do not improve, in any substantial degree, the physical properties of the coated particle as compared with the uncoated particle.

The metallic envelopes which we prefer to employ to encapsulate the abrasive particles of our invention employed in the novel drill structure of our invention differ from the foregoing coatings in composition and crystalline nature. In contrast to these deposits, the deposits of our invention are substantially pure metal envelopes, substantially free of intergranular inclusions.

The metallic envelope of the abrasive in the abrader structure of our invention is composed of crystal grains which are dendrites starting at and extending from the substrate surface, creating a superposition of grain growth interrupted by other grain skeleton deposit on top thereof. The grains thus deposited form a mechanically interlocked grain structure giving to the metal sheath high tensile strength. Such deposits are termed "allotrimorphic."

We prefer to produce the aforesaid encapsulated abrasive of our invention by a process of chemical vapor deposition, by subjecting the abrasive particles to contact with a volatile metal compound at an elevated temperature sufficient to maintain the metal compound in vapor form and contact the vapor with a solid substrate under metal deposition conditions.

The intermetallic bond between the metal matrix and the primary or secondary abrasive increases the retention of the abrasive particle until its cutting life is ended by wearing away of the particle or breaking away of fragments thereof from the portion of the abrasive particles which has become free of the encapsulation at the abrading surface during the abrading action.

While the encapsulation of diamonds when used as the primary abrasive will have the benefits described above, they may be used unencapsulated in the structure of our invention when using encapsulated secondary abrasive as described herein.

When employing unencapsulated diamonds or tungsten carbide as an abrasive particle, cobalt-based, nickel-based, or iron-based alloys are undesirable as metal-bonding agents since in their molten condition they attack the diamonds. They may, however, be used if the aforesaid abrasives are encapsulated in a metal sheath.

Since when using encapsulated diamonds or encapsulated tungsten carbide or other secondary abrasive as above, the particle is protected from attack by the metal, we may use any of the metals referred to above as being suitable for infiltration to establish the continuous phase forming the metal matrix of the structures of our invention.

We prefer to use for encapsulation of the abrasive particles tabulated in Table 1 above tungsten, tantalum, niobium (columbium) and molybdenum, and, among the primary abrasive particles, we prefer to employ diamonds, either the natural or synthetic forms; and as secondary abrasive, we may use tungsten carbide but we prefer to employ alumina, or silicon carbide with alumina most preferred because of the inherent properties and relatively low cost, or boron nitride and prefer to employ tungsten as the encapsulating metal, deposited under conditions to produce pure tungsten of the crystal form as described herein.

Where we employ the metal-encapsulated abrasive in the drill formation by metal bonding the encapsulated abrasive in a metal continuous phase matrix, we prefer to employ as a bonding agent a metal having a significantly lower melting point than the metal sheath of the abrasive substrate. When employing encapsulated or
unencapsulated diamonds as the primary abrasive particle, we prefer to limit the melting point of the metal matrix to a temperature below about 2,800° F., i.e., 1,538° C., in order not to expose the diamonds to excessive temperature which may impair the mechanical strength of the diamonds.

Another useful property for the metal binder is a suitable coefficient of thermal expansion of the metal matrix used as bonding agent. Since, in general, the low melting metals and materials have high thermal coefficients of expansion, in the absence of an encapsulating metal which is wetted by the molten metal, the mass of matrix on cooling would tend to pull away from the abrasive material particularly, thus impairing the bond.

We prefer to employ for the encapsulation of the abrasive particles the reduction of a vapor of the metal compound.

For such purpose, we prefer to select among the metals chosen according to the aforesaid principles of our invention those which form a compound which may be placed in the vapor state in contact with the substrate under conditions to deposit the metal on the substrate surface.

### TABLE 2

<table>
<thead>
<tr>
<th>Compound</th>
<th>B.P. °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molybdenum Pentachloride [MoCl₅]</td>
<td>268</td>
</tr>
<tr>
<td>Molybdenum Hexachloride [MoCl₆]</td>
<td>35</td>
</tr>
<tr>
<td>Molybdenum Carbonyl [Mo(CO)₆]</td>
<td>156.4</td>
</tr>
<tr>
<td>Tungsten Pentaboride [WB₃]</td>
<td>333</td>
</tr>
<tr>
<td>Tungsten Hexaboride [WB₄]</td>
<td>173.6</td>
</tr>
<tr>
<td>Tungsten Pentachloride [WCl₅]</td>
<td>275.6</td>
</tr>
<tr>
<td>Tungsten Hexachloride [WCl₆]</td>
<td>346.7</td>
</tr>
<tr>
<td>Tungsten Carbonyl [W(CO)₆]</td>
<td>175 at 766 m.m.</td>
</tr>
<tr>
<td>Tantalum Pentachloride [TaCl₅]</td>
<td>242</td>
</tr>
<tr>
<td>Tantalum Pentaboride [TaB₃]</td>
<td>229.5</td>
</tr>
<tr>
<td>Titanium Tetaboride [TiB₃]</td>
<td>230</td>
</tr>
<tr>
<td>Titanium Hexafluoride [TiF₆]</td>
<td>236.5</td>
</tr>
<tr>
<td>Titanium Tetrahalide [TiCl₄]</td>
<td>136.4</td>
</tr>
<tr>
<td>Columbium Pentaboride [CbB₃]</td>
<td>361.6</td>
</tr>
<tr>
<td>Columbium Pentfluoride [CbF₇]</td>
<td>236</td>
</tr>
</tbody>
</table>

*Unless otherwise indicated*

We prefer to employ a compound which may be vaporized at a convenient temperature either because of its relatively low boiling point or by reduction of its partial pressure and be introduced into the contact zone with the abrasive particle for conversion to the metal state deposited on the substrate.

The procedure we prefer, because it produces the superior envelope when applied to produce our novel encapsulated abrasive particle, is the conversion of a volatile compound of the metal into the metal deposited on the substrate and a gaseous or vaporous reaction product which may be removed from contact with the encapsulated metal. This leaves an envelope substantially free of included impurities.

For this purpose, we prefer to use the halides or the carbynyls of the metals. For convenience of operation, we prefer to employ those compounds having a boiling point at atmospheric pressure below the reaction temperature.

While compounds which may be placed in the liquid state at which they may be distilled by vacuum distillation or by reduction of their partial pressure by means of a carrier gas are possible, the compounds listed in Table 3, having reasonable boiling points, so that their volatilization may be conveniently allowed, are preferred by us.

In view of the above consideration, the metals whose compounds are listed in Table 2 may be employed; however, we prefer to employ tungsten as an encapsulating metal because of its particular suitability in the drill of our invention. It gives under the conditions of fabrication according to our invention a coating of exceptionally high strength. It is readily wetted by the molten metal matrices described above and forms a strong metallurgical bond with the metal matrices employed in our invention. It is particularly useful where the substrate is diamond or tungsten carbide or other substrates which will react with the tungsten such as those which form cermet with tungsten.

Our preferred primary abrasive is diamond, either unencapsulated or encapsulated as described herein. Where encapsulated with a metal under the preferred conditions as described herein, it will produce a superior abraded structure of longer life. Where encapsulated with tungsten or other suitable metals as described above, it will after the exposed metal sheet in contact with the work has been worn away be exposed to the work but will otherwise be gripped by the encapsulating envelope which is in turn gripped by the metal matrix.

In place of or in addition to the encapsulated diamond, we may use the other abrasives as described above, preferring among them encapsulated alumina but may also use the other secondary abrasives as described above and as is more fully described below.

The invention will be further described by reference to the following FIGS. FIG. 1 is a diagrammatic flow sheet of our preferred process of encapsulation. FIG. 2 is a schematic vertical section through a mold for use in the infiltrant technique of forming a bit according to our invention. FIG. 3 is a partial section of one form of drill bit of our invention. FIG. 4 is a fragmentary view partly in section of a modified mold. FIG. 5 is a view partly in section of a modified drill bit of our invention. FIG. 1 illustrates a flow sheet of our preferred process for producing the novel encapsulated abrasive of our invention. The particles to be coated are placed in the reactor 1, whose cap 2 has been removed. The reactor has a perforated bottom to support the particles of selected mesh size. With cap 2 replaced and the valves 3, 4, 5, and 13 closed, and with valve 7 open, the vacuum pump is started to de-aerate the system. Valve 7 is closed and the system filled with hydrogen from hydron storage 11, valve 5 being open.

The reactor is heated by the furnace 9 to the reaction temperature, for example, from about 1,000° to about 1,200° F. while purging slowly with hydrogen. The hydrogen flow rate is increased until a stabilized bed is established. Hydrogen prior to introduction into the reactor passes through a conventional palladium catalyst to remove any impurities, such as oxygen in the hydrogen. Vaporized metallic compound is discharged from the vaporizing chamber 16, which may if necessary be heated by furnace 14, together with an inert gas, for example, argon from storage 6, into the reaction chamber.

Preferably we desire to employ the volatile metal halides referred to above, although, in some cases, we may use the carbynyls listed in Table 3. Where the halide is employed, the reaction forms hydrogen halide, which is passed through the bubble traps and is ab-
sorbed in the absorber. Where the volatile compound employed is a fluoride, the produce formed is a hydrogen fluoride, and we may use sodium fluoride for that absorption. We prefer to employ hydrogen in stoichiometric excess.

The reaction deposits metal on the substrate and the effluent material, being in the vapor state is discharged, leaving no contaminants on or in the metal. The metal is formed in its pure state.

The rate of metal deposition depends on the temperature, and flow rate of the reactants, being the greater the higher the temperature and the greater the flow rate of the hydrogen and volatile metals compound. After the deposit is formed, the valves 4 and 5 are closed and argon is continued to pass into the reactor and the encapsulated abrasive is allowed to cool to room temperature in the non-oxidizing condition of the argon environment.

The conditions in the reactor, both because of the mesh size and particle size distribution of the particles and because of the velocity of the vapors and gases fluidizes the particles. As will be recognized by those skilled in the art, a dense phase is established in the lower part of the reactor in which the particles are more or less uniformly distributed in violent agitation in the dense phase. This results in a substantially uniform deposit per unit of surface of the particles.

The reaction products and the carrier gases and excess hydrogen enter the upper space termed the disengaging space where they are separated from any entrained particles.

Where the diamond particle is smooth as for example in the case of synthetic diamonds, we may improve the bond of the metal envelope to the substrate diamond surface produced in the process described above by first surface etching of the diamond. The etching of the diamonds will also have an advantage where the metal envelope is produced by other processes such as electrochemical or electrolytic deposition methods. However, for the reasons previously described, the product produced by the process of vapor deposition described above is superior and is preferred by us.

To etch the diamonds, we immerse them in a molten bath of an alkali metal nitrate or alkaline earth nitrate at a temperature below the decomposition temperature, thus in using potassium nitrate, temperature would range from 630°-650°; under 750°; sodium nitrate, about 580°; and under about 700°; barium nitrate, at or above 1,100°. and below its decomposition temperature. We prefer to employ potassium nitrate at about 630° for about an hour. The bath is contained in a nitrogen or other inert gas atmosphere.

At the completion of the heating process, the molten bath is cooled and the cooled bath is then leached with water to dissolve the salt, leaving the etched diamonds which may then be separated and dried.

The degree of etching depends upon the immersion time and a suitable time will be about an hour under which conditions the particles will lose from about one-half to 1 percent of their weight. The surface of the diamonds is roughened and pitted and forms a desirable and improved substrate base.

For purposes of illustration, not as limitations of our invention, the following examples are illustrative of the process of depositing a metal sheath upon a substrate. Diamonds, either synthetic or natural, preferably etched as above, or the alumina, silicon carbide or other abrasive particle such as tungsten carbide of mesh size suitable for fluidizing are introduced into the reactor. The actual mesh size employed depends upon the service to which the abrader is to be placed. For use in oil well bits, we may use particles of size (Tyler mesh) through a 16 and on a 400 mesh (+16 - 400). Preferably we employ 30 to 100 mesh material, for example, -30 + 60 mesh. In depositing tungsten, we may and prefer to employ tungsten hexafluoride, which is contained and vaporized in 10. It is volatile at atmospheric temperatures and need not be heated. In the reactor employed after the system has been deaerated and backfilled, hydrogen flow is established at a low flow rate of about 100 ml/min; and as described above, the temperatures in the reactor having been adjusted to 1,150° F., as measured by the thermocouples, the hydrogen flow is increased to about 1,250-1,350 ml/min, and the flow of the tungsten fluoride vapor to about 150 ml/min and the argon gas is adjusted to about 285 ml/min, all as measured by the flow meters as indicated in FIG. 1, the hydrogen being in stoichiometric excess over the tungsten hexafluoride.

The thickness of the coat of the tungsten on the particle depends on the duration of the treatment and suitably for the 40 to 50 mesh diamonds described above, the coat will be 1 mil thick in about 1 hour. Suitable thickness deposit will run from about 0.1 to about 1.5 mils thick.

In the above example, the substrate surface is completely coated, indicating that the process of vacuum chemical vapor deposition has great throwing power. The outer surface of the coated particles is topographically congruent to the outer surface of the underlying substrate and reproduces it. The interlocked structure produces a coating of high tensile and bending strength.

Since the coating is produced at high temperature, on cooling the contraction of some 1,100° F. will be substantially in excess of the contraction of the substrate as described and the resultant eventual contraction will produce a compress of the underlying abrasive particle. The preferred embodiment of the surface set drill bit, as illustrated in FIGS. 2-4, may be formed in a graphite mold section 18, which is formed with sockets positioned in the interior surface of the mold. Diamond particles 19 are placed in the sockets positioned on the interior surface of the crown end of the mold.

With mold cap 24', section 18b and 18a removed and core 25 with vent holes 26 in position, a layer 20 of particles of tungsten carbide, such as described above, is placed in the mold 18 to cover the protruding diamonds and vibrated in position to compact the powder.

The threaded steel shank 15 is then placed over the mold above the powder 20, spaced from the surface of the mold 18, and held in position with a suitable fixture not shown.

Tungsten-coated alumina particles 17 are introduced into the annulus spaced at the exterior and in the annulus at the interior of the shank 15. The layer of the particles 17 in the exterior annulus reached the level of the top of the mold section 18, but the powder in the interior annulus may, if desired, reach a higher level as shown.

The mold section 18a is then placed over the shank 15 and on the mold section 18. A ring of tungsten-coated iron particles 21 is placed in the exterior annulus over the particle section 17.
The mold section 18b is then set over the shank 15 and on the mold section 18a; and infiltrant metal powder 22, for example, of 200 mesh size such as described above, is introduced into the annulus on the exterior and the annulus at the interior of the shank 15 above the particles 21 and reaching into the space 23.

Where it is desired to employ iron, iron-based alloys, or other metals which would under the conditions of the process deleteriously attack the tungsten carbide or the diamonds, they may be encapsulated. In such case, the iron powder in ring 21 need not be encapsulated.

The ratio of the metal to the total void volume of the mold is desirably such that when the infiltrant metal melts it may fill all of the space between the secondary abrasive particles and cover the exposed diamonds.

As previously described, in carrying out this procedure, we wish to select a temperature of formation which will be below about 2,800°F., in order not to expose the diamonds to an excessive temperature. The binder metal will melt and percolate through the interstices and fill all of the voids as described above and will also wet the metallic shank. If a metallic coating is placed upon the diamond as well as the secondary abrasive particles, the binder metal will wet the surfaces of the encapsulated particles, thus producing a tight bond to the matrix.

The particle sizes of the abrasive particles are chosen to give proper compaction and void area. A particle size through a 30 mesh and on a 60 mesh (−30 + 60) is suitable.

The tungsten-coated iron powder 21 is used to provide a machinable shoulder which acts as a barrier and cover to the exterior section of the abrasive section 17. The tungsten envelope of the iron acts to protect the iron metal from escaping because its melting point will be below the temperature at which the mold is fired and could if it reached the unencapsulated diamonds attack them. It also provides for a machinable mass since the tungsten forms only a thin coat as described above.

The section is beveled as shown at 24 in FIGS. 3 and 5. This will assure that there is no exterior ledge which would otherwise be formed by the tungsten-coated alumina section, or any other secondary abrasive which is substantially unworkable to provide for a bevel surface. In the absence of this beveled section, there would be a danger that the drill bit could hang up on the bore wall or be caught on a casing section in which the drill string is to operate.

When the assembly has cooled, it is removed from the mold and the section 21 is machined as shown in FIGS. 3 and 5, the interior box threads can receive the connector 26 to assemble the drill.

The drill is thus composed of a tubular shank 15. Bonded to the interior tubular surfaces and exterior tubular surface of the shank 15 and over its crown end is a coating of abrasive particles 17 bonded by a metal matrix in the form shown in FIG. 3. The crown of said bit carries the diamonds embedded in said crown and protruding externally therefrom.

The tungsten coating of the iron is also useful where tungsten carbide or other carbides are employed with diamonds or where diamonds are employed with other secondary abrasives.

The encapsulation of the iron with the tungsten will prevent the iron from melting and percolating through the mass to attack the diamond and the tungsten carbide if used.

It will be understood that the iron may be any form of the iron, such as powdered cast iron, steel or other ferrous alloy.

The secondary abrasive used in the section 26 in the above constructions may be a tungsten carbide instead of the alumina.

The particularly useful tungsten carbide when used in either either layer 20 or 17 is one ranging from WC having 6.12 wt. % of carbon to W6C having a carbon content about 3.16 wt. %. A useful material is so-called sintered tungsten carbide and consists of microsized WC crystals and cobalt metal bonded by liquid phase sintering at high temperature. The cobalt content varies from 3 wt. % to over 25 wt. %. This material has a hardness of about 1,250 to 1,350 kg/mm² (Knoop). Another form of eutectic alloy containing about 4 percent by weight of carbon having a hardness in the range of 1,900 to 2,000 kg/mm² (Knoop) may also be used.

The drill described above may also be produced by an impregnation technique by mixing a primary abrasive, for example, diamonds with a secondary abrasive described above, for example, tungsten carbide, or metal-coated tungsten carbide, or metal-coated alumina, silicon carbide or boron nitride, such as described above. We prefer to employ the tungsten-coated alumina for the reasons stated.

In this case, the mold section 18a does not contain pockets for insertion of diamonds but is smooth. In all other respects, the mold is the same as the mold shown in FIG. 2. With the shank 15 and core 25 in position in section 18, a mixture of the metal-coated secondary abrasive and the primary abrasive, for example, diamonds is introduced in the same manner as is the case of 17 in FIG. 2. This forms a layer 26 extending part way up the exterior annulus of 15 and to a higher level in the annulus in the interior side of 15.

The section 18a is then placed in position and the layer 21 introduced. The section 18b is then placed in position and the infiltrant metal 22 is introduced into the space 23 and the cap 24 placed in position. The same procedure is then followed as described in connection with FIG. 2.

The mesh size of the infiltrant metal is suitably through a 200 mesh; and in both forms, the metal may be of the kind previously described as suitable for infiltrant purposes.

The mesh size of the secondary abrasive particles employed in the form shown in FIGS. 2 and 3 as well as in FIGS. 4 and 5 may be the same, and the size diamond particles employed in the mixture with the secondary abrasive used in forming the layer 26 may be equal to that of the secondary abrasive particles. The quantity of the diamond particles may be that of the secondary abrasive particles. The diamond particles and the secondary abrasive are intimately mixed to produce a uniform distribution.

Instead of natural diamonds, we may use artificial diamonds, whether or not etched. Additionally, we may encapsulate the diamonds as well as the secondary abrasive in the manner described above.

Instead of employing a mixture of diamonds and secondary abrasive to form the entire layer shown at 26, we may proceed as in the case of the form described in connection with 2 and 5 employ an initial crown layer formed of the mixture of diamonds and secondary
3,757,878

abrasive particle described for forming the layer 26 in a manner similar to that described for forming the crown layer 20 in FIG. 2. We may then introduce on top of the crown layer the material 17 and the layer of tungsten-coated iron as described in connection with FIG. 2 and complete the operation as described for the formation of the drill in connection with FIGS. 2 and 3.

The drill shown in FIG. 3 and also 5 is composed of a threaded shank 15 having a bore 30 to act as the conduit for mud or other drilling fluid. The shank carries the abrasive coating 17 or 26' welded to the shank by the bonding metal which wets the shank at the high temperatures of the process. The abrasive coating extends part way along the exterior and interior surface of the shank and over the lower end of the shank away from the threaded free end 26', to form the hollow crown end 29 of the drill. In the form shown in FIG. 3, embedded in the abrasive coating at the crown end of the drill are a plurality of closely spaced diamonds 19 embedded in and protruding from the crown end. This is termed a surface set diamond drill.

Where the impregnated type of drill shown in FIG. 5 is formed, the diamonds are not positioned in the crown end but are distributed uniformly throughout the abrasive body carried by the shank, or in a layer adjacent the crown end and the remainder of the abrasive body bonded to the shank.

We claim:

1. In a drill bit comprising a shank, a bore through said shank, the improvement comprising a coating, said coating including abrasive particles, metal matrix bonding said abrasive particles in said coating and bonding said coating to the lower end of said shank, said particles being encapsulated in a metal coating and contained in said metal matrix.

2. In the drill bit of claim 1 in which the abrasive particles are tungsten-coated alumina.

3. The drill bit of claim 1 in which the metal encapsulating said abrasive particles is tungsten, or tantalum, or columbium (niobium), or molybdenum or titanium.

4. In the drill bit of claim 3, said abrasive particles in said coating are metal-encapsulated tungsten carbide, or metal-encapsulated alumina, or metal-encapsulated silicon carbide, or metal-encapsulated boron nitride.

5. The drill of claim 1 in which the coating extends over the crown end of said shank and at said crown end contains a metal-bonded mixture of diamond particles and particles of metal-encapsulated tungsten carbide, or metal encapsulated alumina, or metal-encapsulated silicon carbide, or metal-encapsulated boron nitride.

6. The drill of claim 5 in which the metal-encapsulated said particles is tungsten, or tantalum, or columbium, or molybdenum, or titanium.

7. In the drill bit of claim 5 in which the abrasive particles are tungsten-coated alumina.

8. The drill of claim 1 in which said coating extends over the crown end and contains a mixture of diamond particles and tungsten carbide particles and said coating above said crown is substantially free of diamond particles and contains metal-encapsulated alumina, or metal-encapsulated silicon carbide, or metal-encapsulated boron nitride.

9. The bit of claim 8 in which said encapsulating metal is tungsten, or tantalum, or columbium (niobium), or molybdenum, or titanium.

10. The drill of claim 8 in which the metal-encapsulated abrasive is tungsten-coated alumina.

11. The drill of claim 1 in which said coating extends over the crown end and the coating at said crown end contains a mixture of metal-encapsulated diamond particles and metal-encapsulated tungsten carbide, or metal-encapsulated alumina, or metal-encapsulated silicon carbide, or metal-encapsulated boron nitride and the coating above said crown is substantially free of diamond particles and contains metal-encapsulated tungsten carbide, or metal-encapsulated alumina, or metal-encapsulated silicon carbide, or metal-encapsulated boron nitride.

12. The drill of claim 11 in which said encapsulating metal is tungsten, or tantalum, or columbium (niobium), or molybdenum, or titanium.

13. The drill of claim 11 in which said encapsulating metal is tungsten and the metal-encapsulated abrasive particles other than diamonds are tungsten-encapsulated alumina.

14. The drill of claim 1 in which the coating at the crown end of said shank includes diamond particles.

15. The drill bit of claim 14 in which the abrasive particles are tungsten-coated alumina.

16. The drill bit of claim 14 in which the metal encapsulating said abrasive particles is tungsten, or tantalum, or columbium (niobium), or molybdenum, or titanium.

17. The drill bit of claim 16 in which the metal encapsulating said abrasive particles is tungsten, or tantalum, or columbium (niobium), or molybdenum, or titanium.

18. The drill bit of claim 17, said abrasive particles in said coating are metal-encapsulated tungsten carbide, or metal-encapsulated alumina, or metal-encapsulated silicon carbide, or metal-encapsulated boron nitride.

19. The drill bit of claim 1 in which said coating extends over the crown end of said shank and in which diamond particles are surface set in said end in space configuration over the said end surface forming the crown of said bit.

20. The drill bit of claim 19 in which the metal encapsulating said abrasive particles is tungsten, or tantalum, or columbium (niobium) or molybdenum or titanium.

21. The drill of claim 19 in which the coating at said crown end contains metal-bonded tungsten carbide.

22. In the drill bit of claim 21 in which the coating above said crown end contains tungsten-coated alumina.

23. The drill of claim 21 in which the coating above said crown end contains metal-encapsulated tungsten carbide, or metal-encapsulated alumina, or metal-encapsulated silicon carbide, or metal-encapsulated boron nitride.

24. The drill bit of claim 23 in which the metal encapsulating said abrasive particles is tungsten, or tantalum, or columbium (niobium) or molybdenum or titanium.

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