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(71) Applicant: GENERAL ELECTRIC COMPANY
1 River Road
Schenectady New York 12305(US)

(72) Inventor: White, Luther Lamar
6964 Avery Road
Dublin Ohio 43017(US)
Inventor: Whalen, Paul Donald
4385 Lakeview Drive
Powell Ohio 43065(US)
Inventor: Gigl, Paul Donald
393 Pittsfield Drive
Worthington Ohio 43085(US)
Inventor: Slutz, David Earl
2448 Sandstrom Drive
Worthington Ohio 43085(US)
Inventor: Bovenkerk, Harold Paul
622 Seabury
Worthington Ohio 43085(US)

(74) Representative: Catherine, Alain
General Electric France Service de Propriété Industrielle 18 Rue Horace Vernet
F-92136 Issy-Les-Moulineaux Cedex(FR)

(54) **Drill bits utilizing polycrystalline diamond grit.**

(57) The present invention provides impregnated and surface set rotary drill bits wherein the cutting elements are thermally stable, mesh size polycrystalline diamond abrasive grit of from about 1 micron to about 2000 microns. Such drill bits can be used to drill a broader range of geological formations than could be drilled with prior art single crystal of polycrystalline diamond compact containing drill bits.

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NOVEL DRILL BITS UTILIZING POLYCRISTALLINE DIAMOND GRIT

Background of the Invention

The present invention relates to the field of earth boring bits and, more particularly, to rotary bits incoporating polycrystalline diamond grit as the cutting elements.

It is well known in the art to use diamonds as the cutting elements in drilling products. Early earth boring bits, for example, as described in U.S. Patent Nos. 1,041,568, 1,506,119, 2,136,359 and 2,809,808 utilized natural diamonds as the cutting elements. Such natural diamond containing drill bits are most commonly full face of core-type rotary drill bits and are particularly advantageous in drilling rock or other earth formations, such as, for example, in the drilling of earth and rock for oil wells and the like.

More recently, synthetic diamonds, both single crystal diamonds (SCD) and polycrystalline diamonds (PCD) have been available and have found substantial use as cutting elements in earth boring bits with many recognized advantages. For example, natural diamond bits effect drilling with a plowing action in comparison to crushing as in the case of a roller core bit, whereas synthetic diamonds tend to cut by a shearing action. In the case of rock formations, for example, it is believe that less energy is required to fail the rock in shear than in compression. A further advantage of polycrystalline diamond products is that while all crystalline diamond products preferentially fracture in the (1,1,1), (1,1,0) and (1,0,0) planes, PCD tends to be isotropic and exhibits this same cleavage but on a microscale. Consequently, PCD resists catastrophic large scale cleavage failures. The result is a retained sharpness which appears to resist polishing and aids in cutting.

In general, PCD products are fabricated from synthetic diamond crystals under heat and pressure in the presence of a catalyst-solvent to form the polycrystalline structure. In one form of such product, a sintering aid material is distributed in the interstices between diamond crystals and the PCD table is bonded to a carbide backing. For further details regarding such PCD products, the reader is referred to U.S. Patent No. Re. 32,380, assigned to the same assignee as the present invention. Products of this type are available from General Electric Company under the STRATAPAX trademark.

With early PCD elements, problems arose in the production of certain drilling products because the PCD elements, especially those bonded to a carbide support, tended to be thermally unstable at the temperatures used in the furnacing of the metal matrix bit crown, resulting in catastrophic failure of the PCD elements. It was believed that such failure was due to thermal stress cracks caused by the expansion of the metal or metal alloy used as the sintering aid in the formation of the PCD elements. One means for overcoming this problem is to use brazing techniques to fix the PCD table faced cutter into the drill bit matrix, for example, as described in U.S. Patent No. 4,225,322, assigned to the same assignee of the present invention.

A second solution to this problem was the development of thermally stable PCD products. One thermally stable PCD product is available from General Electric Company under the GEOSET trademark. Such GEOSET drill diamond is a porous product, porosity being achieved by leaching out the non-diamond materials as described in U.S. Patent No. 4,224,380, assigned to the same assignee as the present invention and incorporated herein by reference. Other thermally stable PCD products can be obtained by replacing the porous network of GEOSET drill diamond with a material such as silicon, silicon carbide, or other material having a coefficient of thermal expansion which closely matches that of diamond.

GEOSET PCD products are temperature stable up to about 1200°C and are available in a variety of shapes, e.g., cubic, cylindrical and triangular. GEOSET drill diamond is available in sizes ranging from 0.03 carat to more than 1.0 carat per piece. The prior art teaches that GEOSET drill diamond uses surface set manufacturing technology but has a cutting action very similar to the impregnated concept.

The patent literature contains a number of references directed to drill bits utilizing particular GEOSET drill diamond settings, see for example U.S. Patent Nos. 4,491,188, 4,499,959, 4,515,226, 4,529,047, 4,550,790, 4,697,653 and 4,726,718.

U.S. Patent No. 4,738,689, Gigl et al., assigned to the same assignee as the present invention and incorporated herein by reference, discloses porous polycrystalline diamond compacts possessing enhanced oxidation resistance by virtue of a continuous coating, preferably a metal coating, over the entire surface of the compact.

U.S. Patent No. 4,776,861, assigned to the same assignee as the present invention and incorporated herein by reference, discloses a polycrystalline diamond abrasive grit of from about 1 to 1000 microns in diameter. Such abrasive grit can be used in the manufacture of tools wherein the abrasive grit is held in a binder. Although drill bits are disclosed along with dressing tools, grinding wheels, saws and honing stones as illustrative tools, the cited references and examples are directed to wheels and saws and therefore do not provide the artisan with any guidance on how such abrasive grit is to be used in the manufacture of earth boring drill bits.

Summary of the Invention

It is an object of the present invention to provide drill bits having an increased bit life.

It is another object of the present invention to provide drill bits having an increased rate of penetration.

It is another object of the present invention to provide drill bits capable of drilling geological formations more economically than prior art drill bits.

In accordance with one aspect of the present invention, there is provided a drill bit comprising polycrystalline diamond abrasive grit of from about 1 to 2000 microns in diameter distributed in a metal, alloy or other suitable matrix.

In accordance with another aspect of the present invention, there is provided a drill bit comprising surface set polycrystalline diamond abrasive grit of from about 50 to 2000 microns in diameter as the cutting elements.

Description of the Invention

Impregnated diamond bits of the present invention have a preferably metal or alloy matrix at the drilling surface in which polycrystalline diamond abrasive grit of from about 1 to 2000 microns in diameter ore relatively uniformly distributed. Such impregnated diamond drill bits can be used in place of single crystal diamond impregnated drill bits to drill in medium hard to hard rock formations.

One significant advantage to be obtained by using the impregnated drill bits of the present invention in place of the SCD impregnated drill bits of the prior art is that, unlike the single crystal diamonds which tend to wear smooth or fracture and dislodge from the bit, the polycrystal line abrasive grit employed in the practice of the invention continually generates new cutting surfaces. Also, because of its polycrystalline structure, fracturing will not be sufficient to cause the diamond to dislodge from the bit matrix.

Impregnated diamond bits in accordance with the present invention can employ any of the kerf designs known in the art. For example, a flat or stepped profile can be used in very hard formations, and a rounded profile can be employed in hard formations. Flat and rounded profile bits are also effective in fractured formations. Stepped and double-stepped profiles are frequently utilized in thick-wall bits.

The design of the crown must also ensure that the bit cuts evenly and cost effectively. Furthermore, the diamonds must be cooled efficiently and the material cut or ground must be flushed away effectively. Sufficient cooling and material removal is obtained when the number of waterways is between two and about twelve, depending on the formation to be drilled. Shales and similar soft formations require more water circulation and hence multiple water channels are often used to prevent the bit from gumming up. On the other hand, hard, fine-grained formations require less water circulation and fewer waterways will suffice.

Geometrical characteristics of the crown, in particular the actual diameter "set OD", are very important. To insure that the bit will maintain guage as the matrix wears down, diamond guage stones or diamond kickers as well as tungsten carbide inserts are used as reinforcement. Similar reinforcements are used to insure that the inside diameter of the bit will remain as specified.

The impregnated drill bits of the present invention employ mesh size polycrystalline diamond abrasive grit as the cutting element, typically having a size of from about 1 to 2000 microns and preferably from about 250 to about 1000 microns, i.e. up to about 10 U.S. mesh size, and preferably from about 60 U.S. mesh size to about 10 U.S. mesh size. The most preferred mesh sizes will generally be about 14/16, 18/20, 20/25 and 30/40 U.S. mesh size. As a general guide, the harder the rock, the smaller the diamond required.

Although the concentration of the polycrystalline diamond abrasive grit can vary over a wide range, for example, five to fifty percent by volume, preferably the polycrystalline diamond concentration will be from about five to twenty-fifty volume percent and, most preferably, from about seven to twenty volume percent.

It is especially preferred that the polycrystaline diamond be of the type described in U.S. Pat. No. 4,224,380 or 4,776,861. Briefly, such polycrystalline diamond comprises (i) between about 70 volume percent and 95 volume percent of self-bonded diamond particles, (ii) a metallic phase infiltrated substantially uniformly throughout said component, said phase comprising between about 0.05% and 3% by volume of a catalytic metal or alloy, and (iii) a network of interconnected empty pores dispersed through said polycrystalline diamond.

Alternatively, such network of interconnected empty pores can be infiltrated with a material having a coefficient of thermal expansion about equal to that of diamond, for example, silicon or silicon carbide.

The present invention preferably employs metal coated polycrystalline diamond, for example, as described in U.S. Pat. No. 4,738,689. The use of such a coating provides greater retention in the matrix material and protects against thermal damage in oxidizing environments such as may be experienced with high temperature matrix fabrication.

It is also contemplated that the mesh size polycrystalline diamond be utilized in combination with single crystal diamonds and/or polycrystalline diamond compacts so as to enhance abrasion and impact performance. Preferably the polycrystalline diamond abrasive is present in a concentration of from about 1 to about 20 volume percent and the single crystal natural or synthetic diamond is present in a concentration of from about 1 to about 20 volume perecent.

Any suitable matrix may be used in the practice of the present invention. The function of the matrix in impregnated bits is to hold the diamond particles at the cutting face for so long as they are capable of working efficiently. Its composition will be determined by properties of the rock types for which it is intended. Typical matrices are based on powder metals which give properties of wear resistance, diamond retention, and other advantages that the early cast metal bits did not possess. It is important that the diamonds be uniformly distributed throughout the bond matrix of impregnated bits to insure that the diamond and matrix wear together. The matrix must be hard enough to wear away just fast enough to expose new diamond as required. Typical matrix materials range from very soft bronzes to tungsten carbide, as well as ceramics.

Impregnated drill bits made in accordance with the foregoing disclosure create the opportunity to manufacture thinner wall core bits wee high weight on bit is not possible. Penetration rates can be maintained or increased with reduced bit weight. This can result in improved hole straightness, i.e. reduced bit deviation during drilling.

In accordance with another aspect of the invention, there are provided surface set drill bits having thermally stable polycrystalline diamond abrasive grit of from about 50 to 2000 microns in diameter. Such surface set drill bits can be used in place of larger single crystal diamonds or polycrystalline diamond compacts such as GEOSET. Because the polycrystalline diamonds used in the practice of the present invention have attributes of both single crystal and polycrystalline diamond, the surface set bits can be used to drill a broader range of geological formations than heretofore was possible.

The surface set drill bits of the present invention can employ any kerf designs known in the art. Suitable profiles include the standard flat and round profiles which give good, all around performance, semi-round profiles for use in fractured formations, stepped profiles for higher penetration rates, conical profiles for a bit which is stronger than a stepped profile bit but still having good penetration, and biconical profiles for thick kerf bits used in soft and unfractured formations.

Surface set drill bits in accordance with the present invention utilize the same kinds of thermally stable polycrystalline diamond as is described above for impregnated drill bits. However, the polycrystalline diamond employed in this aspect of the present invention are generally toward the larger end of mesh sizes; for example, preferably from about 60 U.S. mesh size to about 10 U.S. mesh size with from about 30 U.S. mesh size to about 14 U.S. mesh size being especially preferred.

It is contemplated that surface set drill bits of the present invention will employ concentrations and bit designs known in the art. In addition, it is contemplated that the thermally stable polycrystal line diamond abrasive used in the invention may have either irregular shapes or regular shapes, such as, for example, cubic, cylindrical, hexagonal or triangular. Preferably, such polycrystalline diamonds are metal coated and used in combination with single crystal diamonds and/or polycrystalline diamond compacts.

One preferred drill bit design to which the present invention may be adapted is described in U.S. Pat. No. 3,709,308, which is incorporated herein by reference. Briefly, the '308 patent is directed to diamond drill bits wherein cubic diamonds are set in the drilling face of the bit in a manner such that their flat cutting faces are presented to the formation to effect the removal in the nature of a drag bit. The setting of cubic and similar diamonds in generally radial planes results in the presentation of a much larger drilling surface for action on the formation than is available when round diamonds are used.

In many applications it will be desirable to set the polycrystalline mesh diamond so that only a small portion, i.e., less than about 0.5 mm, is exposed above the adjacent metal matrix face of the drill bit. In other applications it may be preferrable to expose a larger portion of the diamond, for example, in accordance with the teachings of U.S. Pat. No. 4,491,188, incorporated herein by reference. The '188 patent generally describes a bit for use in earth boring which comprises a matrix body having portions forming a gage and a face; said face including a plurality of waterways forming pad means between adjacent waterways; each of said pad means including a plurality of spaced polycrystalline diamond cutting elements mounted directly in the matrix during matrix formation; each of said cutting elements being of a predetermined geometric shape with a cutting face and being temperature stable to at least about 1200°C; the said cutting elements including a portion received within the body matrix of said pad means and a portion which extends above the surface of said pad means and which is adapted to form the cutting face of said cutting element, the portion of said cutting elements which forms the cutting face of said cutting elements extending more than 0.5 mm above the surface of the corresponding pad.

Another variation to which the present invention can be adapted is described in U.S. Pat. No. 4,512,426, which is incorporated herein by reference. This patent discloses a rotary bit containing a plurality of teeth incorporating diamond cutting elements of a first and second type. Each type of tooth is particularly adapted to cut a particular type of rock formation. For example, the first type of diamond teeth may be designed to cut soft to medium hard rock formations and the second type of diamond teeth may be designed to cut hard or abrasive rock formations. The first type of teeth may be set on the bit face to have a greater exposure from the bit face than the second type of teeth or vice versa. Thus, for example, the present invention may be practiced by employing POLYMESH polycrystalline diamond from General Electric Company in combination with GEOSET drill diamond or MBS diamond, also available from General Electric.

In another variation, polycrystalline diamond abrasive grit can be surface set or impregnated ahead of or behind polycrystalline diamond compacts for dual cutting action.

Many other variations and modifications may be made by those of ordinary skill in the art without departing from the spirit and scope of the invention.

Claims

1. A rotable bit for use in earth boring, comprising thermally stable, mesh size polycrystalline diamond abrasive grit impregnated into a crown matrix.

2. A bit as in Claim 1, wherein the polycrystalline diamond abrasive grit is from about 1 to 2000 microns.

3. A bit as in Claim 2, wherein the polycrystalline diamond abrasive grit is from about 250 to about 1000 microns.

4. A bit as in Claim 2, wherein the concentration of polycrystalline diamond abrasive grit is from about five to about fifty volume percent.

5. A bit as in Claim 3, wherein the concentration of polycrystalline diamond abrasive grit is from about seven to about twenty volume percent.

6. A bit as in Claim 1, wherein the polycrystalline diamond abrasive grit comprises between about 70 volume percent and 95 volume percent of self-bonded diamond particles, a metallic phase infiltrated substantially uniformly throughout said polycrystalline diamond abrasive grit, said phase comprising between about 0.05% and 3% by volume of a catalytic metal or alloy, and a network of interconnected empty pores dispersed throughout said polycrystal line diamond abrasive grit.

7. A bit as in Claim 6, wherein said network of interconnected empty pores are infiltrated with a material having a coefficient of thermal expansion about equal to the to the coefficient of thermal expanion of diamond.

8. A bit as in Claim 6, wherein the polycrystal line diamond abrasive grit is coated with a metal or ceramic.

9. A rotable bit for use in earth boring, comprising thermally stable, mesh size polycrystalline diamond abrasive grit surface set into a crown matrix.

10. A bit as in Claim 9, wherein the polycrystalline diamond abrasive grit is from about 60 mesh to about 10 mesh.

11. A bit as in Claim 10, wherein the polycrystalline diamond abrasive grit is from about 30 mesh to about 14 mesh.

12. A bit as in Claim 9, wherein the polycrystalline diamond abrasive grit is cubic, cylindrical, hexagonal or triangular in shape.

13. A bit as in Claim 12, wherein the polycrystalline diamond abrasive grit is coated with a metal or ceramic.

14. A bit as in Claim 9, wherein the polycrystalline diamond abrasive grit has more than 0.5 mm of its surface exposed above the adjacent metal matrix of the drill bit.

15. A bit for use in earth boring comprising thermally stable, mesh size polycrystalline diamond abrasive grit in combination with natural or synthetic single crystal diamonds impregnated or surface set in a crown matrix.

16. A bit as in Claim 15, wherein the polycrystalline diamond abrasive grit is present in a concentration of from about 1 to about 20 volume percent and the single crystal natural or synthetic diamond is present in a concentration of from about 1 to about 20 volume percent.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 11 7669

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	EP-A-0 046 374 (DE BEERS) * Abstract; claims; figures *	1,2,4,5,8	E 21 B 10/46
A	EP-A-0 116 403 (DE BEERS) * Abstract; figures *	6	
A,D	US-A-4 224 380 (BOVENKERK) * Abstract *	6	
A,D	EP-A-0 137 711 (GTE VALERON) * Abstract *	1	
A	US-A-3 938 599 (HORN) * Abstract; figures *	1,9,15	
A	US-A-3 718 130 (WING) * Column 3, lines 50-54; figure 1; abstract *	1	
A	US-A-4 173 457 (SMITH) * Abstract *	1	**TECHNICAL FIELDS SEARCHED (Int. Cl.5)**
A	EP-A-0 237 359 (SMITH) * Column 7, lines 6-11; figure 18 *	1	E 21 B
A	US-A-4 460 053 (JÜRGENS) * Figure 3; column 4, lines 4-13 *	1	
A,D	EP-A-0 264 024 (GENERAL ELECTRIC) * Abstract *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29-01-1990	WEIAND T.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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