



(11) **EP 0 967 037 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention
of the grant of the patent:
22.09.2010 Bulletin 2010/38

(51) Int Cl.:
B22F 7/06 ^(2006.01) **E21B 10/573** ^(2006.01)

(21) Application number: **99303237.4**

(22) Date of filing: **27.04.1999**

(54) **Polycrystalline diamond compact cutter with interface**

Polykristallines Diamant-Schneidelement mit Zwischenflächen

Elément de coupe en diamant polycristallin compacte avec interface

(84) Designated Contracting States:
GB IE

(30) Priority: **04.05.1998 US 72363**
15.03.1999 US 267391

(43) Date of publication of application:
29.12.1999 Bulletin 1999/52

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EP-A2- 0 517 510 GB-A- 2 290 329
US-A- 5 711 702

EP 0 967 037 B1

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Description

[0001] The present invention relates to supported polycrystalline diamond compact (PDC) cutters made under high temperature, high pressure (HT/HP) processing conditions, and more particularly to supported PDC compacts having non-planar interfaces between the PDC layer and the cemented carbide support layer. The object of the present invention is to provide a PDC cutter with improved resistance to cracking during installation.

[0002] Abrasive compacts are used extensively in cutting, milling, grinding, drilling and other abrasive operations. The abrasive compacts typically consist of polycrystalline diamond or cubic boron nitride particles bonded into a coherent hard conglomerate. The abrasive particle content of abrasive compacts is high and there is an extensive amount of direct particle-to-particle bonding. Abrasive compacts are made under elevated temperature and pressure conditions at which the abrasive particle, be it polycrystalline diamond or cubic boron nitride, is crystallographically stable.

[0003] Abrasive compacts tend to be brittle and, in use, they are frequently supported by being bonded to a cemented carbide substrate. Such supported abrasive compacts are known in the art as composite abrasive compacts. The composite abrasive compact may be used as such in the working surface of an abrasive tool.

[0004] Fabrication of the composite is typically achieved by placing a cemented carbide substrate into the container of a press. A mixture of diamond grains or diamond grains and catalyst binder is placed atop the substrate and compressed under HT/HP conditions. In so doing, metal binder migrates from the substrate and "sweeps" through the diamond grains to promote a sintering of the diamond grains. As a result, the diamond grains become bonded to each other to form a diamond layer, and that diamond layer is bonded to the substrate along a conventionally planar interface. The metal binder occupies the space between the diamond grains with little or no porosity in the sintered compact. Methods for making diamond compacts and composite compacts are more fully described in United States Patent Nos. 3,141,746 ('746); 3,745,623 ('623); 3,609,818 ('818); 3,850,591 ('591); 4,394,170 ('170); 4,403,015 ('015); 4,794,326 ('326); and 4,954,139 ('139), the disclosures of which are expressly incorporated herein by reference.

[0005] A composite formed in the above-described manner may be subject to a number of shortcomings. For example, the coefficients of thermal expansion and elastic constants of cemented carbide and diamond are different. Thus, during heating or cooling of the PDC, thermally induced stresses occur at the interface between the diamond layer and the cemented carbide substrate. The magnitude of these stresses is dependent on the applied pressure, the temperature of zero stress and the disparity in thermal expansion coefficients and elastic constants.

[0006] Another potential shortcoming which should be

considered relates to the creation of internal stresses within the diamond layer which can result in a fracturing of that layer. Such stresses also result from the presence of the cemented carbide substrate and are distributed according to the size, geometry and physical properties of the cemented carbide substrate and the polycrystalline diamond layer.

[0007] EP-A-0133386 suggests PDC in which the polycrystalline diamond body is completely free of metal binders and is to be mounted directly on a metal support. However, the mounting of a diamond body directly on metal presents significant problems relating to the inability of the metal to provide sufficient support for the diamond body. EP-A-0133386 further suggests the use of spaced ribs on the bottom surface of the diamond layer which are to be embedded in the metal support.

[0008] According to EP-A-0133386, the irregularities can be formed in the diamond body after the diamond body has been formed, e.g., by laser or electronic discharge treatment, or during the formation of the diamond body in a press, e.g., by the use of a mold having irregularities. As regards the latter, it is further suggested that a suitable mold could be formed of cemented carbide; in such case, however, metal binder would migrate from the mold and into the diamond body, contrary to the stated goal of providing a metal free diamond layer. The reference proposes to mitigate this problem by immersing the thus-formed diamond/carbide composite in an acid bath which would dissolve the carbide mold and leach all metal binder from the diamond body. There would thus result a diamond body containing no metal binder and which would be mounted directly on a metal support. Notwithstanding any advantages which may result from such a structure, significant disadvantages still remain, as explained below.

[0009] In summary, EP-A-0133386 proposes to eliminate the problems associated with the presence of a cemented carbide substrate and the presence of metal binder in the diamond layer by completely eliminating the cemented carbide substrate and the metal binder. However, even though the absence of metal binder renders the diamond layer more thermally stable, it also renders the diamond layer less impact resistant. That is, the diamond layer is more likely to be chipped by hard impacts, a characteristic which presents serious problems during the drilling of hard substances such as rock.

[0010] It will also be appreciated that the direct mounting of a diamond body on a metal support will not, in itself, alleviate the previously noted problem involving the creation of stresses at the interface between the diamond and metal, which problem results from the very large disparity in the coefficients of thermal expansion between diamond and metal. For example, the thermal expansion coefficient of diamond is about 45×10^{-7} cm/cm/°C. as compared to a coefficient of $150 - 200 \times 10^{-7}$ cm/cm/°C for steel. Thus, very substantial thermally induced stresses occur in the cutter.

[0011] Recently, various PDC structures have been

proposed in which the diamond/carbide interface contains a number of ridges, grooves or other indentations aimed at reducing the susceptibility of the diamond/carbide interface to mechanical and thermal stresses. In U.S. Patent No. 4,784,023 ('023), a PDC includes an interface having a number of alternating grooves and ridges, the top and bottom of which are substantially parallel with the compact surface and the sides of which are substantially perpendicular the compact surface.

[0012] U.S. Patent No. 4,972,637 ('637) provides a PDC having an interface containing discrete, spaced recesses extending into the cemented carbide layer, the recesses containing abrasive material (e.g., diamond) and being arranged in a series of rows, each recess being staggered relative to its nearest neighbor in an adjacent row. It is asserted in the '637 patent that as wear reaches the diamond/carbide interface, the recesses, filled with diamond, wear less rapidly than the cemented carbide and act, in effect, as cutting ridges or projections. When the PDC is mounted on a stud cutter, as shown in FIG. 5 of the '637 patent, the wear plane 38 exposes carbide regions 42 which wear much more rapidly than the diamond material in the recesses 18. As a consequence, depressions develop in these regions between the diamond filled recesses. The '637 patent asserts that these depressed regions, which expose additional edges of diamond material, enhance the cutting action of the PDC cutter.

[0013] U.S. Patent No. 5,007,207 ('207) presents an alternative PDC structure having a number of recesses in the carbide layer, each filled with diamond, which make up a spiral or concentric circular pattern, looking down at the disc shaped compact. Thus, the structure in the '207 patent differs from the structure in the '637 patent in that, rather than employing a large number of discrete recesses, the structure of the '207 patent uses one or a few elongated recesses which make up a spiral or concentric circular pattern. FIG. 5 in the '207 patent shows the wear plane which develops when the PDC is mounted and used on a stud cutter. As with the '637 patent, the wear process creates depressions in the carbide material between the diamond filled recesses. Like the '207 patent, the '637 patent also asserts that these depressions which develop during the wear process enhance cutting action. In addition to enhancing cutting action, non-planar interfaces have also been presented in U.S. Patent Nos. 5,484,330 ('330), 5,494,477 ('477) and 5,486,137 ('137) which reduce the susceptibility to cutter failure by have having favorable residual stresses in critical areas during cutting.

[0014] EP 0604211 describes a composite tool for drilling bits, comprising an abrasive compact layer bonded to a cemented carbide substrate. The substrate comprises a recess, which introduces a compressive pre-stress in the abrasive compact layer to strengthen that layer.

[0015] GB 2290329 discloses a cutting element configured to redistribute residual stresses encountered during use to the circumferential outer surface thereof, par-

ticularly near the peripheral area of the abrasive layer to reduce the fracture or cracking potential of the abrasive layers.

[0016] EP 0418078 discloses a method of producing a composite abrasive compact, which comprises sintering a particulate component, necessary to form an abrasive surface, to a support structure, by utilising a metallic interface and conditions of elevated temperature and pressure.

[0017] EP 0517510 describes a composite diamond abrasive compact, comprising a diamond compact bonded to a cemented carbide support. The carbide support comprises at least two zones, the first zone containing a predetermined amount of a binder metal, and the second zone containing a lower amount of a binder metal. The second zone extends from the interface of the support and compact, and increases in metal content from the interface to the first zone incrementally, to reduce the stresses introduced into the carbide support during use.

[0018] Whereas the aforementioned patents assert a desirable cutting action in the rock and also favorable residual stresses in during cutting, it is also highly desirable to minimize the diamond layer's susceptibility to fracture during installation into the drill bit.

[0019] In Polycrystalline Diamond (PDC) cutters, the structure of the interface between the tungsten carbide (WC) and the PDC has an important impact on cutter breakage and wear. The composition of the WC support also plays an important role in PDC cutter retention in the bit pocket. The object of the present invention is to provide a PDC cutter with a specific structure and composition to provide higher performance in drilling, mining and quarrying, especially in tough applications where cutter breakage, retention and wear are issues.

[0020] The present invention provides an improved abrasive tool insert comprising an abrasive layer; a cemented carbide core bonded to said abrasive layer; and a cemented carbide outer layer bonded to said core; characterised in that the metal binder content of said core is less than the metal binder content of said outer layer.

[0021] The present invention also provides a tool insert wherein the interface between said abrasive layer and said core is non-planar.

[0022] Preferably the abrasive layer is composed of polycrystalline diamond, the cemented carbide is selected from the group consisting of tungsten, tantalum and titanium carbide and the metal binder is selected from the group consisting of cobalt, iron, nickel, platinum, titanium, chromium, tantalum and alloys thereof. The metal binder content of the core preferably ranges from about 5-15% by weight on average and the metal binder content of the outer layer preferably ranges from about 13-22% by weight on average; more preferably the metal binder content of the core is approximately 5% by weight less than the metal binder content of the outer layer. The interface between the abrasive layer and the core may be a non-planar.

[0023] This PDC cutter is designed with a multi-zone

cemented carbide support to reduce the tendency of the carbide support to break in service, to improve drilling action when the cutter starts to wear, and to strengthen the braze joint holding the cutter to the bit body. The cutter is designed to have stiffer and more brittle material supporting the diamond table while a tougher, cemented tungsten carbide is placed in the region where carbide breakage tends to occur. This can be achieved by increasing the binder content of the material (typically cobalt) which also improves brazability and cutter retention. Finally, it may also have the advantage of lowering the abrasion/wear resistance of the cemented tungsten carbide in this region. This WC structure will help resolve the cutter failures described below.

[0024] Over the past few years many advances have been made in the science of designing and sintering the abrasive layers on these cutters. Whereas prior to these advances, the predominant failure of these cutters occurred in the abrasive layers. Now, the catastrophic type failures tend to occur in the cemented tungsten carbide support. Typically, cracks propagate through the cemented tungsten carbide support and sections fall away resulting in the diamond table being cantilevered and breaking away.

[0025] On cutters that do not crack or break, the abrasive edge (typically diamond) wears during the cutting action and a wear land develops, increasing in area with the progression of cutter wear. These wear lands contact the formation being drilled and slow the cutting action by taking the load from the diamond edge. In order to maintain effective cutting action and rates of penetration, the weight on the bit may be increased, resulting in much higher loads on the cutters. The rubbing of the carbide wear land against the formation generates excessive heat which results in a form of carbide cracking commonly known as "heat checking".

[0026] Cutter retention into the pockets in the bit body is also important in ensuring the success of bit runs. When the braze joint attaching the cutter to the bit body fails and the cutter comes loose, it causes extensive damage to the following cutters and blades. Improving the strength of the braze joint between the cutters and the bit body can improve the overall bit performance.

[0027] The cutter designs of this invention may be applied to PCD cutters with both planar and non-planar interfaces both substantially flat and domed, etc., as well as with cylindrical, stud mounted, conical and other cutter geometries.

[0028] The detailed description below describes the preferred embodiments of the invention and is intended to be read in conjunction with the following set of drawings.

[0029] FIG. 1 shows a typical embodiment of this invention wherein the core of the substrate comprises cemented WC with a 13% Co binder phase and the outer portion of the substrate comprises cemented WC with a 20% Co binder phase. Of course, the actual percentages of Co in the inner and outer layers are not critical. The

important feature for purposes of the present invention is that the Co percentage in the core is less than the Co percentage in the outer layer.

[0030] FIG. 2 shows an example of cracking and breakage in the cemented tungsten carbide support.

[0031] FIG. 3 shows an example of a worn cutter.

[0032] FIG. 4 shows an example of diametrical splitting which results from flexure of the diamond table causing vertical cracks to propagate through the entire cutter.

[0033] FIG. 5 shows a resulting diamond lip protruding over the level of the wear flat with the load being transmitted through the diamond layer.

[0034] Polycrystalline diamond compact (PDC) cutters consist of a polycrystalline diamond table (diamond table) bonded to a carbide substrate. The bond between the diamond table and the carbide support is formed at high temperature, high pressure (HT/HP) conditions. Subsequent reduction of the pressure and temperature to ambient conditions results in stress development in both the diamond table and carbide support due to differences in the thermal expansion and the compressibility properties of the bonded layers. The differential thermal expansion and differential compressibility have opposite effects of stress development as the temperature and pressure are reduced; the differential thermal expansion tending to cause compression in the diamond table and tension in the carbide support on temperature reduction whereas the differential compressibility tends to cause tension in the diamond table and compression in the carbide support. Finite element analysis (FEA) of stress development and strain gage measurements confirm that the differential thermal expansion effect dominates resulting in generally compressive residual stresses in the diamond table.

[0035] A number of methods for achieving the desired result of low Co content in the carbide substrate at the carbide-diamond interface would be immediately apparent to those of skill in the art. Some of these are described below.

[0036] One method involves placing separate pieces of WC into the HT/HP process and assembling them into the desired geometry. For example, the carbide substrate adjacent to the diamond table and its center region extending away from the carbide-diamond interface comprise low Co content. On the other hand, the remainder of the substrate, its outer region, comprises higher Co content carbide.

[0037] Another method involves having a carbide manufacturer supply a graduated Co content carbide substrate in which the carbide manufacturer provides integral carbide substrates which have low Co content in the desired regions. It is important that it be noted that, according to the present invention, the decreased Co content in the carbide substrate is desired both in the region adjacent to the diamond table (i.e., at the carbide-diamond interface) and in the center region extending away from the carbide-diamond interface.

[0038] Yet another method consists of controlling the

removal of Co from the carbide substrate during sintering of the PDC cutter. For example, during sintering, Co contained in the substrate melts and sweeps into the diamond table. Preferential removal of Co from the carbide substrate during the sweep of Co into the diamond table results in a stiffer/harder, lower Co content region. The amount of preferential Co removal can be controlled by altering the geometry of the carbide-diamond interface, and thus the volume fraction ratio of carbide to diamond at the interface.

[0039] The object of the present invention is to provide a higher performance cutter for use in drilling, mining and quarrying. The carbide substrate (preferably Tungsten Carbide (WC)) of the PDC cutter will (1) have improved adhesion of the diamond table to the substrate, (2) have a harder/stiffer center region to support the diamond table, and (3) have a softer/tougher outer region to reduce the tendency for cracking. The cutting action of this product can also be designed to deploy a kerfing cutting action on the rock as the cutter develops a wear flat.

[0040] A typical embodiment of this invention is shown in Figure 1. Core 12 of substrate 10 in this embodiment is made from a cemented WC with a 13% Co binder phase as indicated. Outer portion 14 of substrate 10 is made from a cemented WC with 20% Co binder phase as indicated. (The higher the Co content in the WC, the "softer" the carbide will be.)

[0041] The harder or stiffer carbide is required in core 12 of the cutter to support diamond table 16. See Figure 4. Using "softer" carbide (such as having higher cobalt content) in this region can result in flexure of diamond table 40 causing vertical cracks 42 to propagate through the entire cutter. Failure of this type is commonly known as diametrical splitting and is demonstrated in Figure 4. Outer portion 14 is tougher and softer than core 12. This will reduce the tendency for cracking 20 of the type shown in Figure 2.

[0042] As shown in Figure 3, when brazing to cemented carbides, the braze wears and bonds better to the binder phase than to the carbide crystals. Having the higher cobalt content in this region makes the cutters more brazable, and therefore less likely to detach from the bit body in service.

[0043] Figure 5 shows a "diamond lip" type of cutting edge. The softer carbide in the region of wear land 54 will also wear or erode away more quickly as it abrades against the formation. This will result in the diamond layer 50 protruding over the level of wear land 54 yet remaining flat with the load being transmitted through the diamond layer and consequently resulting in an improved cutting action. This ideal type of diamond cutting edge is typically called a "diamond lip."

[0044] The present invention is valuable as an improved way to manufacture PDC cutters with unique properties. The WC substrate's Co content structure according to the present invention provides a more durable PDC cutter which is less susceptible to cracking and breakage. The primary advantage of this structure being

the enhanced performance and less installation and/or brazing breakage due to the reduced thermal expansion of the carbide substrate.

Claims

1. An abrasive tool insert (10) comprising:

an abrasive layer (16);
a cemented carbide core (12) bonded to said abrasive layer (16);
and a cemented carbide outer layer (14) bonded to said core (12);

characterised in that the metal binder content of said core (12) is less than the metal binder content of said outer layer (14).

2. A tool insert according to claim 1 wherein said abrasive layer (16) is composed of polycrystalline diamond.

3. A tool insert according to claim 1 wherein the metal binder content of said core (12) ranges from about 5-15% by weight on average and the metal binder content of said outer layer (14) ranges from about 13-22% by weight on average.

4. A tool insert according to claim 1 wherein the metal binder content of said core (12) is approximately 5% by weight less than the metal binder content of said outer layer (14).

5. A tool insert according to claim 1 wherein the interface between said abrasive layer (16) and said core (12) is non-planar.

6. A tool insert according to claim 1 wherein said abrasive layer (16) is a polycrystalline diamond layer; wherein said cemented carbide core (12) is a tungsten carbide core layer bonded to said diamond layer; and wherein said cemented carbide outer layer (14) is a tungsten carbide outer layer bonded to said core layer; wherein said core layer (12) has binder metal content ranging from about 5-15% by weight on average; and wherein said outer layer (14) has a binder metal content ranging from about 13-22% by weight on average.

7. A method for manufacturing an abrasive tool insert (10) in the reaction vessel of a high temperature/high pressure apparatus, said method comprising the steps of:

placing a cemented carbide outer layer (14) in said reaction vessel;
placing a cemented carbide core (12) within said

- outer layer (14),
covering said core with a layer of abrasive particles (16); and
subjecting said vessel to high temperature and high pressure,
characterised in that said core (12) has a lower metal binder content than said outer layer (14).
8. A method according to claim 7 wherein the metal binder content of said core (12) ranges from about 5-15% by weight on average and the metal binder content of said outer layer (14) ranges from about 13-22% by weight on average.
9. A method according to claim 7 wherein the metal binder content of said core (12) is approximately 5% by weight less than the metal binder content of said outer layer (14).
10. A method according to claim 7 wherein:
- said cemented carbide outer layer (14) and said cemented carbide core (12) are preformed as a cemented carbide piece (10).

Patentansprüche

1. Ein Schleifwerkzeugeinsatz (10), der Folgendes beinhaltet:
- einen Schleifbelag (16);
einen mit dem Schleifbelag (16) verbundenen Hartmetallträger (12);
und eine mit dem Träger (12) verbundene äußere Hartmetallschicht (14);
dadurch gekennzeichnet, dass der Metallbindemittelgehalt des Trägers (12) geringer als der Metallbindemittelgehalt der äußeren Schicht (14) ist.
2. Werkzeugeinsatz gemäß Anspruch 1, wobei der Schleifbelag (16) aus polykristallinem Diamant besteht.
3. Werkzeugeinsatz gemäß Anspruch 1, wobei der Metallbindemittelgehalt des Trägers (12) im Durchschnitt von ungefähr 5-15 Gewichtsprozent reicht und der Metallbindemittelgehalt der äußeren Schicht (14) im Durchschnitt von ungefähr 13-22 Gewichtsprozent reicht.
4. Werkzeugeinsatz gemäß Anspruch 1, wobei der Metallbindemittelgehalt des Trägers (12) annähernd 5 Gewichtsprozent geringer als der Metallbindemittelgehalt der äußeren Schicht (14) ist.
5. Werkzeugeinsatz gemäß Anspruch 1, wobei die

Grenze zwischen dem Schleifbelag (16) und dem Träger (12) nicht eben ist.

6. Werkzeugeinsatz gemäß Anspruch 1, wobei der Schleifbelag (16) eine Schicht aus polykristallinem Diamant ist;
wobei der Hartmetallträger (12) eine mit der Diamantschicht verbundene Wolframcarbidträgerschicht ist und wobei die äußere Hartmetallschicht (14) eine mit der Trägerschicht verbundene äußere Wolframcarbidschicht ist;
wobei die Trägerschicht (12) im Durchschnitt einen Bindemittelmetallgehalt im Bereich von ungefähr 5-15 Gewichtsprozent aufweist; und
wobei die äußere Schicht (14) im Durchschnitt einen Bindemittelmetallgehalt im Bereich von ungefähr 13-22 Gewichtsprozent aufweist.
7. Ein Verfahren zur Herstellung eines Schleifwerkzeugeinsatzes (10) im Reaktionsgefäß einer Hochtemperatur-/Hochdruck-Vorrichtung, wobei das Verfahren die folgenden Schritte beinhaltet:

Platzieren einer äußeren Hartmetallschicht (14) in das Reaktionsgefäß;
Platzieren eines Hartmetallträgers (12) innerhalb der äußeren Schicht (14),
Abdecken des Trägers mit einer Schicht Schleifpartikel (16) und
Aussetzen des Gefäßes gegenüber hoher Temperatur und hohem Druck,
dadurch gekennzeichnet, dass der Träger (12) einen niedrigeren Metallbindemittelgehalt als die äußere Schicht (14) aufweist.

8. Verfahren gemäß Anspruch 7, wobei der Metallbindemittelgehalt des Trägers (12) im Durchschnitt von ungefähr 5-15 Gewichtsprozent reicht und der Metallbindemittelgehalt der äußeren Schicht (14) im Durchschnitt von ungefähr 13-22 Gewichtsprozent reicht.
9. Verfahren gemäß Anspruch 7, wobei der Metallbindemittelgehalt des Trägers (12) annähernd 5 Gewichtsprozent geringer als der Metallbindemittelgehalt der äußeren Schicht (14) ist.
10. Verfahren gemäß Anspruch 7, wobei:
- die äußere Hartmetallschicht (14) und der Hartmetallträger (12) als ein Hartmetallstück (10) ausgeführt werden.

Revendications

1. Un élément rapporté pour outil abrasif (10) comprenant:

- une couche abrasive (16) ;
un noyau de carbure cimenté (12) collé à ladite couche abrasive (16) ;
et une couche externe de carbure cimenté (14) collée audit noyau (12) ;
caractérisé en ce que la teneur en liant métallique dudit noyau (12) est inférieure à la teneur en liant métallique de ladite couche externe (14). 5
2. Un élément rapporté pour outil selon la revendication 1 dans lequel ladite couche abrasive (16) est composée de diamant polycristallin. 10
3. Un élément rapporté pour outil selon la revendication 1 dans lequel la teneur en liant métallique dudit noyau (12) est comprise en moyenne dans la gamme allant de 5 à 15 % environ en poids et la teneur en liant métallique de ladite couche externe (14) est comprise en moyenne dans la gamme allant de 13 à 22 % environ en poids. 15 20
4. Un élément rapporté pour outil selon la revendication 1 dans lequel la teneur en liant métallique dudit noyau (12) est inférieure de 5 % en poids approximativement à la teneur en liant métallique de ladite couche externe (14). 25
5. Un élément rapporté pour outil selon la revendication 1 dans lequel l'interface entre ladite couche abrasive (16) et ledit noyau (12) est non plane. 30
6. Un élément rapporté pour outil selon la revendication 1 dans lequel ladite couche abrasive (16) est une couche de diamant polycristallin ;
dans lequel ledit noyau de carbure cimenté (12) est une couche de noyau de carbure de tungstène collée à ladite couche de diamant ; et dans lequel ladite couche externe de carbure cimenté (14) est une couche externe de carbure de tungstène collée à ladite couche de noyau ;
dans lequel ladite couche de noyau (12) a une teneur en métal liant comprise en moyenne dans la gamme allant de 5 à 15 % environ en poids ; et
dans lequel ladite couche externe (14) a une teneur en métal liant comprise en moyenne dans la gamme allant de 13 à 22 % environ en poids. 35 40 45
7. Une méthode destinée à la fabrication d'un élément rapporté pour outil abrasif (10) dans la cuve de réaction d'un appareil à température élevée / pression élevée, ladite méthode comprenant les étapes de : 50
- placer une couche externe de carbure cimenté (14) dans ladite cuve de réaction ;
placer un noyau de carbure cimenté (12) à l'intérieur de ladite couche externe (14),
recouvrir ledit noyau d'une couche de particules abrasives (16) ; et 55
- soumettre ladite cuve à une température élevée et à une pression élevée,
caractérisée en ce que ledit noyau (12) présente une teneur en liant métallique inférieure à celle de ladite couche externe (14).
8. Une méthode selon la revendication 7 dans laquelle la teneur en liant métallique dudit noyau (12) est comprise en moyenne dans la gamme allant de 5 à 15 % environ en poids et la teneur en liant métallique de ladite couche externe (14) est comprise en moyenne dans la gamme allant de 13 à 22 % environ en poids.
9. Une méthode selon la revendication 7 dans laquelle la teneur en liant métallique dudit noyau (12) est inférieure de 5 % en poids approximativement à la teneur en liant métallique de ladite couche externe (14).
10. Une méthode selon la revendication 7 dans laquelle :
ladite couche externe de carbure cimenté (14) et ledit noyau de carbure cimenté (12) sont préformés en une pièce de carbure cimenté (10).

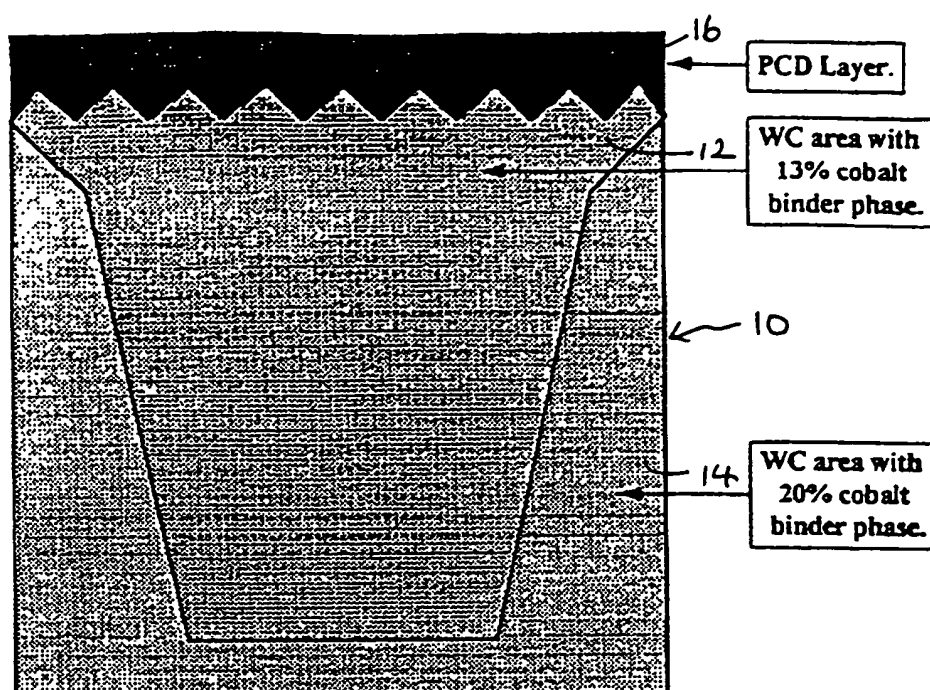


Figure 1.

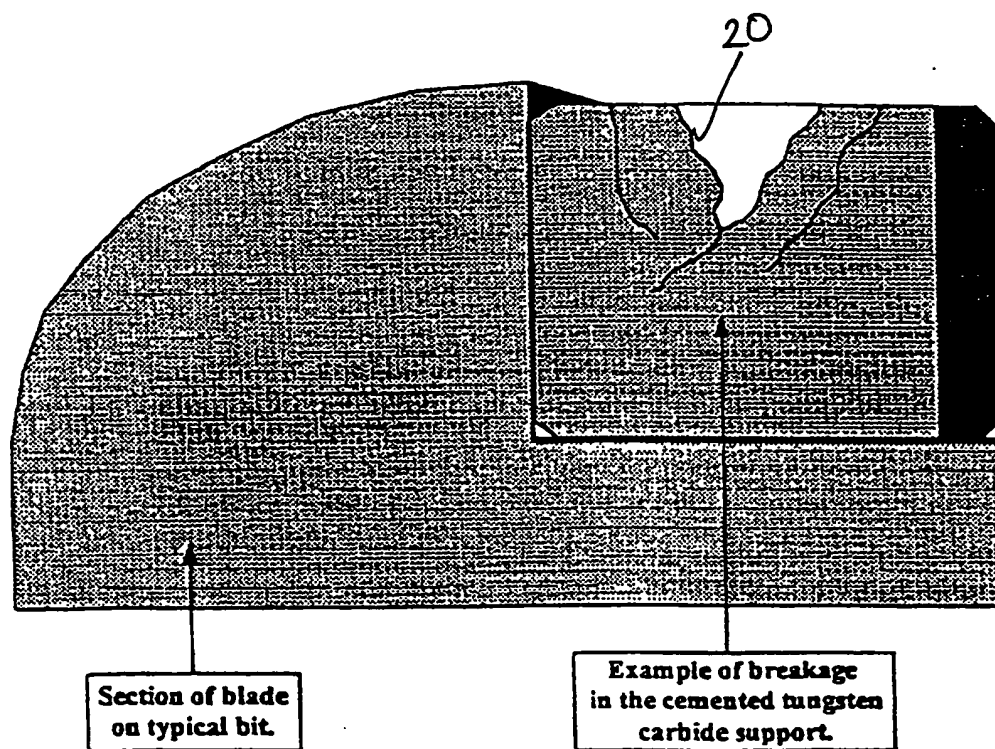


Figure 2.

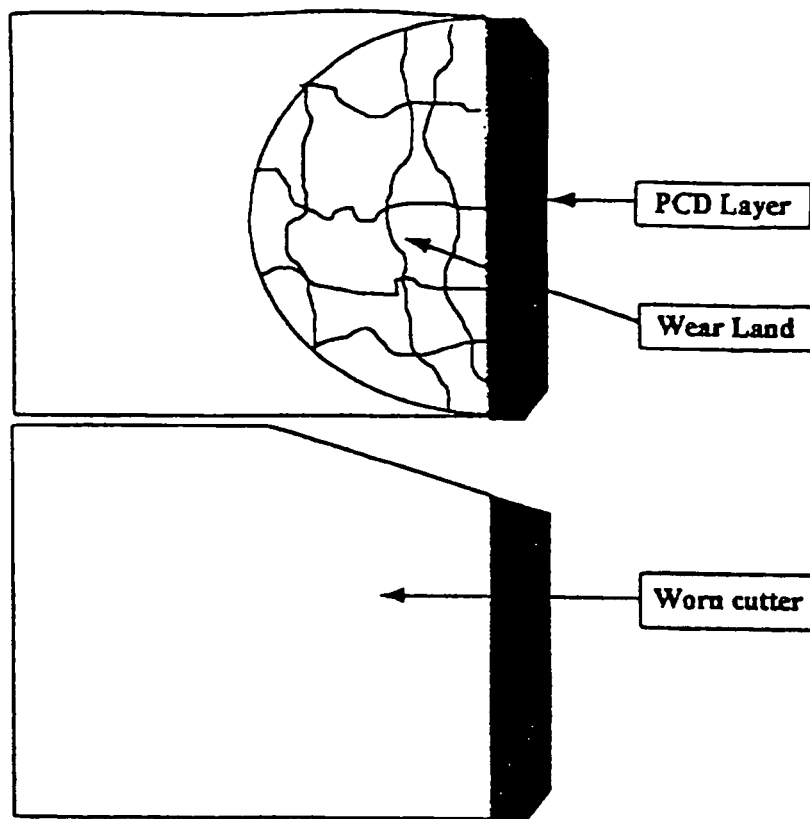


Figure 3

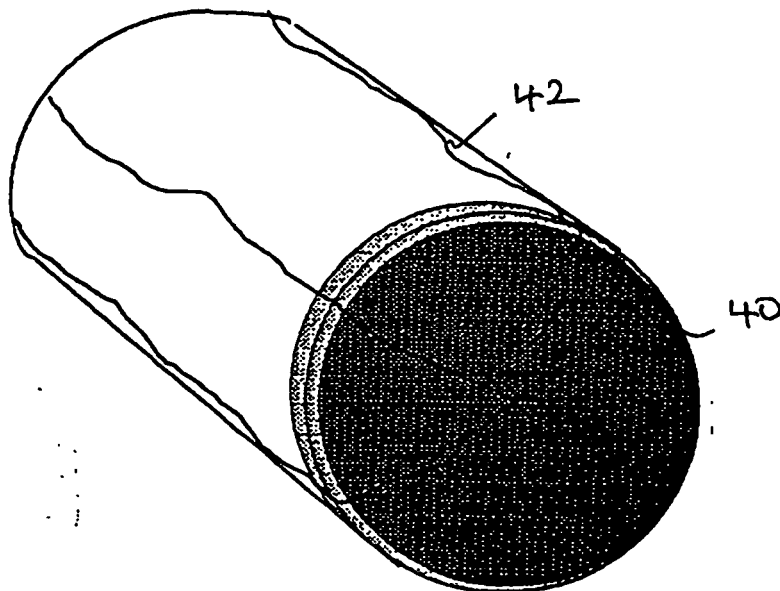


Figure 4

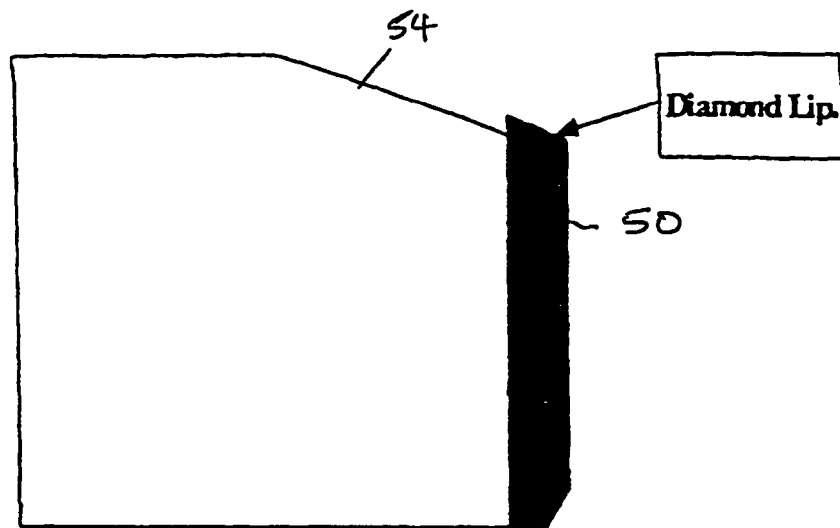


Figure 5

REFERENCES CITED IN THE DESCRIPTION

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