

HARDFACING MATERIALS WITH HIGHLY CONFORMING PROPERTIES

BACKGROUND OF THE INVENTION

Related Application: This nonprovisional patent application claims the benefit of co-pending, provisional patent application United States Serial No. 60/737,003, filed
5 on November 15, 2005, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

Field of the Invention: This invention relates in general to drill bits for well drilling, and in particular to a metallic hardfacing matrix and method of applying the metallic hardfacing matrix to drill bits.

10 State of the Art: Rotary well drilling for oil and gas is primarily accomplished through one of two types of bits. In a rotary cutter bit, the bit body has typically three rotatable cones or cutters. The cones rotate on bearing pins and have teeth or tungsten carbide inserts for disintegrating the earth formation. In the fixed cutter or drag bit type, the bit body has a face which contains cutting elements mounted on fixed blades.
15 The cutting elements are typically polycrystalline diamond. The bit body has drilling fluid passages with nozzles for discharging drilling fluid through junk slots that are located between the blades.

Drag bits are extensively used in directionally drilling, particularly in the technique referred to as steerable drilling. In this method, the drill bit is steered in
20 desired directions for cutting borehole segments as it progresses. A mud motor or turbine is employed with the bit assembly for rotating the drag bit while the drill string remains stationary.

Hardfacing or wear-resistant materials are typically connected to the outer surfaces of drill bits to help reduce wear and maintain the efficiency of the drill bit.
25 Commonly used hardfacing includes tungsten carbide particles that are welded in place on the outer surface of the drill bit. U.S. Reissue Patent Number RE 37,127 provides an in depth discussion of hardfacings, and is incorporated herein by reference in its entirety. Even with skilled welders, imperfections can be present due to varying thicknesses of the weld, shape of the drill bit the hardfacing is being welded upon, and
30 the beads associated with welding processes. Machining can be time-consuming and expensive. Moreover, hardfacing was not welded to inner parts due to narrow clearances and expense.

DISCLOSURE OF THE INVENTION

A method of increasing the durability of a drill bit, which includes the step providing a pliable sheet of a hardfacing matrix material. The pliable sheet of hardfacing material has a nickel and chromium matrix combined with a first element.

5 The first element is selected from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide, and metallic glass. The hardfacing matrix material sheet is placed on a preselected surface of the drill bit. The hardfacing matrix material sheet is then fusion bonded to the drill bit.

The fusion bonding can be performed by heating the drill bit and hardfacing
10 matrix material sheet in a furnace at about 2100 degrees Fahrenheit. The fusion bonding can also be in a furnace at about 2100 degrees Fahrenheit for a duration of between about five minutes and about ten minutes.

In step in which the hardfacing matrix material sheet is placed on the preselected surfaced, an adhesive located on a surface of the hardfacing matrix material
15 sheet can secure the hardfacing matrix material sheet in place relative to the preselected surface of the drill bit prior to the fusion bonding step. The preselected surface can comprise an outer gage surface, and a slot surface between a pair of bit blades. The drill bit can be a drag bit or a tri-cone bit.

The hardfacing matrix material can also comprise a second element, which was
20 not previously selected as the first element. The second element is selected from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide, metallic glass, microcrystalline tungsten carbide and macrocrystalline tungsten carbide. The hardfacing matrix material can further comprise a third element, which was not previously selected as either the first or second elements. The third element is selected
25 from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide, metallic glass, microcrystalline tungsten carbide and macrocrystalline tungsten carbide.

A method of increasing the durability of a drag bit type of drill bit, when the drag bit has a plurality of blades and a slot formed between each pair of adjacent
30 blades. Each of the blades has a cutting region with cutting elements and a gage surface free of cutting elements. The method includes the step of providing a sheet of a hardfacing matrix material comprising a nickel and chromium matrix combined with a first element selected from a group consisting of spherical sintered tungsten carbide,

spherical cast tungsten carbide, and metallic glass. The sheet of a hardfacing matrix material is cut into a pattern corresponding to a preselected surface of the drag bit. The pattern is adhered to the preselected surface of the drag bit. The drill bit, with the pattern adhered thereto is heated in order to bond the pattern to the drag bit.

- 5 The preselected surface can be the gage surface. The preselected surface can be the gage surface and the slot.

 The hardfacing matrix material can also include a second element, which was not previously selected as the first element. The second element is selected from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide,
10 metallic glass, microcrystalline tungsten carbide and macrocrystalline tungsten carbide. The hardfacing matrix material can further include a third element, which was not previously selected as either the first or second elements. The third element is selected from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide, metallic glass, microcrystalline tungsten carbide and macrocrystalline tungsten
15 carbide.

 An earth-boring bit includes a bit body with a bit face at its lower end and a nozzle opening to the bit face for discharging drilling fluid from an interior of the bit body. A plurality of blades are formed on and protrude from the bit face. The plurality of blades extend radially outward from a central portion of the bit face to a gage area at
20 the periphery of the bit body. Each blade carries a plurality of cutters thereon. Each pair of blades define a slot extending therebetween for the passage of drilling fluid and cuttings. A layer of hardfacing material is bonded to a surface of the bit body. The hardfacing material is substantially uniform in thickness and free of weldbeads. The hardfacing material includes a nickel and chromium matrix combined with a first
25 element selected from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide, and metallic glass. A bond region is located between the layer of hardfacing material and the surface of the bit body to which the layer of hardfacing material is bonded.

 The bond region can include nickel and chromium from the layer of hardfacing
30 and iron from the bit body, and the bond region can be formed when the layer of hardfacing is bonded to the surface of the bit body with heat. The surface of the bit body to which the layer of hardfacing is bonded can be the gage surface. The surface

of the bit body to which the layer of hardfacing is bonded can be the slot. The surface of the bit body to which the layer of hardfacing can be within the nozzle.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view showing a drag bit assembly without hardfacing.

5 Figure 2 is a vertical sectional view of the drag bit assembly of Figure 1.

Figure 3 is perspective view of a hardfacing material matrix sheet constructed in accordance with this invention.

Figure 4 is top plan view of the hardfacing material matrix sheet of Figure 3, showing a pattern to be cut therefrom.

10 Figure 5 is a perspective view showing the drag bit assembly of Figure 1, with cutouts from the hardfacing material matrix sheet of Figure 3 being attached thereto.

Figure 6 is an enlarged sectional view of the interface between the outer surface of the drag bit assembly of Figure 1 and the hardfacing material matrix sheet of Figure 3 after fusion bonding.

15 Figure 7 are schematic perspective views of various forms of spherical cast tungsten carbide in accordance with this invention.

BEST MODE(S) FOR CARRYING OUT THE INVENTION

Referring to Figure 1, bit assembly 11 has a body 13 on a lower end. Body 13 has a face 15 on its lower end. A plurality of blades 17 are formed on and protrude from face 15, with six blades 17 being shown in the drawings. Blades 17 lead outward from a central portion of face 15 to a gage area at the periphery of body 13. Blades 17 are separated from each other, defining junk slots 19 between them for the passage of drilling fluid and cuttings. Each blade 17 contains a row of conventional cutters typically polycrystalline diamond (PCD). Nozzles 23 discharge drilling fluid, which flows through junk slots 19 and back up the borehole along with the cuttings. While bit assembly 11 is illustrated as a "drag bit" or steel-bodied bit, it should be readily apparent to those skilled in the art that the teachings herein are also applicable to tri-cone bits, or cast bits, such as those illustrated in Figure 1 of U.S. Reissue Patent Number RE 37,127.

30 A set of primary gage pads 25 is integrally formed on the sides of bit body 13. Each primary gage pad 25 is contiguous with and, in the embodiment shown, extends longitudinally from one of the blades 17. Alternately, primary gage pads 25 could be inclined relative to the axis or curved in a spiral. Each primary gage pad 25 protrudes

from body 13, extending the junk slots 19. Primary gage pads 25 are dimensioned to have an outer surface 26 at the gage or diameter of the borehole being cut. Outer surface 26 contains wear resistant surfaces, but is smooth and free of any cutting structure. Bit body 13, along with blades 17 and gage pads 25, may be formed of a metal matrix composite or steel using a casting or machining process.

Referring to Figure 2, a steel threaded coupling or blank 27 is joined to an upper end of body 13. Blank 27 is bonded to body 13 during the casting process. Blank 27 protrudes from the upper end of body 13 and has threads 29 on its exterior. An axial passage 31 extends through blank 27 and joins nozzles 23 for delivering drilling fluid.

A shank 33 is secured to blank 27. Shank 33 is also formed of steel, rather than of a carbide matrix. Shank 33 is a cylindrical member that may have a length longer than the axial dimension of body 13. Shank 33 has a threaded receptacle 35 which engages threads 29 of blank 27. A chamfer or bevel 37 is formed on the lower end of shank 33. Similarly, a bevel 39 is formed on the upper end of body 13. The opposed bevels 37, 39 create a V-shaped annular cavity. This cavity is filled with a weld material 41, the welding permanently joining shank 33 to bit body 13. Shank 33 has an axial passage 43 which registers with passage 31 for delivering drilling fluid. Shank 33 has a threaded pin 45 on its upper end. Pin 45 is dimensioned for securing to a lower end of a drill string.

Bit assembly 11 operates in a manner that is conventional with other steerable drag bit assemblies. It is normally secured to a turbine or mud motor which is at the lower end of drill string. Drilling fluid pumped down the drill string drives the mud motor, which in turn causes rotation of bit 11. The spaced apart gage pads 25 stabilize bit 11 to condition the borehole wall, preventing ledging and other irregularities.

The hardfacing on outer surfaces and leading and trailing edges typically comprises a tungsten carbide material that is welded into place. Depending on the skill of the welder, welding such hardfacing can create imperfections and high stress zones along the weld bead lines or in the hardfacing deposit that can lead to the hardfacing chipping off or disengaging from the surface it is meant to protect with its wear-resistant properties. Even for skilled welders, the process of welding hardfacing can be time consuming, difficult, and tedious due to the geometry of the surfaces to which the hardfacing material is being applied. Some surfaces, like internal surfaces that engage each other, are simply not available for welded hardfacing.

A hardfacing metal matrix has been used on the internal surfaces of bearings. The hardfacing metal matrix typically comes in the form of a pliable sheet. A desired shape of the hardfacing surface is cut out of the pliable sheet and then fusion bonded onto the target surface, or the surface to be hardfaced. Previous pliable hardfacing
5 sheets comprised a metal matrix that typically included mostly either microcrystalline tungsten carbide or macrocrystalline tungsten carbide with lesser amounts of nickel and chromium.

Referring to Figure 3, a hardfacing matrix sheet 101 is shown in its pliable state. Hardfacing matrix sheet 101 comprises a hardfacing material matrix 103 and an
10 adhesive surface 105 along one surface. Adhesive surface 105 helps to hold hardfacing matrix sheet 101 against the target surface prior to fusion bonding.

Hardfacing material matrix 103 preferably comprises spherical sintered tungsten carbide, spherical cast tungsten carbide, or a nanosteel composite also known as "metallic glass." U.S. Patents 6,689,234 and 6,767,419 provide a discussion of metallic
15 glass and disclose various methods of applying metallic glass to a substrate. U.S. Patents 6,689,234 and 6,767,419 are incorporated herein by reference in their entireties. Matrix 103 can also comprise a combination of at least two of spherical sintered tungsten carbide, spherical cast tungsten carbide, and metallic glass. Microcrystalline and macrocrystalline tungsten carbide can also be added to matrix 103 having spherical
20 sintered tungsten carbide, spherical cast tungsten carbide, or metallic glass, alone or in combination. Crushed cast tungsten carbide and crushed sintered tungsten carbide may also be added to matrix 103 having spherical sintered tungsten carbide, spherical cast tungsten carbide, or metallic glass, alone or in combination.

Referring to Figure 7, spherical cast tungsten carbide 117 can comprise
25 numerous shapes. Preferably, spherical cast tungsten carbide 117 for use in matrix 103 will be substantially shaped like a sphere or spherical-shaped 117a. However, spherical cast tungsten carbide 117, but it can also be shaped like a sphere that has been stretched from its upper and lower surfaces, or prolate-shaped 117b. Alternatively, spherical cast tungsten carbide 117 can be shaped like a sphere that has been compressed from its
30 upper and lower surfaces, or oblate-shaped 117c. Spherical-, prolate-, and oblate-shaped 117a, 117b, 117c shapes of spherical cast tungsten carbide 117 are due to the manufacturing methods of spherical cast tungsten carbide 117 and are useful to illustrate that the name spherical cast tungsten carbide should not limit matrix 103 to

only spherical-shaped 117a rather than including prolate- and oblate-shaped 117b, 117c matrixes of cast tungsten carbide.

Referring to Figure 4, hardfacing matrix sheet 101 is cut along pattern 107 to form a desired shape. As shown in Figure 5, pattern 107 preferably corresponds to a surface on bit assembly 11. Pattern 107 shown in Figure 4, corresponds to outer surface 57. However, as shown in Figure 5, various patterns 107a, 107b can be cut from hardfacing matrix sheet 101 to correspond with desired surfaces on bit assembly. For example, pattern 107a corresponds with outer surface 26, and pattern 107b corresponds with body 13 between blades 17. Moreover, hardfacing matrix sheet 101 can also be cut with patterns to correspond to interior surfaces of bit assembly 11.

Patterns 107a, 107b are placed on the desired surfaces of bit assembly 11. Figure 5, illustrates bit assembly 11 with patterns 107a, 107b being placed onto various desired surfaces. Adhesive 105 initially secures patterns 107a, 107b to the desired surfaces of bit assembly 11. Bit assembly 11 with the secured patterns 107a, 107b attached thereto is placed into a furnace. In the preferred embodiment, bit assembly 11 with patterns 107a, 107b is placed in the furnace for about five to ten minutes at about 2100 degrees Fahrenheit to fusion bond the hardfacing matrix on patterns 107a, 107b onto the desired outer surfaces of bit assembly 11. As will be readily appreciated by those skilled in the art, the exact length of time and exact temperature can vary depending upon the composition of hardfacing material matrix 103 in accordance with the variations described above herein. After fusion bonding patterns 107a, 107b into place, hardfacing material matrix 103 can be machined from a rough surface to a smoother surface as desired.

Referring to Figure 6, a microscopic representation of the interface between hardfacing material matrix 103 on patterns 107a, 107b and the desired outer surfaces bit assembly 11 following fusion bonding is shown. Cladding region 109 comprises hardfacing material matrix 103 with the hardfacing material being densely packed substantially uniformly throughout. As discussed above herein, the particular hardfacing material can be in a nickel and chromium matrix including spherical sintered tungsten carbide, spherical cast tungsten carbide, or metallic glass individually, in combination with each other, or in combination with microcrystalline or macrocrystalline tungsten carbide. Bond region 111 is a true metallurgical bond region located between hardfacing material matrix 103 and the desired outer surfaces of bit

assembly 11 due to the fusion bonding process. Bond region 111 has high interparticle bond strength and helps to reduce chipping, flaking and cracking. Diffusion zone region 113 results from the fusion bonding process. Bond region 111 comprises nickel and chromium from patterns 107a, 107b and iron from the substrate or bit assembly 11.

- 5 Typically, the substrate or bit assembly 11 uniformly retains most of its mechanical properties. Heat treatable region 115 includes the remainder of the substrate of bit assembly 11. Region 115 can be heat treated, if necessary, to restore any mechanical properties of bit assembly 11 that may have deteriorated to the fusion bonding process.

- 10 While the invention has been shown in only some of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes without departing from the scope of the invention. For example, bit assembly can also be a tri-cone bit, or cast bit.

CLAIMS

1. A method of increasing the durability of a drill bit, comprising:
 - (a) providing a pliable sheet of a hardfacing matrix material comprising a nickel and chromium matrix combined with a first element selected from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide, and metallic glass;
 - (b) placing the hardfacing matrix material sheet on a preselected surface of the drill bit; and
 - (c) fusion bonding the hardfacing matrix material sheet to the drill bit.
2. The method of claim 1, wherein step (c) is performed by heating the drill bit and hardfacing matrix material sheet in a furnace at about 2100 degrees Fahrenheit.
3. The method of claim 1, wherein step (c) is performed by heating the drill bit and hardfacing matrix material sheet in a furnace at about 2100 degrees Fahrenheit for a duration of between about five minutes and about ten minutes.
4. The method of claim 1, wherein in step (b), an adhesive located on a surface of the hardfacing matrix material sheet secures the hardfacing matrix material sheet in place relative to the preselected surface of the drill bit prior to step (c).
5. The method of claim 1, wherein the preselected surface comprises an outer gage surface.
6. The method of claim 1, wherein the preselected surface comprises a slot surface between a pair of bit blades.
7. The method of claim 1, wherein the hardfacing matrix material further comprises a second element, which was not previously selected as the first element, selected from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide, metallic glass, microcrystalline tungsten carbide and macrocrystalline tungsten carbide.

8. The method of claim 7, wherein the hardfacing matrix material further comprises a third element, which was not previously selected as either the first or second elements, selected from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide, metallic glass, microcrystalline tungsten carbide and macrocrystalline tungsten carbide.
9. The method of claim 1, wherein the drill bit is a drag bit.
10. The method of claim 1, wherein the drill bit is a tri-cone bit.
11. A method of increasing the durability of a drag bit type of drill bit, the drag bit having a plurality of blades and a slot formed between each pair of adjacent blades, each of the blades having a cutting region with cutting elements and a gage surface free of cutting elements, the method comprising:
- (a) providing a sheet of a hardfacing matrix material comprising a nickel and chromium matrix combined with a first element selected from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide, and metallic glass;
 - (b) cutting the sheet of a hardfacing matrix material into a pattern corresponding to a preselected surface of the drag bit;
 - (c) adhering the pattern to the preselected surface of the drag bit; and
 - (d) heating the drill bit, with the pattern adhered thereto, in order to bond the pattern to the drag bit.
12. The method of claim 11, wherein the preselected surface comprises the gage surface.
13. The method of claim 11, wherein the preselected surface comprises the gage surface and the slot.
14. The method of claim 11, wherein the hardfacing matrix material further comprises a second element, which was not previously selected as the first element, selected from a group consisting of spherical sintered tungsten carbide, spherical cast

tungsten carbide, metallic glass, microcrystalline tungsten carbide and macrocrystalline tungsten carbide.

15. The method of claim 14, wherein the hardfacing matrix material further comprises a third element, which was not previously selected as either the first or
5 second elements, selected from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide, metallic glass, microcrystalline tungsten carbide and macrocrystalline tungsten carbide.

16. An earth-boring bit comprising:
a bit body having a bit face at its lower end and a nozzle opening to the bit face
10 for discharging drilling fluid from an interior of the bit body;
a plurality of blades formed on and protruding from the bit face that extends radially outward from a central portion of the bit face to a gage area at the periphery of the bit body, each blade carrying a plurality of cutters thereon, and each pair of blades defining a slot extending therebetween for the passage of drilling fluid and cuttings;
15 a layer of hardfacing material being bonded to a surface of the bit body, the hardfacing material being substantially uniform in thickness and free of weldbeads, the hardfacing material comprising a nickel and chromium matrix combined with a first element selected from a group consisting of spherical sintered tungsten carbide, spherical cast tungsten carbide, and metallic glass; and
20 a bond region located between the layer of hardfacing material and the surface of the bit body to which the layer of hardfacing material is bonded.

17. The earth-boring bit of claim 16, wherein the bond region comprises nickel and chromium from the layer of hardfacing and iron from the bit body, the bond region being formed when the layer of hardfacing is bonded to the surface of the bit body with
25 heat.

18. The earth-boring bit of claim 16, wherein the surface of the bit body to which the layer of hardfacing is bonded is the gage surface.

19. The earth-boring bit of claim 16, wherein the surface of the bit body to which the layer of hardfacing is bonded is the slot.
20. The earth-boring bit of claim 16, wherein the surface of the bit body to which the layer of hardfacing is within the nozzle.