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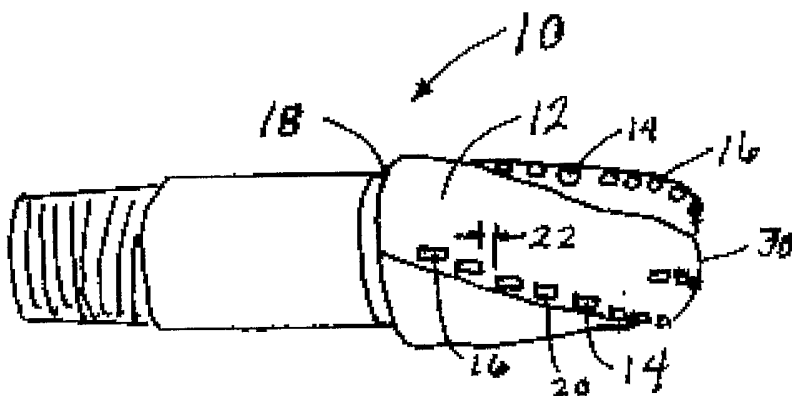
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: HIGH CHROME/NICKEL MILLING WITH PDC CUTTERS



(57) Abstract: A method of downhole milling of an item having high chrome/high nickel content, using polycrystalline diamond cutting elements, exhibiting less wear, requiring less torque and weight, and producing less heat, than prior art tungsten carbide elements.

WO 2006/023951 A1

TITLE OF THE INVENTION

High Chrome/Nickel Milling with PDC Cutters

CROSS REFERENCE TO RELATED APPLICATIONS

5 This application relies upon U.S. Provisional Patent Application No. 60/604,201, filed on 08/24/2004, and entitled "High Chrome/Nickel Milling with PDC Cutters."

STATEMENT REGARDING FEDERALLY SPONSORED

10 RESEARCH OR DEVELOPMENT

Not Applicable

BACKGROUND OF THE INVENTION

Field of the Invention - This invention is in the field of mills used for
15 downhole milling of metal objects, in an oil or gas well.

Background Art - Metals with over 12 % chrome, or over 6% nickel, or over 12 % chrome in combination with over 6% nickel, present unique cutting challenges. Specifically, such metals require substantially more energy to cut, and produce significantly greater cutter wear than conventional metals. They exhibit unusually
20 high friction between the cutter and the base material being cut, and between the cutter and the chip being formed. Previously known methods of cutting these materials involved the use of tungsten carbide cutters. When these materials are being cut with these conventional tungsten carbide cutters, the cutters suffer heavy breakage, wear quickly, require considerably more load and torque, and tend to vibrate or chatter
25 severely. These tungsten carbide cutters exhibit a relatively high coefficient of friction with the high chrome and high nickel materials. The high coefficient of friction increases torque by increasing the sliding force between the cutter and the base material or substrate.

The high friction also increases the force required to make the chip flow up the
30 tungsten carbide cutter face. This increased force requirement directly increases the cutting load, as the force required to hold the tungsten carbide cutter down into the cut is increased. This increased force requirement also indirectly increases the cutting

load, as the chip tends to form a hard "ball" of the material being cut around the outer edge of the tungsten carbide cutter, which effectively blunts the cutter edge.

An important result of the higher friction, higher load, and duller edge is that considerable heat is generated at the cut by the tungsten carbide cutters. This heat increases the wear rate of the conventional tungsten carbide cutters, and the elevated temperature generally increases the strain-to-failure characteristics of the high chrome/high nickel materials, which further increases the cutting energy required.

BRIEF SUMMARY OF THE INVENTION

The present invention comprises the downhole cutting of high chrome/high nickel materials with a cutting tool which is dressed with polycrystalline diamond (PDC) cutters as the primary cutting elements.

The novel features of this invention, as well as the invention itself, will be best understood from the attached drawings, taken along with the following description, in which similar reference characters refer to similar parts, and in which:

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a side elevation view of a first embodiment of a mill used according to the present invention;

Figure 2 is a partial side elevation view of a second embodiment of a mill used according to the present invention;

Figure 3 is a lower end elevation view of the mill shown in Figure 2; and

Figure 4 is a third embodiment of a mill used according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The PDC material of the cutters used according to the present invention, being composed largely of diamond, exhibits less wear by virtue of its hardness, but more importantly has a much lower coefficient of friction with the high chrome/high nickel materials. The low coefficient of friction reduces torque by reducing the sliding force between the cutter and the base material or substrate. The low friction also reduces

the force required to make the chip flow up the cutter face. This low friction directly reduces the cutting load, as the force to hold the cutter down into the cut is reduced, and it indirectly reduces the cutting load, as the chip does not tend to form a hard “ball” of the material being cut around the outer edge. This effectively leaves a sharper cutter edge. An important result of the lower friction, the lower load, and a sharper edge is that considerably less heat is generated at the cut, by the PDC cutters. This lower heat generation decreases the wear rate of the PDC cutters, and the lower temperature generally decreases the cutting energy required.

As shown in Figure 1, a first embodiment of a mill 10 for use in the present invention has a mill body 12, on the periphery of which are arranged and mounted a plurality of PDC cutting elements 14. The PDC cutting elements 14 can be arranged in a plurality of spiral rows 16, arranged generally along the axial dimension of the mill body 12. The mill 10 is designed to be rotated in a selected direction, clockwise when viewed from the top end 18, for the mill shown. The cutting face 20 of each cutting element 14 is oriented toward the direction of rotation. The distance 22 between any two adjacent cutting elements 14 in any given row 16, measured along a line parallel to the longitudinal axis of the mill body 12, is a minimum of 20% of the diameter of the cutting face 20 of either of the two adjacent cutting elements 14.

As shown in Figure 2, the spiral rows 16 of cutting elements 14 can be paired, with each such pair having a leading row 24 and a trailing row 26, with the leading row 24 being in front of the trailing row 26, relative to the selected direction of rotation. The cutting elements 14 in the trailing row 26 can be aligned to follow in the cutting paths established by respective cutting elements 14 in the leading row 24. The cutting elements 14 can be substantially cylindrical, with circular cutting faces 20 as shown, or they can have other shapes, without departing from the present invention. The cutting elements 14 can be mounted directly on the mill body 12 as shown, or they can be mounted on cutting blades (not shown) on the mill body, as is known in the art. The cutting elements 14 can be mounted on the lateral periphery 28 of the mill body 12, and they can be mounted on the lower end face 30 of the mill body 12, as shown in Figure 3. The mill body 12 can be generally tapered from a larger diameter at the upper end 18 thereof to a smaller diameter at the lower end 30 thereof, or it can be cylindrical or any other shape known in the art.

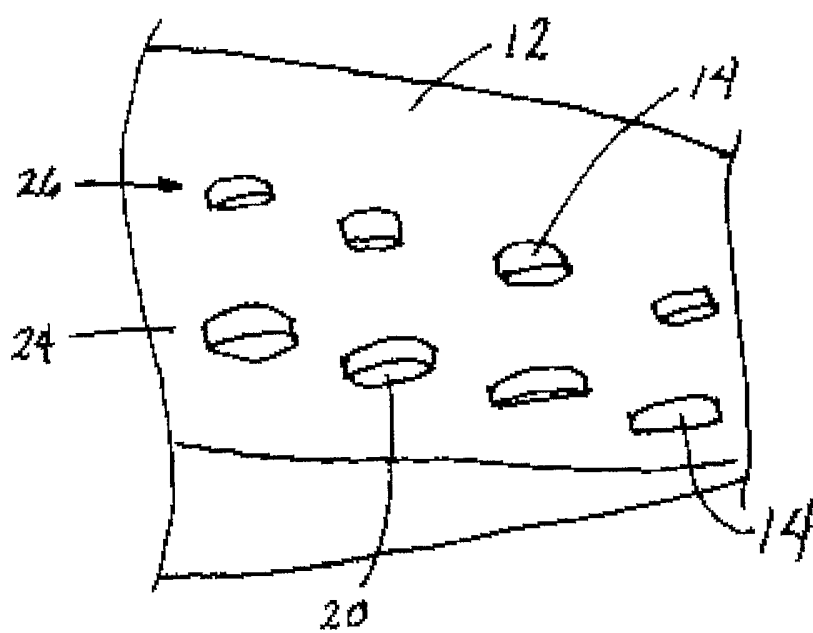
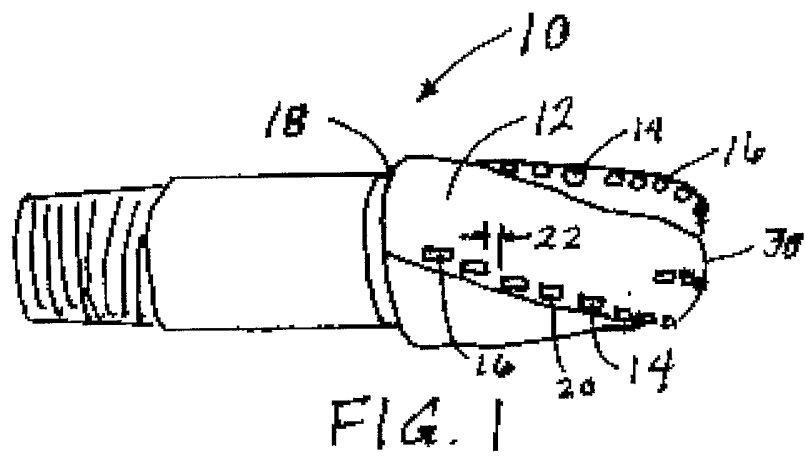
As shown in Figure 4, a fourth embodiment of the mill used in the present invention can have a mill body 32 with an extended tapered shape, with an even greater axial separation between any two adjacent cutting elements 14 in a given row 16.

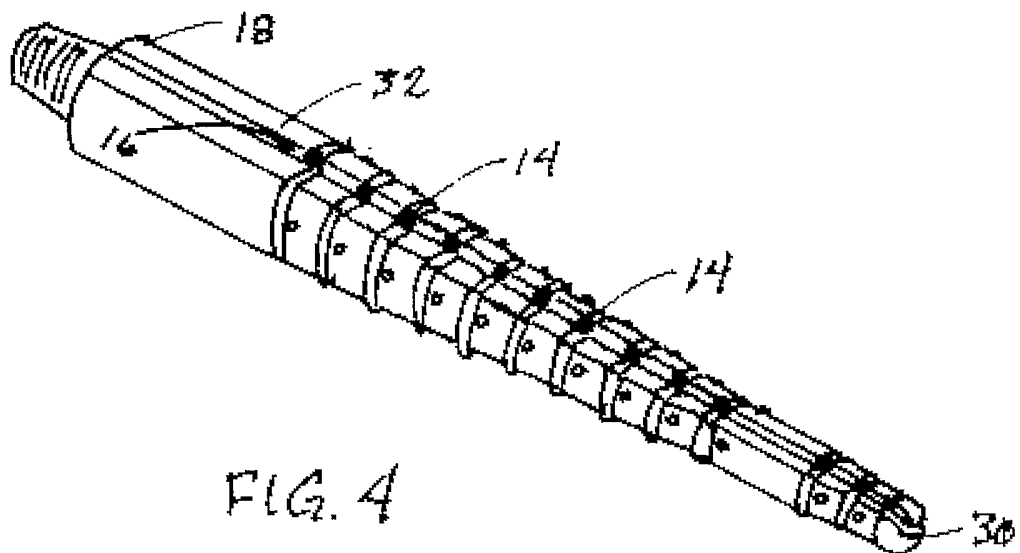
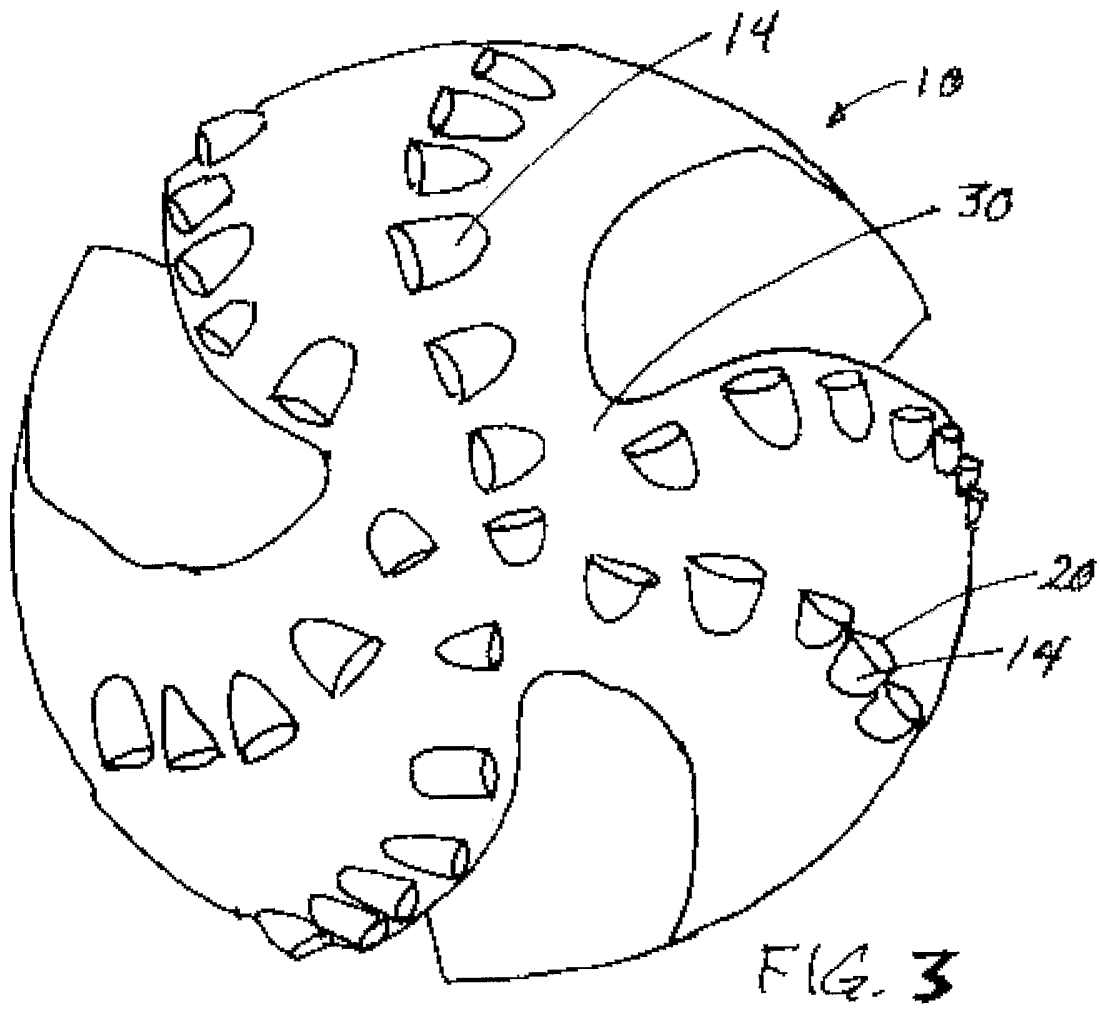
5 In operation, according to the present invention, the mill 10 is rotated while contacting the item to be milled, which is made of a material having a high chrome/high nickel content. The PDC cutting elements 14 remove chips or cuttings of metal from the substrate of the item being milled. Because of the greater hardness and lower coefficient of friction exhibited by the PDC cutting elements, as compared
10 to the prior art tungsten carbide cutting elements, the required torque to turn the mill is less, the required vertical force applied is less, and the cutting edges of the cutting elements 14 remain sharper. In addition, less heat is generated than with the prior art tungsten carbide cutting elements, and the rate of cutting element wear is less than with the prior art tungsten carbide cutting elements.

CLAIMS

We claim:

- 1 1. A method for downhole milling of material having high nickel content or high chrome
2 content, or both, said method comprising:
3 provide a mill body adapted to be attached to a work string, with at least one row of
4 polycrystalline diamond cutting elements mounted adjacent to a peripheral surface of
5 said mill body;
6 lower said mill body into a well bore;
7 rotate said mill body in a selected direction about a longitudinal axis of said mill body to mill
8 said material having high nickel content or high chrome content with said
9 polycrystalline diamond cutting elements.
- 1 2. The method recited in claim 1, further comprising:
2 provide each said cutting element in said at least one row with a cutting face oriented
3 substantially toward said selected direction of rotation of said mill body, with a major
4 transverse dimension on each said cutting face, said major transverse cutting face
5 dimension being measured substantially transverse to said selected direction of
6 rotation of said mill body; and
7 space apart adjacent said cutting elements in said at least one row, said spacing being
8 measured substantially along a line parallel to said longitudinal axis of said mill body;
9 wherein said spacing between any two adjacent cutting elements in said at least one row is at
10 least 20% of said major transverse cutting face dimension on either of said two
11 adjacent cutting elements.
- 1 3. The method recited in claim 1, further comprising orienting said at least one row of
2 said cutting elements substantially along a spiral line along the periphery of said mill body.





INTERNATIONAL SEARCH REPORT

International Application No
PC JS2005/030049

A. CLASSIFICATION OF SUBJECT MATTER
E21B29/00 E21B10/56

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used),

EPO-Internal, WPI Data, TULSA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	RONALD D. CHILDERS ET AL: "PCD Technology Advances Sidetracking Capabilities" SPE 59185, 23 February 2000 (2000-02-23), pages 1-9, XP002354486 the whole document	1-3
Y	US 6 170 576 B1 (BRUNNERT DAVID JOSEPH ET AL) 9 January 2001 (2001-01-09) column 2, lines 53-56 column 3, lines 8,9	1-3
A	US 2004/089480 A1 (DEWEY CHARLES H) 13 May 2004 (2004-05-13) paragraph '0031!	1
A	US 5 320 174 A (TERRELL ET AL) 14 June 1994 (1994-06-14) column 2, lines 40-45	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

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- *O* document referring to an oral disclosure, use, exhibition or other means
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- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- * & * document member of the same patent family

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22/12/2005

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INTERNATIONAL SEARCH REPORT

Information on patent family members

In International Application No
F JS2005/030049

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6170576	B1	09-01-2001	NONE
US 2004089480	A1	13-05-2004	NONE
US 5320174	A	14-06-1994	DE 69321164 D1 29-10-1998 DE 69321164 T2 18-02-1999 EP 0575116 A1 22-12-1993 US 5509480 A 23-04-1996