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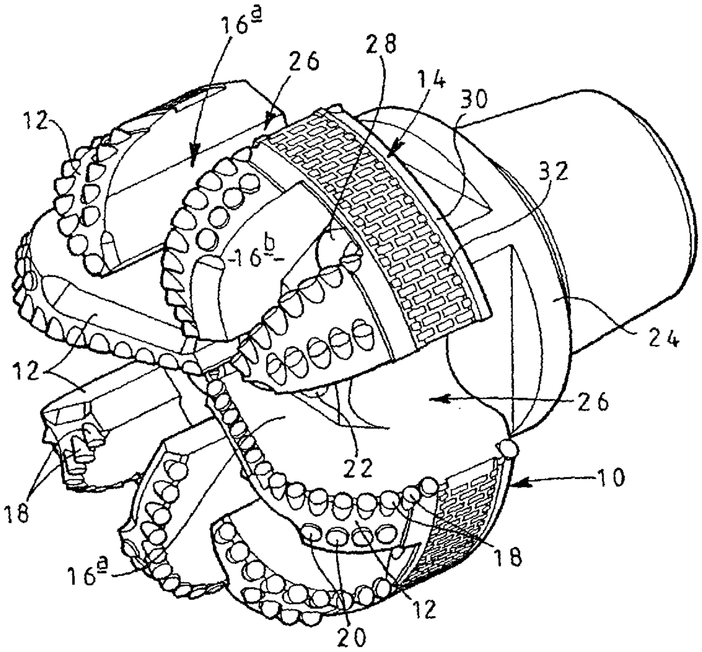
(54) Title: METHOD OF MOUNTING A TSP



(57) Abstract: A method of applying a wear-resistant material to a surface of a downhole component for use in subsurface drilling comprises forming a plurality of bearing elements, applying a layer of an electrically conductive, less hard material to each bearing element, and then bonding each bearing element to the surface of the component by welding or brazing to the surface of the component a part of the surface of the bearing element which comprises said less hard material, wherein the layer is of thickness greater than 0.05 mm.

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"Method of Mounting a TSP"

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to methods of applying a wear-resistant material to a surface of a downhole component for use in subsurface drilling. The method is suitable for use both with drill bits and with other downhole components.

The invention is applicable to downhole components of the kind which include at least one surface which, in use, engages the surface of the earthen formation surrounding the borehole. The invention relates particularly to rotary drill bits, for example of the drag-type kind having a leading face on which cutters are mounted and a peripheral gauge region for engagement with the surrounding walls of the borehole in use or of the rolling cutter kind. The invention will therefore be described with particular reference to polycrystalline diamond compact (PDC) drag-type and rolling cutter type drill bits, although it will be appreciated that it is also applicable to other downhole components having bearing surfaces. For example, bearing surfaces may be provided on downhole stabilisers, motor or turbine stabilisers, or modulated bias units for use in steerable rotary drilling systems, for example as described in British Patent No. 2289909. Such bias units include hinged paddles having bearing surfaces which engage the walls of the borehole in order to provide a lateral bias to the bottom hole assembly.

In all such cases the part of the downhole component providing the bearing surface is not normally formed from a material which is sufficiently wear-resistant to withstand prolonged abrasive engagement with the wall of the borehole and it is therefore necessary to render the bearing surface more wear-resistant. For example, the bodies of rotary drag-type and rolling cutter type drill bits are often machined from steel and it is therefore necessary to apply bearing elements to the gauge portion of such drill bit to ensure that the gauge is not subject to rapid wear through its engagement with the walls of the borehole. This is a particular problem with steel bodied drill bits where the gauge of the bit comprises a single surface extending substantially continuously around the whole periphery of the bit, for example as described in British Patent No. 2326656.

2. Description of Related Art

One well known method of increasing the wear-resistance of the gauge of a drag-type or rolling cutter type drill bit is to form the gauge region with sockets in which harder bearing inserts are received. One common form of bearing insert comprises a circular stud of cemented tungsten carbide, the outer surface of which is substantially flush with the outer surface of the gauge. Smaller bodies of natural or synthetic diamond may be embedded in the stud, adjacent its outer surface. In this case the stud may comprise, instead of cemented tungsten carbide, a body of solid infiltrated tungsten carbide matrix material in which the smaller bodies of natural or synthetic diamond are embedded. Bearing inserts are also known using polycrystalline diamond compacts having their outer faces substantially flush with the gauge surface.

Another known method of increasing the wear-resistance of the gauge surface of a PDC drill bit is to cover the surface of the gauge, or a large proportion thereof, with arrays of rectangular tiles of tungsten carbide. Such tiles may be packed more closely over the surface of the gauge than is possible with bearing inserts, of the kind mentioned above, which must be received in sockets, and therefore allow a greater proportion of the area of the gauge surface to be covered with wear-resistant material at lesser cost. However, it would be desirable to use bearing elements which have greater wear-resistance than tungsten carbide tiles.

A known method for increasing the wear-resistance of the rolling cone cutter in rolling cutter bits is to include one or more rows of inserts on the gauge reaming portion of the rolling cutter. Typically, the inserts are cylindrical bodies which are interference-fitted into sockets formed on the gauge reaming surface of the rolling cutter, as shown in US Patent No. 5,671,817. The inserts may be formed of a very hard and wear and abrasion resistant grade of tungsten carbide, or may be tungsten carbide cylinders tipped with a layer of polycrystalline diamond. In addition, the gauge portion of each bit leg facing the borehole wall may be provided with welded-on hard facing and/or the same type of tungsten carbide cylinders are as fitted into the rolling cutters.

A material which is significantly more wear-resistant than tungsten carbide, and is also available in the form of rectangular blocks or tiles, is thermally stable polycrystalline diamond (TSP). As is well known, thermally stable polycrystalline diamond is a synthetic diamond material which lacks the cobalt which is normally present in the polycrystalline diamond layer of the two-layer compacts which are frequently used as cutting elements for rotary drag-type drill bits. The absence of cobalt from the polycrystalline diamond allows the material to be subjected to higher temperatures than the two-layer compacts without sufficient significant thermal degradation, and hence the material is commonly referred to as "thermally stable".

In one commercially available form of thermally stable polycrystalline diamond the product is manufactured by leaching the cobalt out of conventional non-thermally stable polycrystalline diamond. Alternatively the polycrystalline diamond may be manufactured by using silicon in place of cobalt during the high temperature, high pressure pressing stage of the manufacture of the product.

While TSP has the wear-resistance characteristics appropriate for a bearing element on a downhole component, it has hitherto been difficult to mount TSP on downhole components. Where blocks of TSP are to be used as cutting elements on drag-type drill bits it is necessary either to mould the bit body around the cutting elements, using a well-known powder metallurgy process, or to embed the blocks into bodies of less hard material which are then secured in sockets in the bit body. Where a bearing element is to be applied to a surface of a downhole component for the purpose of wear-resistance, however, it is preferable for the bearing element to be mounted on the surface of the component, particularly if the component is formed by machining, from steel or other metal, so that the bearing element cannot readily be embedded in the component. The present invention therefore sets out to provide novel methods for mounting TSP bearing elements on to a bearing surface of a downhole component.

SUMMARY OF THE INVENTION

According to the present invention, there is provided a method of applying a wear-resistant material to a surface of a downhole component for use in subsurface drilling, the method comprising forming a plurality of bearing elements, applying a layer of an electrically conductive, less hard material to each bearing element, and then bonding each bearing element to the surface of the component by welding or brazing to the surface of the component a part of the surface of the bearing element which comprises said less hard material, wherein the layer is of thickness greater than 0.05mm.

The layer of less hard material may comprise a thin coating pre-applied to some or, preferably, all of the surface of the bearing element. Each bearing element preferably comprises a body of thermally stable polycrystalline diamond. The layer is preferably formed from a material of high electrical conductivity, such as nickel or nickel alloy. In this case the bearing element may be held in position on the surface of the component by electrical resistance welding. The body of thermally stable polycrystalline diamond may be pre-coated with a layer of a carbide-forming metal before application of the coating of less hard material, since the carbide-forming metal may form a stronger bond with the TSP than does the nickel or nickel alloy alone.

Each bearing element may be inter engaged with a locating formation on the surface of the component to which it is welded or brazed. For example, the locating formation may comprise a socket or recess into which the bearing element is at least partly received. The bearing element may be fully received in the socket or recess so that an exposed surface of the bearing element is substantially flush with the surface of the component surrounding the socket or recess.

The use of a layer of less hard material of thickness greater than 0.05mm is advantageous in that it is capable of carrying the electrical current applied thereto during a resistance welding operation without breaking down. The thickness of the layer preferably falls within the range of 0.1mm to 0.3mm. More preferably, the layer thickness falls within the range 0.15mm to 0.25mm, and conveniently within the range of 0.15 to 0.2mm.

The use of a layer of thickness falling within the range 0.15mm to 0.2mm is advantageous in that the resistance welding operation can be performed relatively easily.

After securing the bearing elements in position, a layer of a hard facing material may be applied over and around the bearing elements. The layer may be of depth such that the bearing surfaces of the bearing elements are left exposed, or the bearing surfaces may be covered , some of the hard facing material subsequently being removed, either before or during use.

In any of the above arrangements the downhole component may, as previously mentioned, comprise a drill bit, a stabiliser, a modulated bias unit for use in steerable rotary drilling, or any other downhole component having one or more bearing surfaces which engage the wall of the borehole in use.

Where the component is a drill bit, it may be a rotary drag-type drill bit having a leading face on which the cutters are mounted and a peripheral gauge region for engagement with the walls of the borehole, in which case the methods according to the invention may be used to apply bearing elements to the outer surface of the gauge region.

The methods of the invention may also be applied to increase the wear-resistance of surfaces of roller-cone bits or other types of rock bit.

The invention also includes within its scope a downhole component, such as a drill bit, having at least one surface to which bearing elements have been applied by any of the methods referred to above, and a coated bearing element for use in the methods defined hereinbefore.

BRIEF DESCRIPTION OF THE DRAWINGS

The following is a detailed description of embodiments of the invention, reference being made to the accompanying drawings in which:

Figure 1 is a perspective view of a PDC drill bit to the gauge sections of which wear-resistant materials have been applied in accordance with the method of the present invention,

Figure 2 is a diagrammatic enlarged cross-section of a part of the gauge section of the drill bit, showing the structure of the wear-resistant material,

Figure 3 is a similar view to Figure 2 showing an alternative method of forming the wear-resistant material,

Figure 4 is an enlarged view illustrating the structure of a bearing element mounted in position,

Figure 5 is a perspective view of a rolling cutter drill bit, to the gauge sections of which wear-resistant materials have been applied,

Figure 6 is a view of a stabiliser unit to at least part of which a wear-resistant material has been applied,

Figure 7 is a view of a bias unit to at least part of which a wear-resistant material has been applied,

Figure 8 is a view of a bottom hole assembly of a drill string having tools or components with surfaces to at least some of which a wear-resistant material has been applied, and

Figure 9 is a view of another bottom hole assembly having tools or components with surfaces to at least some of which a wear-resistant material has been applied.

DETAILED DESCRIPTION OF THE INVENTION AND THE PREFERRED EMBODIMENT

Referring to Figure 1: the PDC drill bit comprises a bit body 10 machined from steel and having eight blades 12 formed on the leading face of the bit and extending outwardly from the axis of the bit body towards the peripheral gauge region 14. Channels 16a, 16b are defined between adjacent blades.

Extending side-by-side along each of the blades 12 is a plurality of cutting structures, indicated at 18. The precise nature of the cutting structures does not form a part of the present invention and they may be of any appropriate type. For example, as shown, they may comprise circular preform PDC cutting elements brazed to cylindrical carriers which are embedded or otherwise mounted in the blades, the cutting elements each comprising a preform compact having a polycrystalline diamond front cutting table bonded to a tungsten carbide substrate, the compact being brazed to a cylindrical tungsten carbide carrier. In another form of cutting structure the substrate of the preform compact is of sufficient axial length to be mounted directly in the blade, the additional carrier then being omitted.

Back-up abrasion elements or cutters 20 may be spaced rearwardly of some of the outer cutting structures, as shown.

Nozzles 22 are mounted in the surface of the bit body between the blades 12 to deliver drilling fluid outwardly along the channels, in use of the bit. One or more of the nozzles may be so located that they can deliver drilling fluid to two or more channels. All of the nozzles communicate with a central axial passage (not shown) in the shank 24 of the bit, to which drilling fluid is supplied under pressure downwardly through the drill string in known manner.

Alternate channels 16a lead to respective junk slots 26 which extend upwardly through the gauge region 14, generally parallel to the central longitudinal axis of the drill bit, so that drilling fluid flowing outwardly along each channel 16a flows upwardly through the junk slot 26 between the bit body and the surrounding formation, into the annulus between the drill string and the wall of the borehole.

Each of the other four alternate channels 16b does not lead to a conventional junk slot but continues right up to the gauge region 14 of the drill bit. Formed in each such channel 16b adjacent gauge region is a circular opening 28 into an enclosed cylindrical passage which extends through the bit body to an outlet (not shown) on the upper side of the gauge region 14 which communicates with the annulus between the drill string and the borehole.

Accordingly, the gauge region 14 of the drill bit comprises four peripherally spaced bearing surfaces 30 each bearing surface extending between two junk slots 26 and extending continuously across the outer end of an intermediate channel 16b.

In accordance with the present invention, there is applied to each peripheral bearing surface 30 in the gauge region a wear-resistant layer comprising an array of rectangular bearing elements 32 in mutually spaced relationship on the bearing surface 30, each bearing element being formed, at least in part from thermally stable polycrystalline diamond.

In the example shown in Figure 1 the bearing elements 32 are rectangular and closely packed in parallel rows extending generally axially of the drill bit. However, this arrangement is by way of example only and many other shapes and arrangements of bearing elements may be employed, but still using the methods according to the present invention. For example the bearing elements might be square, circular or hexagonal and may be arranged in any appropriate pattern. Also, the bearing elements may be more widely spaced than is shown in Figure 1 and may cover a smaller proportion of the surface area of the bearing surface 30.

Referring now to Figure 5, a perspective view of a rolling cutter drill bit

100 is shown. The rolling cutter drill bit 100 has a body portion 112 and a plurality of legs 114 which each support rolling cutters 116. A typical rolling cutter 116 has a plurality of cutting inserts 118 arranged in circumferential rows 120. An orifice arrangement 122 delivers a stream of drilling fluid 124 to the rolling cutter 116 to remove the drilled earth, in use. Weight is applied to the rolling cutter drill bit 100, and the bit 100 is rotated. The earth then engages the cutting inserts 118 and causes the rolling cutters 116 to rotate upon the legs 114, effecting a drilling action.

The gauge portion 126 of each leg 114 may define a bearing surface which engages the borehole wall during operation. This engagement often causes excessive wear of the gauge portion 126 of the leg 114. In order to minimise the wear, a plurality of rectangular bearing elements 32 are provided, the elements 32 being spaced apart in either a vertical alignment 128 or horizontal alignment 130 on the gauge portion 126 of the leg(s) 114. The particular arrangement of bearing elements 32 used will depend upon several factors, such as the curvature of the gauge portion 126, the amount of wear resistance required, and the bit size. Although the vertical alignment 128 and the horizontal alignment 130 are shown on separate legs in the figure, it is anticipated that both may be used on a single gauge portion 126 of a leg 114.

Each rolling cutter 116 has a gauge reaming surface 132 which defines a further bearing surface and also experiences excessive wear during drilling. The rectangular bearing elements 32 may be used on the gauge reaming surface 132 to minimise this wear. The advantage of placing the rectangular bearing elements 32 on the gauge reaming surface 132 of the rolling cutter 116 is that they can be placed in a particularly dense arrangement compared to the traditional interference fitted cylindrical cutting elements. The rectangular bearing elements 32 may be placed in a circumferential manner on the gauge reaming surface 132 of the rolling cutter 116 as indicated by numeral 134. Alternately, the rectangular bearing elements 32 may be in a longitudinal arrangement as indicated by numeral 136. It is anticipated that a combination of longitudinal and circumferential arrangements of the rectangular bearing elements 32 would also be suitable.

The method of the present invention also allows the rectangular bearing elements 32 to be placed on the gauge reaming surface 132 of the rolling cutter 116 without particular regard to the placement of the cutting inserts 118. Prior to the invention, great care was required to arrange the cylindrical cutting elements of the gauge reaming surface 132 in a manner that prevented the bases of their mating sockets from overlapping.

Figures 2 and 3 show diagrammatic cross-sections through the bearing surface 30 and applied wear-resistant layer, and methods of applying the wear-resistant layer will now be described with reference to these figures.

As will be seen from Figure 2, the bearing elements 32 lie on the outer bearing surface 30 of the gauge portion 14 of the drill bit and the spaces between adjacent bearing elements 32 are filled with a settable hardfacing material 34.

In one method according to the invention, the bearing elements 32 comprise solid blocks or tiles of TSP and are first attached to the bearing surface 30 in the desired configuration. The settable hardfacing material 34 is then applied to the spaces between the TSP blocks 32 so as to bond to the bearing surface 30 of the drill bit and to the blocks themselves. Upon solidification, the hardfacing material 34 serves to hold the TSP elements 32 firmly in position on the surface 30.

The hardfacing material 34 may be of any of the kinds commonly used in providing a hardfacing to surface areas of drill bits, and particularly to steel bodied drill bits. For example, the hardfacing material may comprise a powdered nickel, chromium silicon, boron alloy which is flame sprayed on to the surface 30 using a well known hardfacing technique. The hardfacing may also be provided by other known techniques such as electrical plating, PDC, and metal spraying.

In the arrangement shown in Figure 2 the hardfacing material 34 is in the form of a broken layer of generally the same depth as the TSP bearing elements 32 so that the outer surfaces of the bearing elements are substantially flush with the outer surface of the hardfacing layer. In the alternative arrangement shown in Figure 3 the hardfacing layer 34 is applied to a depth which is greater than the depth of the elements 32 so as to overlie the outer faces of the bearing elements, as indicated at 36. The overlying layer 36 can be left in position so that, during use of the bit the layer 36 will wear away exposing the surfaces of the TSP bearing elements 32 which will then bear directly on the surface of the wall of the borehole. However, if required, the layer 36 may be ground away to expose the outer surfaces of the bearing elements before the bit is used.

The bearing elements 32 are attached to the bearing surface 30 by electrical resistance welding. Since it is extremely difficult to weld or braze TSP directly to steel using conventional techniques, such as electrical-resistance welding, the TSP blocks are coated with a less hard material, of higher electrical conductivity, before welding or brazing them to the surface 30. For example, the blocks may be coated with a thin layer of nickel or a nickel alloy, for example by using the techniques of electroless plating, CVD, or immersion in a molten alloy. Before coating the TSP with the nickel or nickel alloy, the TSP blocks may first be coated with a suitable carbide-forming metal, since such metal will bond to the TSP forming a firmly attached base surface to which the nickel or nickel alloy coating may subsequently be applied. Once the TSP blocks have had a suitable coating layer applied thereto, the blocks may more readily be welded or brazed to the surface 30, for example by using electrical-resistance spot welding.

As, during the electrical resistance welding process, high currents are applied and must be conducted by the nickel or nickel alloy coating, in order to ensure that the coating is able to withstand the applied current, the coating is of thickness greater than 0.05mm. In order to withstand the current applied in a typical electrical resistance welding process, the coating thickness is preferably within the range 0.1mm to 0.3mm and is preferably within the range 0.15mm to 0.25mm. More preferably, the layer thickness falls within the range 0.15mm to approximately 0.2mm, and the layer thickness is conveniently approximately 0.2mm.

Figure 4 illustrates a bearing element comprising a block 38 of thermally stable diamond coated with a layer 40 of nickel of thickness approximately 0.2mm. Prior to applying the nickel layer 40, a carbide forming material 42 is applied to the block 38. The coated block is then secured in position on a bit body 44 by electrical resistance welding, and a hard facing material 46 applied.

In any of the arrangements described the bearing surface 30 may be preformed with appropriate formations to assist in locating or holding the TSP elements 32 on the surface 30. For example, each element 32 may be partly received in a suitably shaped groove in the bearing surface 30 or in an individual recess which matches the shape of the element. In another arrangement the undersides of the elements 32 are preformed with shaped formations which mechanically inter-engage with corresponding shaped formations on the surface 30.

In any of the described arrangements the sides of the elements 32 may be so shaped that they mechanically interlock with the surrounding hardfacing material. For example, the elements may increase in width towards the surface 30.

In the above-described arrangements, the hardfacing layer 34 serves to hold the TSP elements 32 on the bearing surface 30, the welding or brazing of the elements 32 to the surface 30 merely serving to locate the elements temporarily in the desired configuration on the bearing surface while the hardfacing layer is applied. However, since the above-described coating of the TSP elements enables them to be welded or brazed to the bearing surface 30, arrangements are also possible where the TSP elements are welded or brazed to the bearing surface with sufficient strength that the hardfacing layer 34 may be dispensed with, each element 32 being held on the bearing surface 30 by the welded or brazed joint alone. In this case it may be desirable for the elements 32 to be wholly or partly received in recesses or grooves in the bearing surface 30 in order to improve the strength of the attachment of the elements to the surface.

Similar techniques to these described hereinbefore are suitable for use in securing the bearing elements 32 to the bearing surfaces of the drill bit illustrated in Figure 5.

Although the invention has been described with particular reference to applying a wear-resistant surface to the gauge section of a drag-type or rolling cutter type steel-bodied drill bit, as previously mentioned the invention is not limited to this particular application and may be used for applying TSP-incorporating bearing elements to a bearing surface of any other downhole component, such as a stabiliser, or a modulated bias unit, as described below. The description below is intended to be illustrative of the parts of the components to which a wear-resistant layer should preferably be applied rather than to take the form of a detailed description of these components.

Figure 6 illustrates a stabiliser unit for use in a bottom hole assembly. The stabiliser unit 200 illustrated in Figure 6 includes a plurality of radially outwardly extending blades 202, the outer surfaces 204 of which engage, in use, the wall of the borehole in which the bottom hole assembly is located. These surfaces 204 must be able to withstand the severe abrasion and loads applied thereto, in use. In order to improve the wear resistance of the blades 202, these surfaces 204 are provided with wear-resistant materials using the methods described hereinbefore to secure bearing elements 206 to the surfaces 204 and, if desired, to apply a layer of a hard facing material over or around the bearing elements 206.

The component illustrated in Figure 7 is a rotary steerable unit 208 having a bias pad 210. The bias pad 210 repeatedly engages the wall of the bore, in use to push an associated drill bit to one side as directed by a control unit. It will be appreciated that the bias pad 210 is subject to severe loads and so is subject to wear. In order to improve the wear-resistance of the bias pad 210, a plurality of bearing elements 212 are secured thereto using the method described hereinbefore. If desired, a hard facing material may also be applied to the bias pad using the technique described hereinbefore.

Referring now to Figures 8 and 9, are shown other applications utilising downhole tools 214, 216 having a wear-resistant material applied using the method described hereinbefore. In Figure 8 a number of different tools 214, 216 are shown in the drill string 218. These tools 214, 216 may include, but are not limited to, downhole motors, measuring while drilling tools, logging tools, vibration dampers, shock absorbers, and centralisers. These tools 214, 216 benefit from wear-resistant materials applied by the process of the present invention. In particular, the bottom hole assemblies 220, as shown in Figure 9, are often operated while gravity is pushing them against the borehole wall. Once again the extreme abrasion and loads applied to the sides of these tools make them benefit from the application of wear-resistant materials using the process of the present invention.

Whereas the present invention has been described in particular relation to the drawings attached hereto, it should be understood that other and further modifications apart from those shown or suggested herein, may be made within the scope and spirit of the present invention.

CLAIMS

We claim:

1. A method of applying a wear-resistant material to a surface of a downhole component, the method comprising forming a plurality of bearing elements, applying a layer of an electrically conductive, less hard material to each bearing element, and then bonding each bearing element to the surface of the component using one of a welding process and a brazing process to bond to the surface of the component a part of the surface of the bearing element which comprises said less hard material, wherein the layer is of thickness greater than about 0.05mm.

2. A method as claimed in Claim 1, wherein each bearing element comprises a body of thermally stable polycrystalline diamond.

3. A method as claimed in Claim 1, wherein the layer of less hard material comprises a coating applied to at least part of each bearing element.

4. A method as claimed in Claim 1, wherein the layer of less hard material is of high electrically conductivity.

5. A method as claimed in Claim 4, wherein the layer of less hard material is formed from a material selected from a group consisting of nickel and alloys containing nickel.

6. A method as claimed in Claim 1, wherein each bearing element is bonded to the surface using an electrical resistance welding technique.

7. A method as claimed in Claim 1, further comprising applying a layer of

a carbide forming metal to each bearing element prior to the application of the layer of less hard material thereto.

8. A method as claimed in Claim 1, wherein the layer of less hard material is of thickness of between about 0.1mm and about 0.3mm.

9. A method as claimed in Claim 8, wherein the layer of less hard material is of thickness of between about 0.15mm and about 0.25mm.

10. A method as claimed in Claim 9, wherein the layer of less hard material is of thickness of between about 0.15mm and about 0.2mm.

11. A method as claimed in Claim 1, further comprising a step of applying a layer of a hardfacing material over and around the bearing elements.

12. A downhole component having a surface to which a plurality of bearing elements are bonded, each bearing element having previously had a layer of a less hard, electrically conductive material applied thereto, the layer of less hard material having a thickness greater than about 0.05mm.

13. A downhole component as claimed in Claim 12, and shaped to act as one of a roller cone bit, a fixed cutter bit, a stabiliser unit and a bias unit.

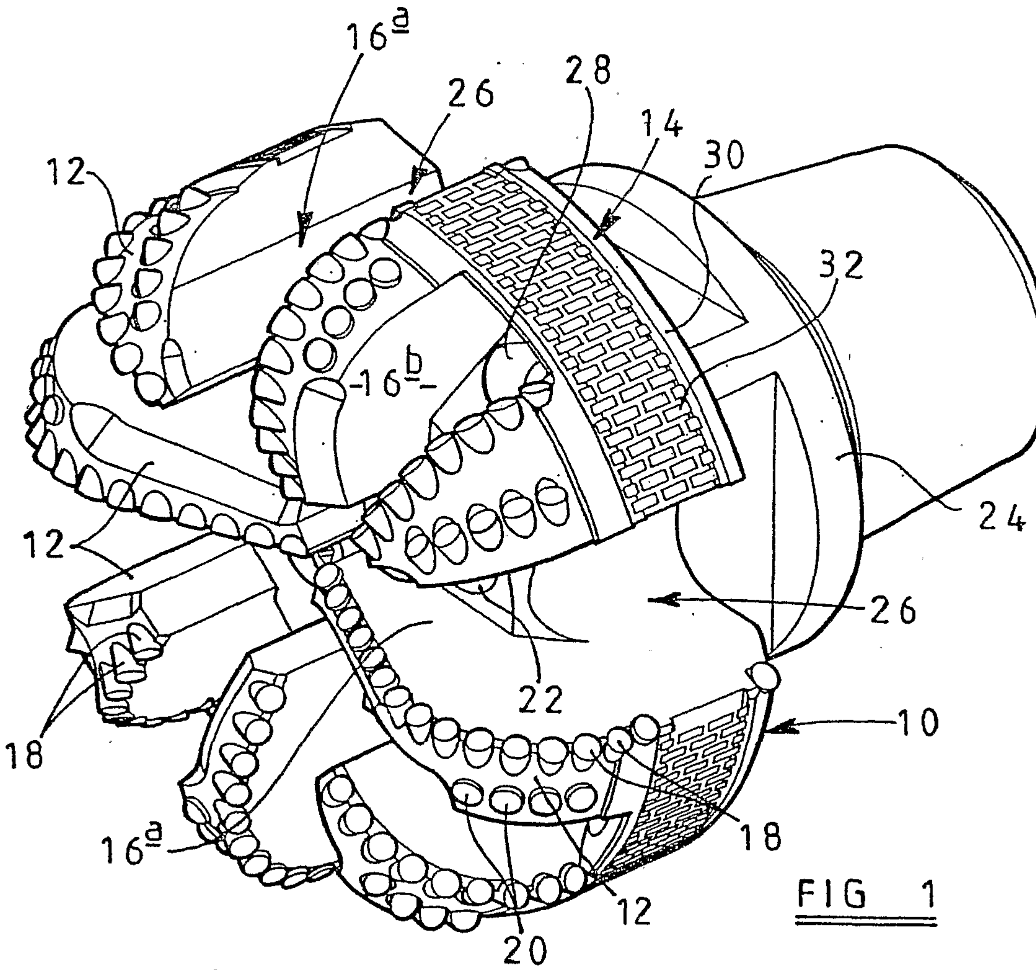


FIG 1

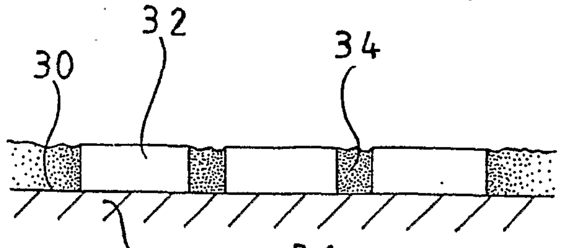


FIG 2

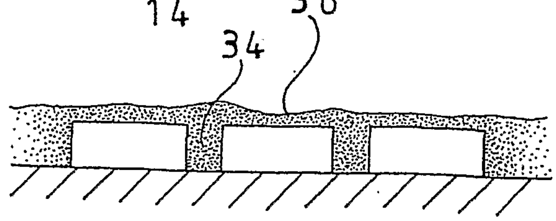


FIG 3

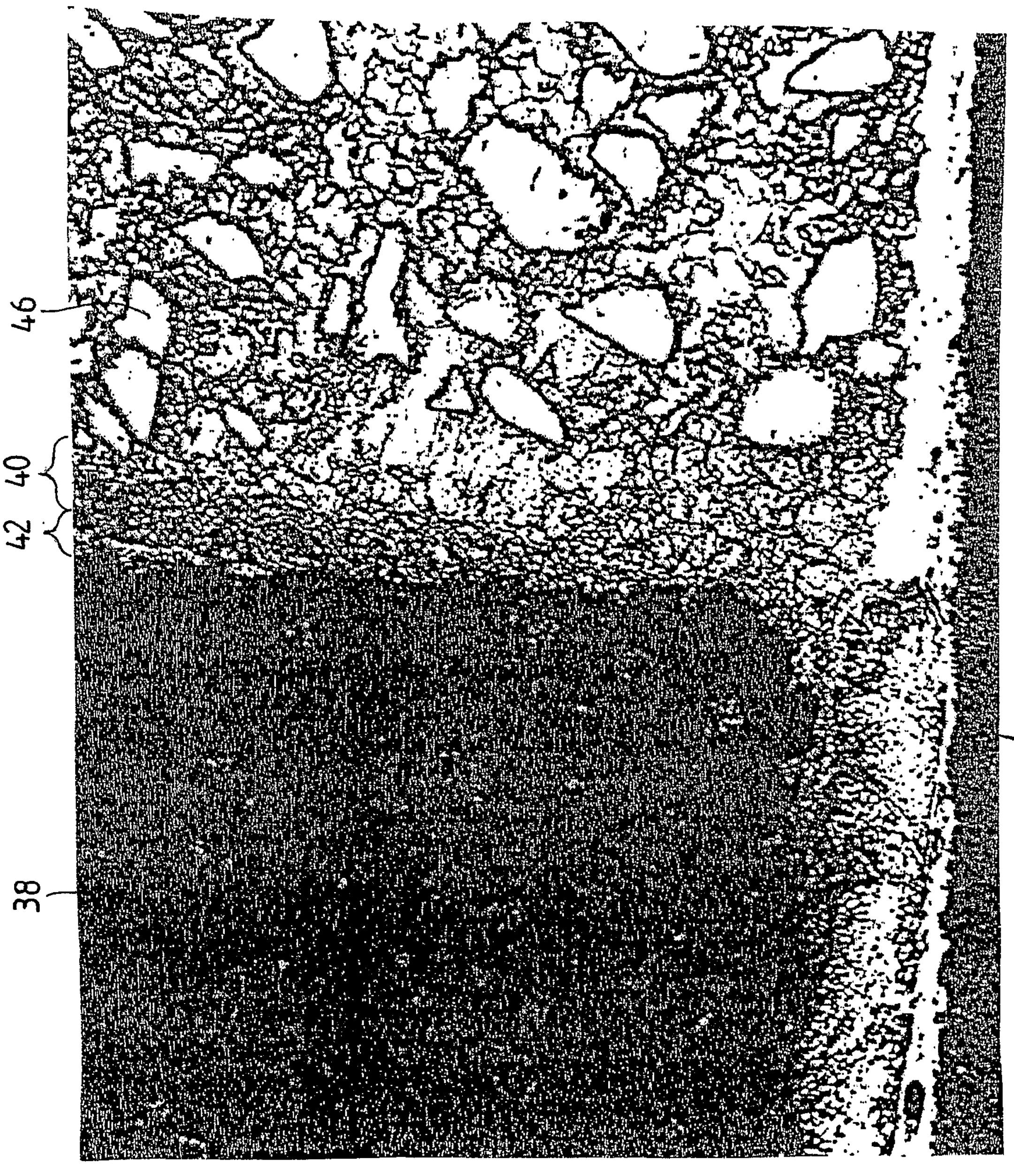
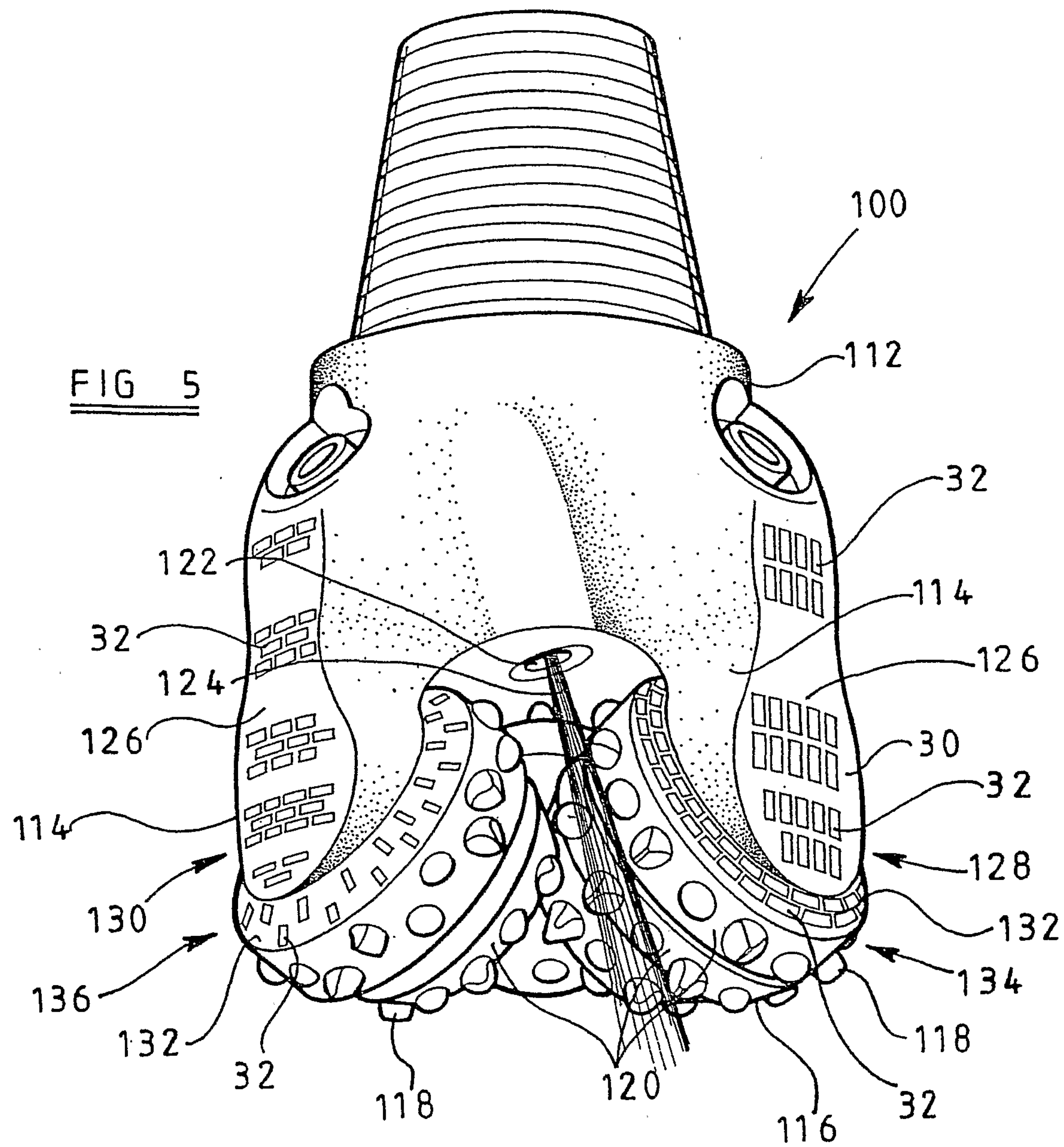


FIG 4

FIG 5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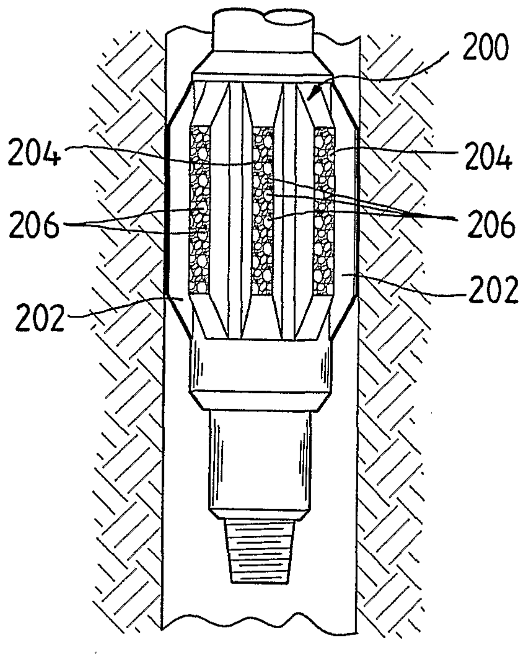

FIG 6

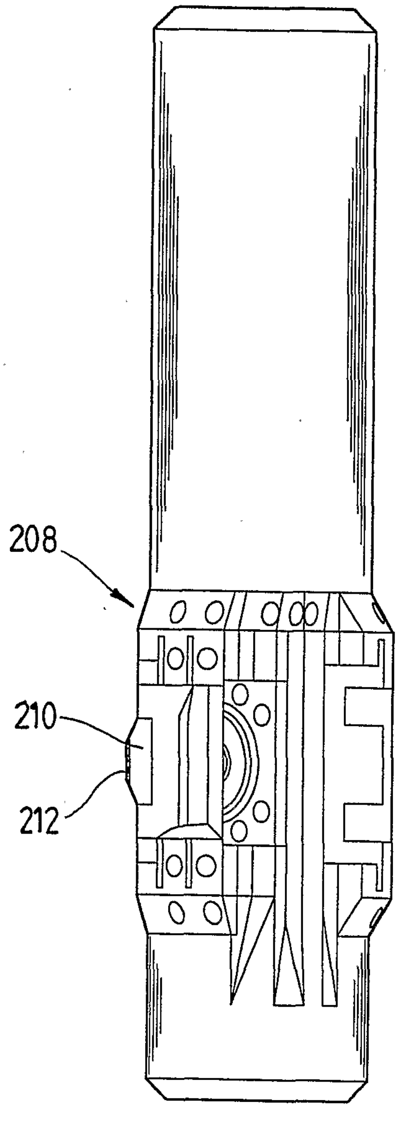

FIG 7

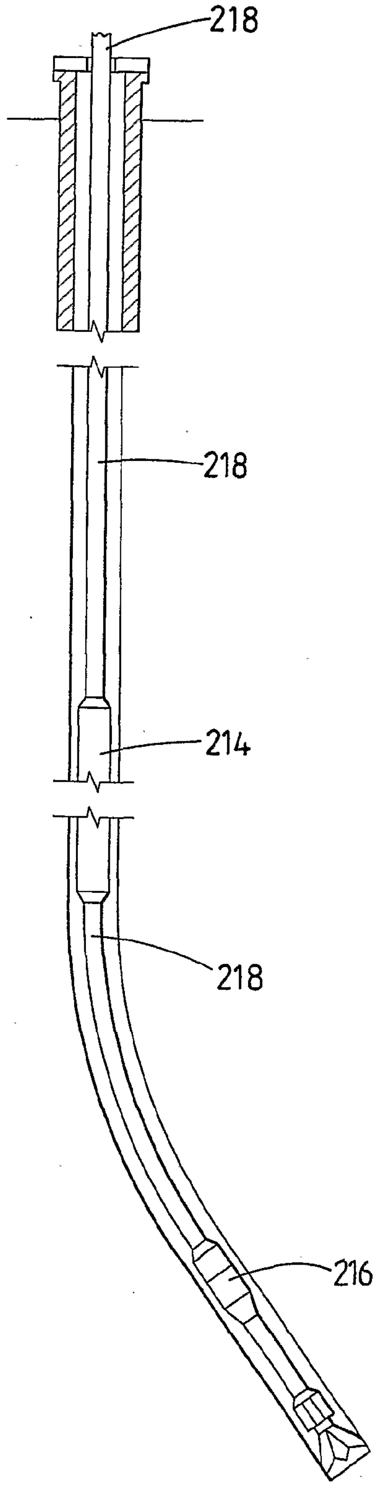

FIG 8

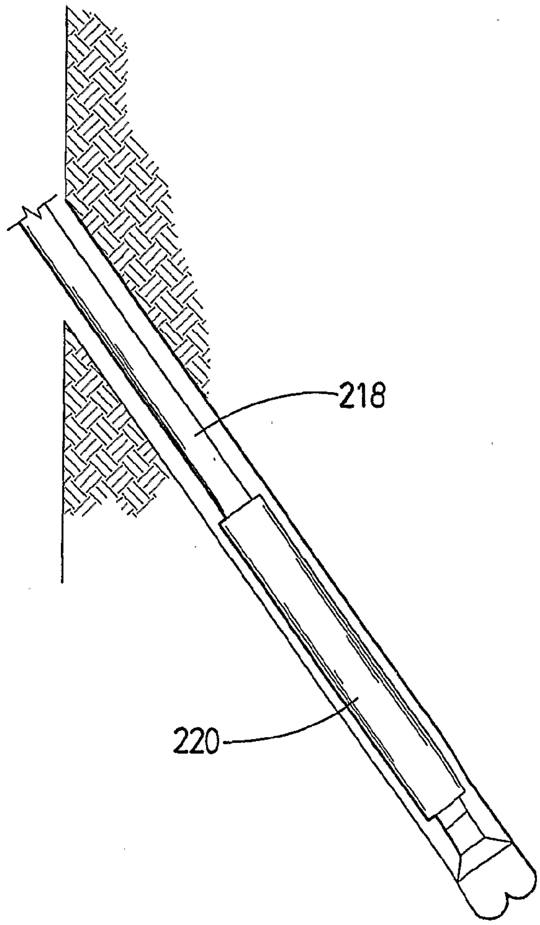

FIG 9

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 01/03510

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B10/46 E21B17/10

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)
IPC 7 E21B B22F B23K C22C

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 October 2001	29/10/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Fonseca Fernandez, H

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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