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(54) Cutter for a rotary drill bit, rotary drill bit with such a cutter, and method of manufacturing such a cutter.

(57) A cutter, for use in a rotary drill bit, comprises a number of thermally stable polycrystalline diamond elements 21 at least partly embedded in a slug 20 of cemented tungsten carbide, the cemented tungsten carbide having been formed by hot pressing with cobalt. The thermally stable polycrystalline diamond may be of the kind in which the interstices between the diamond particles are substantially filled with silicon carbide, or of the kind in which metallic interstitial components have been leached out, and each element has been coated with a protective material, such as nickel.

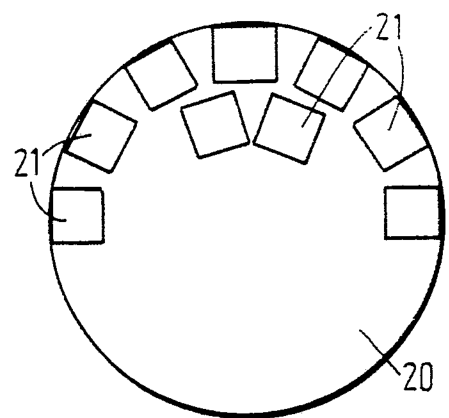

FIG.3

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"Improvements in or relating to rotary drill bits"

The invention relates to rotary drill bits for use in drilling or coring deep holes in subsurface formations, and in particular relates to cutters for use in such drill bits.

Rotary drill bits of the kind to which the present invention is applicable comprise a bit body having a shank for connection to a drill string and an inner passage for supplying drilling fluid to the face of the bit. The bit body carries a plurality of so called "preform" cutters. Each cutter may be mounted directly on the bit body or on a carrier, such as a stud or post, which is received in a socket in the bit body. One common form of preform cutter is a polycrystalline diamond compact comprising a hard facing layer of polycrystalline diamond and a backing layer formed of cemented tungsten carbide. Since the backing layer is of less hard material than the facing layer, the two layer arrangement of the cutting element provides a degree of self-sharpening since, in use, the less hard backing layer wears away more easily than the harder cutting layer.

Usually, the bit body is machined from solid metal, usually steel, or is moulded using a powder metallurgy process in which tungsten carbide powder is infiltrated with metal alloy binder in a furnace so as to form a hard matrix. The maximum furnace temperature required to form the matrix may be of the order of 1050° to 1170°C. Conventional two layer preform cutters of the kind referred to above are not thermally stable at such temperatures and for this reason they normally require to be mounted on the bit body after it has been formed, and this may be a time consuming and costly process. There has accordingly been a demand for cutters which are thermally stable at the infiltration temperature and which may thus be simply mounted on the bit body by locating the cutters in the mould in which the matrix is formed so that they become mounted in the matrix as a result of the forming process.

Partly as a result of this requirement, there are now available polycrystalline diamond cutter elements which are thermally stable at the infiltration temperature of matrix bodied bits. For example, such thermally stable cutter elements have been manufactured and sold by the General Electric Company under the trademark "GEOSET" and by DeBeers under the trademark "SYNDAX 3".

In conventional non-thermally stable polycrystalline diamond cutters, the diamond layer comprises polycrystalline diamond particles bonded together by a high temperature, high pressure process using a cobalt catalyst, with the result that, in the finished cutter, cobalt is present in the interstices between the diamond particles. It is the presence of cobalt, and perhaps other metallic interstitial components, which causes the cutters to be non-thermally stable due, for example, to the significant difference in coefficient of thermal expansion between the cobalt and the diamond. In elements sold under the trademark "GEOSET", thermal stability is achieved by forming the element wholly from polycrystalline diamond, using cobalt but without the tungsten carbide backing layer, and then leaching out the cobalt and any other metallic interstitial components after the cutting element has been formed. For such leaching to be a practical proposition the elements must be small compared with normal non-thermally stable elements which are usually in the form of circular tablets up to 51 mm in diameter. Thus typical "GEOSET" elements are in the shape of an equilateral prismatic triangle having a side length of only 4 mm and a depth of only 2.6 mm. Other shapes are also used, but in each case the elements require to be small to allow the cobalt to be readily leached out.

In "SYNDAX 3" elements, on the other hand, thermal stability is achieved by using silicon instead of cobalt in the formation of the elements so that the interstices between the diamond particles in the finished element contain silicon and/or silicon carbide. The presence of silicon/silicon carbide in the interstices, unlike tne presence of cobalt, does not cause thermal instability of the diamond, so that it is not necessary to leach out the interstitial material. Since no leaching out of metallic interstitial components is required, "SYNDAX 3" elements may be manufactured to the same sizes and shapes as non-thermally stable elements.

Hitherto, it has been the practice to use the small "GEOSET" elements in rotary drill bits in somewhat similar manner to that previously employed for natural diamonds. Although "SYNDAX 3" has been available in larger sizes, this material too has normally been used in the form of small elements in similar manner to natural diamonds.

In an endeavour to permit the use of "GEOSET" elements in similar fashion to the larger two-layer non-thermally stable elements it has been proposed that a plurality of "GEOSET" elements be embedded in a slug of matrix material incorporatng a dispersion of diamond grit, the idea being that the composite element so produced could be of any required shape and size and could thus be used in any of the conventional ways that the larger two-layer non-thermally stable cuttings elements have been used and yet which at the same time would be thermally stable. (In the drill bit industry, "matrix material' is normally understood to mean a material formed by a powder metallurgy process in which metallic powder, usually tungsten carbide, is infiltrated with a metal alloy binder in a furnace so as to form a hard matrix when cooled).

Such composite cutters using "GEOSET" embedded in matrix material are described, for example, in European Patent Specifications Nos. 0,156,264, 0,156,235 and 0,157,278. Such composite cutters, however, suffer from a number of disadvantages.

As previously mentioned, the "GEOSET" elements are thermally stable at the furnace temperatures (1050 to 1170°C) required to form infiltrated tungsten carbide matrix. However, while such matrix material is fairly hard and erosion resistant it is less hard and less erosion resistant than the cemented tungsten carbide normally used as the backing layer in two-layer non-thermally stable cutters. Consequently, the composite cutters described in the above mentioned specifications may be insufficiently erosion resistant and may wear rapidly in use. As the surrounding matrix wears away the diamond elements become freed from the matrix and become lost rendering the cutter ineffective.

However, if attempts are made to embed the "GEOSET" elements in cemented tungsten carbide by conventional hot press techniques, it is found that the polycrystalline diamond of the "GEOSET" element graphitises at the high temperatures (1300 to 1450°C) required in the hot press process, destroying the effectiveness of the cutter. Such conventional hot press techniques for forming cemented tungsten carbide normally employ cobalt and it is possible to form cemented tungsten carbide at lower temperatures which the "GEOSET" elements can stand by using some other catalyst, such as copper, having a lower melting point. However the resulting material is less hard and less erosion resistant than conventional cemented tungsten carbide with cobalt and therefore suffers from similar disadvantages to infiltrated matrix material.

It is believed that the tendency of "GEOSET" elements to graphitise under high temperature is due to the presence of oxygen in the open interstices between the diamond particles from which the cobalt has been leached. It has been found that this tendency of "GEOSET" to graphitise may be reduced by applying to the "GEOSET" elements an outer coating of a protective material, such as nickel. The protective coating renders the elements more stable against oxidation and graphitisation of the diamond particles, and thus allows the elements to be subjected to the high temperatures necessary for hot pressing in cemented tungsten carbide.

The tendency to graphitise at high temperatures is not a characteristic of "SYNDAX 3" elements where the interstices are filled with silicon and/or silicon carbide and consequently "SYNDAX 3" elements tend to be thermally stable at higher temperatures than uncoated "GEOSET" elements. In particular, "SYNDAX 3" elements have been found to be thermally stable for short periods at the temperatures necessary to form cemented tungsten carbide with cobalt using conventional hot press techniques.

Since "SYNDAX 3" elements have been available in large sizes it has not hitherto been considered advantageous to embed small elements of "SYNDAX 3" in less hard material to form composite cutting elements. In any case, if this were to be done in accordance with the teaching of the prior art as set out for example in the above mentioned European patent specifications, the resulting composite element would still have the disadvantages of such elements as mentioned above and would be inferior to large integral "SYNDAX 3" elements.

According to the present invention, however, there are provided composite cutters using small "SYNDAX 3"-type elements, or coated "GEOSET" elements, embedded in hot pressed cemented tungsten carbide using cobalt. Where "SYNDAX 3" is used such cutters have the advantage that they may be significantly cheaper to manufacture than integral one piece "SYNDAX 3"-type cutters since the total volume of "SYNDAX 3"-type material in a cutter of a given size is reduced since the elements need only extend to those parts of the cutter which provide the cutting edge. At the same time, in the case of both "SYNDAX 3" and coated "GEOSET" elements, the rest of the composite cutter is sufficiently hard and erosion resistant to minimise damage to the cutter and loss of the polycrystalline diamond elements in use. Furthermore, the cemented tungsten carbide in which the elements are embedded may be so arranged in relation to the elements that the composite cutter has a similar self-sharpening characteristic as described above in relation to two-layer non-thermally stable cutters.

According to the invention, therefore, there is provided a cutter, for use in a rotary drill bit, comprising a number of thermally stable polycrystalline diamond elements at least partly embedded in a slug of cemented tungsten carbide, the cemented tungsten carbide having been formed by hot pressing with cobalt.

As previously mentioned, the thermally stable polycrystalline diamond may be of the kind in which the interstices between the diamond particles are substantially filled with silicon material. The expression "silicon material" should be understood to include silicon and silicon carbide since, as mentioned above, both substances are likely to be present in the interstices of a "SYNDAX 3"-type element. Also, the presence in the interstices of traces of other substances is not excluded.

Alternatively, the thermally stable polycrystalline diamond may be of the kind in which metallic interstitial components have been leached out, and each element has been coated with a protective material, such as nickel.

The references above to the tungsten carbide having been formed by hot pressing with cobalt does not exclude the use of other additives to the tungsten carbide powder and cobalt.

Each cemented tungsten carbide slug may have a front surface, a rear surface and a peripheral surface and in this case at least one polycrystalline diamond element is preferably so located in the slug as to have surfaces thereof disposed at the front surface and at the peripheral surface respectively of the slug. In this case the polycrystalline diamond element may extend, in the direction of the depth of the slug, only part of the way from the front surface towards the rear surface of the slug so that the portion of the slug between the polycrystalline diamond element and the rear surface of the slug acts as a backing layer to the polycrystalline diamond element so as to provide a degree of self-sharpening of the cutter in the vicinity of the polycrystalline diamond element in use of the cutter.

Each polycrystalline diamond element may be of substantially constant cross-section between two opposite end faces thereof, one of said end faces lying in, and substantially co-planar with, the front surface of the slug.

In this case, each polycrystalline diamond element has a peripheral surface and preferably a portion of the peripheral surface of each element lies substantially in the peripheral surface of the slug.

The slug of cemented tungsten carbide may be of any convenient shape and dimensions. For example, it may be in the form of a tablet or block of substantially uniform thickness and cross-section as it extends from the front surface to the rear surface thereof. The slug may be circular in shape or may be in the form of a semi-circle or a segment or sector of a circle. Alternatively, the slug may be generally rectangular: for example it may be square.

In any of the forms of cutter referred to above, there may be provided an array of polycrystalline diamond elements extending around only a part of the periphery of the slug. In use, a cutter having this feature will be so orientated on the drill bit that the part of the periphery of the slug carrying the array of polycrystalline diamond elements forms the cutting edge of the cutter and engages the formation being cut.

The array may comprise, for example, essentially a single row of polycrystalline diamond elements or a single row of such elements with further polycrystalline diamond elements disposed inwardly of the row with respect to the periphery of the slug.

The polycrystalline diamond elements in the row, or each row, of elements may be disposed closely adjacent one another so as to extend substantially continuously around said part of the periphery of the slug. One or more further rows of polycrystalline diamond elements may also be disposed in the peripheral surface of the slug intermediate the front surface and rear surface thereof. Thus, where there are a plurality of rows of elements in the front surface as well as a plurality of rows of elements in the peripheral surface, the elements effectively define a three-dimensional array of elements.

The invention includes within its scope a cutting structure, for mounting on a rotary drill bit, comprising a cutter of any of the kinds referred to above mounted on a carrier. The carrier may, for example, comprise a stud or post to be received in a socket in the bit body. The cutter may be brazed, bonded or otherwise attached to the carrier.

The invention also includes a rotary drill bit of the kind first referred to including a plurality of cutting structures of the last mentioned kind mounted on the bit body, or a drill bit of the kind first referred to wherein cutters of any of the kinds referred to above are directly mounted, by brazing or otherwise, on the bit body.

The invention also provides a method of manufacturing a cutter for use in a rotary drill bit comprising forming by hot pressing with cobalt a slug of cemented tungsten carbide, and incorporating in the slug, during the hot pressing process, a number of thermally stable polycrystalline diamond elements.

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

Figure 1 is a side elevation of a typical drill bit which is suitable for use with cutters in accordance with the invention,

Figure 2 is an end elevation of the drill bit shown in Figure 1,

Figures 3 to 13 show diagrammatically, by way of example, a number of alternative cutter arrangements in accordance with the invention,

Figure 14 is a front elevation of a typical cutting structure incorporating a cutter in accordance with the invention, and

Figure 15 is a side elevation of the cutting structure of Figure 14.

Referring to Figures 1 and 2, there is shown a full bore drill bit of a typical kind to which cutters in accordance with the present invention are applicable.

The bit body 10 is typically formed of tungsten carbide matrix infiltrated with a binder alloy, and has a threaded shank 11 at one end for connection to the drill string.

The operative end face 12 of the bit body is formed with a number of blades 13 radiating from the central area of the bit and the blades carry cutting structures 14 spaced apart along the length thereof.

The bit gauge section 15 includes kickers 16 which contact the walls of the borehole to stabilise the bit in the borehole. A central passage (not shown) in the bit body and shank delivers drilling fluid through nozzles 17 in the end face 12 in known manner, to cool and clean the cutting structures.

It will be appreciated that this is only one example of the many possible variations of the type of bit to which the invention is applicable, including bits where the body is machined from steel.

Each cutting structure 14 comprises a cutting element 18 mounted on a carrier 19 in the form of a stud which is located in a socket in the bit body 10. Each cutter 18 is in the form of a circular tablet, the rear surface of the cutter being bonded, for example by brazing, to a suitably orientated surface on the stud 19.

The form of cutting structure shown is by way of example only and any suitable shape of cutter may be employed, mounted on any suitable form of carrier. Alternatively, in other types of rotary drill bit, the cutters are mounted directly on the bit body and such arrangements are also within the scope of the invention.

Figure 3 shows a typical cutter in accordance with the invention which may be directly used as one of the cutters 18 in a drill bit of the kind shown in Figures 1 and 2.

Referring to Figure 3, the cutter comprises a slug 20 in the form of a generally circular tablet of cemented tungsten carbide. Embedded in the cemented tungsten carbide are a plurality of generally rectangular tablets 21 of thermally stable polycrystalline diamond material. Seven such elements are spaced apart in a row around one half of the periphery of the slug 20 so that one side of each element 21 lies at the periphery of the slug so as to form part of the peripheral surface of the cutter. Inwardly of the outer row of elements are located two further elements adjacent the mid point of the first row of elements.

In use, the cutter is so orientated on the drill bit that the first part of the cutter to engage the formation being drilled is in the vicinity of the central element in the outer row of elements.

The elements 21 may extend through the full thickness of the slug 20 or may extend from the front face of the slug only part of the way through the thickness and towards the rear face. The thickness of the slug between the elements and the rear face of the slug then provides, in effect, a less hard backing layer for the elements so as to provide a degree of self-sharpening in similar fashion to a conventional non-thermally stable two layer cutter.

In the alternative form of cutter shown in Figure 4, the tungsten carbide slug 22 is in the form of a sector of a circle and generally square polycrystalline diamond elements 23 are embedded in the tungsten carbide so as to extend along the two straight sides of the slug leading to the apex. Further elements 24 are disposed inwardly of the apex. In use, the cutter is mounted on the drill bit so that the polycrystalline diamond element at the apex of the slug first engages the formation.

Figure 5 also shows a sector shaped slug 25 of tungsten carbide and in this case generally triangular polycrystalline diamond elements 26, 27 are arranged in two rows around the arcuate side of the slug. The polycrystalline diamond elements 26 in the outer row have one side thereof lying along the peripheral edge of the slug whereas the polycrystalline diamond elements 27 in the inner row have their apices directed outwardly and are interleaved between the outer polycrystalline diamond elements 26.

The cutter shown in Figures 6a and 6 b comprises a generally cubic slug 28 of cemented tungsten carbide in which are embedded generally cubic polycrystalline diamond elements 29. Figure 6a is a front view of the cutter and it will be seen that on the front cutting face there are exposed two rows of polycrystalline diamond elements. Figure 6b is a side view of the cutter and it will be seen that a further row of polycrystalline diamond elements is disposed between the front face 30 and the rear face 31 of the slug. Thus, in this arrangement, the polycrystalline diamond elements 29 form a three-dimensional array of elements.

In the cutter of Figures 7a and 7b the cemented tungsten carbide slug 32 is in the form of a circular cylindrical tablet of constant thickness having three polycrystalline diamond elements 33 arranged around part of its periphery. As will be seen from Figure 7b, each polycrystalline diamond element has one face exposed in the front cutting face of the slug and one cutting face exposed at the periphery of the slug, but does not extend through the full thickness of the slug.

Figures 8a and 8b show a somewhat similar circular tablet 34 where the polycrystalline diamond elements comprise a central square element 35 between two triangular elements 36. Again the polycrystalline diamond elements extend only partly through the thickness of the slug and it will be appreciated that the layer of tungsten carbide behind each polycrystalline diamond element acts as a less hard backing layer to each element and thus provides a degree of self-sharpening for the cutter, taken as a whole.

Figure 9 shows another generally sector shaped slug in which are embedded four polycrystalline diamond elements 38 in the form of circular tablets of uniform thickness. The apex of the sector is rounded, as indicated at 39, and one of the polycrystalline diamond elements lies at the apex closely adjacent the rounded portion. In use the cutter is disposed on a drill bit so that the apex 39 first engages the formation.

Figure 10 shows a semi-circular slug 40 of tungsten carbide having alternating rectangular and triangular polycrystalline diamond inserts 41 and 42 around the arcuate portion of its periphery.

In the arrangement of Figure 11 the tungsten carbide slug 43 is oblong having an arcuate portion 44 along one of its longer edges, along which edge are embedded, in close proximity to one another, rectangular polycrystalline diamond elements 45. In this arrangement the polycrystalline diamond elements are closely adjacent one another so as to provide a substantially continuous polycrystalline diamond cutting edge to the cutter.

Figure 12 shows a somewhat similar form of cutter in which three elongate rectangular polycrystalline diamond elements 46 are disposed along the arcuate edge 47 of a generally oblong slug 48. Further square polycrystalline diamond elements 49 are embedded in the slug 48 inwardly of the elements 46.

Figure 13 shows a cutter 50 in the form of a circular tablet of constant thickness. The cutter comprises a circular polycrystalline diamond element 51 embedded in a larger circular slug 52 of cemented tungsten carbide. In this case the cutter will be orientated on the drill bit so that the part of the cutter, indicated at 53, where the polycrystalline diamond is exposed at the surface of the slug first comes into contact with the formation being drilled. It will be appreciated that the circular tablet cutter shown in Figure 13 may be used in any similar way to conventional two layer non thermally stable circular cutters.

Figures 14 and 15 show a typical form of cutting structure, for a rotary drill bit, in which cutters in accordance with the invention may be used. The structure comprises a generally cylindrical stud 54 formed, for example, of cemented tungsten carbide. The stud is formed, adjacent one end, with an inclined surface 55 leading to a rebate 56. Received in the rebate 56 is a semicircular cutting element 57. The cutter is of the type previously described and comprises elements 58 of thermally stable polycrystalline diamond embedded in a slug of cemented tungsten carbide. The cutter may be secured within the rebate 56 by brazing.

In use, cutting structures generally of the kind shown in Figures 14 and 15 are mounted on the body of the rotary drill bit by securing the studs 54 within sockets in the bit body. For example, the studs may be secured in the sockets by brazing and/or shrink-fitting. Any of the other forms of cutter previously described may also be mounted on studs, or other forms of carrier, to provide a cutting structure for mounting on a drill bit. Alternatively, the cutters may, in some cases, be mounted directly on the bit body.

In any of the above described arrangements, the polycrystalline diamond elements may extend wholly or only partly through the thickness of the slug of tungsten carbide. Although one surface of each element is preferably flush with the surface of the tungsten carbide slug, the invention includes within its scope arrangements in which some or all of the elements project from the surface of the slug to a certain extent.

In accordance with the invention, in all the arrangements described above by way of example, the polycrystalline diamond elements may be of the kind in which the interstices between the diamond particles are filled with silicon material, i.e. silicon and/or silicon carbide, with or without the presence of other interstitial components, or may be of the kind in which the metallic interstitial components have been leached out and the element has been coated with protective material, such as nickel. The slug is formed of cemented tungsten carbide using cobalt. The polycrystalline diamond inserts are embedded in the slug during formation of the slug by a hot pressing process in a furnace, possibly, but not necessarily, in a vacuum or hydrogen atmosphere. The temperature of formation of the cemented tungsten carbide, as is well known, is likely to be 1300°C to 1450°C for a brief period, but polycrystalline diamond material of the two kinds referred to may be thermally stable under such conditions. As previously mentioned, suitable forms of thermally stable polycrystalline diamond material are that manufactured and sold by de Beers under the trade name "SYNDAX 3", and that sold under the trade name "GEOSET", when suitably coated.

"SYNDAX 3" is currently produced in the form of large discs of 34 mm diameter and 2.5 mm or 3 mm in thickness. The small polycrystalline diamond elements employed in the invention may be cut from such discs using a computer controlled laser or other suitable method.

The polycrystalline diamond elements may simply be held in the tungsten carbide slug mechanically but a metallurgical bond between the elements and the tungsten carbide may also be achieved by suitable coating, or further coating, of the polycrystalline diamond elements before they are embedded in the tungsten carbide.

As previously mentioned, one of the advantages of the invention is that the cost of each cutter may be less than the cost of a similar cutter formed entirely from polycrystalline diamond in view of the smaller volume of polycrystalline diamond employed. The saving in cost is particularly great in the described arrangements where the polycrystalline diamond elements are located mainly in the vicinity of the cutting edge of the cutter and are not distributed over the entire cutting face of the cutter.

It will be appreciated that this latter aspect of the present invention is equally applicable to composite cutters using "GEOSET" in a matrix slug as described in the above-mentioned European Patent Specifications Nos. 0,156,264, 0,156,235 and 0,157,278. In the arrangements described in these prior specifications the polycrystalline diamond elements are distributed over the entire cutting face of each cutter, but a substantial saving in cost, without significant loss of effectiveness, could be achieved by locating the majority of the polycrystalline diamond elements in the vicinity of the cutting edge, that is to say the edge of the cutter which, in use, is first presented to the formation. This would reduce the number of polycrystalline diamond elements required.

Accordingly, the invention also includes within its scope a cutter, for use in a rotary drill bit, comprising a number of thermally stable polycrystalline diamond elements at least partly embedded in a slug of less hard material, a majority of the polycrystalline diamond elements being located in the vicinity of the cutting edge of the cutter. Each polycrystalline diamond element may be of the kind in which the interstices between the diamond particles are substantially filled with silicon material, i.e. silicon or silicon carbide, and the slug is of tungsten carbide cemented with cobalt, or each polycrystalline diamond element may be of the kind in which the interstitial components have been leached out and the slug is of matrix material.

In either case, the arrangement of the polycrystalline diamond elements in the slug may, for example, be of any of the kinds described above with reference to Figures 1 to 8 or Figures 10 to 13 of the accompanying drawings.

Claims

1. A cutter, for use in a rotary drill bit, characterised by a number of thermally stable polycrystalline diamond elements (21) at least partly embedded in a slug (20) of cemented tungsten carbide, the cemented tungsten carbide having been formed by hot pressing with cobalt.

2. A cutter according to Claim 1, characterised in that the thermally stable polycrystalline diamond is of the kind in which the interstices between the diamond particles are substantially filled with silicon material.

3. A cutter according to Claim 1, characterised in that the thermally stable polycrystalline diamond is of the kind in which metallic interstitial components have been leached out, and each element has been coated with a protective material.

4. A cutter according to Claim 3, characterised in that the protective coating is nickel.

5. A cutter according to any of Claims 1 to 4, characterised in that the cemented tungsten carbide slug (20) has a front surface, a rear surface and a peripheral surface and at least one polycrystalline diamond element (21) is so located in the slug as to have surfaces thereof disposed at the front surface and at the peripheral surface respectively of the slug.

6. A cutter according to Claim 5, characterised in that at least one polycrystalline diamond element (33) extends, in the direction of the depth of the slug (32), only part of the way from the front surface towards the rear surface of the slug so that the portion of the slug between the polycrystalline diamond element and the rear surface of the slug acts as a backing layer to the element.

7. A cutter according to Claim 5 or Claim 6, characterised in that each polycrystalline diamond element (21,33) is of substantially constant cross-section between two opposite end faces thereof, one of said end faces lying in, and being substantially coplanar with, the front surface of the slug (20,32).

8. A cutter according to Claim 7, characterised in that a portion of the peripheral surface of each element (21,33) lies substantially in the peripheral surface of the slug (20,32).

9. A cutter according to any of Claims 1 to 9, characterised in that the slug (21,32) of cemented tungsten carbide is in the form of a tablet of

substantially uniform thickness and cross-section as it extends from the front surface to the rear surface thereof.

10. A cutter according to Claim 9, characterised in that the shape of the tablet is in the form of a circle (Fig. 3), a semi-circle (Fig. 10), a segment of a circle (Fig. 11), a sector of a circle (Fig. 5), a rectangle or a square (Fig. 6).

11. A cutter according to any of Claims 1 to 10, characterised in that there is provided an array of polycrystalline diamond elements (21,33) extending around only a part of the periphery of the slug (20,32).

12. A cutter according to Claim 11, characterised in that the array comprises a single row of polycrystalline diamond elements (33).

13. A cutter according to Claim 11, characterised in that the array comprises a single row of polycrystalline diamond elements (21) extending around only a part of the periphery of the slug (20) with further polycrystalline diamond elements disposed inwardly of the row with respect to the periphery of the slug.

14. A cutter according to Claim 12 or Claim 13, characterised in that the polycrystalline diamond elements (45) in the row, or each row, of elements are disposed closely adjacent one another so as to extend substantially continuously around said part of the periphery of the slug (43).

15. A cutter according to any of Claims 12 to 14, characterised in that one or more further rows of polycrystalline diamond elements (29) are also disposed in the peripheral surface of the slug (30) intermediate the front surface and rear surface thereof.

16. A cutting structure, for mounting on a rotary drill bit, comprising a cutter (Fig. 14) according to any of the preceding claims mounted on a carrier (54).

17. A cutting structure according to Claim 16, characterised in that the carrier comprises a stud (54) to be received in a socket in the bit body.

18. A cutter for use in a rotary drill bit, comprising a number of thermally stable polycrystalline diamond elements at least partly embedded in a slug of less hard material, the slug having a front surface, a rear surface and a peripheral surface, characterised in that at least one polycrystalline diamond element (29) is so located in the slug (28) as to have a surface thereof disposed at the front surface (30) of the slug and to extend only part of the distance from the front surface towards the rear surface (31) of the slug, and at least one further polycrystalline diamond element being located in the slug intermediate the front surface and rear surface thereof.

19. A cutter according to Claim 18, characterised in that there is provided an array of polycrystalline diamond cutting elements (29) having surfaces thereof at the front surface (30) of the slug, and an array of polycrystalline diamond elements located in the slug intermediate the front surface and rear surface (31) thereof.

20. A cutter according to Claim 19, characterised in that at least one of said arrays of polycrystalline diamond elements (29) includes a row of elements each of which has a surface lying substantially at the peripheral surface of the slug.

21. A rotary drill bit comprising a bit body having a shank (11) for connection to a drill string, an inner passage for supplying drilling fluid to the face of the bit, and a plurality of cutters (14) mounted on the bit body, characterised in that at least one of said cutters comprising a number of thermally stable polycrystalline diamond elements at least partly embedded in a slug of cemented tungsten carbide, the cemented tungsten carbide having been formed by hot pressing with cobalt.

22. A rotary drill bit according to Claim 21, characterised in that the bit body is formed from steel.

23. A rotary drill bit according to Claim 21 or Claim 22, characterised in that said cutter is directly mounted on the bit body.

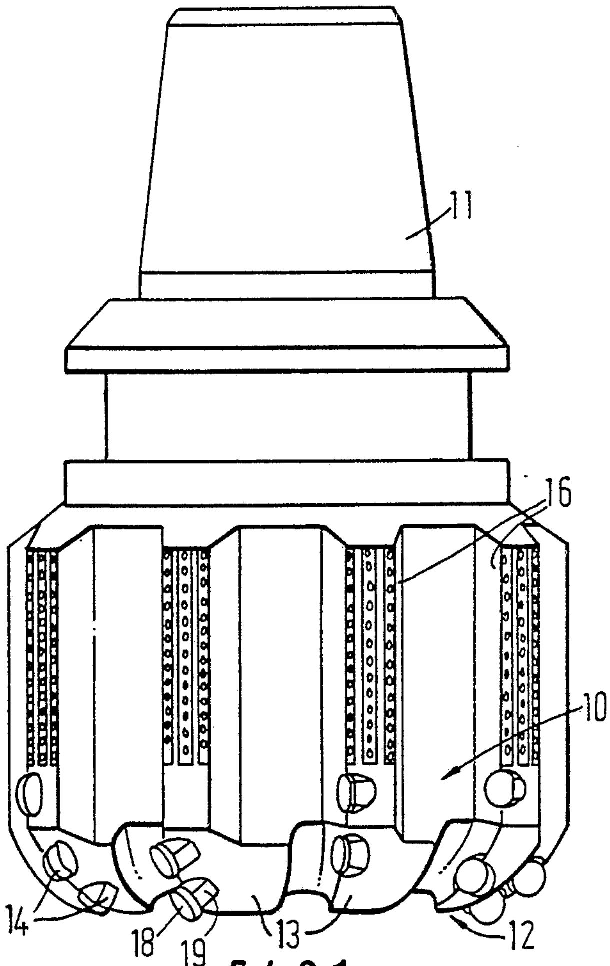
24. A rotary drill bit according to any of Claims 21 to 23, characterised in that said cutter is mounted on a carrier which is received in a socket in the bit body.

25. A method of manufacturing a cutter for use in a rotary drill bit characterised by forming by hot pressing with cobalt a slug of cemented tungsten carbide, and incorporating in the slug, during the hot pressing process, a number of thermally stable polycrystalline diamond elements.

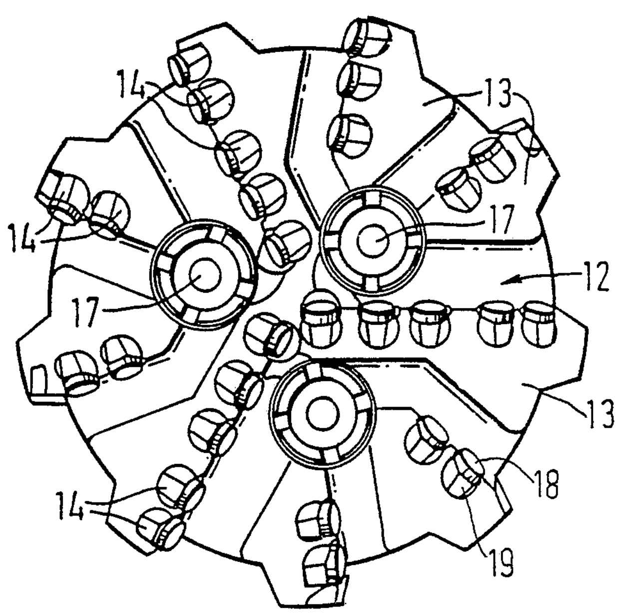
26. A cutter, for use in a rotary drill bit, comprising a number of thermally stable polycrystalline diamond elements at least partly embedded in a slug of less hard material, characterised in that a majority of the polycrystalline diamond elements are located in the vicinity of the cutting edge of the cutter.

27. A cutter according to Claim 26, characterised in that each polycrystalline diamond element is of the kind in which the interstices between the diamond particles are substantially filled with silicon material, and the slug is of tungsten carbide cemented with cobalt.

28. A cutter according to Claim 26, characterised in that each polycrystalline diamond element is of the kind in which the interstitial components have been leached out and the slug is of matrix material.



F I G.1



F I G.2

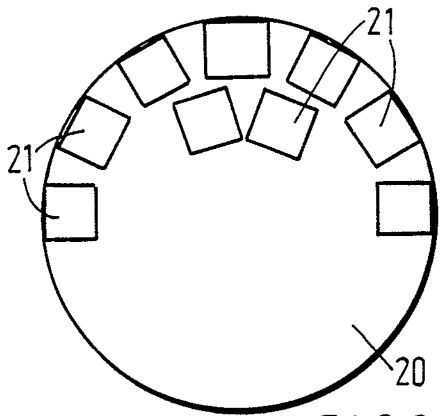


FIG.3

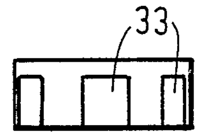


FIG.7b

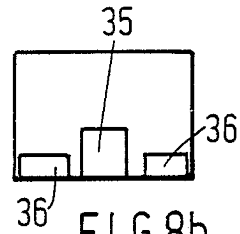


FIG.8b

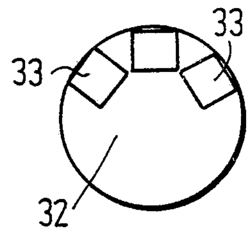


FIG.7a

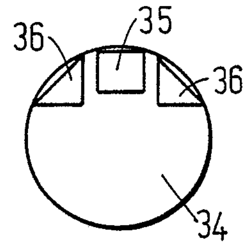


FIG.8b

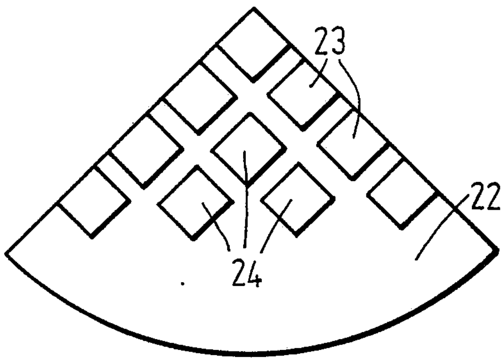


FIG.4

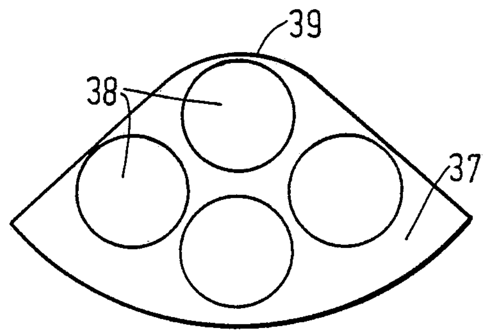


FIG.9

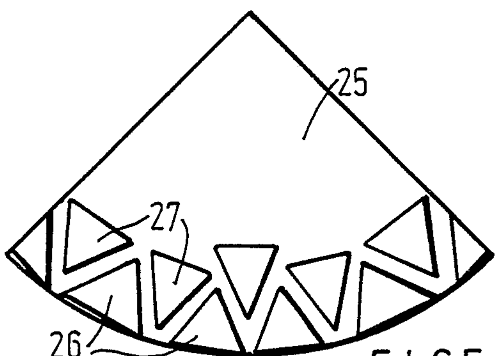


FIG.5

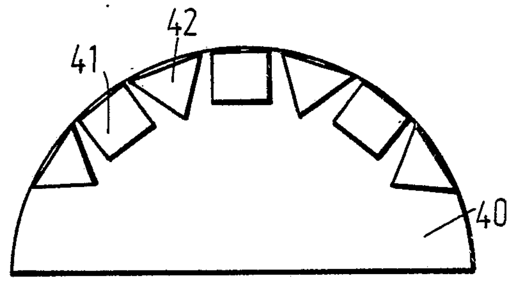


FIG.10

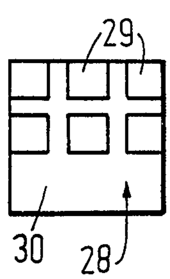


FIG.6a

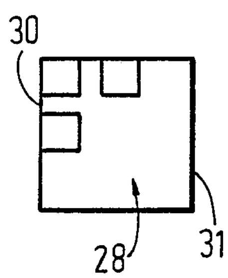


FIG.6b

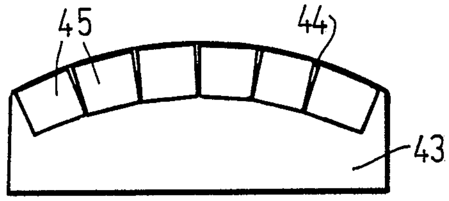


FIG.11

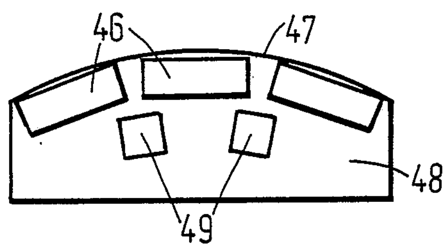


FIG.12

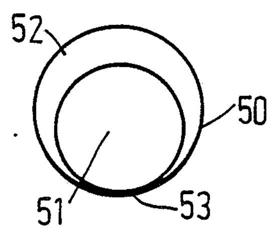


FIG.13

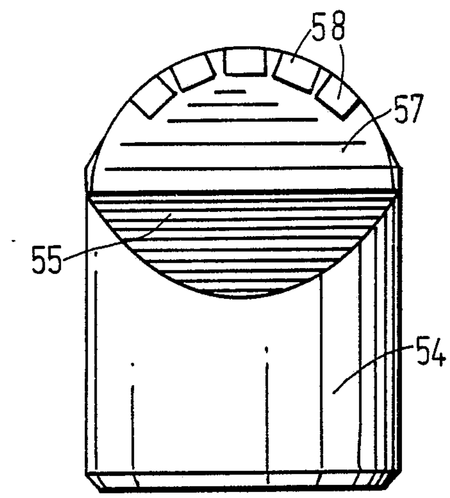


FIG.14

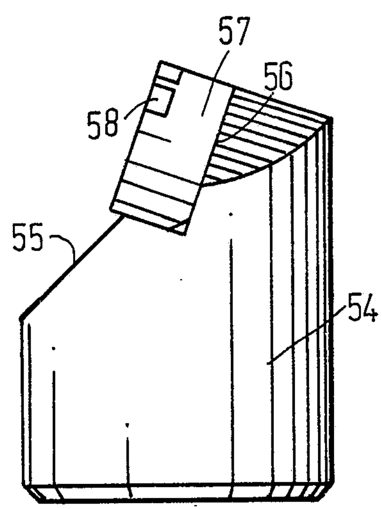


FIG.15