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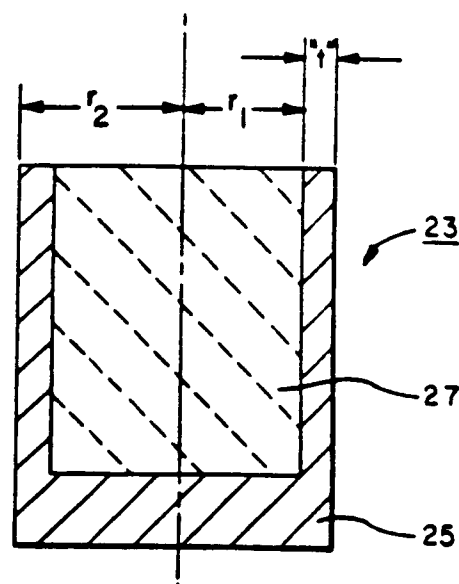
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(54) **Improved rock bit and compact inserts and method of manufacture.**

(57) Apparatus and a method are shown for manufacturing a diamond filled compact (11, 23, 29, 31, 41, 43, 53, 55) of the type used as a cutting insert which is received in a cutting insert pocket in a drill bit face. Also shown is a fixed cutter earth boring drill bit (84) using the compact. The compact includes a hard metal jacket (13) having an open end and an open interior. The open interior is substantially filled with diamond (19). The diamond filled jacket is subjected to a temperature and a pressure sufficient to sinter the diamond and integrally form a diamond core within the hard metal jacket. The outer dimensions of the hard metal jacket are then reduced to a size selected to conform to a cutting insert pocket provided on the face of a drill bit. The compact is mounted over the cutting surfaces of the one-piece fixed cutter drill bit.

**FIG. 2**

The present invention relates generally to an improved compact useful as a wear resistant insert in an earth boring tool, to its method of manufacture, more specifically, to such a compact formed with a hard metal jacket and an integrally formed, diamond filled core, and to fixed cutter earth boring bits having such compacts as wear resistant inserts.

Wear resistant inserts or compacts are utilized in a variety of earth boring tools where the inserts form rock cutting, crushing, chipping or abrading elements. In rotary well drilling, some geological formations are drilled with bits having cutting structures of wear resistant (usually sintered tungsten carbide) compacts held in receiving apertures in rotatable cones. In such bits, there is usually on each cone a group of cylindrical compacts that define a circumferential heel row that removes earth at the corner of the bore hole bottom. Further, it is common to insert additional cylindrical compacts, called "gage" compacts, on a "gage" surface that intersects a generally conical surface that receives the heel row compacts. These gage compacts protect the gage surfaces to prevent erosion of the metal of the cones that supports the heel row compacts. As a result, fewer heel compacts are lost during drilling and the original diameter of the bit is better maintained due to decreased wear. Moreover, the gage compacts also ream the hole to full "gage" after the heel compacts are worn to an undersigned condition.

Fixed cutter bits, either steel bodied or matrix, are also utilized in drilling certain types of geological formations effectively. While these bits do not feature rotatable cones, they also have wear resistant inserts advantageously positioned in the "shoulder" or "gage" regions on the face of the bit which are essential to prolong the useful life of the bit.

A typical prior art wear resistant insert was manufactured of sintered tungsten carbide, a composition of mono and/or ditungsten carbide cemented with a binder typically selected from the iron group, consisting of cobalt, nickel or iron. Cobalt generally ranged from about 6 to 16% of the binder, the balance being tungsten carbide. The exact composition depended upon the usage intended for the tool and its inserts.

In recent years, both natural and synthetic diamonds have been used, in addition to tungsten carbide compacts, as cutting inserts on rotary and fixed cutter rock bits. In fact, it has long been recognized that tungsten carbide as a matrix for diamonds has the advantage that the carbide itself is wear resistant and offers prolonged matrix life. U.S. Patent No. 1,939,991 to Krusell describes a diamond cutting tool utilizing inserts formed of diamonds held in a medium such as tungsten carbide

mixed with a binder of iron, cobalt, or nickel.

In some prior art cutting tools, the diamond component of the tool was formed by the conversion of graphite to diamond. U.S. Patent No. 3,850,053 describes a technique for making cutting tool blanks by placing a graphite disk in contact with a cemented tungsten carbide cylinder and exposing both simultaneously to diamond forming temperatures and pressures. U.S. Patent No. 4,259,090 describes a technique for making a cylindrical mass of polycrystalline diamond by loading a mass of graphite into a cup-shaped container made from tungsten carbide and diamond catalyst material. The loaded assembly is then placed in a high temperature and pressure apparatus where the graphite is converted to diamond. U.S. Patent No. 4,525,178 shows a composite material which includes a mixture of individual diamond crystals and pieces of precemented carbide.

U.S. Patent No. 4,148,368 shows a tungsten carbide insert for mounting in a rolling cone cutter which includes a diamond insert embedded in a portion of the work surface of the tungsten carbide cutting insert in order to improve the wear resistance thereof. Various other prior art techniques have been attempted in which a natural or synthetic diamond insert was utilized. For instance, there have been attempts in the prior art to press-fit a natural or synthetic diamond within a jacket, with the intention being to engage the jacket containing the diamond within an insert receiving opening provided on the bit face or cone. These attempts were not generally successful since the diamonds tended to fracture or become dislodged in use.

There continues to exist a need for improvements in earth boring bits and in compacts of the type utilized as wear resistant inserts in earth boring bits, particularly in the gage, heel and shoulder regions, which will improve the useful life of such bits.

A need also exists for such an improved wear resistant insert for an earth boring bit which has improved abrasion resistance and diamond retention characteristics.

Summary of The Invention

The improved compact of the invention is used as a wear resistant insert in a drill bit of the type used to drill earthen formations. The improved compact has an outer, generally cylindrical hard metal jacket. The compact has an inner core of integrally formed polycrystalline diamond. The compact has an exposed, top surface at least 75% of which is exposed polycrystalline diamond. An additional layer of hard metal can be added to the base of the compact in order to provide room for

an edge chamfer or to otherwise facilitate subsequent assembly operations. Another characteristic of the improved compact of the invention is that the thickness of the hard metal jacket is no greater than 1/2 the radius of the diamond cylinder core since the diamond is not utilized to strengthen or reinforce a tungsten carbide work surface, but instead substantially makes up the work surface itself. The improved cutter bits of the invention utilize strategically placed compacts of the invention as wear resistant inserts.

The improved compacts is manufactured by placing a diamond powder within a hard metal jacket provided as either a cup or cylinder. The loaded jacket is then capped and placed into a high temperature and pressure apparatus and exposed to diamond sintering conditions to sinter the diamond grains into a raw blank comprised of a core of integrally formed sintered polycrystalline diamond surrounded by the hard metal jacket. The resulting blank can then be removed from the apparatus and shaped to form a compact having a variety of cutting forms.

In the preferred method, a generally cylindrical, hard metal jacket is provided having at least one initially open end and an open interior. The open interior has an internal diameter which is at least 5% greater than the final required diameter. The cylindrical jacket also has an initial thickness which is preferably twice as thick as the final thickness of the finished compact. The interior of the jacket is substantially filled with diamond and the initially open end of the jacket is covered with a cap. The diamond filled jacket is then subjected to a temperature and pressure sufficient to sinter the diamond. The outer diameter of the jacket is then reduced by finally sizing the outer diameter to a size selected to conform to the cutting insert pocket provided on the drill bit.

The bit of the invention utilizes the compacts in insert receiving pockets provided in the gage and shoulder regions of the one-piece bits increasing gage wear resistance and the useful life of the bits.

Additional objects, features and advantages will be apparent in the written description which follows.

Brief Description of the Drawings

Figure 1 is a side, cross-sectional view of a raw blank of an improved compact of the invention as used in the bit of the invention, prior to shaping or chamfering, the compact having oppositely arranged, exposed diamond surfaces; Figure 2 is a cross-sectional view similar to Figure 1 of a compact having an extra base layer of metal and an oppositely arranged, exposed diamond surface;

Figure 3 is a cross-sectional view similar to Figure 1 showing a gage compact with oppositely exposed diamond surfaces;

Figure 4 is a view similar to Figure 2 showing a gage compact with only one exposed diamond surface;

Figures 5-6 are similar to Figures 1-2 but illustrate heel row compacts having shaped upper extents;

Figure 7-8 are similar to Figures 1-2 but show inner row compacts having shaped upper extents;

Figure 9 is a flow diagram illustrating the steps in the method used to form the improved compacts of the invention;

Figure 10 is an isolated view of a raw blank fitted with end caps in the first step of the method of forming the improved compacts of the invention;

Figure 11 is a side, partial cross-sectional view of a rolling cone rock bit using the diamond filled compacts of the invention; and

Figure 12 is a top, plan view of a fixed cutter bit of the invention utilizing the wear resistant inserts of the invention manufactured in accordance with Figures 1-11.

Detailed Description of the Invention

Figures 1 and 2 are cross-sectional views of raw blanks of the type which can be shaped to form, for instance, cutter bit gage, heel, shoulder, and inner row compacts of the invention. The blank 11 shown in Figure 1 includes an outer, generally cylindrical jacket 13 which, in this case, has initially open ends 15, 17. Preferably, the jacket 13 is formed of a suitable metal or sintered carbide which will be referred to as a "hard metal jacket" for purposes of this description.

Although a sintered carbide, such as tungsten carbide is the preferred hard metal for the jacket material, it will be understood that other carbides, metals and metal alloys can be utilized as well. For instance, other possible jacket materials include INVAR, cobalt alloys, silicon carbide alloys and the like. As will be further explained, the purpose of the jacket 13 in the present method is to facilitate later machining and shaping of the compact and to facilitate insertion of the compact into a cutting insert pocket on a drill bit. Since the jacket 13 is not the primary work surface of the compact, it is not a requirement of the present invention that the jacket be formed of tungsten carbide.

The compact 11 has an inner core 19 of integrally formed polycrystalline diamond, the polycrystalline diamond comprising at least about 10%, and preferably 50 to 75% or more by volume of the compact 11. The compact has a top surface

21, which comprises the work surface of the compact, at least 75% of which is exposed polycrystalline diamond. As will be explained, the polycrystalline diamond core 19 is formed by filling the hard metal jacket 13 with diamond powder and by sintering the diamond in a high pressure high temperature apparatus for a time and to a temperature sufficient to sinter the diamond and integrally form the diamond core within the jacket 13.

The compact blank 23 of Figure 2 is identical to the blank of Figure 1 except that an additional layer of hard metal 25 is added to the base of the compact to give the compact a cup-like appearance and to provide room for additional machining during later shaping operations. In both cases, the cylindrical diamond core 27 has a radius " r_1 " surrounded by a jacket having cylindrical sidewalls of a generally uniform thickness " t ", the jacket having a radius " r_2 ." The thickness of the jacket sidewalls " t " is preferably no greater than $1/2$ the radius " r_1 " of the cylindrical diamond core 19.

The compact blanks shown in Figures 1 and 2 can be shaped to form a variety of wear resistant inserts useful in earth boring tools. For instance, Figures 3 and 4 are cross-sectional views of gage row compacts formed by suitably shaping the blanks of Figures 1 and 2. The gage row compacts are characterized by flat, exposed diamond surfaces 33, 35 and also have chamfered top and bottom edges 37, 39 and 38, 40, respectively.

Figures 5 and 6 illustrate heel row compacts 41, 43 which feature generally arcuate upper extents 45, 47 and chamfered upper edges 49, 51.

Figures 7 and 8 show inner row compacts 53, 55 which also feature chisel-shaped upper exposed diamond extents 57, 59 and chamfered top edges 61, 63.

Figures 11 and 12 illustrate different types of earth boring drill bits which can utilize the improved compacts of the invention. Figure 11 is a quarter sectional view of a rolling cone bit 65 having three rotatable cones, such as cone 67, each mounted on a shaft 81 and having wear resistant inserts 69 used as earth disintegrating teeth. A bit body 71 has an upper end 73 which is externally threaded to be secured to a drill string member (not shown) used to raise and lower the bit in a well bore and to rotate the bit during drilling. The bit 65 will typically include a lubricating mechanism 75 which transmits a lubricant through one or more internal passages 77 to the internal friction surfaces of the cone 67 and have a retaining means 68 for retaining the cone 67 on the shaft 81.

The wear resistant inserts 69 which form the earth disintegrating teeth on the rolling cone bit 65 are arranged in circumferential rows, here designated by the numerals 83, 85 and 87, and re-

ferred to throughout the remainder of this description as the gage, heel and inner rows, respectively. These inserts were, in the past, typically formed of sintered tungsten carbide.

Figure 12 is a plan view of the bit face and nose region of a portion of a typical single piece, fixed cutter drill bit of the invention, designated generally as 84, sometimes referred to as a "diamond bit." The diamond earth boring bits will be understood by those skilled in the art to include both steel bodied bits and "matrix" bits. Such bits have a body including a solid bit face 78 on one end and a shank on the opposite end (not shown) with means for connection to a drill string for rotation about a longitudinal axis. The bit face 78 increases in external diameter between a nose region 86 and a gage region 88 at which the bit drills a hole of full diameter. Those cutters located adjacent the gage, such as cutter 82 in Figure 12 are sometimes referred to as "shoulder or heel" cutters and, along with the gage cutters can advantageously employ the improved compacts of the invention. The steel bodied bits are machined from a steel block and typically have cutting elements which are press-fit into openings provided in the bit face. The matrix bit shown in Figure 12 is formed by coating a hollow tubular steel mandrel in a casting mold with metal bonded hard material, such as tungsten carbide. The casting mold is of a configuration which will give a bit of the desired form. The cutting elements 80 are typically either polycrystalline diamond compacts cutters braised within an opening provided in the matrix backing or are thermally stable polycrystalline diamond cutters which are cast within recesses provided in the matrix backing. The cutting inserts are often placed either in straight or spiraling rows extending from a central location 86 on the bit face out to the full bit diameter 88. Alternately, cutting elements are set in individual mountings placed strategically around the bit face.

The method of forming the wear resistant inserts of the invention used in the bits of the invention will now be described with reference to the flow diagram shown in Figure 9 and with reference to Figure 10. In the first step of the method, illustrated as 90 in Figure 9, a hard metal jacket 94 is formed having at least one initially open end 96 and an open interior 98. The open interior (98 in Figure 10) is preferably 5% larger than that needed in the final dimension. The thickness of the jacket 94 in step 1 is also generally twice as thick as that required in the final product. The hard metal jacket can conveniently be made from cemented tungsten carbide, other carbides, metals and metal alloys. For instance, the jacket can be formed from INVAR, cobalt alloys, silicon carbide alloys, and the like, as well as refractory metals such as Mo, Co,

Nb, Ta, Ti, Zr, W, or alloys thereof.

The open interior 98 of the jacket is then substantially filled with diamond powder 100 in a step 102. The diamond can conveniently be any diamond or diamond containing blend which can be subjected to high pressure and high temperature conditions to sinter the diamond material and integrally form a core of diamond material within the interior 98 of the surrounding jacket 94. For instance, the diamond 100 can comprise a diamond powder blend formed by blending together diamond powder and a binder selected from the group consisting of Ni, Co, Fe and alloys thereof, the binder being present in the range from about 0 to 10% by weight, based on the total weight of diamond powder blend. A number of diamond powders are commercially available including the GE 300 and GE MBS Series diamond powders provided by General Electric Corporation and the De-Beers SDA Series.

After filling the interior 98 of the hard metal jacket 94 with diamond powder blend, the jacket is fitted with tight fitting end caps 104, 106 and run in a high pressure high temperature apparatus in a step 108. The high pressure and temperature apparatus exposes the loaded jacket 94 to conditions sufficient to sinter the powdered diamond and integrally form a diamond core within a surrounding hard metal jacket.

Ultra high pressure and temperature cells are known in the art and are described, for instance, in U.S. Patents 3,913,280 and 3,745,623 and will be familiar to those skilled in the art. These devices are capable of reaching conditions in excess of 40 kilobars pressure and 1,200 °C temperature.

In the next step 110 (Figure 9) of the method of the invention, the outside diameter of the hard metal jacket 94 is reduced to a size selected to conform to an insert receiving pocket provided on a drill bit, remembering that the hard metal jacket 94 was initially provided with a thickness preferably twice as thick as that required in the final product.

In the next step of the method 112, the compact is lapped, surface ground, or electro discharge ground to provide a smooth top surface on the wear resistant insert and to achieve the final height desired. It will be understood by those skilled in the art that steps 110 and 112 could be interchanged in order.

For the gage row compacts (illustrated as Figures 3 and 4 and 83 in Figure 11) the next step 114 is to grind the final chamfers on the top and bottom surfaces of the compact followed by bright tumbling in a step 116 to remove any sharp edges. The final gage row compact, as illustrated in Figures 3 and 4 has a basically planar top surface which is predominantly of exposed diamond material.

In the case of heel and inner row compacts, the next step after O.D. grinding and surface grinding is to shape the top surface to the desired final configuration in a step 118 using known machining techniques. The preferred shaping technique is Electro Discharge Machining (EDM) and can be used, e.g., to produce a heel row wear resistant insert having a dome or chisel shape. Standard EDM shaping techniques can be utilized in this step, such as those used in the manufacture of tungsten carbide dies and punches. After EDM shaping, the bottom surface of the compact may be chamfered in a step 120 and the part can be bright tumbled in a step 122 to complete the manufacturing operation.

An invention has been provided with several advantages. The methods of the invention can be used to manufacture both an improved diamond filled compact which can be used as a wear resistant insert in a variety of drill bit configurations and an improved earth boring bit utilizing the novel diamond filled compacts as wear resistant inserts. The wear resistant inserts of the invention have a top or work surface which is at least 75% polycrystalline diamond. The present wear resistant inserts can be provided as substantially all diamond material with only a thin jacket of hard metal to facilitate machining and mounting of the inserts in the drill bit face. By manufacturing compacts having only thin surrounding jackets of hard metal and substantially diamond filled cores, an insert can be provided offering improved wear resistance and life over standard tungsten carbide inserts or the diamond coated compacts of the past such as standard stud-mounted PDC inserts. These compacts can be advantageously used as wear resistant inserts in the gage and heel rows of rolling cone bits, as well as in the gage and shoulder regions of fixed cutter bits to extend the useful life of such bits.

Since the diamond material is not utilized to protect a larger tungsten carbide work surface in the present invention, it is not necessary that the outer jacket be formed of tungsten carbide. A number of other carbides, alloys or hard metals can be utilized for the outer jacket. The diamond core is intended to be the complete working surface of the compacts of the invention. The carbide or metal jacket is provided only for ease of manufacture and to facilitate fitting the inserts into the drill bit face. Because the diamond core is integrally formed within the hard metal jacket, it is not subject to becoming shattered or dislodged as would be a diamond embedded within a work surface of a tungsten carbide insert. The compacts of the invention can be manufactured economically using existing diamond sintering techniques.

While the invention has been shown in only

one of its forms, it is not thus limited but is susceptible to various changes and modifications without departing from the spirit thereof.

Claims

1. A compact (11, 23, 29, 31, 41, 43, 53, 55) useful as an insert in an earth boring bit (84) having a body provided with a shank on one end for connection with a drill string for rotation about a longitudinal axis and a solid bit face on the other end, openings in the face of the bit for mounting cutter inserts for cutting an earth formation as the bit is rotated, and a cutter insert mounted in each opening, the cutter compact characterized by:

an outer hard metal jacket (13);

an inner core (19) in the jacket of integrally formed polycrystalline diamond material subjected to a high pressure and a high temperature to sinter the diamond material.

2. A compact in accordance with claim 1 characterized by:

the inner core (19) comprises at least 10% by volume of the compact; and

the compact has a top surface at least 75% of which is exposed polycrystalline diamond material.

3. A compact in accordance with claim 2 characterized by:

the polycrystalline core of the compact is formed with a top surface of any one of the shapes including generally planar, dome, chisel, or conical.

4. A compact in accordance with claim 2 characterized by:

the core is formed in the shape of a cylinder; and the jacket surrounding the core has cylindrical side walls of a generally uniform thickness no greater than one half the radius of the cylindrical core within the jacket.

the diamond material forming the core is selected from the group consisting of diamond powder in diamond powder blends formed by blending together diamond and a binder selected from the group consisting of Ni, Co, Fe and alloys thereof.

6. A compact in accordance with claim 5 characterized by:

the hard metal jacket is formed of a sintered metal carbide.

7. A method of manufacturing a diamond filled compact in accordance with any one of claims 1-6 characterized by:

forming the hard metal jacket having at least one initially open end and an open interior;

substantially filling the open interior of the jacket with the diamond material;

subjecting the diamond filled jacket to a temperature and a pressure sufficient to sinter the diamond material forming an integral diamond core within the hard metal jacket; and

reducing the outer dimension of the hard metal jacket to a size selected to conform to the openings of the earth boring bit surface.

8. A method in accordance with claim 7 characterized by:

covering the initially open end of the hard metal jacket with a cap.

9. A method in accordance with claim 8 characterized by:

the open interior of the hard metal jacket has an internal diameter which is at least 5% larger than the final required diameter of the compact; and

the hard metal jacket has a thickness which is initially at least twice as thick as the final thickness required for the compact.

10. A fixed cutter earth boring bit (84) including a body provided with a shank on one end for connection with the drill string for rotation about a longitudinal axis and a solid bit face on the other end having body surfaces provided with openings for mounting compacts on the body surfaces characterized by:

a compact mounted in each of the body surface openings, the compact being formed in accordance with any one of claims 1-9 inclusive.

11. An earth boring bit in accordance with claim 10 characterized by:

the earth boring bit is of a type having the body including the solid bit face on one end and the bit increasing in external diameter between a nose and a gage region, the compacts being mounted in the gage region.

12. An earth boring bit in accordance claim 10 characterized by:

the earth boring bit is of a type having a body including a solid bit face on one end, the bit face including a circumferential heel row of the compacts to remove earth at the bottom corner of a bore hole.

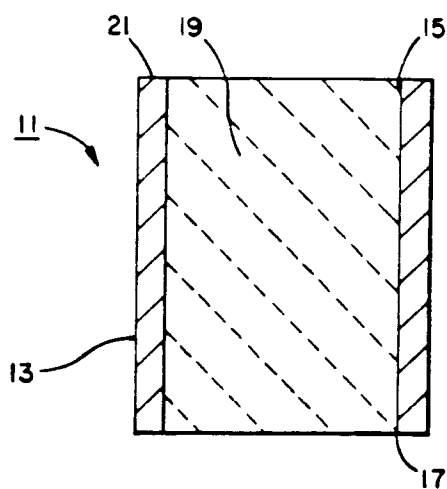


FIG. 1

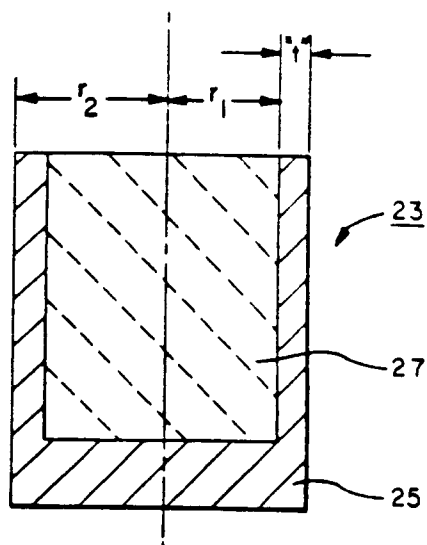


FIG. 2

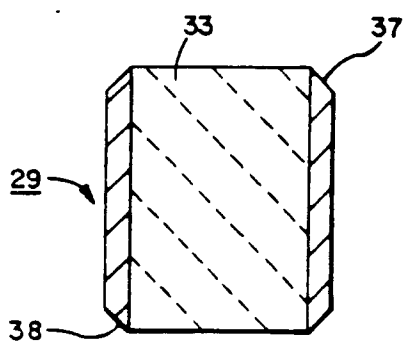


FIG. 3

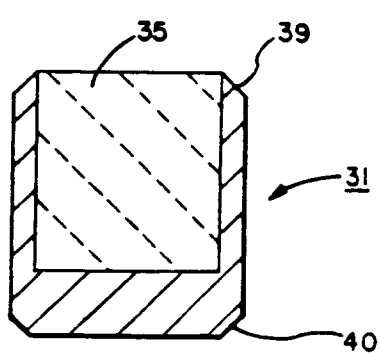


FIG. 4

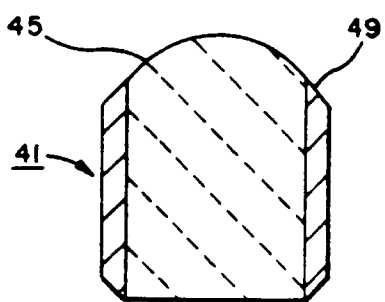


FIG. 5

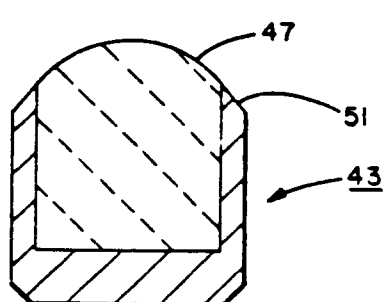


FIG. 6

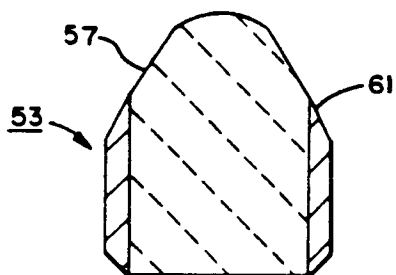


FIG. 7

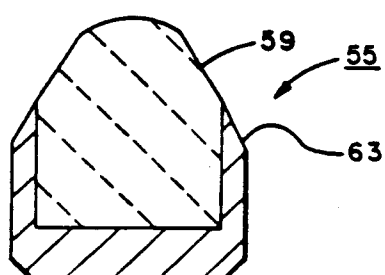


FIG. 8

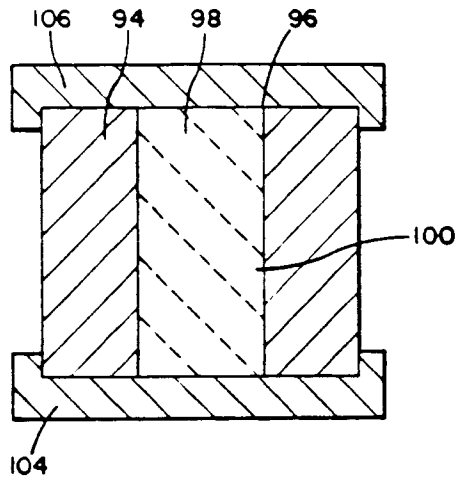


FIG. 10

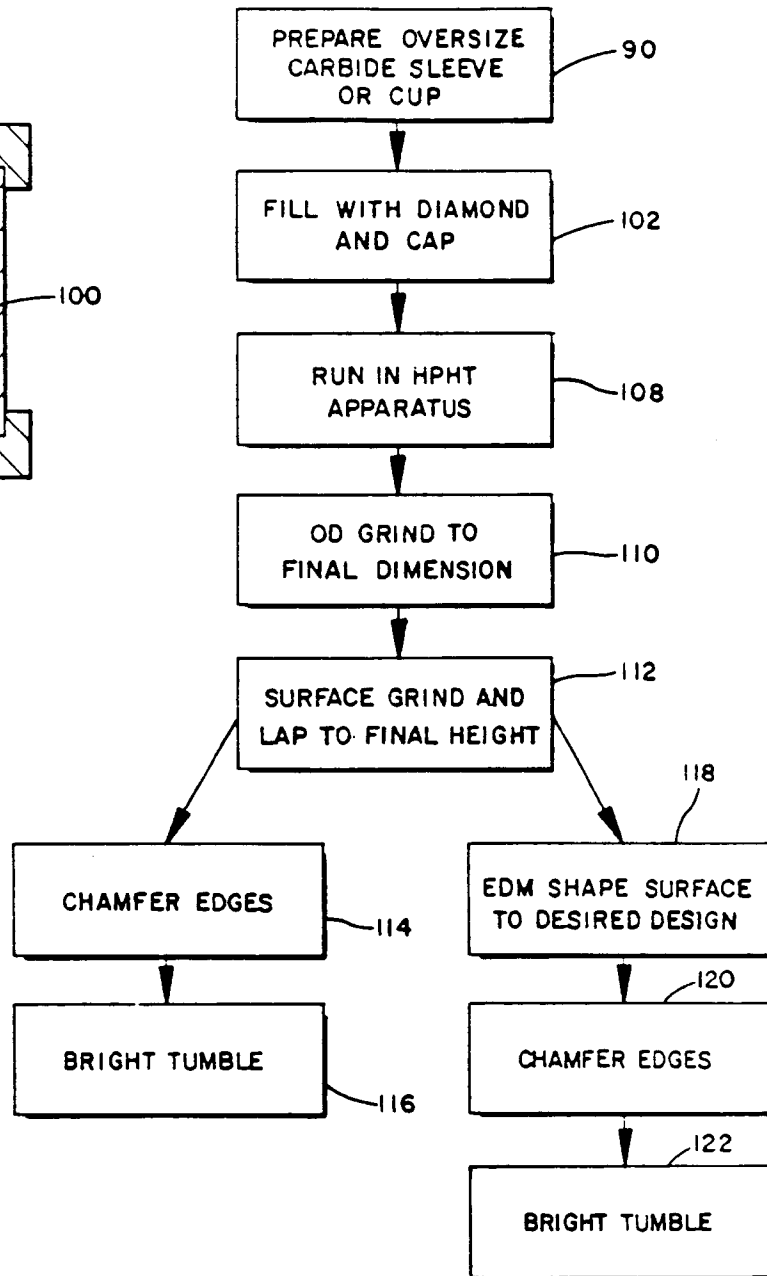
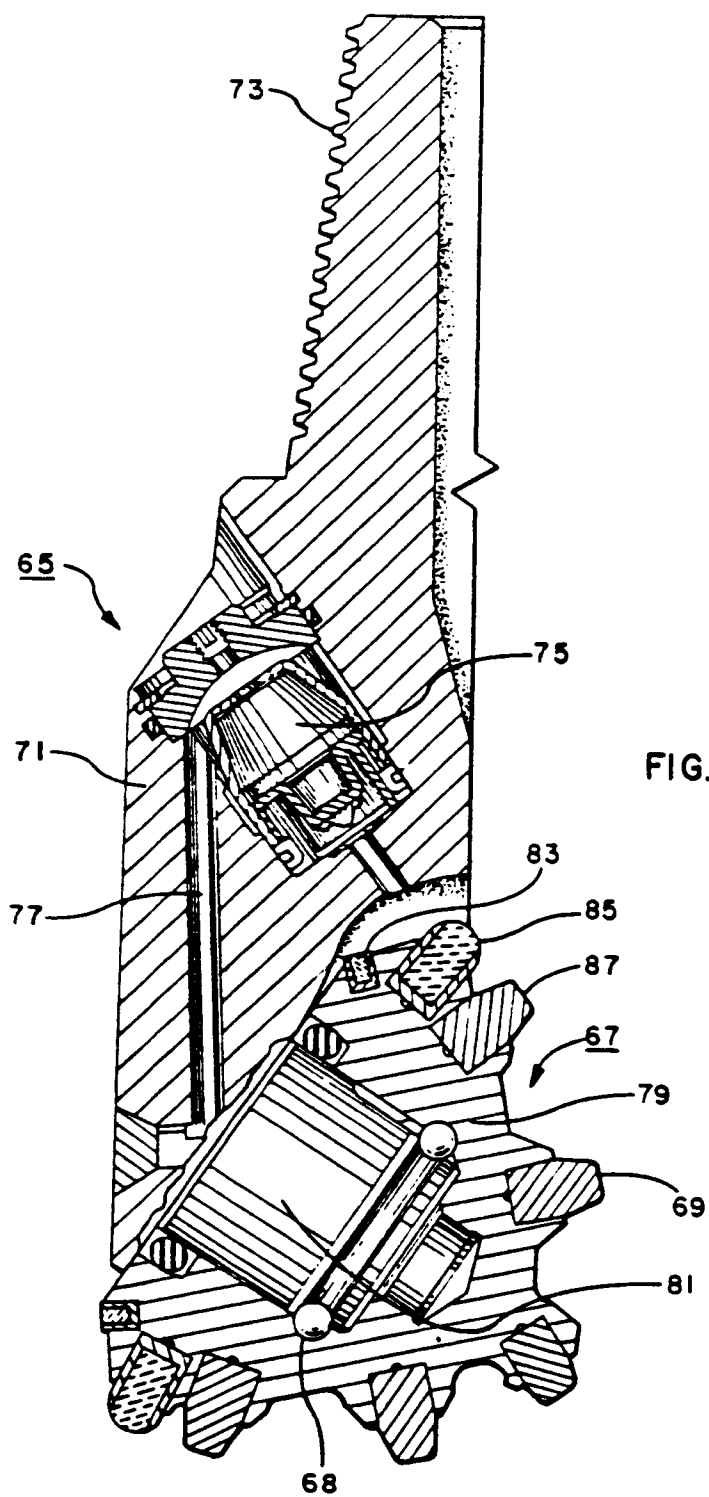


FIG. 9



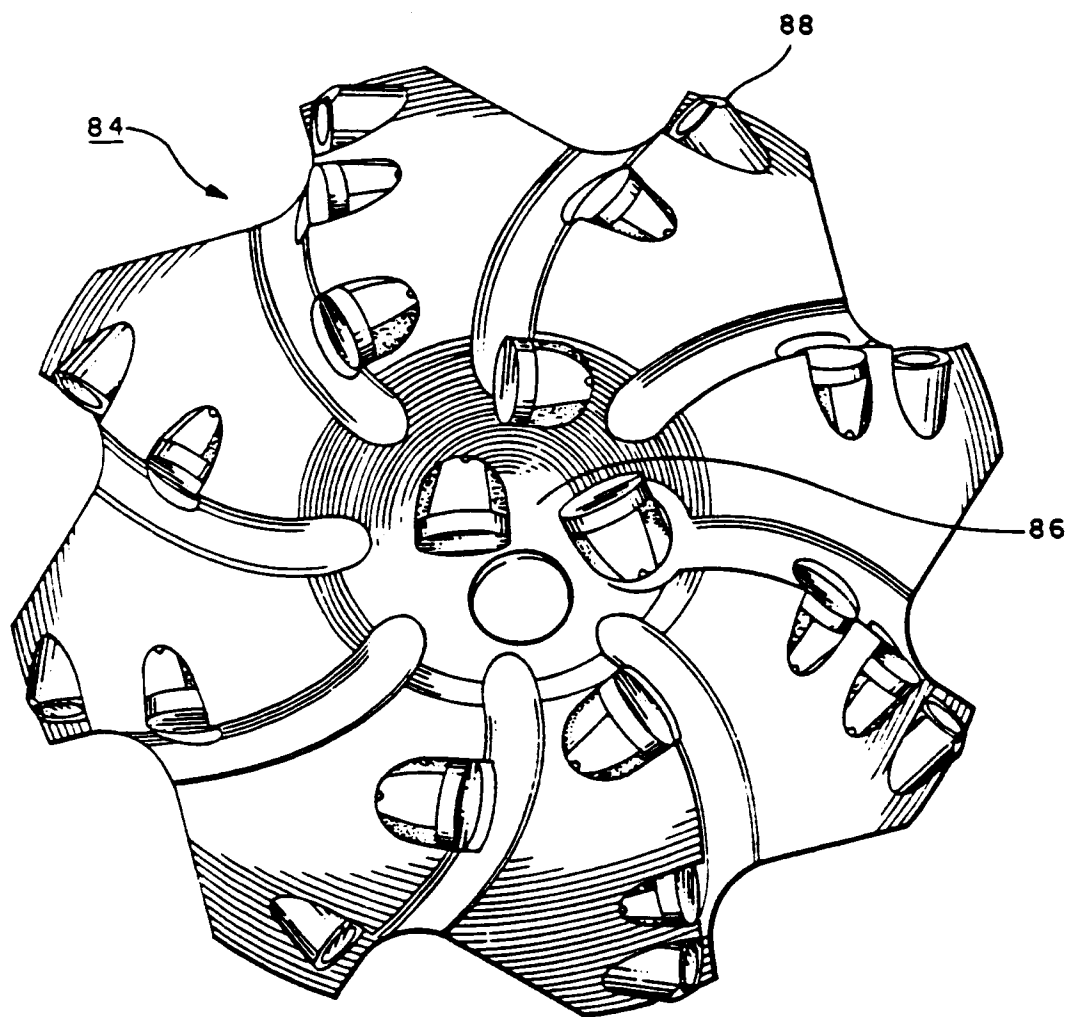


FIG. 12



European Patent
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EUROPEAN SEARCH REPORT

Application Number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 92103262.9
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 5)
X	EP - A - 0 029 535 (GENERAL ELECTRIC COMPANY) * Fig. 1 *	1, 5, 6, 8	E 21 B 10/46
A		2, 3, 4, 7, 9, 10, 11, 12	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 5)
			E 21 B 10/00 B 21 K 5/00 B 21 K 21/00 B 24 D 3/00 B 26 D 1/00 B 23 B 27/00
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 08-05-1992	Examiner BRUNHUBER
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	