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(54) Improvements in or relating to rotary drill bits and methods of manufacture thereof.

(57) A method of manufacturing a rotary drill bit at least partly from cast iron comprises forming a hollow mould in the configuration of at least a portion of the bit body, and casting said portion of the bit body in the mould by a casting process which includes the steps of pouring molten cast iron into the mould and then cooling in the mould so that the cast iron solidifies to form said portion of the bit body. The method includes the further step of subjecting the cast iron to treatment, during the casting process, which results in at least one surface portion of the cast iron bit body becoming hardened. The hardening treatment may comprise adding an iron carbide forming additive, such as boron or tellurium, to the cast iron before it is poured, or by chill hardening during solidification, or by coating the interior of the mould, before pouring, with a wash of iron carbide forming material, such as tellurium or by controlling the rate of cooling after solidification so as to effect the formation of martensite.

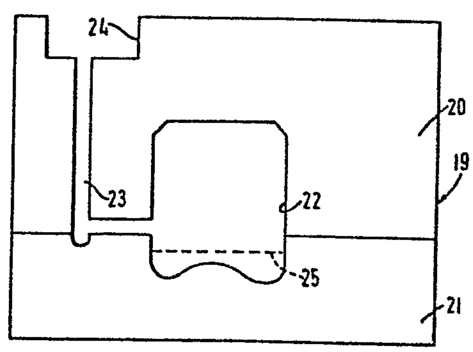

FIG.3

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"Improvements in or relating to rotary drill bits and methods of manufacture thereof"

The invention relates to rotary drill bits for use in drilling or coring deep holes in subsurface formations. In particular, the invention is applicable to rotary drill bits of the kind comprising a bit body having an external surface on which are mounted a plurality of cutting elements for cutting or abrading the formation, and an inner passage for supplying drilling fluid to one or more nozzles at the -external surface of the bit. The nozzles are so located at the surface of the bit body that drilling fluid emerging from the nozzles flows past the cutting elements, during drilling, so as to cool and/or clean them.

Although not essential to the present invention, the cutting elements may be in the form of so-called "preform" cutting elements in the shape of a tablet, often circular, having a superhard cutting face formed of polycrystalline diamond or other superhard material.

Conventionally there are two main methods of manufacturing such drill bits. In one common type of drill bit the bit body is machined from steel and the surface of the bit body is formed with sockets which receive pegs or studs on which the cutting elements are mounted. In the second common type of bit the bit body is formed by a powder metallurgy process in which a hollow mould is first formed, for example from graphite, in the configuration of the bit body. The mould is packed with powdered material such as tungsten carbide, usually around a steel blank, and the powdered material is then infiltrated with a metal alloy in a furnace so as to form a hard matrix. If the cutting elements are of a kind which are not thermally stable at the infiltration temperature, formers are mounted on the interior surface of the mould so as to define in the finished bit body sockets or other locations where cutting elements may be subsequently mounted.

Steel bodied bits are generally simpler and cheaper to manufacture than matrix bodied bits. However, they are more susceptible to erosion during drilling and, for this reason, they are sometimes provided with a hard surface coating, for example of tungsten carbide, which adds to the complexity and cost of production.

On the other hand, although matrix bodied bits are more resistant to erosion, their manufacture is complex and costly due largely to the high material cost and to the additional processes involved. Matrix bodied bits also may be made with the matrix at the surface more erosion resistant than that inside the bit body.

The present invention sets out to provide a new method of manufacturing a rotary drill bit using cast iron, in which at least some of the disadvantages of the known steel-bodied and matrix-bodied bits may be overcome.

British Patent Specification No. 1,574,884 discloses the use of cast iron in the manufacture of cutting bodies suitable for working or cutting material, such as cutting tips or inserts in rock drilling or chip forming machines. In such products it is necessary for surface portions of the product to be sufficiently hard to be resistant to erosion and damage during use of the product. Specification No. 1,574,884 describes a method of providing a hard surface which requires the encasting of a hard metal, such as a sintered hard carbide, e.g. tungsten carbide, in the cast iron. Such methods have not, however, proved satisfactory in practice due to the high cost of the process and the difficulties of ensuring that the carbide is securely bonded within the cast iron.

U.S. Patent Specification No. 4,499,795 describes the use of cast iron in the manufacture of a rotary drill bit. In this case the inner surface of a mould is packed or coated over selected portions with particles of sintered tungsten carbide or similar sintered refractory hard metal and then cast iron is melted and poured into the mould. In this case, also, therefore, the hard surface of the finished bit is provided by tungsten carbide.

The present invention provides methods of manufacturing a rotary drill bit using cast iron where the cast iron itself forms the necessary hardened surface portions of the drill bit, the steps of the method being such as to effect the necessary hardening of the cast iron during the casting process.

According to the invention there is provided a method of manufacturing a rotary drill bit comprising forming a hollow mould in the configuration of at least a portion of the bit body, and casting said portion of the bit body in the mould by a casting process which includes the steps of pouring moulten cast iron into the mould and then cooling in the mould so that the cast iron solidifies to form said portion of the bit body, the method including the further step of subjecting the cast iron to treatment, during said casting process, which results in at least one surface portion of the cast iron bit body becoming hardened.

Said hardening treatment may comprise adding to at least part of the molten cast iron, before it is poured into the mould, an iron carbide-forming additive, whereby said part of the cast iron, upon solidification, contains massive inclusions of cementite. Said additive may comprise boron or tellurium. Approximately $^{1}/_{2}$% of additive may be added to the molten cast iron.

If required the molten cast iron may be poured into the mould in two successive pourings, said additive being added only to the cast iron in the first pouring so as to harden only the portion of the bit body which is lowermost in the mould.

In an alternative method according to the invention said hardening treatment comprises the step of chill hardening a portion of the surface of the bit body by accelerated cooling of said surface portion during the solidification part of the casting process, said accelerated cooling being at a rate to produce massive inclusions of cementite in the solidified surface portion.

Said chill hardening may be effected by locating a metal heat sink in the mould adjacent said surface portion of the bit body which is to be hardened.

There may be mounted on the interior of the mould, prior to pouring the cast iron into the mould, formers which project into the mould cavity so as to form sockets in the solidified cast iron bit body, said formers being in close thermal contact with said metal heat sink, whereby the interior of each socket is chill hardened.

In a further method according to the invention said hardening treatment comprises the step, before pouring the cast iron into the mould, of coating at least part of the interior surface of the mould with a material which reacts with the cast iron, during solidification thereof, to form massive inclusions of cementite in at least one surface portion of the bit body. Said coating material may be tellurium.

In a still further method according to the invention said hardening treatment comprises controlling the rate of cooling of the bit body, after solidification of the cast iron and during the subsequent cooling portion of the casting process, in such manner as to effect the formation of martensite in at least one surface portion of the bit body.

The invention includes within its scope a rotary drill bit comprising a bit body having an external surface on which are mounted a plurality of cutting elements for cutting or abrading the formation being drilled, a number of nozzles at the external surface of the bit, and an inner passage for supplying drilling fluid to the nozzles, at least a portion of the bit body being formed from cast iron and at least a part of the surface of the cast iron being hardened during the casting process.

In a drill bit manufactured according to the methods of the invention, it is preferably those parts of the bit body which are particularly subject to erosion during drilling, for examples the areas around the nozzles and cutting elements, which are hardened to increase their resistance to such erosion. At the same time, provided a suitable form of cast iron is used, the rest of the bit body may be accurately machined or otherwise worked after it has been cast. Thus the present invention may combine the simplicity of manufacture of steel bodied bits with the erosion resistance of matrix bodied bits and, indeed, the erosion resistance of a drill bit according to the invention will be superior to that of a steel bodied bit and may also be superior to that of a matrix bodied bit.

IN THE DRAWINGS:

Figure 1 is a side elevation of a typical drill bit of the kind to which the invention is applicable,

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

Figure 3 is a vertical section through a mould showing the manufacture of a drill bit by one method according to the invention, and

Figure 4 is a vertical section through a mould showing the manufacture of a drill bit by another method according to the invention.

Referring to Figures 1 and 2, the body 10 of the drill bit is formed of cast iron by the method to be described, 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 has a gauge section including kickers 16 which contact the wall 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 clean and/or cool the cutting elements.

In the particular arrangement shown each cutting structure 14 comprises a preform cutting element mounted on a carrier in the form of a stud which is located in a socket in the bit body. Normally, each preform cutting element is circular and comprises a thin facing layer of polycrystalline diamond bonded to a backing layer of tungsten carbide. However, 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 each preform cutting element comprises a unitary layer of thermally stable polycrystalline diamond material.

Figure 3 illustrates a method of manufacturing a bit body of the kind shown in Figures 1 and 2.

Referring to Figure 3, a two-part mould 19 is formed from suitable material, such as sand. The two-part mould comprises an upper part 20 and a lower part 21 which between them define a mould cavity 22. The mould cavity has an internal configuration corresponding generally to the required surface shape of the bit body or a portion thereof. A passage 23 is formed in the upper mould part 20 and leads to the mould cavity 22 from a pouring chamber 24 at the upper surface of the mould part 20.

To produce the cutting face configuration of the drill bit shown in Figures 1 and 2, the mould may be formed with elongate recesses corresponding to the blades 13 of the drill bit. Spaced apart along each blade forming recess will be a plurality of sockets each of which receives a cylindrical former (not shown), the object of the formers being to define in the bit body sockets to receive the studs on which the cutting elements are mounted. Accordingly, the formers will be of the same cross-sectional shape as the studs, for example circular or rectangular.

There is also provided in the mould 19, at each desired location for a nozzle 17, a socket (not shown) which receives one end of an elongate former (not shown) which extends into the mould space so as to form in the bit body a socket in which a nozzle may be subsequently inserted.

In one method according to the invention cast iron is melted and poured into the mould via the chamber 24 and passage 23. While the cast iron is molten and before it is is poured into the mould, there is added to the molten cast iron an additive having the property of causing iron carbide (cementite) to be formed in the cast iron during solidification. Suitable additives are boron and tellurium and approximately $^1/_2$% of additive may be added to the molten cast iron.

After the mould cavity 22 has been filled with the molten cast iron with the additive, the mould is allowed to cool and by the time solidification of the cast iron has occurred, the additive will have caused the inclusion of massive bodies of cementite in the cast iron, thus substantially hardening the cast iron.

As previously mentioned, it may be desirable for only the lower surface portion of the bit body to be hardened, the upper portion of the bit body being softer so as to be machinable. To achieve this, the cast iron is poured into the mould in two portions. The first portion contains the boron or tellurium additive and is sufficient to fill only the bottom of the mould up to a certain level, as indicated for example by the line 25 in Figure 3. The remainder of the mould cavity is then filled with cast iron without the additive. As a result, only the lower surface portion of the body will be hardened by the inclusion of massive cementite.

In another method in accordance with the invention the internal surface of the mould cavity is coated, before introduction of the molten cast iron into the mould, with a material which reacts with the cast iron, during solidification, to effect surface hardening thereof by the production of massive inclusions of cementite. A suitable material is a wash of tellurium over the interior surface of the mould or a part thereof. Thus, where it is only required that the lower portion of the bit body be hardened, the tellurium wash is coated over only the lower part of the mould cavity, that is to say up to the level of the line 25 in Figure 3.

In a further method according to the invention, the hardening of the cast iron is effected by controlling the rate of cooling of the bit body after solidification has occurred. Thus, after the cast iron in the mould has solidified suitable controlling of the rate of cooling of the mould will result in the production of martensite which has the effect of hardening the cast iron.

A still further method in accordance with the invention is illustrated with respect to Figure 4.

In this case the lower part 21 of the mould is provided with a heat sink in the form of a chill plate 26. The size and initial temperature of the chill plate 26, which may comprise a body of graphite, machined steel or cast iron, is selected so as to accelerate the rate of cooling of the cast iron in the lower part of the mould cavity and thus effect hardening of the cast iron in that locality by the process as known "chill hardening". As is well known, in chill hardening the production of massive inclusions of cementite in the cast iron occurs.

Preferably the chilling at the surface of the bit body effected by the chill plate 26 is at a rate sufficient to cause the formation of cementite (iron carbide) so that at the surface itself, the material is almost entirely composed of cementite, the proportion of cementite decreasing with distance inwardly from the chilled surface.

As previously mentioned, normally cutting elements, or carriers for cutting elements such as studs or pegs, are secured within sockets in the surface of the finished bit body by brazing. Cast iron is normally difficult to braze due to the presence of surface graphite and, accordingly, it is advantageous to chill harden the surface of the body within sockets being formed in the bit body during its formation to receive cutting elements or their carriers, since the hardening reduces the amount of graphite present at the surface of each socket, thus facilitating brazing. Thus the aforementioned formers may be of metal and in close thermal contact with the chill plate 26 so as to chill harden the cast iron defining the sockets.

Although any form of cast iron may be employed in the methods according to the invention, it preferably comprises a spheroidal graphite cast iron in which, in known manner, graphite is precipitated in nodular form by the addition of magnesium or some other suitable material. Alternatively the cast iron may be of the type known as "grey" cast iron, or may be compacted graphite cast iron containing titanium or some other material.

CLAIMS

1. A method of manufacturing a rotary drill bit comprising forming a hollow mould in the configuration of at least a portion of the bit body, and casting said portion of the bit body in the mould by a casting process which includes the steps of pouring molten cast iron into the mould and then cooling in the mould so that the cast iron solidifies to form said portion of the bit body, the method including the further step of subjecting the cast iron to treatment, during said casting process, which results in at least one surface portion of the cast iron bit body becoming hardened.

2. A method according to Claim 1, wherein said hardening treatment comprises adding to at least part of the molten cast iron, before it is poured into the mould, an iron carbide-forming additive, whereby said part of the cast iron, upon solidification, contains massive inclusions of cementite.

3. A method according to Claim 2, wherein said additive is selected from boron and tellurium.

4. A method according to Claim 2, wherein approximately $^1/_2$% of additive is added to the molten cast iron.

5. A method according to Claim 2, wherein the molten cast iron is poured into the mould in two successive pourings, said additive being added only to the cast iron in the first pouring so as to harden only the portion of the bit body which is lowermost in the mould.

6. A method according to Claim 1, wherein said hardening treatment comprises the step of chill hardening a portion of the surface of the bit body by accelerated cooling of said surface portion during the solidification part of the casting process, said accelerated cooling being at a rate to produce massive inclusions of cementite in the solidified surface portion.

7. A method according to Claim 6, wherein said chill hardening is effected by locating a metal heat sink in the mould adjacent said surface portion of the bit body which is to be hardened.

8. A method according to Claim 7, wherein there are mounted on the interior of the mould, prior to pouring the cast iron into the mould, formers which project into the mould cavity so as to form sockets in the solidified cast iron bit body, said formers being in close thermal contact with said metal heat sink, whereby the interior of each socket is chill hardened.

9. A method according to Claim 1, wherein said hardening treatment comprises the step, before pouring the cast iron into the mould, of coating at least part of the interior surface of the mould with a material which reacts with the cast iron, during solidification thereof, to form massive inclusions of cementite in at least one surface portion of the bit body.

10. A method according to Claim 9, wherein said coating material is tellurium.

11. A method according to Claim 1, wherein said

hardening treatment comprises controlling the rate of cooling of the bit body, after solidification of the cast iron and during the subsequent cooling portion of the casting process, in such manner as to effect the formation of martensite in at least one surface portion of the bit body.

12. A rotary drill bit comprising a bit body having an external surface on which are mounted a plurality of cutting elements for cutting or abrading the formation being drilled, a number of nozzles at the external surface of the bit, and an inner passage for supplying drilling fluid to the nozzles, at least a portion of the bit body being formed from cast iron and at least a part of the surface of the cast iron being hardened during the casting process.

13. A rotary drill bit according to Claim 12, wherein the hardened surface portion of the bit body comprises massive inclusions of cementite in the cast iron.

14. A rotary drill bit according to Claim 12, wherein the hardened surface portion of the bit body comprises martensite.

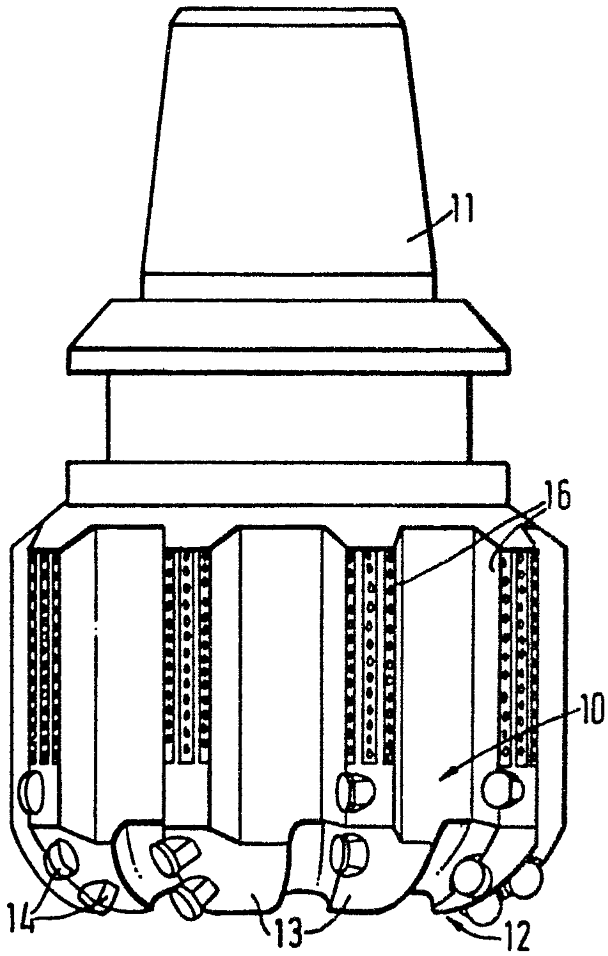

FIG.1

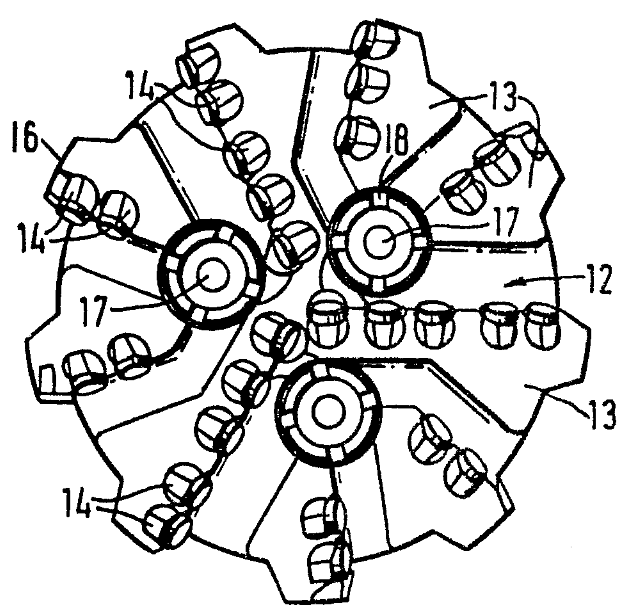

FIG.2

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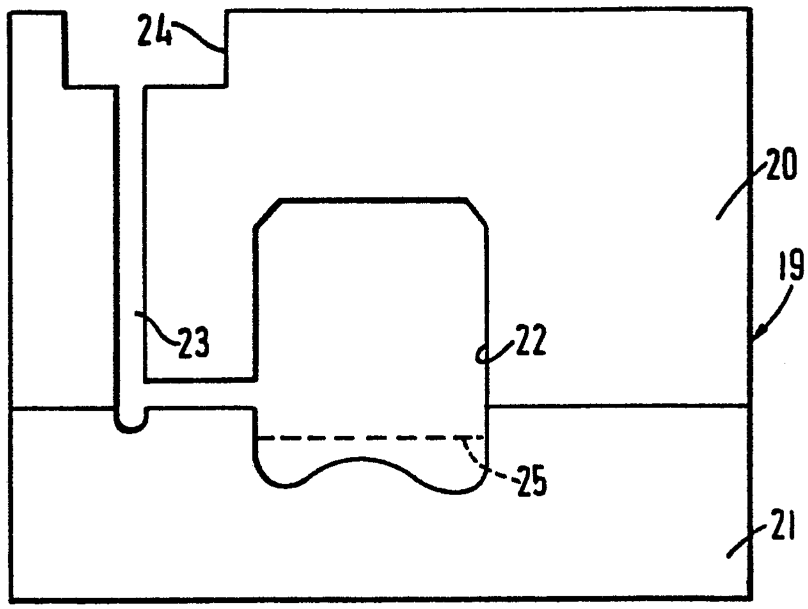

FIG.3

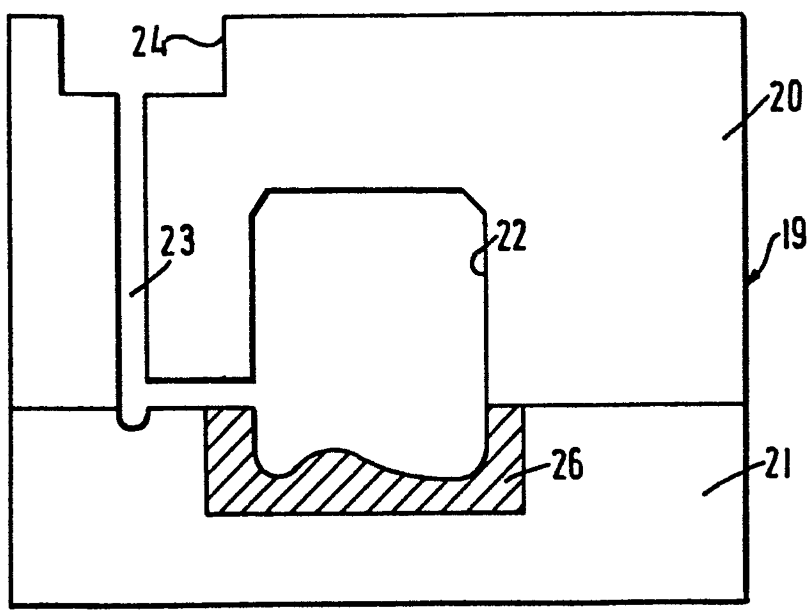

FIG.4