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(54) PERCUSSIVE DRILL BIT WITH MULTIPLE SETS OF FRONT CUTTING INSERTS

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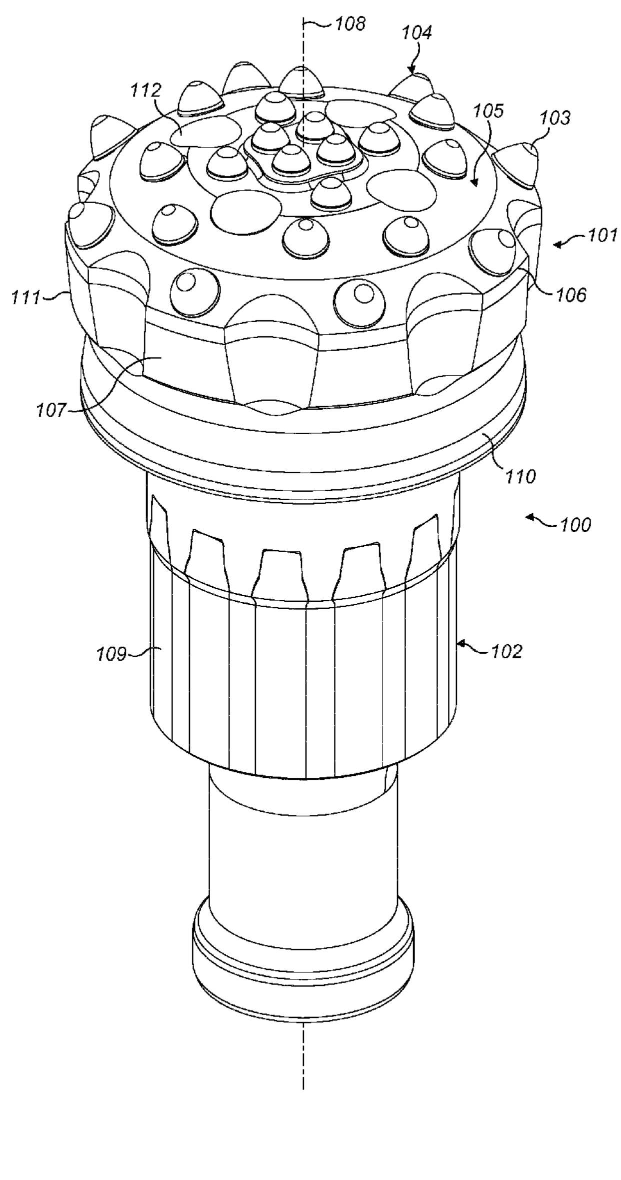
(57) ABSTRACT

A percussive rock drill bit includes a head provided with an elongate shank. A plurality of front cutting inserts are distributed at a front face of the head and are grouped into a plurality of sets, with each set being positioned at a different radial distance from a central axis. Each set of inserts includes the same number of inserts to maximize drilling rate and service lifetime of the drill bit.



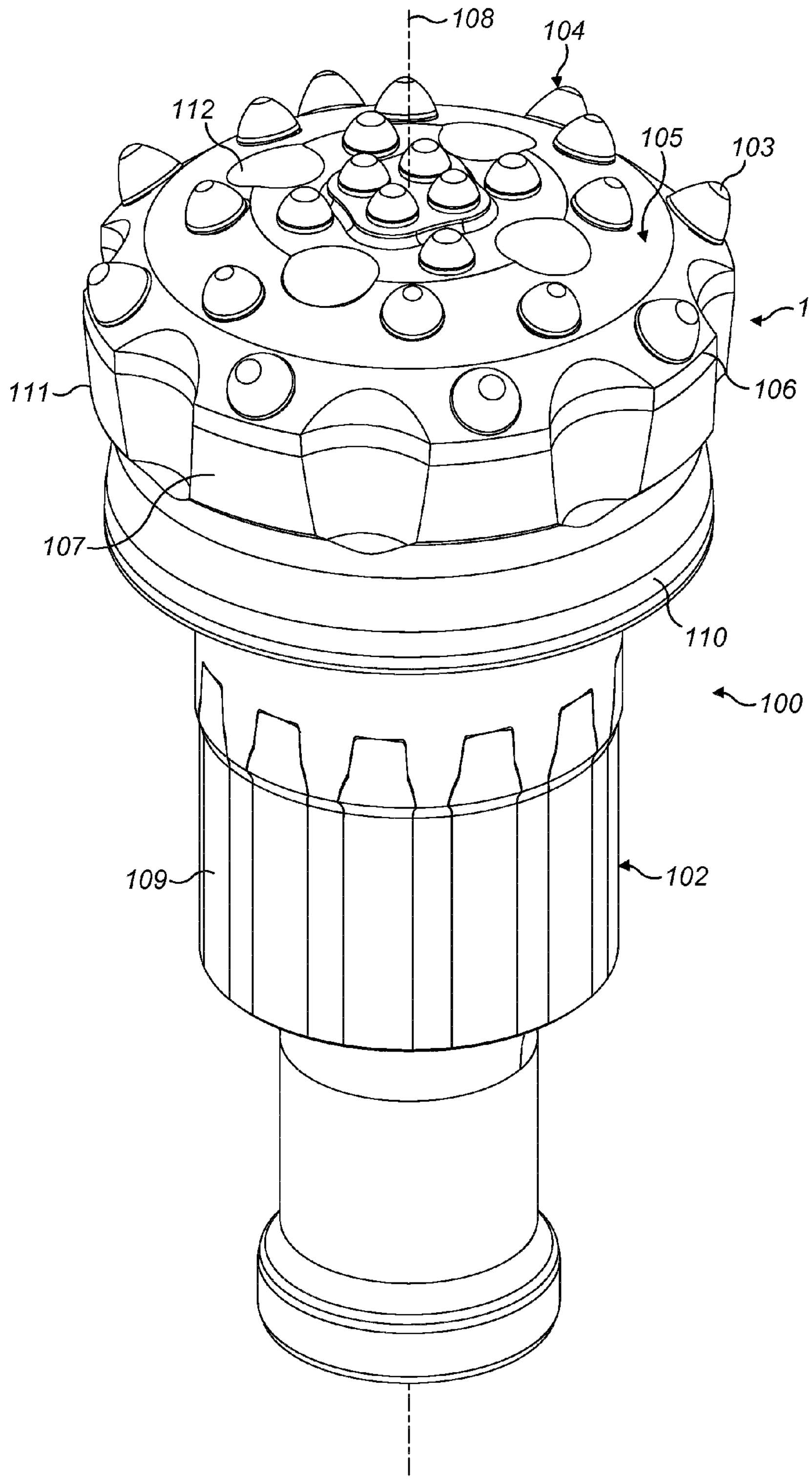


FIG. 1

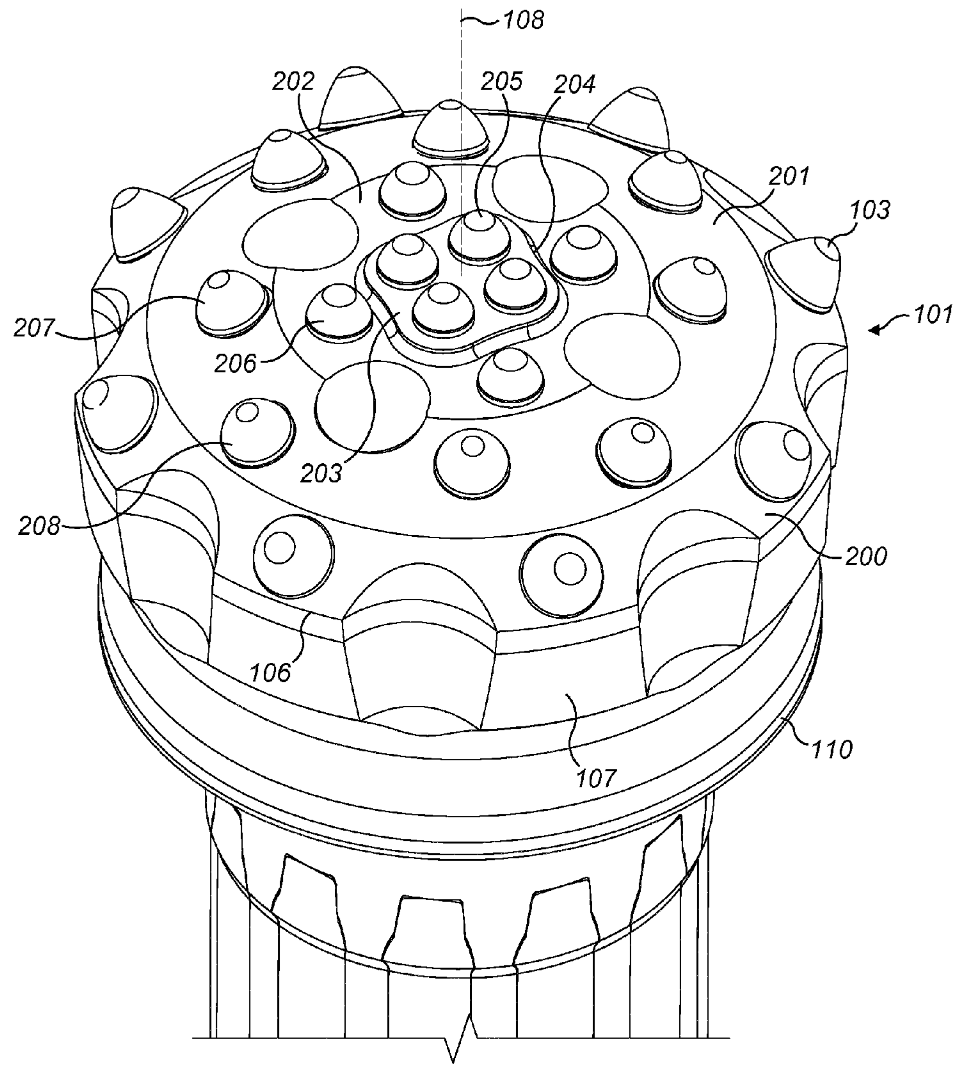


FIG. 2

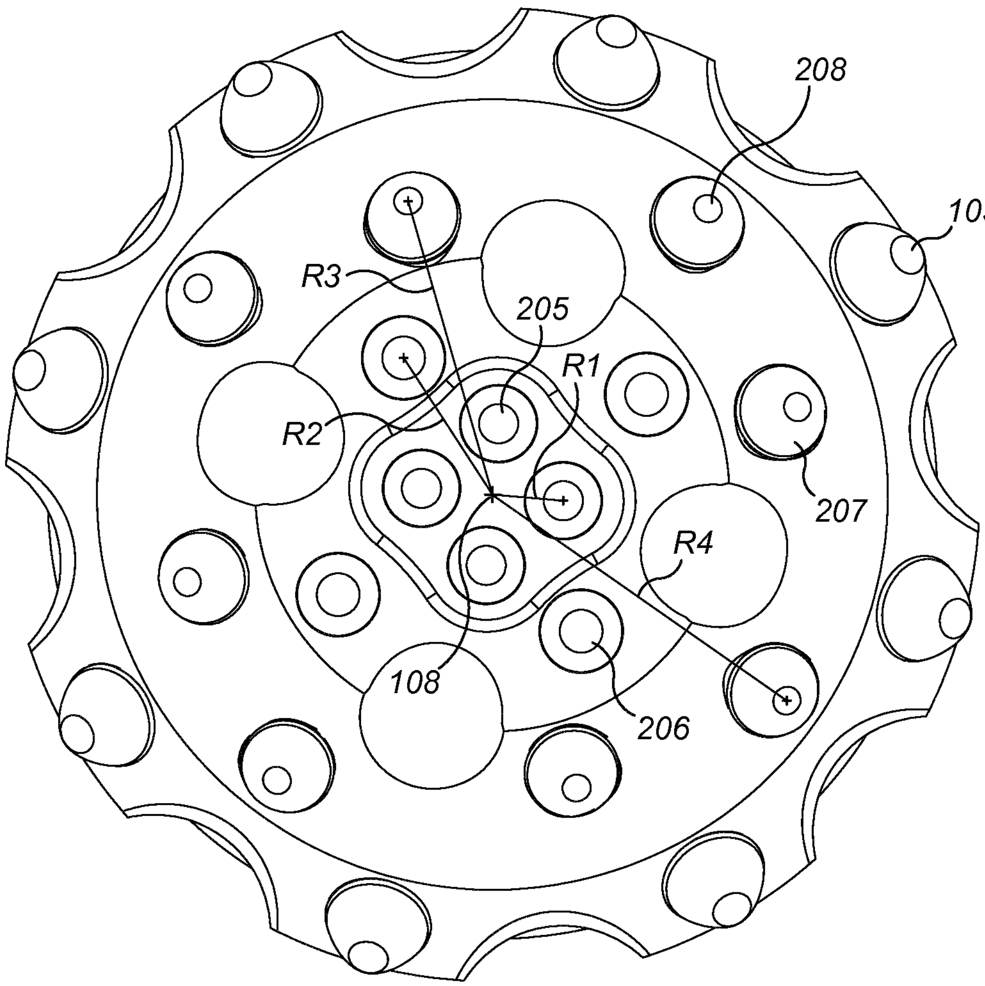


FIG. 3

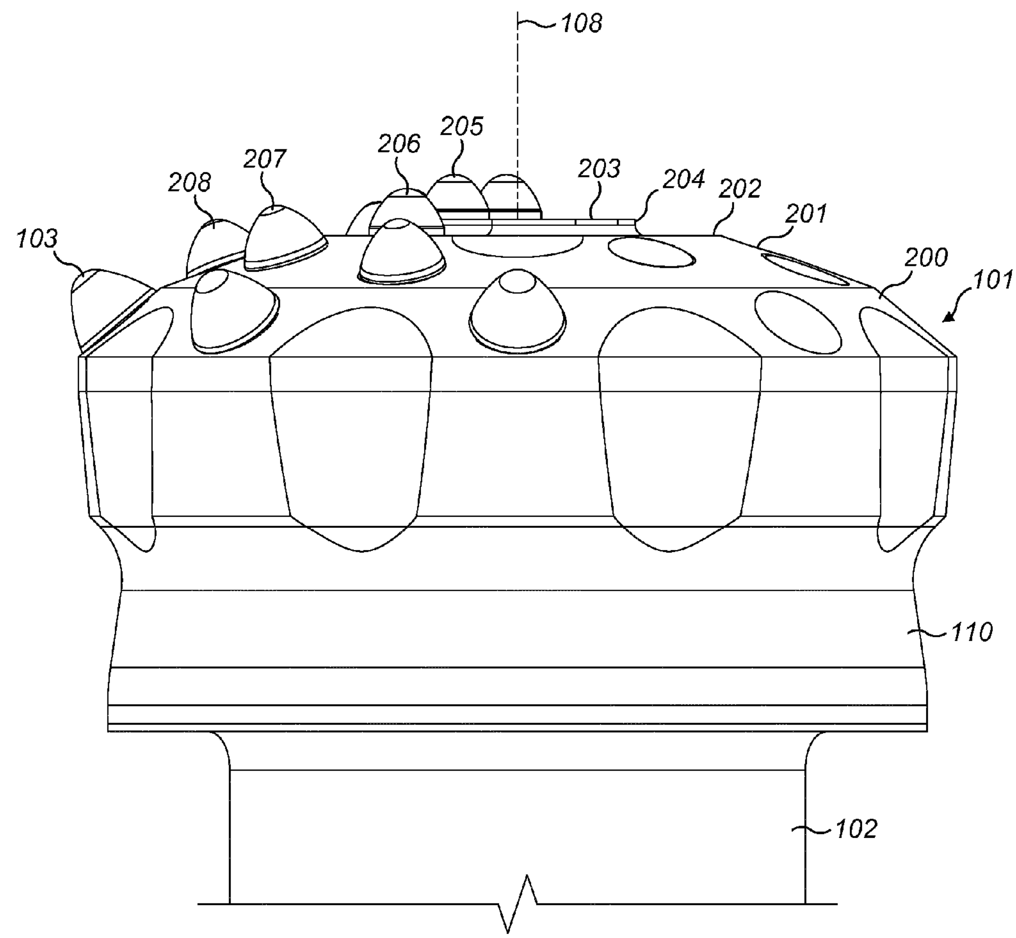


FIG. 4

PERCUSSIVE DRILL BIT WITH MULTIPLE SETS OF FRONT CUTTING INSERTS

FIELD OF INVENTION

[0001] The present invention relates to a percussive rock drill bit and in particular, although not exclusively, to a drill bit formed with a cutting head mounting a plurality of front cutting inserts arranged into sets with each set distributed at different radial positions at a front face of the cutting head.

BACKGROUND ART

[0002] Percussion drill bits are widely used both for drilling relatively shallow bores in hard rock and for creating deep boreholes. For the latter application, drill strings are typically used in which a plurality of rods are interconnected to advance the drill bit and increase the depth of the hole. In 'top hammer drilling' a terrestrial machine is operative to transfer a combined impact and rotary drive motion to an upper end of the drill string whilst a drill bit positioned at the lower end is operative to crush the rock and form the boreholes. In 'down the hole' drilling the impact is delivered not through the upper end of the string, but by a hammer directly connected to the drill bit within the hole.

[0003] The drill bit typically comprises a drill head that mounts a plurality of hard cutting inserts, commonly referred to as buttons. Such buttons comprise a carbide based material to enhance the lifetime of the drill bit. Conventionally, the drill bit comprises a plurality of gauge buttons distributed circumferentially at an outer perimeter of the head that are configured to engage material to be crushed and to determine the diameter of the borehole. The head also mounts a plurality of front buttons provided at a front face of the head for engaging material to be crushed at the axial forwardmost region of drilling. Example percussive drill bits are disclosed in U.S. Pat. No. 3,357,507; U.S. Pat. No. 3,388,756, U.S. Pat. No. 3,955,635; US 2008/0087473; US 2008/0078584; WO 2012/17460; WO 2006/033606; WO 2009/067073; U.S. Pat. No. 7,527,110; U.S. Pat. No. 7,392,863; EP 2592216; WO 2012/038428 and EP 2383420.

[0004] Commonly, the cutting inserts are distributed over the front face in sets or seemingly randomly at different locations not on a common circumferential path. Typically, the multiplicity of inserts increases progressively from the radially inner to radially outer region of the front face. In order for the bit to advance into the rock during drilling, each insert must crush the rock in its circumferential path. Where a particular region of the front face includes a single insert, a full 360° rotation is needed to advance the bit axially forward. Accordingly, the inserts at those regions of the bit with the fewer neighbouring inserts have a higher wear rate and also limit the penetration rate of the bit. Accordingly, what is required is a drill bit that addresses these problems.

SUMMARY OF THE INVENTION

[0005] It is a primary objective of the present invention to provide a percussive drill bit that is configured to maximise a penetration rate into rock during drilling and to maximise the service lifetime of the bit as far as possible.

[0006] It is a further specific objective to provide a distribution of hardened cutting inserts at a drill head part of the bit that is optimised to withstand frictional wear consistently at varying radial positions from the axial centre of the bit. It is a further specific objective to configure the front buttons to maximise the drilling rate via their organisation and distribution at the front face relative to the bit axis and a perimeter edge of the drill bit head.

[0007] According to a first aspect of the present invention there is provided a percussive rock drill bit comprising: a head provided at one end of an elongate shank, the head having a forward facing front face defined by a perimeter edge; a plurality of front cutting inserts distributed at the front face at different radial positions between a central axis extending through the drill bit and the perimeter edge of the front face; wherein the front cutting inserts are grouped into a plurality of sets with each set comprising the same number of inserts and positioned at a different radial distance from the axis and each insert of each respective set is positioned at substantially the same radial distance characterised in that: each insert of each set is positioned circumferentially between a pair of inserts of a neighbouring radially outer and/or radially inner set such that the positions of the inserts of neighbouring sets are staggered circumferentially.

[0008] Reference within this specification to a 'cutting insert' encompasses alternative and equivalent terms such as cutting buttons and the like being specifically adapted to comprise a hardness that is greater than the main body of the bit.

[0009] Reference within this specification to 'each insert of each respective set positioned at substantially the same radial distance' encompasses the axial centres of each of the inserts within each set positioned on the same circumferential path and at the same radial separation distance from the axis. The term also encompasses the axial centres of at least some of the insert within each respective set being positioned radially outside or inside other inserts within the same set. Such a variation includes the positioning of the axial centre of one or more inserts within a set so as to be eccentric (off-set) relative to the other inserts within the same set by up to a diameter (D), a radius, a third diameter (D/3) or a quarter diameter (D/4) of the inserts within the set.

[0010] Reference within this specification to 'angular distance' encompasses the angle between the inserts and in particular the angle between neighbouring inserts in the circumferential direction.

[0011] Circumferentially staggering the positions of the neighbouring sets of inserts is advantageous for a number of reasons. Firstly, by positioning the inserts of one set circumferentially between the inserts of a neighbouring radially outer and/or radially inner set, the diameters of the inserts of the neighbouring sets may overlap radially to provide a more compact design. Such an arrangement also maximises the number of inserts that may be embedded at the front face. Additionally, positioning the inserts of the different sets so as to be circumferentially off-set relative to one another provides a more efficient and effective cutting action at the drill hole bottom. In particular, such an arrangement has been found to be more effective to break the rock as the cutting grooves created in the rock overlap which acts to chip or fragment the rock to be propelled radially outward over the cutting face.

[0012] Optionally, each set comprises from three to six cutting inserts. Preferably, each set comprises four inserts. Such an arrangement represents an optimised compromise between minimising wear of the inserts and also minimising an overall weight of the cutting bit that naturally increases with a larger number of inserts.

[0013] Preferably, each set comprises from two to eight sets of front cutting inserts. Optionally, the bit comprises four sets of inserts. Optionally, an inner set of the inserts represents a radially innermost set of front buttons. Optionally, the drill bit comprises an additional set of innermost front buttons that comprises a number of cutting inserts being less than the number of inserts within the radially outer sets (with each of these radially outer sets comprising the same number of cutting inserts in accordance with the subject invention). An additional set of innermost inserts having a lower number of inserts relative to the radially outer sets may be advantageous for use with smaller diameter drill bit heads.

[0014] Optionally, a diameter of the inserts of each set increases in a direction radially outward from the axis. Alternatively, a diameter of the inserts within all or some of the sets may be substantially equal. Such configurations are beneficial to maximise the service lifetime of the drill bit having consideration of the different angular velocities of the inserts within the different sets. That is, the radially outer sets may comprise larger diameter inserts relative to the inner sets to compensate for the increased angular velocity during drilling so as to provide a uniform insert wear rate across all sets.

[0015] Optionally, a central region of the front face is positioned axially forward of the perimeter edge. Optionally, the front face is generally convex such that a central region of the front face is positioned axially forward of the perimeter edge. The front face may be dome-shaped that is tilted axially rearward towards the shank such that a radially innermost part of the front face is positioned axially forward relative to a perimeter edge of the head. According to further embodiments, the axially forward region of the head may be substantially planar or flat or comprise a cavity so as to be generally concave having a peripheral collar that projects axially forward of a radially innermost region within which is mounted the plurality of sets of inserts. In some embodiments, the annular collar of the head may comprise one or a plurality of sets of the front buttons in addition to gauge buttons.

[0016] Advantageously, the head and shank are formed integrally. Such an arrangement is advantageous to provide a robust and reliable bit configured to withstand the significant torque and axial loading forces transmitted during percussive drilling. Additionally, the bit head is formed as a single piece component integrally with the elongate shaft to optimise the strength of the bit to provide a rigid bit that is not susceptible to independent movement of separate components which is otherwise disadvantageous with multi-component bits.

[0017] Preferably, the front face is formed as a single and common support substrate for the inserts such that all the inserts are embedded in a single common face. Such an arrangement is advantageous to distribute the loading forces uniformly at the front face to maximise the service lifetime of the bit and to minimise wear. The inserts are embedded directly in the bit head, via the front face, and are not mounted via an intermediate and detachable body. Such an arrangement is advantageous to provide a structurally robust configuration such that the inserts are resistant to the torque and axial forces encountered during use.

[0018] Preferably, an angle between neighbouring inserts within each respective set is substantially equal. That is, the separation distance between neighbouring inserts in a circumferential direction around the central axis within each set is substantially equal. Preferably the angle between neighbouring inserts (within each set) is substantially equal for all sets at the front face. Preferably, a distance in the circumferential direction between neighbouring inserts within each set increases between the sets in a direction radially outward from the central axis. As will be appreciated, the increase in circumferential separation distance between inserts within the sets in a direction progressively outward from the axis is a consequence of the uniform angular separation between neighbouring inserts within all sets.

[0019] Optionally, the positions of the inserts of at least two sets overlap radially. Optionally the positions of the inserts of three, four, five, six or all sets overlap radially. Optionally the radially inner, radially outer and/or mid-radial sets comprise inserts that are positioned to overlap radially. Such a configuration optimises the cutting efficiency of the bit head and maximises the penetration rate as the density of the distribution of the cutting grooves in the rock is enhanced as at least some of the as-formed grooves overlap radially.

[0020] Optionally, the drill bit may comprise a first inner set positioned radially innermost at or towards the axis relative to other sets; and a first intermediate set positioned radially between the first inner set and a gauge group of cutting inserts positioned at or towards the perimeter edge. Optionally, the drill bit may further comprise a second intermediate set positioned radially intermediate the first intermediate set and the gauge group. Optionally, the drill bit may further comprise a second inner set positioned radially intermediate the first inner set and the first intermediate set. Such an arrangement is beneficial to maximise the drilling rate and service lifetime of the drill bit configured with a domed or convex front face. As will be appreciated, a number of different sets of inserts may vary according to the size, geometry and shape profile of the bit head including in particular flat and concave front face regions.

[0021] According to a second aspect of the present invention there is provided percussive drilling apparatus comprising a drill bit as claimed herein.

BRIEF DESCRIPTION OF DRAWINGS

[0022] A specific implementation of the present invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

[0023] FIG. **1** is an external perspective view of a drill bit comprising a plurality of front cutting inserts distributed and arranged into groups or sets at a head part of the bit according to a specific implementation of the present invention;

[0024] FIG. **2** is a further perspective view of the head part of the drill bit of FIG. **1**;

[0025] FIG. **3** is a plan view of the front face of the head of FIG. **2**;

[0026] FIG. **4** is a side elevation view of the head of FIG. **2**.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT OF THE INVENTION

[0027] Referring to FIGS. **1** to **4** a drill bit **100** comprises a drill head **101** formed at one end of a generally elongate shaft **102** with both head **101** and shaft **102** centred on a longitudinal axis **108**. Shaft **102** comprises splines **109** to engage with corresponding splines of a drive tool (not shown) that surrounds the shaft **102** during use. Head **101** comprises an axially forward section **111** and an axially rearward skirt section **110** that interfaces with shaft **102**. Section **111** comprises a larger diameter than skirt **110** and is defined, in part, by an annual outermost perimeter edge **106**. A forward facing front face indicated generally by reference **105** projects axially forward from edge **106** such that the forward facing part of section **111** is generally convex and comprises a dome-shaped profile when viewed from the side or in cross section. Forward head section **111** tapers rearwardly from edge **106** via a short longitudinally extending trailing surface **107** that mates with an axially forward region of skirt **110**.

[0028] Front face **105** may be considered to be segmented radially into a plurality of annular regions extending between axis **108** and perimeter edge **106**. In particular, face **105** comprises an outer peripheral region **200** that is defined at its perimeter by edge **106**. Region **200** is chamfered to taper rearwardly relative to axis **108** so as to be declined relative to a radially innermost region **203** that is aligned substantially perpendicular to axis **108**. Region **203** is axially raised to form a platform **204** that is upstanding from a first intermediate region **202**. Region **202** is also aligned substantially perpendicular to axis **108**. The first intermediate region **202** is surrounded by a second intermediate region **201** that is chamfered to taper rearwardly relative to axis **108**. Second intermediate region **201** is positioned radially between the first intermediate region **202** and the perimeter region **200**. The declined angle by which region **201** extends from axis **108** is less than the corresponding angle by which peripheral region **200** extends relative to axis **108**. Accordingly, and as indicated in FIG. **4**, regions **200** to **203** collectively define a generally convex front face **105** that projects axially forward from perimeter edge **106**.

[0029] Head **101** mounts a plurality of hardened cutting inserts indicated generally by references **103** and **104** formed from a carbide based material such as cemented carbide or tungsten carbide for example. According to the specific implementation, inserts **103**, **104** are generally dome-shaped. However, according to further specific embodiments, inserts **103**, **104** may have axially forward cutting tips that are rounded, conical, ballistic, semi-spherical, flat or pointed according to conventional cutting insert configurations. The inserts **103**, **104** are embedded in head section **111** so as to stand axially proud of front face **105**. As will be appreciated, gauge inserts **103** are positioned at or towards perimeter edge **106** to determine and maintain a predetermined diameter of the borehole during formation. Gauge inserts **103** are tilted radially outward so as to be generally inclined and outward facing from axis **108** consistent with peripheral region **200**.

[0030] Referring to FIGS. **2** and **3**, inserts **104** that are positioned radially within gauge inserts **103** are grouped into a plurality of sets with each set positioned at a different radial distance from axis **108**. Additionally, each insert **104** of each set is positioned at the same radial separation from axis **108** such that the inserts **104** of each set are positioned at a common circumferential path around axis **108**.

[0031] According to the specific embodiment, inserts **104** are divided into a first inner set **205** positioned radially innermost at or towards axis **108** and mounted within inner region **203**. A second inner set **206** surrounds first set **205** and is mounted at region **202**. A first intermediate set **207** surrounds second inner set **206** and is mounted at region **201**. A second intermediate set **208** (also mounted at region **201**) is positioned radially outside first intermediate set **207** and radially inside the group of gauge inserts **103**. Advantageously, to maximise the service lifetime and to maximise the penetration rate of bit **100**, each set **205** to **208** comprises the same number of inserts **104** being four inserts per set according to the present embodiment. Accordingly, during rotation of bit **100** about axis **108**, each insert **104** of each set is configured to collectively define an annular cutting path when bit **100** is rotated through 90° during drilling. This is to be contrasted with conventional arrangements where for example the innermost set **205** comprises a single insert **104** that is required to be rotated through 360° to complete a single annular cutting path within the rock. As will be appreciated, the penetration rate of the present bit **100** is appreciably greater than conventional arrangements and the wear of the inserts is lower and more evenly distributed.

[0032] First and second intermediate sets **207**, **208** comprise inserts **104** having axes that are inclined to taper radially outward from axis **108** consistent with the angled orientation of region **201** (relative to axis **108**) within which sets **207**, **208** are mounted. In contrast, inserts **104** within first and second inner sets **205**, **206** have axes that are aligned substantially parallel with axis **108**. As illustrated in FIG. **4**, the angle by which the inserts **104** of first and second intermediate sets **207**, **208** extend radially outward from axis **108** is less than a corresponding angle by which gauge inserts **103** tilt radially outward from axis **108**.

[0033] Referring of FIG. **3**, each insert **104** of first inner set **205** is separated from axis **108** by the same radial separation distance R**1**. Each insert **104** of the second inner set **206** is separated from axis **108** by the same radial separation distance R**2**. Each insert **104** of the first intermediate set **207** is separated from axis **108** by the same radial separation distance R**3**. Each insert **104** of the second intermediate set **208** is separated from axis **108** by the same radial separation distance R**4**. According to the present embodiment, R1<R2<R3<R4. However, the magnitude of the sequential increase from R**1** to R**4** (via R**2** and R**3**) is-non uniform according to the present embodiment.

[0034] According to the present embodiment, an angle by which adjacent inserts **104** (neighbouring in a circumferential direction) are separated is 90° within all sets **205** to **208**. That is, the angle between adjacent inserts **104** of each set is uniform and equal over all sets **205** to **208**. Such a configuration is advantageous in that the inserts wear consistently at varying radial positions from the axial centre of the bit and the bit penetration rate is maximised.

[0035] Referring to FIG. **3**, the position of each set of inserts **205** to **208** is circumferentially staggered at front face **105**. That is, each insert **104** of each set **205** to **208** is positioned circumferentially between two inserts **104** of a neighbouring radially inner or radially outer set **205** to **208**. In particular, each insert **104** of set **205** is positioned circumferentially between the inserts **104** of set **206**; the inserts **104** of set **206** are positioned circumferentially between the inserts **104** of set **205** and **207**; the inserts of set

207 are positioned circumferentially between the inserts 104 of sets 206 and 208 and the inserts 104 of set 208 are positioned circumferentially between the inserts 104 of set 207. According to the specific implementation, the inserts 104 of set 208 are also positioned circumferentially between the gauge inserts 103. Additionally, and when viewed in plan as illustrated in FIG. 3, the respective diameters of the inserts 104 of at least some of the sets overlap radially with this being possible due to the circumferential staggering of the inserts of neighbouring sets. In particular, the diameters of the inserts 104 of sets 207 and 208 overlap radially. Also, as will be noted from FIG. 3, each insert 104 of each set is positioned approximately mid-way circumferentially between the pair of inserts 104 of the neighbouring set. With this configuration, the inserts of all sets are spaced apart so as to be positioned as far apart as possible at front face 105. Such an arrangement is advantageous to maximise the cutting efficiency of each insert and provide a structurally strong bit. The circumferential staggering of the inserts and the radial overlap between inserts 104 of sets 207, 208 is further advantageous to provide a radially compact head 101 and to maximise the number of sets 205 to 208 embedded at front face 105. The present configuration functions to aggressively break the rock at the drill hole bottom, due in part, to partial radial overlap of sets 207, 208 and the grouping of the inserts 104 into the sets (206, 208) positioned at different radial distances from axis 108.

[0036] The mounting of the first inner set 205 at platform 204 is advantageous to provide collaring as the inserts of set 205 meet the rock initially during drilling. Such an arrangement is also considered to be beneficial for enhancing penetration speed due to the provision of a local 'lower' level within the rock into which cracks may form during drilling. Additionally, the raised or convex front face 105 having raised innermost region 203 is beneficial to minimise the risk of cracks within head 101 originating from flushing holes 112 extending within head 101.

[0037] According to the present embodiment, a diameter of inserts 104 of the first inner set 205 is less than a corresponding diameter of second inner set 206. Similarly, a diameter of the inserts 104 of the first and second inner sets 205, 206 is less than a corresponding diameter of inserts 104 of the first and second intermediate sets 207, 208. As shown, and according to the present embodiment, a diameter of the gauge inserts 103 is greater than each one of the inner and intermediate inserts 104 of sets 205 to 208. However, according to further embodiments, a diameter of inserts 104 over all sets 205 to 208 may be substantially equal or may be smaller or larger than the diameter of gauge inserts 103.

[0038] According to further embodiments, the axially forward facing region of head section 111 may be substantially planar (flat) or comprise a concave region defined by an axially forward extending perimeter collar. Additionally, head 101 may comprise peripheral axially extending flushing channels associated with each flushing hole 112 to facilitate axially rearward transport of the flushing fluid and the rock fragments and fines.

[0039] Additionally, according to further embodiments, head 101 may comprise an additional innermost set of inserts 104 positioned radially within set 205 comprising the same number or less inserts (at the same and common radial position) relative to the radially outer sets 205 to 208. That is, an innermost set of inserts 104 may comprise one, two or three inserts 104 whilst the radially outer sets 205 to 208 may comprise four or more inserts with the inserts 104 of each set positioned at the same radial separation distance R1 to R4 relative to axis 108.

1. A percussive rock drill bit comprising:
- a head provided at one end of an elongate shank, the head having a forward facing front face defined by a perimeter edge; and
- a plurality of front cutting inserts distributed at the front face at different radial positions between a central axis extending through the drill bit and the perimeter edge of the front face, wherein the front cutting inserts are grouped into a plurality of sets, each set including an equal number of inserts positioned at a different radial distance from the axis, each insert of each respective set of inserts being positioned at substantially the same radial distance and positioned circumferentially between a pair of inserts of a neighbouring radially outer and/or radially inner set inserts, such that the positions of the inserts of neighbouring sets are staggered circumferentially.

2. The drill bit as claimed in claim 1, wherein each set includes from three to six inserts (104).

3. The drill bit as claimed in claim 2, wherein each set includes four inserts.

4. The drill bit as claimed in claim 1, further comprising from two to eight sets of front cutting inserts.

5. The drill bit as claimed in claim 1, wherein a diameter of the inserts within at least some of the sets increases in a direction radially outward from the axis.

6. The drill bit as claimed in claim 1, wherein a central region of the front face is positioned axially forward of the perimeter edge.

7. The drill bit as claimed in claim 1, wherein the front face is generally convex such that a central region of the front face is positioned axially forward of the perimeter edge.

8. The drill bit as claimed in claim 1, wherein the inserts of at least two sets overlap radially.

9. The drill bit as claimed in claim 1, wherein one of the sets represents a radially innermost set of the front cutting inserts, the innermost set comprising having the same number of inserts as the radially outer sets.

10. The drill bit as claimed in claim 1, further comprising a radially innermost group of front inserts that include a number of inserts being less than the number of inserts within each of the sets that are positioned radially outside the sets.

11. The drill bit as claimed in claim 1, further comprising:
- a first inner set of inserts positioned radially innermost at or towards the axis relative to other sets; and
- a first intermediate set of inserts positioned radially between the first inner set and a gauge group of cutting inserts positioned at or towards the perimeter edge.

12. The drill bit as claimed in claim 11, further comprising a second intermediate set of inserts positioned radially intermediate the first intermediate set and the gauge group of inserts.

13. The drill bit as claimed in claim 12, further comprising a second inner set of inserts positioned radially intermediate the first inner set and the first intermediate set of inserts.

14. The drill bit as claimed in claim 13, wherein the inner and intermediate sets are positioned at different axial positions with the first inner set (205) of inserts positioned axially forwardmost and the second intermediate set of

inserts positioned axially rearwardmost, the gauge group of inserts being positioned axially rearward of the second intermediate set.

15. Percussive drilling apparatus comprising:

a drill bit, the drill bit including a head provided at one end of an elongate shank, the head having a forward facing front face defined by a perimeter edge, and a plurality of front cutting inserts distributed at the front face at different radial positions between a central axis extending through the drill bit and the perimeter edge of the front face, wherein the front cutting inserts are grouped into a plurality of sets, each set including an equal number of inserts positioned at a different radial distance from the axis, each insert of each respective set of inserts being positioned at substantially the same radial distance and positioned circumferentially between a pair of inserts of a neighbouring radially outer and/or radially inner set inserts, such that the positions of the inserts of neighbouring sets are staggered circumferentially

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