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(54) **ROCK DRILL BIT AND A DRILLING ASSEMBLY FOR PERCUSSIVE ROCK DRILLING**

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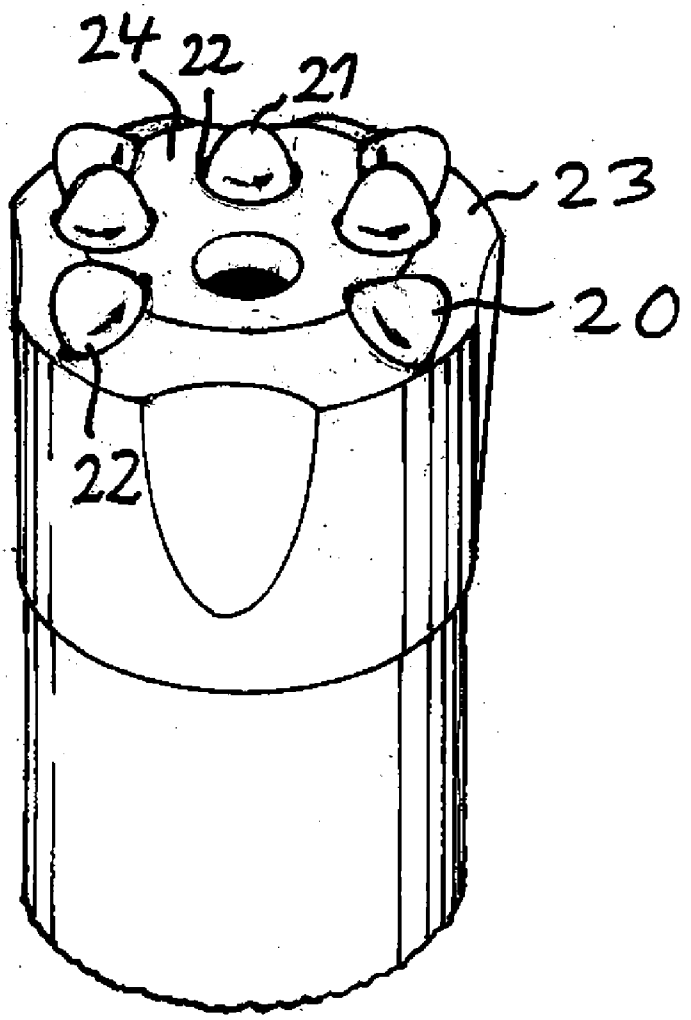
(57) **ABSTRACT**

A rock drill bit for percussive drilling includes a bit head attached at an end of a drill element of a drilling assembly. The bit head has a diameter larger than that of the drill element. The bit head has at a front end as seen in the intended drilling direction a plurality of buttons distributed thereon to engage material to be crushed. At least one of the buttons is allowed to rotate about its own symmetry axis.



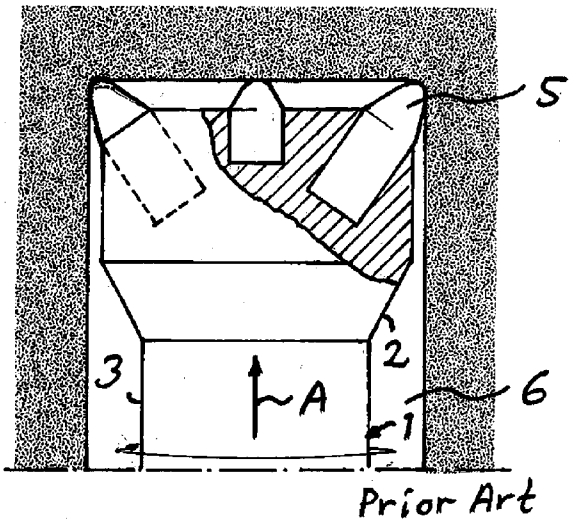


Fig 1

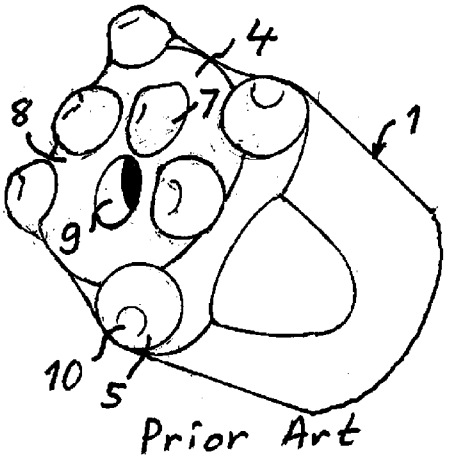


Fig 2

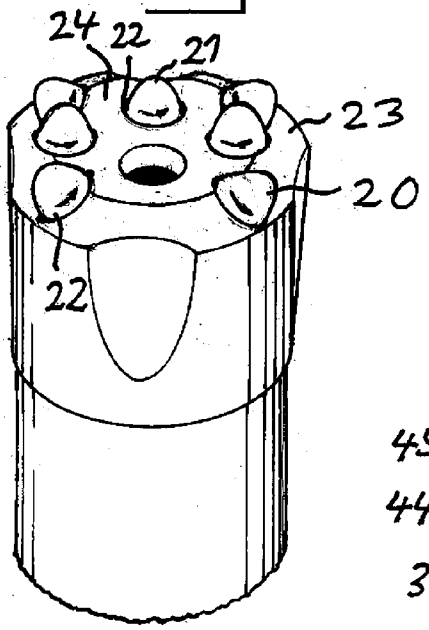


Fig 3

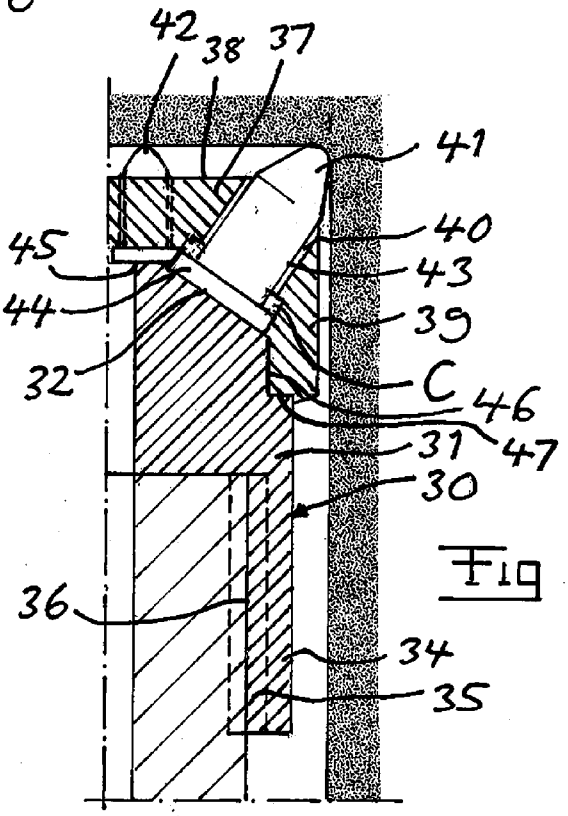


Fig 4

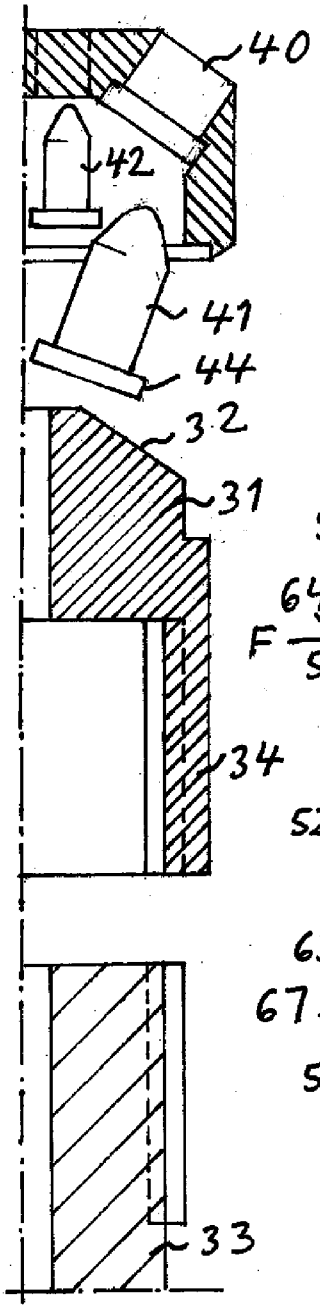


Fig 5

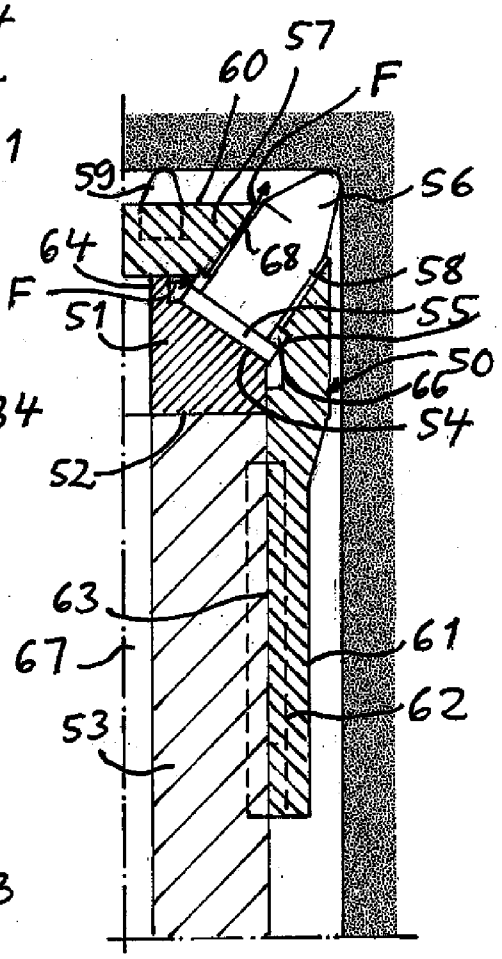


Fig 6

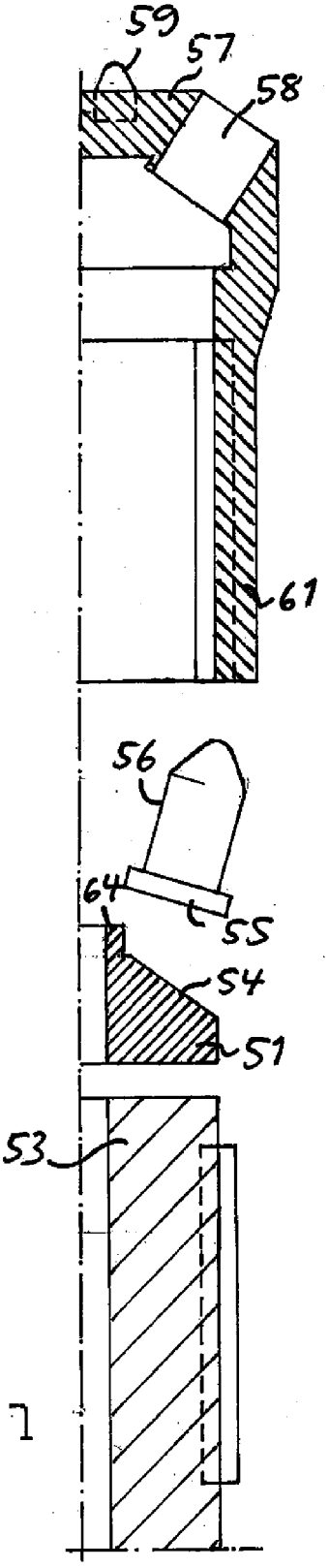


Fig 7

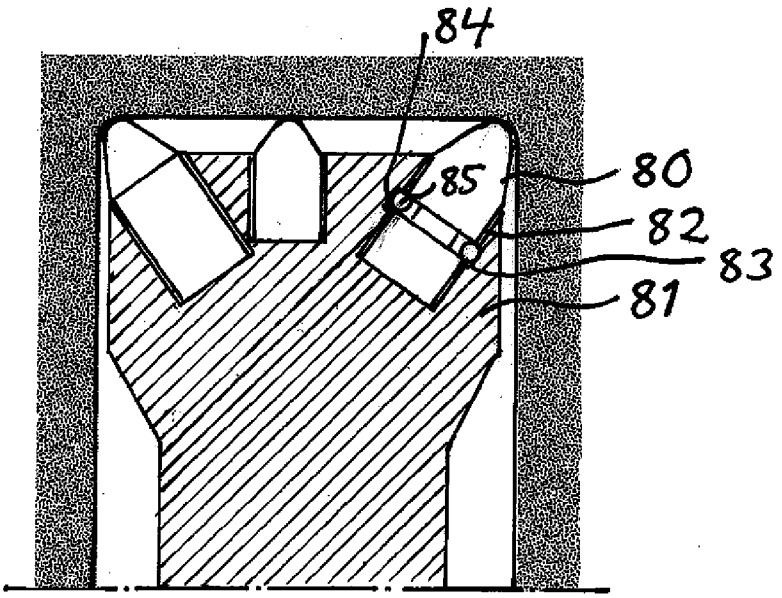


Fig 8

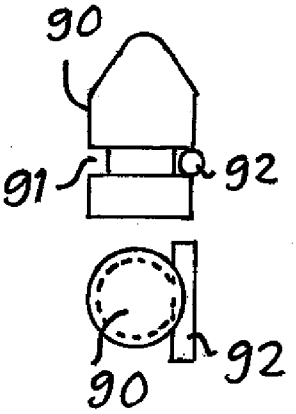


Fig 9

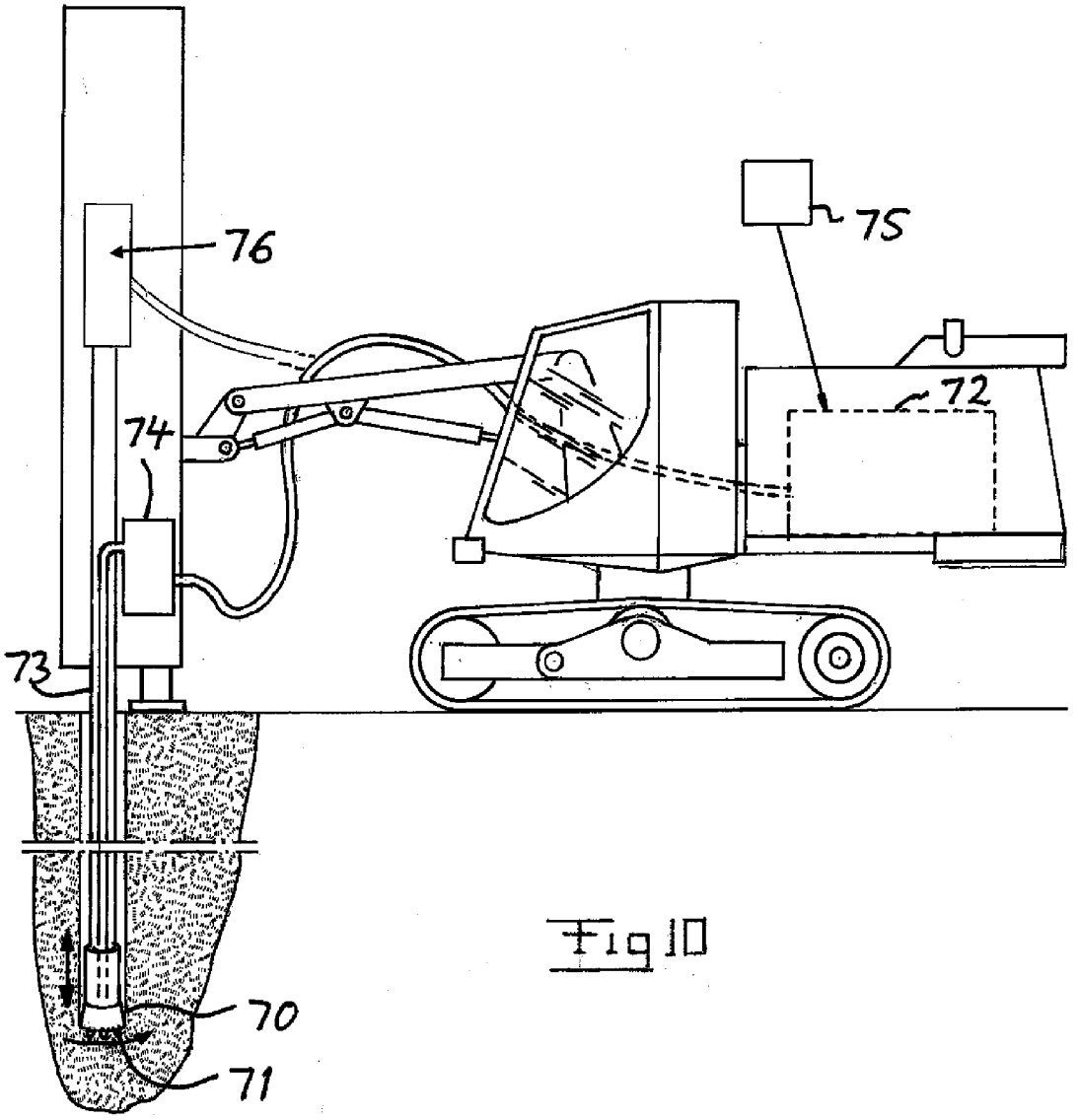


Fig 10

ROCK DRILL BIT AND A DRILLING ASSEMBLY FOR PERCUSSIVE ROCK DRILLING

TECHNICAL FIELD OF THE INVENTION AND BACKGROUND ART

[0001] The present invention relates to a rock drill bit for percussive drilling comprising a bit head configured to be attached at an end of a drill element of a drilling assembly and having a diameter larger than that of said drill element, said bit head having at a front end as seen in the intended drilling direction a plurality of buttons distributed over said bit head and configured to engage material to be crushed, as well as a drilling assembly for percussive rock drilling according to the preamble of the independent claim therefor.

[0002] The invention is not restricted to any type of drilling assembly for use of a said rock drill bit, but the former may be a down-the-hole hammer drill just as well as a top hammer drill, although the rock drill bit shown is especially intended for the latter type.

[0003] Furthermore, said rock drill bit may have any conceivable size and has normally a diameter of 30 mm-300 mm. The same absence of limitations applies to the intended percussion frequency and rotational speed of the rock drill bit in operation, although it may be mentioned that these are typically within the ranges 20 Hz-100 Hz and 20-500 revolutions per minute, respectively, but the invention does not exclude the use of the rock drill bit in high frequency assemblies operating at a frequency above 250 Hz and which may reach more than 1 kHz.

[0004] A known so-called standard rock drill bit **1** of the type defined in the introduction will now be described while referring to both FIG. **1** and FIG. **2**. The drill bit has a bit head **2** configured to be attached at an end of a drill element, for example in the form of a drill tube or drill rod, of a drilling assembly and having a diameter larger than that of a said drill element. This drill element is not shown in these figures but may be intended to be received in a so-called skirt **3** integral with a bit head and having a smaller diameter than the bit head. Other ways of connecting the drill bit to the drill element are conceivable and known within the art. The bit head has at a front end **4** as seen in the intended drilling direction a plurality of gauge buttons **5** distributed along the circumference of the bit button head **2**. The gauge buttons are configured to engage material to be crushed and to determine the diameter of a hole **6** (see FIG. **1**) to be drilled by the rock drill bit. These gauge buttons are made of hard material, such as cemented carbide or tungsten carbide. Front buttons **7** also of hard material are arranged on a front surface **8** for engaging material to be crushed. It is also indicated how a flush channel opens at the front by a flushing hole **9** in the front surface.

[0005] In operation the gauge buttons **5** will engage and break rock close to the walls of a hole **6** in which the rock drill bit with said rod is located and the front buttons **7** will break rock closer to the centre of such a hole by impacts carried out by the rock drill bit in the direction of the arrow A. The drill bit will rotate somewhat, typically about 5°, between each such impact.

[0006] The operation efficiency of a rock drill bit of this type is of course an important feature and this may be expressed as the penetration rate of the rock drill bit defined as the length of a hole drilled per time unit (meter/minute). The penetration rate of known rock drill bits of this type is dependent upon the wear of said buttons, especially the gauge buttons. It is indicated in FIG. **2** that during the operation of such a rock drill bit material is abraded at the periphery of the gauge buttons resulting in a flat surface **10** there, which makes them less sharp and reduces the penetration rate. These flat surfaces **10** will during the operation of the rock drill bit grow and finally result in a diameter of a hole drilled determined by said gauge buttons being so much reduced that the rock drill bit has to be replaced. It is of course an ongoing attempt to increase the penetration rate and prolong the life time of a rock drill bit of the type defined in the introduction.

SUMMARY OF THE INVENTION

[0007] The object of the present invention is to provide a rock drill bit of the type defined in the introduction being improved in at least some aspect with respect to such rock drill bits already known.

[0008] This object is according to the invention obtained by providing such a rock drill bit in which at least one of said buttons is configured or allowed to rotate about its own symmetry axis. By rotatably fitting at least one said button in the bit head this button will while drilling be influenced by the impacts thereof and rotation of the rock drill bit to rotate about its own symmetry axis, so that the parts of said button engaging rock will vary and the button will be evenly worn and by that self-sharpened. This means that this button will thanks to the self-sharpening effect maintain its contribution to the penetration rate of the rock drill bit longer than would it be fixed in the bit head.

[0009] According to an embodiment of the invention said plurality of buttons includes gauge buttons distributed along the circumference of said bit head and configured to determine the diameter of a hole to be drilled by the rock drill bit, and at least one of said gauge buttons is configured or allowed to rotate about its own symmetry axis. This means that this gauge button will thanks to said self-sharpening effect maintain its contribution to the penetration rate of the rock drill bit until this gauge button has been worn so much that the diameter of a said hole drilled determined thereby has reached a minimum acceptable level. However, this will take longer than would said at least one gauge button be fixed with respect to the bit head, so that the lifetime of the rock drill bit may also be prolonged.

[0010] According to another embodiment of the invention the rock drill bit comprises a first member having a substantially circumferential ring surface defining a substantially frusto-conical shape as seen in the intended drilling direction, and said at least one gauge button has a base portion resting on said ring surface configured to transfer impact forces to the gauge button and to allow said base portion to move thereon when rotating. Transfer of impact forces to the gauge button by such a surface acting on said base portion of said at least one gauge button may increase the efficiency of the impacts and reduce stresses on said gauge button.

[0011] According to another embodiment of the invention the rock drill bit comprises a second member defining said front end of said bit head and having said plurality of gauge buttons extending out thereof, and said at least one gauge button allowed to rotate is arranged in a hole in said second member and allowed to move with respect to walls defining said hole when rotating.

[0012] According to another embodiment of the invention constituting a further development of the embodiment last mentioned said at least one gauge button allowed to rotate has a base portion with a larger cross-section than the rest of the

gauge button, and at least a part of said hole in said second member has a cross-sectional area being smaller than that of said base portion so as to maintain the gauge button received in said second member. By arranging such a base portion in form of a shoulder said at least one gauge button may reliably be maintained in said second member of the rock drill bit while being allowed to rotate.

[0013] According to another embodiment of the invention said hole is a through-hole, and said gauge button is arranged with the base portion thereof on a rear side of said hole as seen in the intended drilling direction.

[0014] According to another embodiment of the invention said first member has means configured to secure this member to a said drill element. This means that the rock drill bit may be secured to a drill element through said first member providing said ring surface for transfer of impact forces to said at least one gauge button.

[0015] According to another embodiment of the invention the rock drill bit has both a said first and second member and comprises means configured to secure said second member to said first member, which means that said ring surface will be located inside the bit head behind said second member. Said means configured to secure said second member to said first member is according to another embodiment of the invention configured to releasably secure these members to each other, which means that a second member with gauge buttons may be removed and replaced when the diameter determined by the gauge buttons has reached the minimum limit while keeping said first member, so that not the entire rock drill bit has to be replaced resulting in saving of costs.

[0016] According to another embodiment of the invention said first member is a ring configured to be supported on and/or secured to an end of said drill element. Such a so-called pusher ring is of particular interest and results in a simple construction of the rock drill bit if the rock drill bit also comprises means for securing said second member and by that said rock drill bit to a said drill element. In such a case the first member has neither to be secured to a drill element nor to said second member, but it will be kept in place by said second member.

[0017] According to another embodiment of the invention a majority of said gauge buttons are allowed to rotate about their own symmetry axis, and according to a further embodiment of the invention all said gauge buttons of the rock drill bit are allowed to rotate about their own symmetry axis. The advantages of arranging gauge buttons so as to be allowed to rotate will be the greater the more of the gauge buttons that are so arranged resulting in a said prolonged life time of the rock drill bit and a high penetration rate maintained over a longer time.

[0018] According to another embodiment of the invention said bit head has a front surface provided with a plurality of front buttons configured to engage material to be crushed. These front buttons may be fixed with respect to said front surface, but according to another embodiment of the invention at least one of said front buttons is allowed to rotate about its own symmetry axis, which will result in an even wear of said front button and by that a self-sharpening action thereof, so that it will carry out its task more efficiently and over a longer time than would it be fixed with respect to said front surface of the bit head.

[0019] According to another embodiment of the invention said at least one front button has a design similar to that of said at least one gauge button, and said second member is configured to receive said at least one front button similarly to said at least one gauge button.

[0020] According to another embodiment of the invention a majority of said front buttons or all said front buttons are allowed to rotate about their own symmetry axes.

[0021] According to another embodiment of the invention the rock drill bit comprises a flush channel extending through said bit head and having at least one flushing hole opening at said front end and passing the circumference of at least one said button allowed to rotate about its own symmetry axis. By letting the flushing medium, such as water, flowing over the circumference of such a button allowed to rotate surfaces and spaces of said bit head and said button allowing said rotation will be kept clean while eliminating any wear problems while the button is rotating inside a hole in which it is received in said bit head.

[0022] According to another embodiment of the invention said at least one button allowed to rotate is arranged in a hole in said bit head and allowed to move with respect to walls defining said hole when rotating, said at least one button is provided with a circumferential annular groove, said walls defining said hole have a female member, and the rock drill bit comprises means configured to engage said groove and said female member so as to lock said button in said hole while allowing it to rotate. This is a preferable and simple way of locking said button with respect to said bit head while allowing it to freely rotate.

[0023] According to another embodiment of the invention said female member is an annular groove in said hole walls, and said engaging means comprises a ring of elastic material. This allows easy mounting of said button in said hole by pushing it thereinto while compressing said ring, which will when arriving to said annular groove in said hole walls expand and lock the button in place while allowing it to freely rotate.

[0024] According to another embodiment of the invention said engaging means comprises a pin configured to be pushed into said groove and said female member for being fixed with respect to said bit head and lock said button in said hole while allowing it to rotate. Such a lock pin will also by simple means provide a reliable locking of said button in said hole of the bit head while allowing it to freely rotate.

[0025] The invention also relates to a drilling assembly for percussive rock drilling according to the appended independent claim for such an assembly. Such a drilling assembly makes it possible to carry out rock drilling with a high penetration rate over a longer time and while replacing the rock drill bit thereof more seldom with respect to such drilling assemblies utilizing known rock drill bits.

[0026] The invention also relates to a use of a rock drill bit according to the invention for percussive rock drilling into earth material, such as rock.

[0027] Further advantages as well as advantageous features of the invention will appear from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] With reference to the appended drawings, below follows a specific description of embodiments of the invention cited as examples.

[0029] In the drawings:

[0030] FIG. **1** is a very simplified view of a rock drill bit according to prior art in operation,

[0031] FIG. **2** is a perspective view of a rock drill bit according to prior art after some time of operation,

[0032] FIG. **3** is a perspective view illustrating the principle of a rock drill bit according to the present invention,

[0033] FIG. **4** shows a longitudinal section through a part of a rock drill bit according to a first embodiment of the invention in operation,

[0034] FIG. **5** is an exploded view of the rock drill bit according to FIG. **4**,

[0035] FIG. **6** is a view corresponding to FIG. **4** of a rock drill bit according to a second embodiment of the invention,

[0036] FIG. **7** is an exploded view of the rock drill bit according to FIG. **6**,

[0037] FIG. **8** is a simplified view corresponding to FIG. **4** of a rock drill bit according to a third embodiment of the invention,

[0038] FIG. **9** is a simplified view of a button allowed to rotate in a bit head of a rock drill bit according to a fourth embodiment of the invention, and

[0039] FIG. **10** is a very simplified view of a drilling assembly for percussive rock drilling according to an embodiment of the present invention in operation.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0040] FIG. **3** shows very schematically the principle of a rock drill bit according to the present invention, in which all gauge buttons **20** and all front buttons **21** are configured or allowed to rotate about their own symmetry axis by being received in holes **22** in a substantially circumferential ring surface **23** defining a substantially frusto-conical shape as seen in the intended drilling direction and in a front surface **24**, respectively. The buttons are preferably of tungsten carbide.

[0041] A rock drill bit **30** according to a first embodiment of the present invention will now be described while making reference to FIGS. **4** and **5**. The rock drill bit comprises a first member **31** having a substantially circumferential ring surface **32** defining a substantially frusto-conical shape as seen in the intended drilling direction. This first member **31** is provided with means configured to secure this member to a drill element **33**, in which this securing means is formed by a sleeve-like portion **34** of the first member **31** provided with engagement means in the form of an internal thread **35** configured to engage engagement means in the form of an external thread **36** on the drill element.

[0042] The rock drill bit further comprises a second member **37** defining a front end **38** of a bit head **39** of the rock drill bit. This second member is provided with a plurality of through holes **40** receiving the gauge buttons **41** and front buttons **42** while allowing these to rotate about their own symmetry axis. The through-holes **40** each have a diameter slightly exceeding (suitably by a diameter difference in the order of 30-80 μm) the diameter of the respective button received therein for allowing the button to move with respect to walls **43** in the second member **37** defining said hole when rotating. However, this difference in diameter has been exaggerated in this figure and also in the embodiment shown in FIG. **6** and described below for better illustrating this feature. The gauge buttons as well as the front buttons are provided with a base portion **44** with larger cross-section than the rest of the button and also than the respective hole **40** so as to maintain the button received in the second member.

[0043] A gauge button **41** rests by the base portion **44** thereof on said ring surface **32** configured to transfer impact forces to the gauge button and allow the base portion to move thereon when rotating. This means that impact forces are transferred to the gauge buttons from a surface **32** located inside the drill bit. The first member has also surfaces **45** directed in an intended drilling direction for supporting base portions of front buttons and transferring impact forces thereto while allowing these base portions to move on these surfaces **45** when rotating. Furthermore, the bit head **39** will through a shoulder **47** on the first member **31** provide a clearance C with respect to this member **31**, so that the button **41** may rotate freely without jamming. Particular measures are taken for flushing the surfaces and spaces surrounding the button, which will be explained more in detail below.

[0044] The rock drill bit comprises means **46** configured to secure the second member **37** to the first member **31**. The securing means is preferably configured to releasably secure these members to each other, for instance by mutually securing them by engagement of threads. This would then mean that it would be possible to remove said second member with buttons for replacement while keeping the first member after the buttons have been that much worn that they have to be replaced. Welding or press fitting are other possible alternatives of said securing means **46** easier to accomplish.

[0045] When carrying out percussive drilling with the rock drill bit shown in FIGS. **4** and **5** as illustrated in FIG. **4** the buttons thereof will be allowed to rotate about their own axes, which means that the gauge buttons **41** will be worn evenly and maintain their sharpness, so that a high penetration rate may be maintained over a long period of time and the diameter of the hole defined by the gauge buttons will be reduced more slowly than would the gauge buttons be fixedly arranged in the bit head.

[0046] FIGS. **6** and **7** illustrate a rock drill bit **50** according to a second embodiment of the invention. This rock drill bit has a first member **51** in the form of a ring configured to be supported on and/or secured to an end **52** of a drill element **53** and having a ring surface **54** forming a support for a base portion **55** of each gauge button **56** in the same way as the corresponding surface **32** in the embodiment shown in FIGS. **4** and **5**. Thus, impact forces will through this surface be transferred to the gauge buttons while the base portions thereof are allowed to move thereon when rotating.

[0047] A second member **57** of the rock drill bit has through holes **58** receiving said gauge buttons and allowing them to move with respect to walls of these holes when rotating. The front buttons **59** are, as an example, in this embodiment fixedly secured to a front end **60** of the second member **57**.

[0048] The second member **57** is in this embodiment provided with means for securing this member to a drill element **53** by having a sleeve-like portion **61** designed to receive a drill element and having engagement means in the form of an internal thread **62** for engaging with engagement means in the form of an external thread **63** on the drill element for releasably securing said second member to the drill element and by that also keeping said ring **51**, a so-called pusher ring, in place. The first member **51** is provided with a collar **64**, so that the first **51** and second **57** members are fixed with respect to each other while leaving a clearance **66** therebetween for the button to freely rotate. Proper flushing of a button allowed to rotate is also important. It is indicated in FIG. **6** that the rock drill bit has a conventional flush channel **67** extending through the bit head. The flush channel has also at least one

flushing hole **68** (see the arrows F indicating the flow of flushing medium) opening at the first end **60** and passing the clearance **66** and the circumference of the button **56** allowed to rotate. This will keep said clearance **66** clear and eliminates wear problems while the button rotates inside the hole **58**. The function of this embodiment of the invention in operation appears clearly from the above discussion of inter alia the first embodiment of the present invention.

[0049] A part of a rock drill bit according to a third embodiment of the invention is very schematically shown in FIG. **8**. This rock drill bit is provided with alternative means to lock a button **80** to a drill bit head **81** while allowing the button to rotate. A blind hole **82** in the bit head designed to receive the button **80** is provided with an annular groove **83**, and the button **80** is provided with a corresponding annular groove **84** receiving an elastic lock ring **85**, for example a ring, such as a C-ring, made from steel. When the button **80** is pushed into the hole **82** the lock ring will first be compressed until reaching the groove **83** in the bit head. It will then expand outwards into that groove and lock the button to the bit head **81** while allowing the button to rotate.

[0050] FIG. **9** illustrates an alternative way of locking a button **90** to a bit head not shown in a rock drill bit according to a fourth embodiment of the invention while allowing the button to rotate. This is achieved by providing the button **90** with an annular groove **91** as in the embodiment shown in FIG. **8**. However, a lock pin **92** is used instead of a lock ring, and this lock pin is after pushing the button **90** into a corresponding hole in the bit head pushed into the groove **91** while locking the button in place and still allowing it to rotate about its own symmetry axis.

[0051] FIG. **10** illustrates very schematically a drilling assembly for percussive rock drilling according to the present invention having a rock drill bit **70** according to an embodiment of the invention provided with gauge buttons **71**. This drilling assembly is a so-called top hammer drill acting upon the rock drill bit from a location above the ground and has power means **72**, such as diesel engine and hydraulic pump, configured to drive the rock drill **76**, which in turn makes said drill element **73** and the rock drill bit to rotate and carry out percussions and by that crush the rock. A design of the drilling assembly as a down-the-hole hammer equipment is also within the scope of the present invention.

[0052] The drilling assembly has also means **74**, such as a compressed air generator, configured to flush cuttings resulted from engagement of the gauge buttons and the front buttons of the drill bit away from the region occupied by the drill bit. The drilling assembly has a control arrangement **75** configured to control the operation of the power means **72** so as to adapt the frequency of impacts and the rotational speed of the drill bit. It has turned out that drill bits according to the present invention with buttons allowed to rotate about their own symmetry axis are particularly well suited to be used in drilling assemblies controlled to have frequencies above 250 Hz, preferably above 350 Hz and most preferred in the range of 350 Hz-1000 Hz.

[0053] Drilling with a drilling assembly according to FIG. **8** with a rock drill bit according to the present invention will be more efficient than with rock drill bits already known, since the penetration rate may be kept at a high level longer and the stops needed for replacing the rock drill bit or parts thereof will be less frequently occurring.

[0054] It is preferable that the base portion of each rotatable button rests against or contacts the bottom of the hole to transfer impact forces to the button and while allowing the base portion to move thereon when rotating.

[0055] The invention is of course not in any way restricted to the embodiments described above, but many possibilities to modifications thereof would be apparent to a person with skill in the art without departing from the scope of the invention as defined in the appended claims.

[0056] The number and positions of the buttons of the rock drill bit may differ a lot with respect to the embodiments shown in the figures.

[0057] "Substantially" used in the expressions "substantially a frusto-conical shape" and "substantially circumferential ring" also cover the case when cutting recesses or grooves and/or gauge buttons intersect the ring, as shown in the figures.

[0058] The disclosures in EP Patent Application No. 10178387.6, from which this application claims priority, are incorporated herein by reference.

1. A rock drill bit for percussive drilling comprising a bit head attached at an end of a drill element of a drilling assembly and having a diameter larger than a diameter of said drill element, said bit head having a front end and as seen in the intended drilling direction a plurality of buttons at the front end and distributed over said bit head and configured to engage material to be crushed wherein at least one of said buttons is allowed to rotate about its own symmetry axis.

2. A rock drill bit according to claim **1**, wherein said plurality of buttons include gauge buttons distributed along the circumference of said bit head and configured to determine the diameter of a hole to be drilled by the rock drill bit, wherein at least one of said gauge buttons is allowed to rotate about its own symmetry axis.

3. A rock drill bit according to claim **2**, further comprising a first member having a substantially circumferential ring surface defining a substantially frusto-conical shape as seen in the intended drilling direction, and wherein said at least one gauge button has a base portion resting on said ring surface configured to transfer impact forces to the at least one gauge button and to allow said base portion to move thereon when rotating.

4. A rock drill bit according to claim **3**, further comprising a second member defining said front end of said bit head and having said plurality of gauge buttons extending out thereof, and wherein said at least one rotating gauge button is arranged in a hole in said second member and allowed to move with respect to walls defining said hole when rotating.

5. A rock drill bit according to claim **4**, wherein said at least one rotating gauge button has a base portion with a larger cross-section than the rest of the plurality of gauge buttons, and wherein at least a part of said hole in said second member has a cross-sectional area being smaller than that of said base portion so as to maintain the gauge button received in said second member.

6. A rock drill bit according to claim **5**, wherein said hole is a through hole, and said gauge button is arranged with the base portion thereof on a rear side of said hole as seen in the intended drilling direction.

7. A rock drill bit according to claim **3**, wherein said first member has means configured to secure said first member to said drill element.

8. A rock drill bit according to claims **4**, further comprising means configured to secure said second member to said first member.

9. A rock drill bit according to claim **8**, wherein said means configured to secure said second member to said first member is configured to releasably secure the members to each other.

10. A rock drill bit according to claim **3**, wherein said first member is a ring configured to be supported on and/or secured to an end of a said drill element.

11. A rock drill bit according to claim **4**, further comprising means for securing said second member and said rock drill bit to a said drill element.

12. A rock drill bit according to claim **2**, wherein a majority of said gauge buttons are is allowed to rotate about their respective symmetry axes.

13. A rock drill bit according to claim **2**, wherein all of said gauge buttons of the rock drill bit are allowed to rotate about their respective symmetry axes.

14. A rock drill bit according to claim **1**, wherein said bit head has a front surface provided with a plurality of front buttons configured to engage material to be crushed.

15. A rock drill bit according to claim **14**, wherein at least one of said plurality of front buttons is allowed to rotate about its respective symmetry axis.

16. A rock drill bit according to claim **15**, wherein said at least one front button has a design similar to that of said at least one gauge button, said second member being configured to receive said at least one front button similarly to said at least one gauge button.

17. A rock drill bit according to claim **15**, wherein a majority of said front buttons or all said front buttons are allowed to rotate about their respective symmetry axis.

18. A rock drill bit according to claim **1**, further comprising a flush channel extending through said bit head and having at least one flushing hole opening at said front end and passing the circumference of at least one of said buttons and being allowed to rotate about its respective symmetry axis.

19. A rock drill bit according to claim **1**, wherein said at least one rotating button is arranged in a hole in said bit head and allowed to move with respect to walls defining said hole when rotating, said at least one button being provided with a circumferential annular groove and said walls defining said hole having a female member, wherein the rock drill bit includes means configured to engage said groove and said female member so as to lock said button in said hole while allowing it to rotate.

20. A rock drill bit according to claim **19**, wherein said female member is an annular groove located in said hole walls, and said engaging means comprises a ring of elastic material.

21. A rock drill bit according to claim **19**, wherein said engaging means comprise a pin configured to be pushed into said groove and said female member for being fixed with respect to said bit head and to lock said button in said hole while allowing it to rotate.

22. A drilling assembly for percussive rock drilling comprising:

a rock drill bit;

power means configured to act upon said rock drill bit to rotate the drill bit and carry out impacts for engaging material to be crushed; and

a control arrangement to control the operation of said power means.

23. A drilling assembly according to claim **22**, wherein the control arrangement controls said power means to obtain a frequency of said impacts exceeding 250 Hz, exceeding 350 Hz or being in the range of 350 Hz-1000 Hz.

24. (canceled)

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