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**Drill string cartridge back-cut stabiliser tool**

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## ABSTRACT

A drill string stabiliser and back-cut tool, the tool being in the form of a cartridge and configured for mounting to an upper portion of a bottom hole assembly for resizing a borehole as the drill string is extracted, the tool comprising an elongate cartridge body including a wear surface proximal of the tool toward the string and a plurality of cutting elements disposed distally of the wear surface and radially and axially staggered with respect to the borehole, wherein the wear surface is configured for the engagement of the wear surface with the borehole to direct the tool within the borehole during drilling to reduce damaging contact between the cutting elements and side formations of the borehole.

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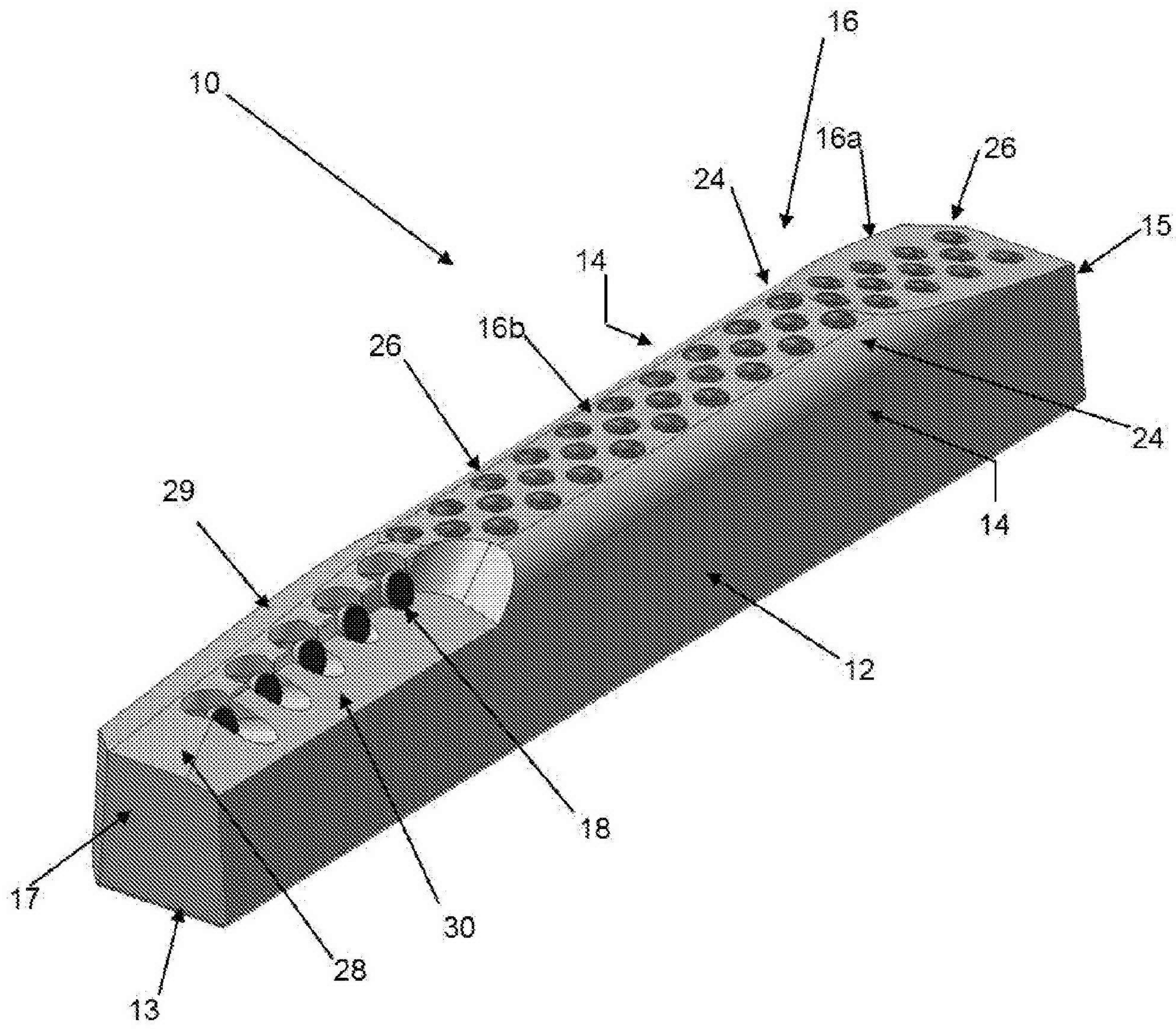


FIGURE 1

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# DRILL STRING CARTRIDGE BACK-CUT STABILISER TOOL

## FIELD OF THE INVENTION

The present invention relates to a drill string back-cut stabiliser tool in the form of a cartridge. The present invention also relates to a drill string stabiliser and bi-directional reaming tool which can cut in forward and backward directions.

## BACKGROUND OF THE INVENTION

Boreholes can be drilled as vertical and horizontal holes, and prior art provides sufficient technology to frequently achieve continued alignment along a single axis, both when the drilling string penetrates the ground and upon withdrawal. The general construction of commercially successful roller rotary reamers are shown in the applicant's Australian patent nos. 594885 and 675186.

However difficulties are encountered when boreholes are drilled firstly vertically downwardly, and then curve to an inclined or horizontal direction, and maintaining of complete control is very important but very difficult to achieve. A borehole drilling bit may at some time in its operation cut the hole undersize due to wear of gauge on the bit. This is slightly improved by the use of rotary roller reamers. The borehole reamers which are generally used employ reamer bodies which are generally cylindrical and rotatable about longitudinal cylindrical axes, each body having recesses which extend inwardly from the body outer surface, and those recesses contain freely rotatable reamer rollers, each reamer body being rotatable over a fixed spindle.

Relevant prior art to this invention and known to the Applicant is its own Australian Patent no. 594885 and International Patent Application no. PCT/AU94/00691. The former Application discloses a reamer having a plurality of hard inserts projecting therefrom (or continuous with the outer surface of the reamer in some instances), and the reamer was carried in respective end blocks in a recess in a reamer body. The arrangement for retention of the blocks utilising wedge surfaces was an important aspect of that invention. The second Application PCT/AU94/00691 related primarily to improvements in lubrication, but in this invention the features of the latter Application are not used. However even with the improvements which have been disclosed in the above specifications, difficulty is still encountered when the drill bit is required to traverse a curve, particularly upon withdrawal, when the string tends to straighten. The tendency to straighten sometimes causes the drill string to lock into the borehole, whereupon abandonment is unavoidable. This sometimes occurs even when a curve is not intentionally traversed. Since the cost of a drill string is very high, it is the main object of this invention to provide improvements which will make it easier to withdraw a drill string when in a tight borehole.

So as to maintain control of the drill string, it is known to use a stabiliser tool having projecting wear pad assemblies. Generally a stabiliser tool includes recesses containing projecting pad assemblies arranged in a spaced configuration, with each pad assembly generally having two outer blocks and a central wedge block. The recesses have at least two side walls that diverge radially inwardly by an included angle providing an undercut recess surface. An example of such a stabiliser tool can be found in the Applicant's prior patent AU774745.

Despite previous advances in borehole drilling, such as those mentioned above, there is still a need to improve removal of a drill string and prevent it becoming stuck in a borehole. AU774745 proposes tipped cutters on a stabilisation tool, however, although effective at facilitating removal of the drill string, the cutters can be damaged in use, rendering them ineffective when required.

Examples of the invention seek to solve, or at least ameliorate, one or more disadvantages of previous stabiliser tools or to at least provide a useful alternative.

**SUMMARY OF THE INVENTION**

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According to one aspect of the present invention, there is provided a drill string stabiliser and back-cut tool, the tool being in the form of a cartridge and configured for mounting to an upper portion of a bottom hole assembly for resizing a borehole as the drill string is extracted, the tool comprising an elongate cartridge body including a wear surface proximal of the tool toward the string and a plurality of cutting elements disposed distally of the wear surface and radially and axially staggered with respect to the borehole, wherein the wear surface is configured for the engagement of the wear surface with the borehole to direct the tool within the borehole during drilling to reduce damaging contact between the cutting elements and side formations of the borehole, wherein the cartridge body includes a locking face having a tapered side wall and is configured for receipt in a recess configured for receiving a rotary roller reamer, and wherein the cartridge body is configured for being wedge locked into position using a pair of wedge locks that engage with the locking face and are secured to the drill string so that the cartridge body is securely fixed to the drill string in use.

According to a preferred embodiment, the wear surface is tapered and reduces in size in a drilling direction. Preferably, the tool further comprises a first deflection surface extending along a side of the tool for deflecting debris away from the cutting elements during drilling of the borehole. Preferably, the first deflection surface is a generally planar inclined surface which is parallel to and offset from a longitudinal axis of the drill string so as to present the first deflection surface to a wall of the borehole during drilling.

The tool can further comprise a second deflection surface extending along a side of the tool for deflecting material toward the cutting elements during extraction from the borehole. The second deflection surface can be a generally planar inclined surface which is parallel to and offset from a longitudinal axis of the drill string so as to present the second deflection surface to a wall of the borehole during drilling.

According to another aspect of the present invention, there is provided a drill string stabiliser and reaming tool, the tool being in the form of a cartridge and configured for mounting to a bottom hole assembly for resizing a borehole as the drill string is advanced or extracted in the borehole, the tool comprising an elongate cartridge body including forward and rearward reaming sections, each including a plurality of cutting elements radially and axially staggered with respect to the borehole, and a wear surface between the reaming sections, wherein the wear surface is configured for the engagement of the wear surface with the borehole to direct the tool within the borehole during drilling to reduce damaging contact between the cutting elements and side formations of the borehole, wherein the cartridge body includes a locking face having a tapered side wall and is configured for receipt in a recess configured for receiving a rotary roller reamer, and wherein the cartridge body is configured for being wedge locked into position using a pair of wedge locks that engage with the locking face and are secured to the drill string so that the cartridge body is securely fixed to the drill string in use.

The wear surface can have a plurality of wear elements arranged on the wear surface. Preferably, the wear elements are tungsten carbide discs fixed to or within the cartridge body.

According to another aspect of the present invention, there is provided a kit comprising three tools of the above described type, wherein the cutting elements of each tool are axially offset.

According to another aspect of the present invention, there is provided a drill string comprising at least three tools or a kit of the above described type, each tool being circumferentially spaced about an upper portion of the drill string.

The drill string can further comprise a plurality of rotary roller reamers disposed on the drill string at a location below the tools.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Preferred embodiments of the invention will be further described, by way of non-limiting example only, with reference to the accompanying drawings in which:

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Figure 1 is a perspective view of a drill string stabiliser and back-cut tool of one embodiment of the invention;Figure 2 is another perspective view of the tool and lockdown wedges for fixing the tool to a drill string body;

Figure 3 is a close side view of the tool fitted in a reamer body; and

Figure 4 is a perspective view of a drill string stabiliser and reaming tool of another embodiment of the invention.

**DETAILED DESCRIPTION**

According to a preferred embodiment of the invention there is provided a drill string stabiliser and back-cut tool 10. The tool 10 is in the form of a cartridge and configured for mounting to a reamer body 11 (see Figure 3) at an upper portion of a bottom hole assembly for resizing a borehole as the drill string is extracted so as to effectively allow the drill string to cut its way out of the borehole.

The tool 10 comprises an elongate cartridge body 12 configured for receipt in a recess of a bottom hole assembly which is ordinarily configured for receiving a rotary roller reamer, such as those disclosed in AU594885, AU705965, AU774745 or AU2004269049. Advantageously, the tool 10 can be interchanged with a rotary roller reamer in the drill string, as required. In the illustrated embodiment, the cartridge body 12 is wedge locked into position in the reamer body 11, using a pair of wedge locks 20, as illustrated in Figure 2. In this regard, the cartridge body 12 is formed with a locking faces 14 having a tapered side wall so that once inserted in the recess and base 13 is brought into contact with the drill string and the wedge locks 20 secured with bolts 22, the cartridge body 12 is securely fixed to the drill string.

The cartridge body 12 has a wear surface 16, collectively illustrated as 16a and 16b, proximal of the tool (near lower end face 15 and toward the drill bit) and a plurality of cutting elements 18 disposed distally of the wear surface 16 (toward upper end face 17). The wear surface 16 is configured to direct the stabilisation tool 10 within the borehole during drilling into the hole and retracting out of the hole to reduce damaging contact between the cutting elements 18 and side formations. Those skilled in the art will appreciate that during retraction the wear surface 16 will first contact any side formations, before the cutting elements 18 do, so as to direct the tool over the formations and prevent, or at least reduce the likelihood of, damaging the cutting elements 18.

In the illustrated embodiment, the wear surface 16 is tapered and reduces in size in a drilling direction to provide a guide when drilling by engagement of the wear surface 16 with the borehole. In some embodiments, the wear surface 16 may be generally planer, though with rounded edges 24 to effectively wipe the walls of the borehole. In other embodiments, such as those illustrated, the wear surface 16 may include two portions 16a, 16b to progressively guide the tool 10 within the borehole during drilling.

The wear surface 16 may be formed of hardened steel to reduce wear, though in the described embodiment it is formed of mild steel and provided with a plurality of wear elements 26 arranged on the wear surface 16. It will be appreciated that the wear elements 26 may be formed of many different materials, though are preferably tungsten carbide discs or buttons fixed to or within the cartridge body 12. In this regard, the wear elements 26 may be secured to the wear surface 16 or received and secured within recesses formed in the cartridge body 12. In some embodiments, the wear elements 26 are replaceable. It will also be appreciated that the wear elements 26 may take other forms and shapes, such as elongate or linear members for example.

The cutting elements 18 are radially and axially staggered with respect to the borehole. In this regard, as illustrated in Figure 3, a distal most cutting element 18e, which is closer to the bottom hole assembly, is disposed radially outermost with respect to the other cutting elements 18a, 18b, 18c, 18d. A proximal most cutting element 18a, which is furthest from the bottom hole assembly is disposed radially innermost with respect to the other cutting elements 18b, 18c, 18d and 18e. Cutting elements 18b, 18c, and 18d are preferably disposed in a liner progression between innermost cutting element 18a and outermost cutting element 18e, though may be otherwise staggered, such as along a curved path for example. The result of such an arrangement is that the cutting elements 18 are configured to progressively resize the borehole so that the drill string can effectively cut its way out of the borehole, much quicker than previously possible with a rotary roller reamer. In progressively resizing the hole, cutting element 18a first contacts the wall of the borehole, then cutting elements 18b, 18c, 18d and then 18e.

In preferred embodiments, the cutting elements 18 are formed of polycrystalline diamond, though it will be appreciated that other commercially available materials may also be used.

The number of cutting elements used is chosen having regard to the particular application and size of the borehole. As the cutting elements 18 progressively widen the borehole, it has been found that five cutting elements works sufficiently well. However, although five cutting elements are used in the illustrated embodiments, it will appreciated that in other embodiments, more cutting elements, such as six or seven for example, or less than five, such as three or four for example, may also be used. Furthermore, a single cutting element having a plurality of cutting surfaces may similarly be provided. Such a cutting element may be formed so as to be interchangeable with the cutting elements 18a to 18e illustrated.

Also, the angle of inclination of the cutting elements 18 may be chosen having regard to the particular application and size of the borehole. In the present example, cutting elements 18 are angled in a plane which is parallel to a longitudinal axis of the drill string and inclined relative to the longitudinal axis at an angle in the range of 4 to 8 degrees, and preferably at 6 degrees. In some embodiments, it may be desirable to angle the cutting elements 18 relative to a leading edge of the drill string, at an angle in the range of 0 to 25 degrees, and preferably at 20 degrees.

Also, the size of the cutting elements 18 may be chosen having regard to the particular application and size of the borehole. In the present example, cutting elements having a 13mm diameter may be used, though larger cutting elements having a 24mm diameter for example, or smaller cutting elements having a diameter less than 13mm, may also be used.

Behind the cutting elements 18, when operating in a rotational direction during extraction, there is provided a first deflection surface 28 extending along a side of the tool 10 at least at portion of the tool 10 near the cutting elements 18 for deflecting debris away from the cutting elements 18 during drilling of the borehole. In front of the cutting elements 18, when operating in a rotational direction during extraction, a second deflection surface 30 extending along a side of the tool 10 at least at a portion of the tool 10 near the cutting elements, is provided for deflecting material toward the cutting elements 18 during extraction from the borehole.

The first deflection surface 28 is provided with a relief surface in the form of an angled face 29. The first deflection surface 28 is configured for protecting the cutting elements 18, while the second deflection surface 30 is provided for directing material onto the cutting elements. In the illustrated embodiment, both the first and second deflection surfaces 28, 30 are generally planar inclined surfaces which are parallel to and offset from a longitudinal axis of the drill string. The first deflection surface 28 is inclined so as to present the first deflection surface 28 to a wall of the borehole during drilling. The second deflection surface 30 is oppositely orientated and inclined so as to present the second deflection surface 30 to a wall of the borehole during drilling.

Although illustrated as generally planar, either or both of the first or second deflection surfaces 28, 30 may also be curved and they may also be inclined relative to a longitudinal axis of the drill string. In the illustrated embodiment, the first deflection surface 28 is formed with a longitudinal taper to match the progressively varying radial displacement of the cutting elements 18 and provide a lead-in to the first cutting element 18a in use, to reduce the chance of the cutting element 18a becoming damaged from large impacts. The angled lead-in portion of the first deflection surface 28 may also be provided with a wear and/or stabilising surface, which may or may not be configured in the same or a similar manner to wear surface 16 described above. To prevent jamming of the drill string, the second deflection surface 30 has a curved taper as it transitions to the wear surface 16.

Figure 4 illustrates tool 110 according to another preferred embodiment of the invention. Tool 110 shares common features with tool 10 and like features are labelled with like numbers incremented by 100.

Tool 110 is a drill string stabiliser and bidirectional reaming tool and is configured for cutting as the drill string is advanced or retracted in the borehole. Tool 110 is also in the form of a cartridge and configured for mounting to a reamer body 11 (see Figure 3) of a bottom hole assembly for resizing a borehole as the drill string is advanced or extracted in the borehole, to effectively allow the drill string to cut its way into or out of the borehole.

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Tool 110 can be fitted anywhere along the drill string, though may preferably be fitted to an upper portion like tool 10.

Tool 110 also comprises an elongate cartridge body 112 configured for receipt in a recess of a bottom hole assembly which is ordinarily configured for receiving a rotary roller reamer, such as those disclosed in AU594885, AU705965, AU774745 or AU2004269049. Advantageously, the tool 110 can be interchanged with a rotary roller reamer in the drill string, as required. In the illustrated embodiment, the cartridge body 112 is wedge locked into position in the reamer body 11, using a pair of wedge locks 120. In this regard, the cartridge body 112 is formed with a locking faces 114 having a tapered side wall so that once inserted in the recess and base 113 is brought into contact with the drill string and the wedge locks 120 secured with bolts 122, the cartridge body 112 is securely fixed to the drill string.

The tool 110 includes forward and rearward reaming sections 150, 152, each including a plurality of cutting elements 118 radially and axially staggered with respect to the borehole. Between the reaming sections 150, 152 is a wear surface 116 which is configured for the engagement of the wear surface 116 with the borehole to direct the tool 110 within the borehole during drilling to reduce damaging contact between the cutting elements and side formations of the borehole.

The wear surface 116 may be generally planer, though with rounded edges 124 to effectively wipe the walls of the borehole.

The wear surface 116 may be formed of hardened steel to reduce wear, though in the described embodiment it is formed of mild steel and provided with a plurality of wear elements 126 arranged on the wear surface 116. It will be appreciated that the wear elements 126 may be formed of many different materials, though are preferably tungsten carbide discs or buttons fixed to or within the cartridge body 112. In this regard, the wear elements 126 may be secured to the wear surface 116 or received and secured within recesses formed in the cartridge body 112. In some embodiments, the wear elements 126 are replaceable. It will also be appreciated that the wear elements 126 may take other forms and shapes, such as elongate or linear members for example.

The cutting elements 118 are radially and axially staggered with respect to the borehole. Cutting element 118d, which is closest to the wear surface 116 on both the reaming sections 150, 152 is disposed radially outermost with respect to the other cutting elements 118a, 118b, 118c. An outermost cutting element 118a, which is furthest from wear surface 116 on both the reaming sections 150, 152 is disposed radially innermost with respect to the other cutting elements 118b, 118c and 118d. Cutting elements 118b and 118c are preferably disposed in a liner progression between innermost cutting element 118a and outermost cutting element 118d, though may be otherwise staggered, such as along a curved path for example. The result of such an arrangement is that the cutting elements 118 are configured to progressively resize the borehole so that the drill string can effectively cut its way into or out of the borehole, much quicker than previously possible with a rotary roller reamer. In progressively resizing the hole, cutting element 118a first contacts the wall of the borehole, then cutting elements 118b, 118c and then 118d, whether the drill string is being advanced or retracted.

In preferred embodiments, the cutting elements 118 are formed of polycrystalline diamond, though it will be appreciated that other commercially available materials may also be used. The number of cutting elements used is chosen having regard to the particular application and size of the borehole. As the cutting elements 118 progressively widen the borehole, it has been found that five cutting elements works sufficiently well for a back-cut tool and four cutting elements for each end of a bi-directional tool. Although four cutting elements are used in the illustrated embodiments, it will appreciated that in other embodiments, more cutting elements, such as five, six or seven for example, or less than four, such as two or three for example, may also be used. Furthermore, a single cutting element having a plurality of cutting surfaces may similarly be provided. Such a cutting element may be formed so as to be interchangeable with the cutting elements 118a to 118d illustrated.

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Also, the angle of inclination of the cutting elements 118 may be chosen having regard to the particular application and size of the borehole. In the present example, cutting elements 118 are angled in a plane which is parallel to a longitudinal axis of the drill string and inclined relative to the longitudinal axis at an angle in the range of 4 to 8 degrees, and preferably at 6 degrees. In some embodiments, it may be desirable to angle the cutting elements 118 relative to a leading edge of the drill string, at an angle in the range of 0 to 25 degrees, and preferably at 20 degrees.

Also, the size of the cutting elements 118 may be chosen having regard to the particular application and size of the borehole. In the present example, cutting elements having a 13mm diameter may be used, though larger cutting elements having a 24mm diameter for example, or smaller cutting elements having a diameter less than 13mm, may also be used.

Behind the cutting elements 118, when operating in a rotational direction during insertion, there is provided a first deflection surface 128 extending along a side of the tool 110 so that at least at portion of the tool 110 near the cutting elements 118 is configured for deflecting debris away from the cutting elements 118 during drilling of the borehole. In front of the cutting elements 118, when operating in a rotational direction during extraction, a second deflection surface 130 extending along a side of the tool 110 at least at a portion of the tool 110 near the cutting elements, is provided for deflecting material toward the cutting elements 118 during extraction from the borehole.

The first deflection surface 128 is provided with a relief surface in the form of an angled face 129. The first deflection surface 128 is configured for protecting the cutting elements 118, while the second deflection surface 130 is provided for directing material onto the cutting elements. In the illustrated embodiment, both the first and second deflection surfaces 128, 130 are generally planar inclined surfaces which are parallel to and offset from a longitudinal axis of the drill string. The first deflection surface 128 is inclined so as to present the first deflection surface 128 to a wall of the borehole during drilling. The second deflection surface 130 is oppositely orientated and inclined so as to present the second deflection surface 130 to a wall of the borehole during drilling.

Although illustrated as generally planar, either or both of the first or second deflection surfaces 128, 130 may also be curved and they may also be inclined relative to a longitudinal axis of the drill string. In the illustrated embodiment, the first deflection surface 128 is formed with a longitudinal taper to match the progressively varying radial displacement of the cutting elements 118 and provide a lead-in to the first cutting element 118a in use, to reduce the chance of the cutting element 118a becoming damaged from large impacts. The angled lead-in portion of the first deflection surface 128 may also be provided with a wear and/or stabilising surface, which may or may not be configured in the same or a similar manner to wear surface 116 described above. To prevent jamming of the drill string, the second deflection surface 130 has a curved taper as it transitions to the wear surface 116.

In use, three tools 10, 110 circumferentially spaced 120 degrees around the drill string are used. Each of the tools 10, 110 used may be slightly differently configured to optimise extraction-cutting as adjacent tools subsequently contact formations on the borehole wall. One example of such optimisation is that the cutting elements 18, 118 of each tool are axially offset so that each tools 10, 110 is configured to cut a slightly different, helical path. The offset of the cutting elements 18, 118 will be determined having regard to the size of the cutting elements. In examples having 13mm cutting elements 18, 118, the axial offset may be approximately 00.3”. In examples having larger cutting elements the axial offset may be larger.

The tool 10, 110 may be supplied in a kit or package of three similar tools. By providing the tool 10, 110 in this manner, and in a cartridge body 12, 112 configured for receipt in a recess for a rotary roller reamer, the tool 10, 110 may be selectively used and required and easily interchangeable. The tool 10, 110 may also be used in conjunction with rotary roller reamers fitted to the drill string.

In other embodiments, the tool 10, 110 may be installed in a separate body for connection to an upper portion of the drill string, which may or may not already be fitted with rotary roller reamers.

The embodiments have been described by way of example only and modifications are possible within the scope of the invention disclosed.

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that the prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

Throughout this specification and claims which follow, unless the context requires otherwise, the word “comprise”, and variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers or steps but not the exclusion of any other integer or group of integers.

**CLAIMS**

1. A drill string stabiliser and back-cut tool, the tool being in the form of a cartridge and configured for mounting to an upper portion of a bottom hole assembly for resizing a borehole as the drill string is extracted, the tool comprising an elongate cartridge body including a wear surface proximal of the tool toward the string and a plurality of cutting elements disposed distally of the wear surface and radially and axially staggered with respect to the borehole, wherein the wear surface is configured for the engagement of the wear surface with the borehole to direct the tool within the borehole during drilling to reduce damaging contact between the cutting elements and side formations of the borehole, wherein the cartridge body is configured for receipt in a recess configured for receiving a rotary roller reamer, and wherein the cartridge body includes a locking face having a tapered side wall and is configured for being wedge locked into position using a pair of wedge locks that engage with the locking face and are secured to the drill string so that the cartridge body is securely fixed to the drill string in use.

2. A tool according to claim 1, wherein the wear surface is tapered and reduces in size in a drilling direction.

3. A tool according to claim 1 or claim 2, further comprising a first deflection surface extending along a side of the tool for deflecting debris away from the cutting elements during drilling of the borehole.

4. A tool according to claim 3, wherein the first deflection surface is a generally planar inclined surface which is parallel to and offset from a longitudinal axis of the drill string so as to present the first deflection surface to a wall of the borehole during drilling.

5. A tool according to any preceding claim, further comprising a second deflection surface extending along a side of the tool for deflecting material toward the cutting elements during extraction from the borehole.

6. A tool according to claim 5, wherein the second deflection surface is a generally planar inclined surface which is parallel to and offset from a longitudinal axis of the drill string so as to present the second deflection surface to a wall of the borehole during drilling.

7. A drill string stabiliser and reaming tool, the tool being in the form of a cartridge and configured for mounting to a bottom hole assembly for resizing a borehole as the drill string is advanced or extracted in the borehole, the tool comprising an elongate cartridge body including forward and rearward reaming sections, each including a plurality of cutting elements radially and axially staggered with respect to the borehole, and a wear surface between the reaming sections, wherein the wear surface is configured for the engagement of the wear surface with the borehole to direct the tool within the borehole during drilling to reduce damaging contact between the cutting elements and side formations of the borehole, wherein the cartridge body includes a locking face having a tapered side wall and is configured for receipt in a recess configured for receiving a rotary roller reamer, and wherein the cartridge body is configured for being wedge locked into position using a pair of wedge locks that engage with the locking face and are secured to the drill string so that the cartridge body is securely fixed to the drill string in use.

8. A tool according to any preceding claim, wherein the wear surface has a plurality of wear elements arranged on the wear surface.

9. A tool according to claim 8, wherein the wear elements are tungsten carbide discs fixed to or within the cartridge body.

10. A kit comprising three tools according to any preceding claim, wherein the cutting elements of each tool are axially offset.

11. A drill string comprising at least three tools according to any one of claims 1 to 9 or the kit claim 10, each tool being circumferentially spaced about an upper portion of the drill string.

12. A drill string according to claim 11, further comprising a plurality of rotary roller reamers disposed on the drill string at a location below the tools.

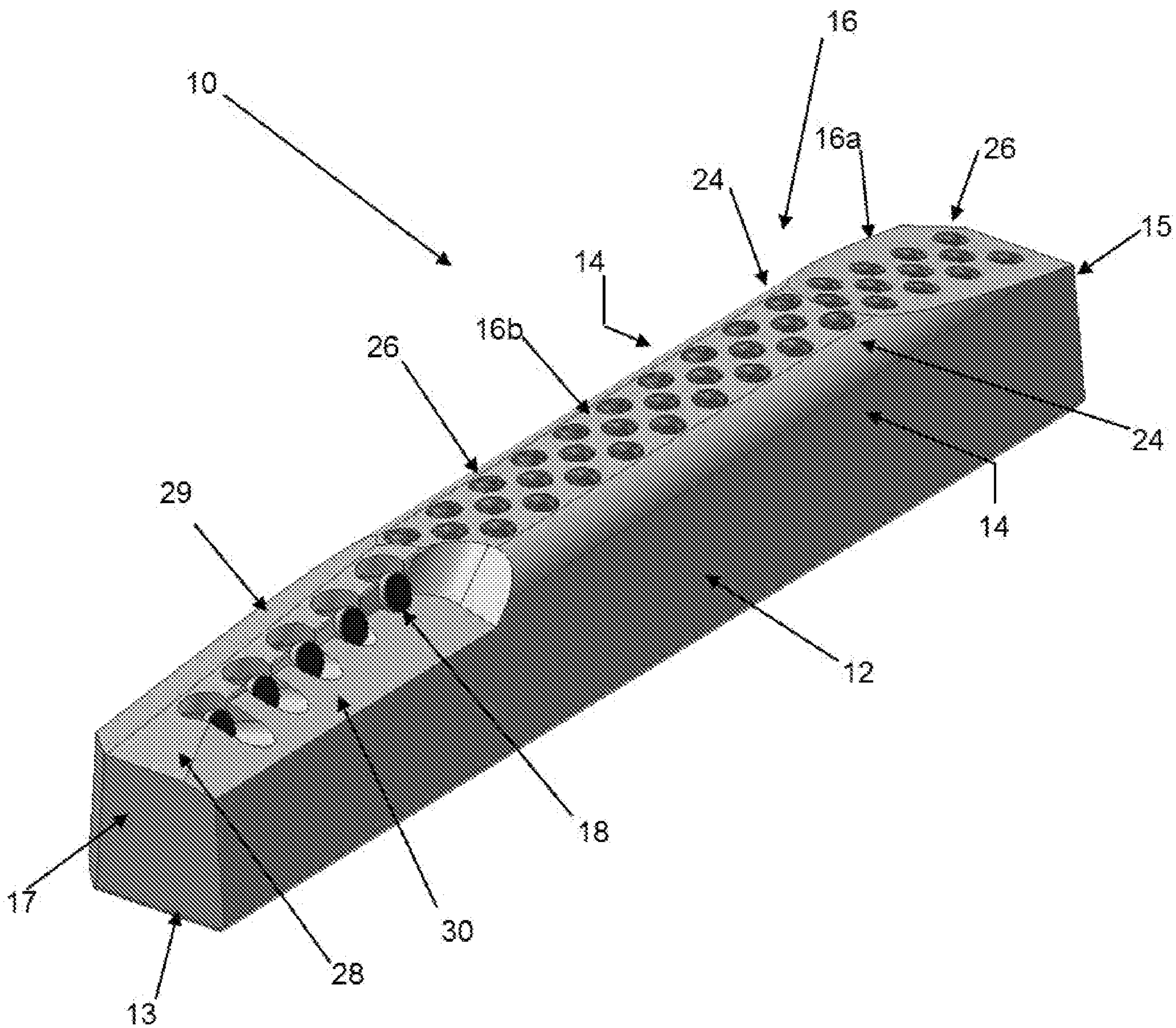


FIGURE 1

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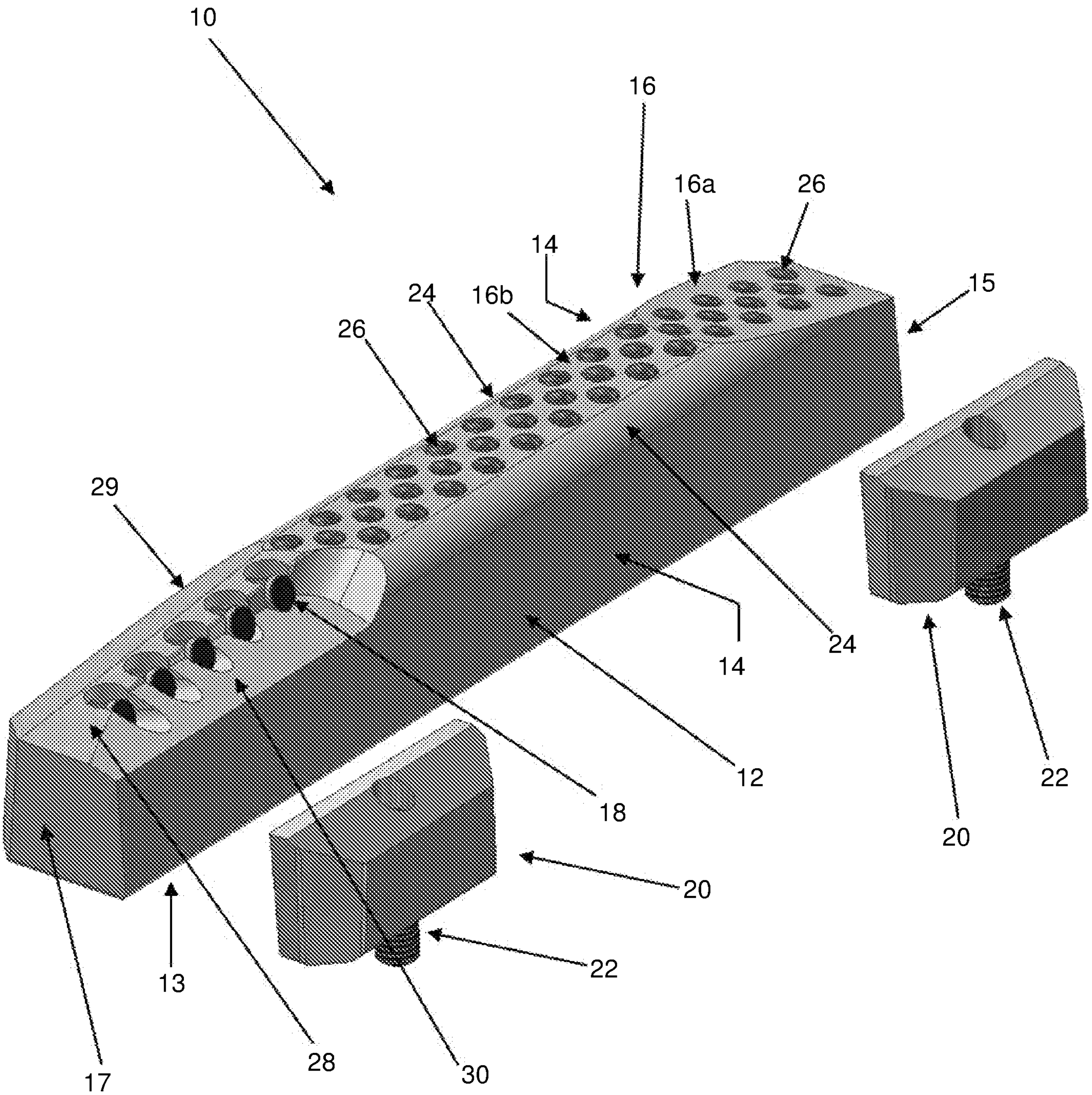


FIGURE 2

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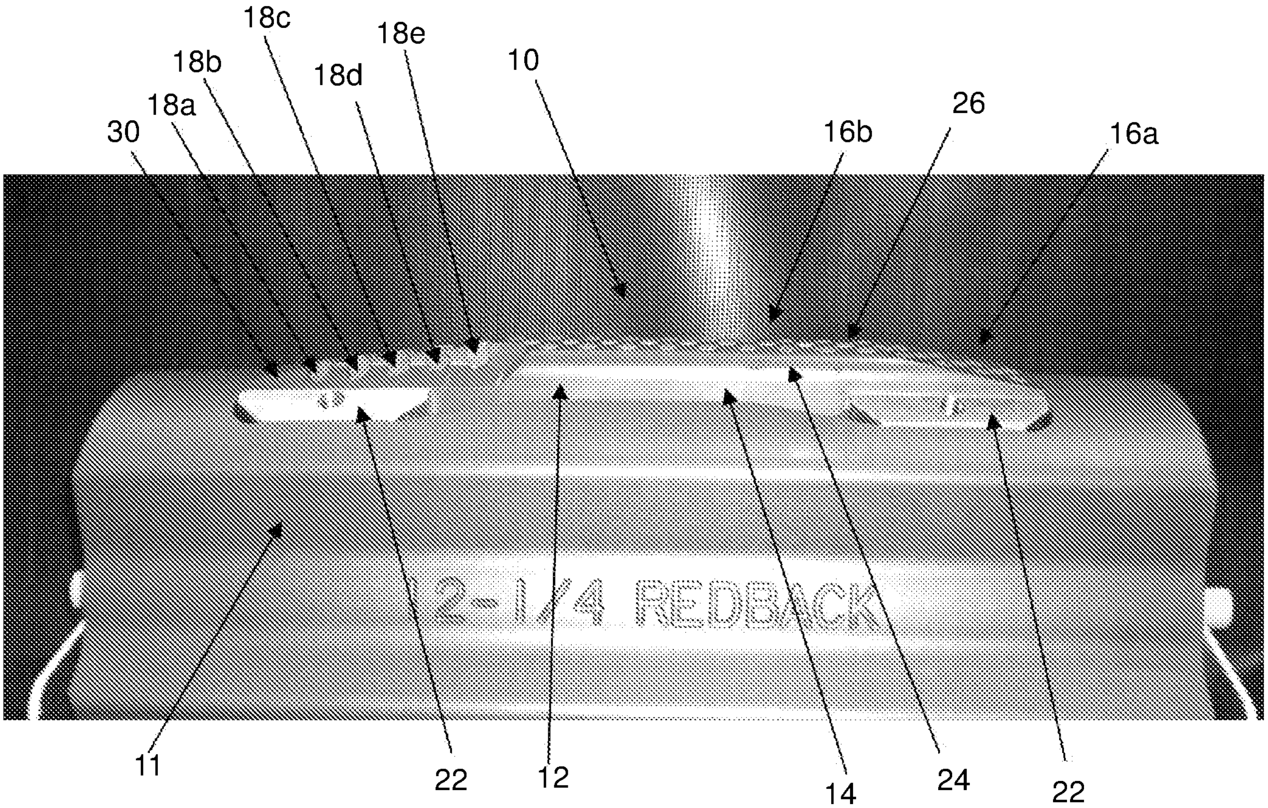


FIGURE 3

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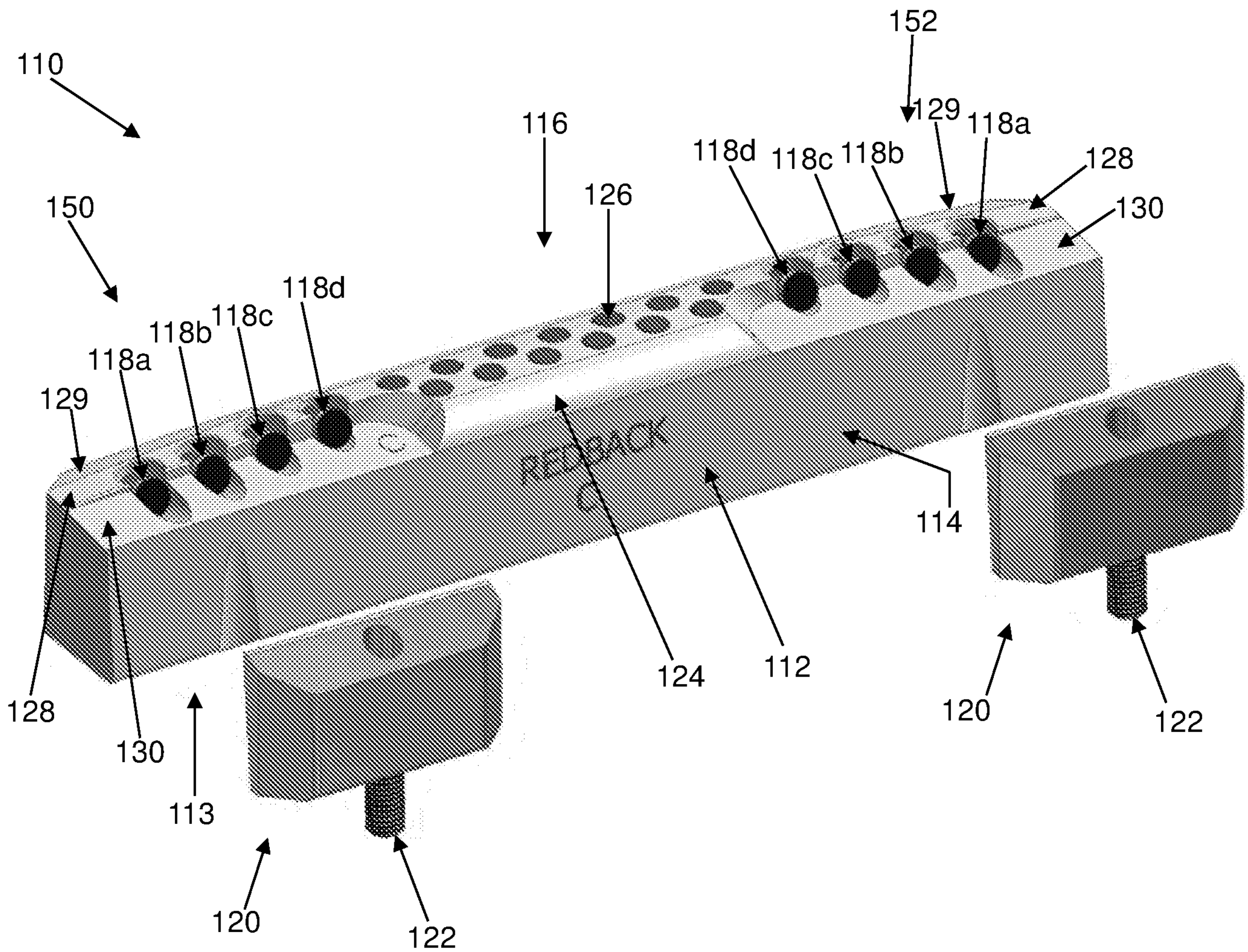


FIGURE 4