A downhole tool has a body with a bore formed at least partially therethrough. A cutter block may be coupled to the body and move radially outward from the body in response to an increased pressure in the bore. The cutter block may include an outer surface that transitions from a first portion to a second portion, with the first portion being downhole of the second portion. A radius of curvature between the first and second portions may be less than about 7 cm. The second portion or a line tangential thereto may be oriented at an angle from about 60° to about 120° with respect to a central longitudinal axis of the body. A plurality of cutting elements may be disposed on the outer surface of the cutter block. At least one of the cutting elements may be disposed at least partially on the first or second portion of the outer surface.

Related U.S. Application Data

Provisional application No. 61/908,597, filed on Nov. 25, 2013.
CUTTER BLOCK FOR A DOWNHOLE UNDERREAMER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. provisional application 61/908,597 filed Nov. 25, 2013, the entirety of which is incorporated by reference.

FIELD OF THE INVENTION

[0002] Aspects relate to drilling wellbores. More specifically, aspects relate to cutter blocks for downhole reamers.

BACKGROUND

[0003] After a subterranean bore is drilled, an underreamer is oftentimes used to enlarge the diameter of the bore. The underreamer is run into the bore in a retracted state. In the retracted state, one or more cutter blocks of the underreamer are folded into the body of the underreamer such that the cutter blocks are positioned radially-inward from the surrounding casing or bore wall. Once the underreamer reaches the desired depth in the bore, the underreamer is actuated into an expanded state. In the expanded state, the cutter blocks move radially-outward and into contact with the bore wall.

[0004] The cutter blocks each include a plurality of cutting elements designed to remove or displace rock through shearing fracture and/or brittle fracture to increase the diameter of the bore. The cutting elements remove rock through shearing fracture by gouging into the rock formation and volumetrically displacing the rock by compressing and fracturing the rock along local, leading shear planes. The cutting elements remove rock through brittle fracture by penetrating into the rock formation, which causes cracks to propagate and radiate outwardly. The cracks may join or combine with other proximate cracks, allowing a greater amount of rock to be removed than through shearing fracture.

[0005] Conventional cutter blocks have the cutting elements disposed thereon in a gradual bore enlarging profile. Cutting elements arranged in this manner, however, may lead to an overreliance on shearing fracture (as opposed to brittle fracture) for rock removal. As a result, the amount of rock that is removed per unit time (and energy) is not optimized. In addition, conventional cutter blocks have cutting elements disposed on a relatively large portion of the axial length of the cutter blocks. This increases the lateral forces generated during drilling operations, which causes instability of the underreamer. This instability leads to a reduced drilling efficiency (i.e., a lower rate of penetration or “ROP”). What is needed, therefore, is an improved system and method for enlarging the diameter of a bore, e.g., a wellbore or borehole.

SUMMARY

[0006] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

[0007] A cutting tool is disclosed. The cutting tool may have a body. A cutter block may be coupled to the body and move radially outward from the body. The cutter block may include an outer surface that transitions from a first portion to a second portion, the first portion and the second portion remaining stationary relative to each other with the first portion being downhole of the second portion. A radius of curvature between the first and second portions may be less than about 7 cm. The second or more uphole portion or a line tangential thereto may be oriented at an angle from about 60° to about 120° with respect to a central longitudinal axis of the body. A plurality of cutting elements may be disposed on the outer surface of the cutter block. At least one of the cutting elements may be disposed at least partially on the first or second portion of the outer surface.

[0008] In another implementation, a downhole tool may include a body. A cutter block may be coupled to the body and move radially outward from the body. The cutter block may include an outer surface that transitions from a first portion to a second portion, the first portion and the second portion remaining stationary relative to each other with the first portion defined as being downhole of the second portion. An angle between the first portion or a line tangential thereto and the second portion or a line tangential thereto may be from about 60° to about 120°. The second portion or the line tangential thereto may be oriented at an angle from about 60° to about 120° with respect to a central longitudinal axis of the body. A plurality of cutting elements may be disposed on the outer surface of the cutter block. At least one of the cutting elements may be disposed at least partially on the second portion of the outer surface.

[0009] In yet another implementation, the downhole tool may include a body. A cutter block may be coupled to the body and move radially outward from the body. A plurality of cutting elements may be disposed at least partially on the outer surface of the cutter block. At least 50% of the cutting elements may be positioned between first and second points along a length of the cutter block. A distance between the first and second points may be 30% of the length of the cutter block, and the first point may be at a downhole end portion of the cutter block.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the recited features may be understood in detail, a more particular description, briefly summarized above, may be had by reference to one or more implementations, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings are illustrative implementations, and are, therefore, not to be considered limiting of its scope.

[0011] FIG. 1 depicts a cross-section side view of an illustrative downhole tool for increasing a diameter of a wellbore, according to one or more implementations disclosed.

[0012] FIG. 2 depicts a perspective view of an illustrative cutter block of the downhole tool shown in FIG. 1, according to one or more implementations disclosed.

[0013] FIG. 3 depicts a portion of a leading side surface of the cutter block shown in FIG. 2.

[0014] FIG. 4 depicts a portion of an outer surface of the cutter block shown in FIG. 2.

[0015] FIG. 5 depicts a plan view of the lower end portion of the cutter block shown in FIG. 2.

[0016] FIG. 6 depicts a profile view of the cutting elements of three circumferentially offset cutter blocks shown in a single plane after the downhole tool has been rotated about its longitudinal axis, according to one or more implementations disclosed.
FIG. 7 depicts a view of a leading side surface of another illustrative cutter block, according to one or more implementations disclosed.

FIG. 8 depicts a view of an outer surface of the cutter block shown in FIG. 7.

FIG. 9 depicts a view of a leading side surface of another illustrative cutter block, according to one or more implementations disclosed.

DETAILED DESCRIPTION

FIG. 1 depicts a cross-sectional side view of an illustrative downhole tool 100 for increasing a diameter of a subterranean bore 180, e.g., a wellbore, borehole, subterranean tunnel or the like, according to one or more implementations. The downhole tool 100 includes an underreamer having a tool body 110 with a central longitudinal axis 111 extending therethrough. A tool bore 112 may be formed at least partially through the tool body 110. The tool body 110 may include a first or “upper” end portion 114 and a second or “lower” end portion 116.

One or more cutter blocks 200 may be movably coupled to the tool body 110. The number of cutter blocks 200 may range from about 1, 2, or 3 to about 4, 6, 8, 10, or more. For example, the tool body 110 may have three cutter blocks 200 coupled thereto that are circumferentially offset from one another. As shown in FIG. 1, the cutter blocks 200 are in a retracted position. In the retracted position, the cutter blocks 200 are folded into corresponding recesses in the tool body 110 such that the outer surfaces 240 of the cutter blocks 200 are substantially aligned with or positioned radially inward from the outer surface 118 of the tool body 110.

The cutter blocks 200 are arranged and designed to actuate from the retracted position into an expanded position. When actuating into the expanded position, the cutter blocks 200 move toward the first end portion 114 of the tool body 110 and radially outward until the outer surfaces 240 of the cutter blocks 200 are positioned radially outward from the outer surface 118 of the tool body 110. The cutter blocks may cut, grind, or scrape a wall 182 of the subterranean bore 180 to increase the diameter thereof when in the expanded position.

The downhole tool 100 may also include a chamber 120 positioned radially outward from the tool bore 112 and in fluid communication therewith. As discussed in greater detail below, a piston 122 and a drive ring 124 may be arranged and designed to move axially within the tool body 110 in response to an increased pressure in the tool bore 112 and the chamber 120. Movement of the piston 122 and drive ring 124 toward the first end portion 114 of the tool body 110 may cause the cutter block 200 to actuate from the retracted position into the expanded position. This movement also compresses a spring 126 or other biasing device positioned within the tool body 110 and adjacent the cutter block 200.

FIG. 2 depicts a perspective view of the cutter block 200 of the downhole tool 100 shown in FIG. 1, according to one or more implementations. The cutter block 200 may include a body 210 having a first or “upper” end portion 214 and a second or “lower” end portion 216. A plurality of cutting elements 220 may be disposed at least partially on the outer surface 240 of the cutter block 200. The cutting elements 220 may include polycrystalline diamond cutters (“PDCs”) or the like. The cutting elements 220 may be conical or frustoconical (i.e., stingers), shear type cutters, semi-round top (“SRT”) cutters, ballistic cutters, chisel cutters, or the like. The cutting elements 220 are adapted to cut, grind, or scrape the wall 182 of the subterranean bore 180 (see FIG. 1) to increase the diameter thereof.

A plurality of stabilizing pads or inserts 230 may be disposed on the outer surface 240 of the cutter block 200 and positioned at least partially between the cutting elements 220 and the upper end portion 214 of the cutter block 200. As shown, the stabilizing inserts 230 are positioned in two axial rows on the outer surface 240 of the cutter block 200; however, as may be appreciated, the stabilizing inserts 230 may be positioned in any orientation on the outer surface 240 of the cutter block, and any number of stabilizing inserts 230 may be used. In at least one implementation, the stabilizing inserts 230 may be or include tungsten carbide inserts, or the like. The stabilizing inserts 230 are adapted to absorb and reduce vibration between the cutter block 200 and the wall 182 of the subterranean bore 180 (see FIG. 1).

The cutter block 200 may have a plurality of splines 252 disposed on the longitudinal side surfaces 250 thereof. The splines 252 may be or include offset edges or protrusions adapted to engage and translate within corresponding grooves or channels in the tool body 110 of the downhole tool 100. The splines 252 (and the corresponding grooves) may be oriented at an angle with respect to the central longitudinal axis 111 through the tool body 110 (see FIG. 1). The angle may range from a low of about 10°, about 15°, or about 20° to a high of about 25°, about 30°, about 35°, or more. For example, the angle may be between about 10° and about 30°, about 15° and about 25°, or about 17° and about 23°. The engagement of the splines 252 and corresponding grooves enable the cutter block 200 to move with respect to the tool body 110 of the downhole tool 100 at a predetermined angle. The cutter block 200 may simultaneously move toward the first end portion 114 of the tool body 110 and radially outward at the angle discussed above (e.g., between about 15° and about 25°, or about 17° and about 23°), thereby actuating into the expanded position.

The cutter block 200 may have a length 260 (aligned with an x-axis) ranging from about 10 cm, about 20 cm, about 30 cm, about 40 cm, or about 50 cm to about 60 cm, about 80 cm, about 100 cm, about 150 cm, or more. The cutter block may have a height/depth 262 (aligned with a y-axis) ranging from about 2 cm, about 3 cm, about 4 cm, or about 5 cm to about 6 cm, about 8 cm, about 10 cm, about 15 cm, about 20 cm, or more. The cutter block 200 may have a width 264 (z-axis) ranging from about 2 cm, about 3 cm, about 4 cm, or about 5 cm to about 6 cm, about 8 cm, about 10 cm, about 15 cm, or more.

FIG. 3 depicts a view of a portion of a leading side surface 250 of the cutter block 200 shown in FIG. 2. A first portion 242 of the outer surface 240 of the cutter block 200 (or a line tangential thereto) may be substantially parallel to an inner surface 254 of the cutter block 200 and/or the longitudinal axis 111 of the downhole tool 100 (see FIG. 1). As used herein, “substantially parallel” means within +/-20° of parallel. The first portion 242 of the outer surface 240 may be a first distance 266 from the inner surface 254 of the cutter block 200.

The first portion 242 of the outer surface 240 may transition to a second portion 244 of the outer surface 240. The second portion 240 of the outer surface 240 (or a line tangential thereto) may be oriented at an angle with respect to the inner surface 254 of the cutter block 200 and/or the longitudinal axis 111 of the downhole tool 100 (for clarity, such angle is external to the cutter block 200) from about 50° to
about 150°, e.g., the angle may be about 50°, about 60°, about 70°, about 80°, about 90°, about 100°, about 110°, about 120°, about 130°, about 140°, or about 150°, or any angle therebetween. The radius of curvature from or between the first portion 242 to the second portion 244 may be less than about 20 cm, less than about 15 cm, less than about 10 cm, less than about 8 cm, less than about 6 cm, less than about 4 cm, less than about 2 cm, or less than about 1 cm. In another implementation, the first and second portions 242, 244 of the outer surface 240 (or lines tangential thereto) may be oriented at an angle with respect to one another (for clarity, such angle is external to the cutter block 200) from about 50° to about 150°, e.g., the angle may be about 50°, about 60°, about 70°, about 80°, about 90°, about 100°, about 110°, about 120°, about 130°, about 140°, or about 150°, or any angle therebetween.

The second portion 244 of the outer surface 240 may transition to a third or “gauge” portion 246 of the outer surface 240. The third portion 246 of the outer surface 240 may be substantially parallel to the inner surface 254 of the cutter block 200 and/or the longitudinal axis 111 of the downhole tool 100. The third portion 246 of the outer surface 240 may be positioned farther from the lower end portion 216 of the cutter block 200 than the first portion 242 of the outer surface 240. The radius of curvature from the second portion 244 to the third portion 246 may be less than about 20 cm, less than about 15 cm, less than about 10 cm, less than about 8 cm, less than about 7 cm, less than about 6 cm, less than about 4 cm, less than about 2 cm, or less than about 1 cm. In another implementation, the second and third portions 244, 246 of the outer surface 240 (or lines tangential thereto) may be oriented at an angle with respect to one another (for clarity, such angle is an interior angle inside of the cutter block 200 between second and third portions 244, 246 of outer surface 240) from about 50° to about 150°, e.g., the angle may be about 50°, about 60°, about 70°, about 80°, about 90°, about 100°, about 110°, about 120°, about 130°, about 140°, or about 150°, or any angle therebetween.

A distance 268 between the third portion 246 of the outer surface 240 and the inner surface 254 may be greater than the distance 266 between the first portion 242 of the outer surface 240 and the inner surface 254. A ratio of the distance 266 to the distance 268 may be from about 1.0:1.2 to about 1.0:1.5, about 1.0:1.5 to about 1.0:2.0, about 1.0:2.0 to about 1.0:2.5, about 1.0:2.5 to about 1.0:3.0, or about 1.0:3.0 to about 1.0:5.0, or any ratio therebetween.

At least 50% to as much as 100% of the cutting elements 220, e.g., at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, or as much as 100%, or any percentage therebetween, may be positioned between first and second points 273, 274 along the length 260 of the body 210 (FIG. 2). A distance 276 between the first and second points 273, 274 may be about between 10% to about 50% of the length 260 of the body 210, e.g., distance 276 may be about 10%, about 20%, about 30%, about 40%, or about 50%, or any percentage therebetween, of length 260 of body 210. As shown, the first point 273 may be at or approximate the lower end portion 216 of the body 210. Arranging the cutting elements 220 in this manner may reduce the lateral vibrations experienced by the cutter block 200 and the downhole tool 100.

A distance 270 (measured along the y-axis) between an apex of the cutting element 220, e.g., 220-1, closest to the inner surface 254 and the apex of the cutting element 220, e.g., 220-5, farthest from the inner surface 254 may range from about 0.5 cm, about 1 cm, about 1.5 cm, about 2 cm, or about 2.5 cm to about 3 cm, about 4 cm, about 5 cm, about 7.5 cm, about 10 cm, or more. For example, the distance 270 may be from about 0.5 cm to about 2 cm, about 1 cm to about 4 cm, about 2 cm to about 5 cm, about 4 cm to about 8 cm, about 6 cm to about 10 cm, or about 0.5 cm to about 10 cm. When central longitudinal axes through two adjacent cutting elements 220 are substantially parallel, a distance between an apex of the first of the cutting element 220 and an apex of the second of the cutting element 220 (measured along the central longitudinal axes) may be less than about 10 mm, less than about 8 mm, less than about 6 mm, less than about 4 mm, less than about 2 mm, less than about 1 mm, less than about 0.5 mm, or less than about 0.1 mm.

A distance 272 (measured along the x-axis) between an apex of the cutting element 220, e.g., 220-1, closest to the lower end portion 216 of the cutter block 200 and the apex of the cutting element 220, e.g., 220-7, farthest from the lower end portion 216 of the cutter block 220 may range from about 2 cm, about 4 cm, about 6 cm, about 8 cm, or about 10 cm to about 15 cm, about 20 cm, about 25 cm, about 30 cm, about 40 cm, or more. For example, the distance 272 may be from about 2 cm to about 5 cm, about 4 cm to about 8 cm, about 6 cm to about 10 cm, about 10 cm to about 20 cm, about 20 cm to about 30 cm, or about 2 cm to about 20 cm.

A ratio of the distance 270 to the distance 272 may be from about 1:1 to about 1:2, about 1:2 to about 1:3, about 1:3 to about 1:5, about 1:5 to about 1:10, or about 1:10 to any ratio therebetween. A ratio of the distance 272 to the length 260 of the cutter block 200 may range from about 1:2 to about 1:3, about 1:3 to about 1:5, about 1:5 to about 1:10, about 1:10 to about 1:15, or about 1:15 to any ratio therebetween.

An angle 224 between the x-axis and a central longitudinal axis 223 through one of the cutting elements 220, e.g., 220-1, in the x-y plane may range from about –90° to about +90°, e.g., about –90°, about –75°, about –60°, about –45°, about –30°, about –15°, or about 0° to about 15°, about 30°, about 45°, about 60°, about 75°, or about 90°, or any angle therebetween. For example, the angle 224 may be from about 0° to about +/-20°, about +/-10° to about +/-30°, about +/-20° to about +/-40°, about +/-30° to about +/-50°, about +/-40° to about +/-60°, about +/-50° to about +/-70°, about +/-60° to about +/-80°, about +/-70° to about +/-90°, or about 0° to about +/-90°. As used herein, a positive angle is measured counterclockwise from the horizontal axis, and a negative angle is measured clockwise from the horizontal axis. The angle 224 is shown as about positive 30° in FIG. 3. Seven cutting elements 220 are shown for illustrative purposes: 220-1, 220-2, 220-3, 220-4, 220-5, 220-6, and 220-7. However, it may be appreciated, that more or fewer cutting elements 220 may be used.

The first cutting element 220-1 may be positioned at least partially in the first and/or second portion 242, 244 of the outer surface 240 of the cutter block 200. The angle 224 between the x-axis and the central longitudinal axis 223 through the first cutting element 220-1 in the x-y plane may be from about 20° to about 40°, about 30° to about 50°, about 40° to about 60°, or about 50° to about 70°. The second cutting element 220-2 may be positioned at least partially in the second and/or third portion 244, 246 of the outer surface 240 of the cutter block 200. The angle between the x-axis and the central longitudinal axis through the second cutting element
220-2 in the x-y plane may be from about 0° to about 10°, about 5° to about 15°, about 10° to about 20°, or about 20° to about 30°. The third cutting element 220-3 may be positioned at least partially in the second and/or third portion 244, 246 of the outer surface 240 of the cutter block 200. The angle between the x-axis and the central longitudinal axis through the third cutting element 220-3 in the x-y plane may be from about 20° to about 40°, about 30° to about 50°, about 40° to about 60°, or about 50° to about 70°. The fourth cutting element 220-4 may be positioned at least partially in the second and/or third portion 244, 246 of the outer surface 240 of the cutter block 200. The angle between the x-axis and the central longitudinal axis through the fourth cutting element 220-4 in the x-y plane may be from about 40° to about 60°, about 50° to about 70°, or about 60° to about 80°. The fifth cutting element 220-5 may be positioned at least partially in the second and/or third portion 244, 246 of the outer surface 240 of the cutter block 200. The angle between the x-axis and the central longitudinal axis through the fifth cutting element 220-5 in the x-y plane may be from about 60° to about 70°, about 70° to about 80°, or about 80° to about 90°.

[0038] FIG. 4 depicts a view (in the x-z plane) of a portion of the outer surface 240 of the cutter block 200 shown in FIG. 2. An angle 226 between the x-axis and the central longitudinal axis 223 through one of the cutting elements 220, e.g., 220-1, in the x-z plane may range from about 90° to about 90°, e.g., about 50°, about 75°, about 60°, about 45°, about 30°, about 15°, or about 0° to about 15°, about 30°, about 45°, about 60°, about 75°, about 90°, or any angle therebetween. For example, the angle 226 may be from about 0° to about 10°, about 10° to about 20°, about 20° to about 30°, about 30° to about 40°, about 40° to about 50°, about 50° to about 60°, about 60° to about 70°, or about 70° to about 80°. The angle 226 may be about 0°, about 10°, about 20°, about 30°, about 40°, about 50°, or about 60°.

[0039] The angle 226 between the x-axis and the central longitudinal axis 223 through the first cutting element 220-1 in the x-z plane may be from about 10° to about 50°, about 20° to about 30°, about 30° to about 40°, or about 40° to about 50°. The angle 226 between the x-axis and the central longitudinal axis through the second cutting element 220-2 in the x-z plane may be from about 10° to about 30°, or about 20° to about 40°. The angle 226 between the x-axis and the central longitudinal axis through the third cutting element 220-3 in the x-z plane may be from about 10° to about 30°, about 20° to about 40°, or about 30° to about 50°. The angle 226 between the x-axis and the central longitudinal axis through the fourth cutting element 220-4 in the x-z plane may be from about 30° to about 50°, about 40° to about 60°, about 50° to about 70°, or about 60° to about 80°. The angle 226 between the x-axis and the central longitudinal axis through the fifth cutting element 220-5 in the x-z plane may be from about 30° to about 50°, about 40° to about 60°, about 50° to about 70°, or about 60° to about 80°.
about 1° to about 20°, e.g., about 1° to about 5°, about 5° to about 10°, or about 10° to about 20°.

[0044] As shown in FIG. 6, the first cutting element 222-1 on the second cutter block (element/block not shown but cutting pattern of cutting element shown) may be offset along the length 260 (FIG. 2) and the height/depth 262 (FIG. 2) from the first cutting element 220-1 on the first cutter block 200. In addition, the angle 225-1 between the x-axis and the central longitudinal axis through the first cutting element 221-1 of the second cutter block in the x-y plane may be different (e.g., shows greater but may be less) than the corresponding angle 224-1 of the first cutting element 220-1 of the first cutter block 200 by about 1° to about 10°.

[0045] FIG. 7 depicts a view of a leading side surface 750 of another illustrative cutter block 700, and FIG. 8 depicts a view of an outer surface 740 of the cutter block 700 shown in FIG. 7, according to one or more implementations disclosed herein. The cutter block 700 shown in FIG. 7 may be similar to the cutter block 200 shown in FIGS. 2-5; however, the outer surface 740 of the cutter block 700 shown in FIG. 7 may include additional stepped portions 744, 745, 746.

[0046] As illustrated in FIG. 7, the third portion 743 of the outer surface 740 (similar to the third portion 246 of outer surface 240 illustrated in FIG. 3) may transition to a fourth portion 744 of the outer surface 740. The fourth portion 744 of the outer surface 740 of the cutter block 700 may be substantially parallel to the inner surface 754 of the cutter block 700 and/or the longitudinal axis 111 of the downhole tool 100 (see FIG. 1). A distance 766 between the fourth portion 744 of the outer surface 740 and the inner surface 754 may be less than the distance 765 between the third portion 743 of the outer surface 740 and the inner surface 754. The distance 766 may be substantially the same as the distance 764 between the first portion 741 of the outer surface 740 and the inner surface of the cutter block 700.

[0047] The fourth portion 744 of the outer surface 740 may transition to a fifth portion 745 of the outer surface 740. The fifth portion 745 of the outer surface 740 may be substantially perpendicular to the inner surface 754 of the cutter block 700 and the longitudinal axis 111 of the downhole tool 100. As used herein “substantially perpendicular” means within ±20° of perpendicular. The radius of curvature from the fourth portion 744 to the fifth portion 745 may be from less than about 20 cm, less than about 15 cm, less than about 10 cm, less than about 8 cm, less than about 6 cm, less than about 4 cm, less than about 2 cm, or less than about 1 cm. In another implementation, the fifth and sixth portions 745, 746 of the outer surface 740 may be oriented at an angle with respect to one another from about 50° to about 150°, e.g., about 50°, about 60°, about 70°, about 80°, or about 90° to about 100°, about 110°, about 120°, about 130°, about 140°, or about 150°, or any angle therebetween.

[0048] The fifth portion 745 of the outer surface 740 may transition to a sixth portion 746 of the outer surface 740. The sixth portion 746 of the outer surface 740 may be substantially parallel to the inner surface 754 of the cutter block 700 and the longitudinal axis 111 of the downhole tool 100. The sixth portion 746 of the outer surface 740 may be positioned farther from the lower end portion 716 of the cutter block 700 than the fourth portion 744 of the outer surface 740. The radius of curvature from the fifth portion 745 to the sixth portion 746 may be less than about 20 cm, less than about 15 cm, less than about 10 cm, less than about 8 cm, less than about 6 cm, less than about 4 cm, less than about 2 cm, or less than about 1 cm.
In another implementation, the fourth and fifth portions 944, 945 of the outer surface 940 may be oriented at an angle with respect to one another from about 50° to about 150°, e.g., about 50°, about 60°, about 70°, about 80°, or about 90° to about 100°, about 110°, about 120°, about 130°, about 140°, or about 150°, or any angle therebetween.

[0053] A distance 965 between the third portion 943 of the outer surface 940 and the inner surface 954 may be greater than the distance 964 between the first portion 941 of the outer surface 940 and the inner surface 954. In addition, a distance 967 between the fifth portion 945 of the outer surface 940 and the inner surface 954 may be greater than the distance 965 between the third portion 943 of the outer surface 940 and the inner surface 954. As shown, the fourth and fifth portions 944, 945 of the outer surface 940 may be positioned closer to the upper end portion 914 of the cutter block 900 than the first, second, and third portions 941, 942, 943 of the outer surface 940.

[0054] The cutting elements 920 on the first, second, and/or third portions 941, 942, 943 of the outer surface 940 of the cutter block 900 may be arranged and designed to increase the diameter of the subterranean bore 180 to a first increased diameter. The cutting elements 920 on the fourth and fifth portions 944, 945 of the outer surface 940 of the cutter block 900 may be arranged and designed to further increase the diameter of the subterranean bore 180 to a second increased diameter.

[0055] Referring to FIGS. 1-9, in operation, the downhole tool 100 may be run into the subterranean bore 180 on a drill pipe or drill string with the cutter blocks 200 in the retracted position. Once positioned at the desired depth in the subterranean bore 180, the cutter blocks 200 may be actuated into the expanded position. To actuate the downhole tool 100, a pump at the surface may cause a drilling fluid to flow down through the drill string and into the tool bore 112 of the downhole tool 100. This may cause a pressure of the fluid in the tool bore 112 and the chamber 120 to increase. The increased pressure of the fluid may exert a force on the piston 122 and the drive ring 124 toward the upper end portion 114 of the downhole tool 100. When this force exceeds the biasing opposing force exerted by the spring 126, the cutter blocks 200 may simultaneously move toward the upper end portion 114 of the downhole tool 100 and radially outward (i.e., into the expanded position).

[0056] The downhole tool 100 may be rotated about its longitudinal axis 111 and moved axially within the subterranean bore 180. As the downhole tool 100 moves within the subterranean bore 180, the cutting elements 220 on the cutter blocks 200 may cut, grind, or scrape the wall 182 of the subterranean bore 180 to increase the diameter thereof. To actuate the cutter blocks 220 back into the retracted state, the pump may decrease the fluid flow through the drill string and the tool bore 112 of the downhole tool 100. This may cause the pressure of the fluid in the tool bore 112 and the chamber 120 to decrease. When the force exerted by the fluid decreases below the opposing force exerted by the spring 126, the cutter blocks 200 may simultaneously or near simultaneously move toward the lower end portion 116 of the downhole tool 100 and radially inward (i.e., into the retracted position).

[0057] As used herein, the terms “inner” and “outer”; “up” and “down”; “upper” and “lower”; “upward” and “downward”; “above” and “below”; “inward” and “outward”; and other like terms refer to relative positions to one another and are not intended to denote a particular direction or spatial orientation. The terms “couple,” “coupled,” “connect,” “connection,” “connected,” “in connection with,” and “connecting” refer to “in direct connection with” or “in connection with via one or more intermediate elements or members.”

[0058] Although only a few example implementations have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example implementations without materially departing from “Cutter Block for a Downhole Underreamer.” Accordingly, all such modifications are intended to be included within the scope of this disclosure. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Thus, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface, in the environment of fastening wooden parts, a nail and a screw may be equivalent structures.

[0059] Certain implementations and features have been described using a set of numerical upper limits and a set of numerical lower limits. It should be appreciated that ranges including the combination of any two values, e.g., the combination of any lower value with any upper value, the combination of any two lower values, and/or the combination of any two upper values are contemplated unless otherwise indicated. Certain lower limits, upper limits and ranges appear in one or more claims below. All numerical values are “about” or “approximately” the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

[0060] Various terms have been defined above. To the extent a term used in a claim is not defined above, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Furthermore, all patents, test procedures, and other documents cited in this application are fully incorporated by reference to the extent such disclosure is not inconsistent with this application and for all jurisdictions in which such incorporation is permitted.

What is claimed is:

1. A cutting tool, comprising:
   a body;
   a cutter block coupled to the body and adapted to move radially outward from the body, the cutter block including an outer surface that transitions from a first portion to a second portion, the first portion and the second portion remaining stationary relative to each other with the first portion being downhole of the second portion, a radius of curvature between the first and second portions being less than about 7 cm, the second portion or a line tangential thereto being oriented at an angle from about 60° to about 120° with respect to a central longitudinal axis of the body; and
   a plurality of cutting elements disposed on the outer surface of the cutter block, at least one of the plurality of cutting elements being disposed at least partially on the first or second portion of the outer surface.

2. The cutting tool of claim 1, wherein the radius of curvature is less than about 5 cm, and wherein the angle is from about 75° to about 105°.

3. The cutting tool of claim 1, wherein a first one of the cutting elements is at least partially disposed on the first portion of the outer surface of the cutter block, and wherein a
second one of the cutting elements is at least partially disposed on the second portion of the outer surface of the cutter block.

4. The cutting tool of claim 3, wherein the first portion of the outer surface of the cutter block is substantially parallel to the central longitudinal axis through the body.

5. The cutting tool of claim 1, wherein a first distance between an apex of a cutting element closest to an inner surface of the cutter block and an apex of a cutting element farthest from the inner surface of the cutter block is from about 0.5 cm to about 10 cm, and wherein the first distance is measured in a direction perpendicular to the central longitudinal axis through the body.

6. The cutting tool of claim 5, wherein a second distance between an apex of a cutting element closest to an end portion of the cutter block and an apex of a cutting element farthest from the end portion of the cutter block is from about 2 cm to about 20 cm, and wherein the second distance is measured in a direction parallel to the central longitudinal axis through the body.

7. The cutting tool of claim 6, wherein a ratio of the first distance to the second distance is from about 1:1 to about 1:10.

8. The cutting tool of claim 1, wherein an angle between a central longitudinal axis extending through a first one of the cutting elements and an X-axis in an X-Y plane is from about −90° to about 90°, the X-axis being aligned with a length of the cutter block, and a Y-axis being aligned with a height of the cutter block.

9. The cutting tool of claim 1, wherein an angle between a central longitudinal axis extending through a first one of the cutting elements and an X-axis in an X-Z plane is from about −90° to about 45°, the X-axis being aligned with a length of the cutter block, and a Z-axis being aligned with a width of the cutter block.

10. The cutting tool of claim 1, wherein an angle between a central longitudinal axis extending through a first one of the cutting elements and a Y-axis in a Y-Z plane is from about −45° to about 90°, the Y-axis being aligned with a height of the cutter block, and a Z-axis being aligned with a width of the cutter block.

11. A downhole tool, comprising:

a body;
a plurality of cutting elements disposed on the outer surface of the cutter block, at least one of the plurality of cutting elements being disposed at least partially on the second portion of the outer surface.

12. The downhole tool of claim 11, wherein the angle between the first portion or the line tangential thereto and the second portion or the line tangential thereto is from about 75° to about 105°.

13. The downhole tool of claim 11, wherein the angle between the second portion or the line tangential thereto and the central longitudinal axis of the body is from about 75° to about 105°.

14. The downhole tool of claim 11, further comprising another one of the plurality of cutting elements is at least partially disposed on the first portion of the outer surface of the cutter block.

15. The downhole tool of claim 11, wherein the first portion of the outer surface of the cutter block is substantially parallel to the central longitudinal axis through the body.

16. A downhole tool, comprising:

to move radially outward from the body,
a plurality of cutting elements disposed at least partially on the outer surface of the cutter block, at least 50% of the elements being positioned between the first and second points along a length of the cutter block, a distance between the first and second points being 30% of the length of the cutter block, and the first point being at an end portion of the cutter block.

17. The downhole tool of claim 16, wherein the first portion is at a downhole end portion of the cutter block.

18. The downhole tool of claim 16, wherein at least 80% of the cutting elements are positioned between the first and second points, and wherein the distance is 20% of the length of the cutter block.

19. The downhole tool of claim 16, wherein the outer surface transitions from a first portion to a second portion, the first portion being downhole of the second portion, a radius of curvature between the first and second portions being less than about 7 cm, the second portion or a line tangential thereto being oriented at an angle from about 60° to about 120° with respect to a central longitudinal axis of the body, and at least one of the cutting elements being disposed at least partially on the second portion of the outer surface.

20. The downhole tool of claim 16, wherein the outer surface transitions from a first portion to a second portion, the first portion being downhole of the second portion, an angle between the first portion or a line tangential thereto and the second portion or a line tangential thereto being from about 60° to about 120°, the second portion or the line tangential thereto being oriented at an angle from about 60° to about 120° with respect to a central longitudinal axis of the body, and at least one of the cutting elements being disposed at least partially on the second portion of the outer surface.