A rotary tool for drilling subterranean material is disclosed. The rotary tool includes a tool body having a distal crown end comprising a circumferential series of raised cutting blades with recessed junk slots therebetween. Cutting elements are located proximate a leading peripheral edge of the raised cutting blades and cutting control structures are located interiorly of the cutting elements at a leading surface of an adjacent junk slot. Cutting control structures are releasably secured to the tool body in the adjacent junk slot whereby a used rotary tool is refurbishable by removing worn cutting control structures without degradation to the tool body and replacing the worn cutting control structures by installing new cutting control structures in the worn cutting control structures' locations.
METHOD OF MANUFACTURING AND REPAIRING FIXED-CUTTER DRAG-TYPE ROTARY TOOLS WITH CUTTING CONTROL STRUCTURES

FIELD OF TECHNOLOGY

[0001] The present application relates generally to rotary tools used for drilling subterranean material. More particularly, the present application is directed to a method of manufacturing and repairing rotary tools for drilling subterranean material having cutting control structures releasably secured to the tool body.

BACKGROUND

[0002] Fixed-cutter drag-type rotary drill bits having natural and synthetic diamond cutting elements affixed to a distal crown of the bit body have been employed in subterranean drilling for many decades. Rotary drag-type drill bits are typically comprised of a bit body having a Shank for connection to a drill string and encompassing an inner channel for supplying drilling fluid to the face of the bit through nozzles or other apertures. Drag bits may be cast and/or machined from metal, typically steel, or may be formed from wear-resistant metal particles (typically tungsten carbide (WC)) infiltrated at high temperatures with a liquefied (typically copper-based) binder material to form a matrix. Such bits may also be formed with layered-manufacturing technology, as disclosed in U.S. Pat. No. 5,433,280 incorporated herein by reference.

[0003] Drag bits herein disclosed include polycrystalline diamond compact (PDC) cutters typically comprised of a large diamond table (usually of circular, semi circular or tombstone shape) which presents a generally planar cutting face. A cutting edge (sometimes chamfered or beveled) is formed on one side of the cutting face which, during boring, is at least partially embedded into the formation so that the formation is received against at least a portion of the cutting face. As the bit rotates, the cutting face moves against the formation and shavings of formation material (cuttings) are sheared off and are forced up the surface of the cutter face. In brittle materials at atmospheric pressure the formation cuttings easily separate from the cutter face and break down into small particles that are transported out of the bore hole via circulating drilling fluid. Another cutting then begins to form in the vicinity of the cutting edge, is forced up the face of the cutting surface, and breaks off in a similar fashion. Such action occurring at each cutting element on the bit removes formation material over the entire face of the bit and so causes the bore hole to become progressively deeper.

[0004] However, for ductile formations under pressure that exhibit plastic properties, such as highly pressurized deep shafts, mudstones, and silstones, the formation cuttings have a marked tendency to stay intact and adhere to the cutting face of the cutting element. If the cutting is not broken into smaller pieces or removed from the cutting face, the cuttings collect as a mass of cuttings ahead of the PDC cutting elements and eventually clog the junk slots with drilled-up material. Once this phenomenon, termed bit balling, occurs the bit ceases to drill effectively.

[0005] U.S. Pat. No. 6,328,117 to Berzas et al. discloses apparatus for the prevention of bit balling that includes a chip breaker affixed upon fixed-cutter, rotary-type drill bits used in drilling subterranean formations. The chip breaker includes a knife-like protrusion positioned proximate a cutting element and adjacent a fluid course defined by the bit body. As formation cuttings are generated during drilling, the cuttings move over the protrusion and are split or scribed by the protrusion. Even in view of such improvements disclosed in the aforementioned prior art, rotary tools are still susceptible to bit balling during drilling of subterranean material. Operating rotary tools at an excessively high great depth of cut (DOC) may generate more formation cuttings than can be consistently broken or cleared from the bit face and back up the bore hole via the junk slots on the face of the bit. Furthermore, chip breakers disclosed in the prior art are exposed to extremely large loads that can cause the chip breaker to either be eroded or entirely removed from the bit body.

[0007] It is therefore necessary to provide the industry with an apparatus and method for breaking down and dispersing formation cuttings that collect on the body of fixed-cutter drag-type rotary tools regardless of the size, shape or composition of the cutting and regardless of the type of subterranean material encountered by the rotary tool. Fixed-cutter drag-type rotary tools such as rotary drill bits, casing bits, reamers, bi-center rotary drill bits, reamer wings, down-hole milling tools, bi-center drill bits, or other drilling tools known in the art for utilizing cutting elements may benefit from the present disclosure and, as used herein, the term “rotary drill bit” encompasses any and all such apparatuses.

SUMMARY

[0008] The application herein provides apparatus and methods for releasably securing cutting control structures to a tool body of a rotary tool for drilling subterranean material. The rotary tool includes a tool body having a distal crown end comprising a circumferential series of raised cutting blades with recessed junk slots therebetween. Cutting elements are located proximate a leading peripheral edge of one of said raised cutting blades and cutting control structures are located interiorly of said cutting elements at a leading surface of an adjacent junk slot. The cutting control structures provide a means for splitting, breking, twisting and/or diverting cuttings, chips or shavings that collect on the cutting face of a cutting element during drilling of subterranean material. The cutting control structures are releasably secured to the tool body in an adjacent junk slot whereby a used rotary tool is refurbishable by removing and replacing worn cutting control structures without degradation to the tool body. The embodiments disclosed herein permit rapid removal and replacement of cutting control structures that become worn or removed during drilling of subterranean material. The embodiments disclosed herein also enable easy modification of the location of cutting control structures in field operations thereby optimizing the position of cutting control structures depending on the drilling conditions. Furthermore, a variety of cutting control structures such as splitters, breakers, diverters and wedges can be configured on a single tool body for optimal break-up and dispersion of cuttings during drilling operations.

[0009] The foregoing and other objects, features and advantages of the disclosure will become more readily apparent from the following detailed description of the preferred embodiments as disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Embodiments of the present application will now be described, by way of example only, with reference to the attached Figures, wherein:
FIG. 1 is a perspective side view of a first embodiment rotary-type drill bit in accordance with the present disclosure;

FIG. 2 is a partial sectional view of a second embodiment of a rotary-type drill bit illustrating cutting control structures mounted on a carrier releasably secured to the bit body;

FIG. 3 is a partial sectional view of a formation chip being modified by a cutting control structure on a drill bit in accordance with the present disclosure;

FIG. 4 is a perspective view of the cutting control structures mounted to a carrier on a cutting blade of a rotary-type drill bit;

FIG. 5 is another perspective view of the cutting control structures mounted to a carrier on a cutting blade of a rotary-type drill bit;

FIG. 6 is a perspective view of a carrier having cutting control structures releasably mounted thereon;

FIGS. 7A-7C are examples of single cutting control structures releasably securable to a bit body;

FIG. 8 is an example of a removable cutting control structure according to the present disclosure with a press fit engagement to the bit body;

FIG. 9 is a second example of a removable cutting control structure according to the present disclosure with a press fit engagement to the bit body;

FIG. 10 is an example of a removable cutting control structure according to the present disclosure with a screw engagement to the bit body; and

FIG. 11 is a partial sectional view of a removable cutting control structure that is welded, brazed, press fit or shrink fit into a recess in the bit body according to the present disclosure.

DETAILED DESCRIPTION

It will be appreciated that for simplicity and clarity of illustration, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. In addition, numerous specific details are set forth in order to provide a thorough understanding of the example embodiments described herein. However, it will be understood by those of ordinary skill in the art that the example embodiments described herein may be practiced without these specific details. In other instances, methods, procedures and components have not been described in detail so as not to obscure the embodiments described herein. Also, the description is not to be considered as limiting the scope of the embodiments described herein.

Referring to FIG. 1, a drill bit 10 in accordance with the present disclosure comprises a body 12 having a threaded connection 14 at a proximal end 16 thereof and a crown 18 at a distal end 20 thereof. The crown 18 includes a plurality of longitudinally extending blades 22 that define a plurality of fluid courses 23 with adjacent junk slots 24 thereinbetween. Along each blade 22, proximate the distal end 20 of the body 12, is a plurality of cutting elements 25 attached to the leading peripheral edge 27 of the blades 22 and oriented to cut into a subterranean formation upon rotation of the bit 10.

The drill bit 10 as illustrated in FIG. 1 is of a drag bit that can include polycrystalline diamond compact (PDC) cutters typically comprised of a large diamond table usually of circular, semi-circular or other shape) which presents a generally planar cutting face. While this type of drill bit is illustrated, the disclosure as contained herein can be equally applied to other types of tools used in drilling or otherwise modifying a subterranean material. These subterranean materials can include man-made material such as concrete and steel among other materials. Other examples of tools to which this disclosure could apply have been indicated in the background.

As illustrated, the fluid courses 23 and adjacent junk slots 24 are defined by the following surfaces: a first, leading side wall 26, a second, trailing side wall 28 and a bottom surface 30. The leading side wall 26 provides a surface adjacent the cutting face 29 of the cutting elements 25. A plurality of cutting control structures 31 are each releasably secured to the leading side wall 26 interiorly of a cutting element 25. In addition, each cutting control structure 31 preferably has a longitudinal axis L that is in substantial alignment with the center C of the adjacent cutting face 29 so that, as formation cuttings are generated during drilling, the cutting control structure 31 modifies the size, shape or directional path of the cutting that comes in contact with the cutting control structure 31. It is noted that the orientation or 65 alignment of the longitudinal axis L relative to the cutting face 29 may be engineered based on the location of the cutting element 25 on the bit 10 and the predicted direction of formation cutting generation over the cutting face 29. Accordingly, as formation cuttings, also referred to herein as shavings or formation chips, are cut by the cutting elements 25, the cuttings slide over the cutting face 29 and across the leading side wall 26 adjacent the cutting elements 25 are modified by the cutting control structures 31, and are carried away by drilling fluid flowing through the fluid course 23.

In hard drilling applications that involve drilling hard subterranean material, the cutting control structures 31 may be formed from at least one of the group comprising polycrystalline diamond compact (PDC), thermally stable polycrystalline diamond (TSP), cubic boron nitride (CBN), polycrystalline cubic boron nitride (PCBN), carbide and ceramics. In soft drilling applications that involve drilling relatively softer material, the cutting control structures 31 may be formed from at least one of the group comprising copper, aluminum and plastic. Furthermore, cutting control structures 31 include splitters, breakers, diverters and/or wedges. A chip breaker 31 or splitter 31 includes a knife-like protrusion positioned proximate a cutting element 25. As formation chips, shavings or cuttings are generated during drilling, the cuttings move over the protrusion and are split or scoured by the protrusion. Chip diverters and wedges include a blunt protrusion that is generally wedge-shaped and positioned proximate a cutting element 25. As formation chips, shavings or cuttings are generated during drilling, the cuttings move over the protrusion and are deflected or dispersed from the cutting face 29. Other suitable geometries for splitters, breaker, diverters and wedges will be discussed in further detail below.

The cutting control structures are especially useful in ductile formations under pressure, such as pressurized shales, mudstones, and siltstones; the cuttings of those materials have a marked tendency to stay intact and adhere to the cutting face of the cutting element. If the cutting is not broken into smaller pieces or removed from the cutting face, the cuttings collect and build up as a mass of cuttings ahead of the cutting elements and eventually clog the junk slots with material. As described herein, the cutting control structures encourage at least one of breaking apart, splitting, and divergence of the cutting from the cutting surfaces.
In a second embodiment shown in FIG. 2, cutting control structures 31 are fixably mounted to a carrier 50 at an upper surface 52 of an exposed end 51 of the carrier 50. The cutting control structures 31 are fixably mounted to the carrier 50 and positioned relative to a cutting element 25 such that the cutting control structures 31 lie in a potential flow path of cuttings generated by the operating cutting element 25. The carrier 50 is releasably secured to the leading side wall 26 such that the upper surface 52 of the carrier 50 is elevated above the leading side wall 26. As a result, at least a portion of the cutting control structures 31 lie in an elevated plane relative to the cutting element 25 and can be configured to project over the cutting face 29 of the cutting element 25 to enhance the dispersion of cuttings from the cutting face 29. While in the illustrated embodiment the carrier 50 has a top surface 52 that is raised relative to the face of the leading side wall 26, the carrier 50 can be mounted approximately flush with the leading side wall 26 and a portion of the cutting control structure 31 that lies above the cutting element can be configured to project over the cutting face 29 of the cutting element 25.

In another embodiment, the carrier 50 is releasably secured to the leading side wall 26 such that the upper surface 52 of the carrier 50 is flush-oriented with the leading side wall 26 of the adjacent junk slot 24. Additionally, the cutting control structures 31 can be configured such that they do not project over the cutting face 29 of the cutting element 25, thereby easing disengagement and replacement of worn cutting control structures 31.

FIG. 3 illustrates a means for releasably securing the cutting control structure 31 to the leading side wall 26. A carrier 50 comprises an exposed end 51 having an upper surface 52 and an anchoring end 55 having a top anchoring portion 54 and a releasable anchorage 56. The cutting control structure 31 is fixably mounted to the carrier 50 at the upper surface 52 of the exposed end 51 of the carrier 50. The releasable anchorage 56 includes a substantially cylindrical portion 57 that is releasably secure the carrier 50 to a retention recess 82 within the leading side wall 26. The retention recess 82 can be formed by boring a threaded cylindrical passage into the leading side wall 26. The substantially cylindrical portion 57 of the releasable anchorage 56 is threaded to releasably secure the carrier 50 to the retention recess 82 by screwing the substantially cylindrical portion 57 into the retention recess 82. Additionally, a top anchoring portion 54 of the anchoring end 55 of the carrier 50 can have a larger cross-sectional area compared to the cylindrical portion 57 or other portions of the releasable anchorage 56. The top anchoring portion 54 is configured to fit within a top portion recess 80 that accommodates the top anchoring portion 54. Increasing the cross-sectional area of the top anchoring portion 54 increases the surface area contacting the leading side wall 26, thereby distributing the stresses and loads exerted on the carrier 50 during drilling.

In another embodiment, to further secure the carrier 50 to the leading side wall 26, the retention recess 82 can be formed by boring a threaded cylindrical passage through the leading side wall 24 and through a rear surface of the cutting blade. The carrier 50 is releasably secured to the retention recess 82 by screwing the substantially cylindrical portion 57 into the retention recess 82. In at least one embodiment the distal end 56 of releasable anchorage 56 can also be fastened with a nut to the rear surface of the cutting blade (not shown).

In other embodiments, the carrier 50 can be releasably secured to the bit body 12 by welding, brazing, bonding, using studs, shrink fitting a portion of the carrier 50 to the bit body 12 and/or friction fitting a portion of the carrier 50 to the bit body 12. For example, the upper surface 52 of the exposed end 51 of the carrier 50 could be welded, brazed and/or bonded around its perimeter. In another embodiment, it is also possible to braze the top anchoring portion 54 of the cutting control structure 31 within the retention recess 82. Other mechanisms that secure the releasable anchorage 56 of the cutting control structure include the implementation of threaded engagements, locking mechanisms, studs, friction fitting, press fitting and the like.

As illustrated in FIG. 3, formation cutting 40 may be both split and lifted or split, lifted and twisted and/or dispensed from leading side wall 26 by cutting control structure 31 relative to cutting face 29 of cutting element 25 and leading side wall 26. By splitting and lifting the cutting 40 away from leading side wall 26, the unsupported portion 44 of the cutting 40 that is exposed to the flow of drilling fluid is weakened by drilling fluid penetrating into cracks and pores and can be relatively easily broken away from the rest of the cutting 40 by the force of drilling fluid flowing through the fluid course. Segments 42 of cutting 40, one of which is viewable in FIG. 3 with the other directly therebehind, will typically have two additional sides 41 exposed to the action of the drilling fluid for further break-up of segments 42 away from the rest of the cutting 40. The cutting control structure 31 can further deflect and/or disperse the cutting from the cutting face 29 into an adjacent junk slot 24 (not shown). Therefore, the cutting control structures 31 of this embodiment may modify the shape, size or directional path of the cuttings generated while drilling.

FIGS. 4 and 5 illustrate an embodiment with cutting control structures 31 fixably mounted to a carrier 50 at an upper surface 52 of the exposed end 51 of the carrier 50. FIG. 4 provides a perspective view of the cutting face 29 of the cutting elements 25. FIG. 5 provides a side perspective view of the cutting elements 20 along with cutting control structures 31. The carrier 50 is releasably secured to the leading side wall 26. In the illustrated embodiment, the adjacent cutting control structures 31 are spaced apart on the carrier 50 at distance-X that is not equivalent to the spacing distance-Y between adjacent cutting elements 25. The spacing between adjacent cutting control structures 31 relative to the spacing between adjacent cutting elements 25 may vary in order to optimize the contact between cutting control structures 31 and cuttings based on the directional path (such as line A) that cuttings follow during drilling of subterranean material. The spacing between adjacent cutting control structures 31 relative to the spacing between adjacent cutting elements 25 may be maintained such that the angle between the directional path of two flow patterns of cuttings across a pair of adjacent cutters is constant across the pair of adjacent cutters 25 and a pair of corresponding adjacent cutting control structures 31. In another embodiment, the adjacent cutting control structures are spaced apart on the carrier 50 at distance-X substantially equal to a spacing distance-Y between cutting elements 25 on the raised cutting blade. Maintaining an equivalent distance between adjacent cutting control structures 31 relative to the distance between adjacent cutting elements 25 is useful if adjacent cutting elements 25 are arranged substantially linearly and/or produce a flow pattern of cuttings in a substantially linear directional path.

While the embodiments shown in FIGS. 2, 4, and 5 have three cutting control structures mounted on the top sur-
face 52 of the carrier 50, other arrangements of the cutting control structures are considered within the scope of this disclosure. For instance, a pair of cutting control structures 31 can be affixed to the carrier 50. Additionally, the cutting control structures 31 can be arranged such that more than three are provided on the carrier. As will be described below, the cutting control structures 31 can also be individually releasably secured to the tool body.

[0036] FIG. 6 illustrates another embodiment of a carrier 50 with a plurality of cutting control structures 31 fixedly mounted to the carrier 50. The carrier 50 comprises an exposed end 51 having an upper surface 52 and an anchoring end 55 having a top anchoring portion 54 and a releasable anchorage 56. The cutting control structures 31 are fixedly mounted to the carrier 50 at the upper surface 52 of the carrier 50. The releasable anchorage 56 comprises a substantially cylindrical and threaded portion 62 for releasably securing the carrier 50 to the bit body 12. In accordance with this embodiment, the carrier 50 may be secured to the bit body by screwing the substantially cylindrical and threaded portion 62 into a threaded recess in the bit body. The carrier 50 may be unscrewed and replaced with another carrier 50 when one or a plurality of cutting control structures 31 become worn or broken from use in drilling subterranean material, thereby making a drill bit 10 refurbishable.

[0037] FIGS. 7A-7C illustrate several other embodiments of cutting control structures 31 in accordance with the present disclosure. In FIG. 7A, the cutting control structure 31 is illustrated as having a cone-shaped protrusion or protrubance 30. The cutting control structure 31 includes an exposed end 51 having an upper surface 52 and an anchoring end 55 having a top anchoring portion 54 and a releasable anchorage 56. The releasable anchorage 56 comprises a substantially cylindrical and threaded portion 62 for releasably securing the cutting control structure 31 to the bit body 12. In accordance with this embodiment, the cutting control structure 31 can be secured to the bit body 12 by screwing the substantially cylindrical and threaded portion 62 into a threaded recess in the bit body. The cutting control structure 31 can be unscrewed and replaced with another cutting control structure 31 when the cutting control structure 31 becomes worn or broken from use in drilling subterranean material, thereby making a drill bit 10 refurbishable. Although the cutting control structure 31 is not mounted to a carrier in this embodiment, one or more cutting control structures 31 illustrated in this embodiment can be mounted to a carrier that is releasably secured to the bit body in any number of ways herein disclosed.

[0039] In FIG. 7C, the cutting control structure 31" is illustrated as a semi-cylindrical shaped protrusion or protrubance 30". The cutting control structure 31" includes an exposed end 51 having an upper surface 52 and an anchoring end 55 having a top anchoring portion 74 and a releasable anchorage 76. The releasable anchorage 76 includes a substantially cylindrical and threaded portion 78 for releasably securing the cutting control structure 31" to the bit body 12. In accordance with this embodiment, the cutting control structure 31" can be secured to the bit body 12 by screwing the substantially cylindrical and threaded portion 78 into a threaded recess in the bit body 12. The cutting control structure 31" can be unscrewed and replaced with another cutting control structure 31" when the cutting control structure 31" becomes worn or broken from use in drilling subterranean material, thereby making a drill bit 10 refurbishable. Although the cutting control structure 31" is not mounted to a carrier in this embodiment, one or more cutting control structures 31" illustrated in this embodiment can be mounted to a carrier that is releasably secured to the bit body in any number of ways herein disclosed.

[0040] In other embodiments the cutting control structures 31 may have substantially rectangular-shaped, diamond-shaped, knifelike protrusions and/or any other shape of protrusion that would be understood by one of ordinary skill in the art as effective in modifying the shape, size or directional path of cuttings formed during drilling of subterranean material.

[0041] FIG. 8 illustrates another means for releasably securing a cutting control structure 31 to the bit body. In accordance with FIG. 8, a cutting control structure 31 includes a protrusion 30, an exposed end 51 having upper surface 52 and an anchoring end 55 having a top anchoring portion 54 and a releasable anchorage 56. The releasable anchorage 56 is of generally smaller diameter than the top anchoring portion 54. The releasable anchorage 56 has a locking surface 107, which has formed thereon a series of sharp edged radial projections 112 such as circular ridges or barsbs comprised of a hard material. A retention recess 109 is preformed or drilled in the bit body 12 forming a cavity or socket for insertion of the releasable anchorage 56. An annular sleeve element 105 of metal or other suitable material may be placed in the retention recess 109 and is shown extending into the retention recess 109 to form a shoulder 114. The sleeve element 105 has a hardness value less than that of the sharp edged radial projections 112 so that the releasable anchorage 56 may be inserted with force into the sleeve element 105 and retained by friction within the sleeve element 105 by the sharp ridges of barsbs 112. The cutting control structure 31 may be forcibly removed and replaced with another control structure 31 when the cutting control structure 31 becomes worn or broken from use in drilling subterranean material, thereby making a drill bit 10 refurbishable.

[0042] As shown in FIG. 8, the sleeve element 105 does not cover the center bottom region 111 of the retention recess 109. While in FIG. 9, the sleeve element 105 is constructed such that the center bottom region 111 of the retention recess 109 is covered by sleeve element 105. The shape, size and degree of overlay of the sleeve element 105 in the retention
recess 109 can be varied depending upon the degree of support needed in the retention recess 109 and depending on the material used for constructing the sleeve 105 and the locking surface 107.

[0043] FIG. 10 illustrates another means for releasably securing a cutting control structure 31 to the bit body 12. The cutting control structure 31 includes a protrusion 30 fixed to an upper surface 52 of an exposed end 51. The cutting control structure 31 further includes an anchoring end 55 having a top anchoring portion 54 and a releasable anchorage 56. The releasable anchorage 56 includes a substantially cylindrical and threaded portion 108 for releasably securing the cutting control structure 31 to the bit body 12. A sleeve 115 is mounted within a cavity 106 formed in the bit body 12. The sleeve 115 accommodates the top anchoring portion 54 of the cutting control structure 31 and is also shaped to accommodate the corresponding substantially cylindrical and threaded portion 108 of the releasable anchorage 56. A distal end 110 of the substantially cylindrical and threaded portion 108 of the releasable anchorage 56 passes through the sleeve 115 and is threadably engaged with the bit body 12. The threaded engagement of the releasable anchorage 56 to the bit body 12 fixes the sleeve 115 to the bit body 12 and allows the sleeve 115 and the cutting control structure 31 to be removed and replaced.

[0044] In other embodiments, the cutting control structure 31 can be releasably secured to the bit body 12 by welding, brazing, bonding, using studs, shrunk fitting a portion of the cutting control structure 31 to the bit body 12 and/or friction fitting a portion of the cutting control structure 31 to the bit body 12. For example, the upper surface 52 of the cutting control structure 31 could be welded, brazed and/or bonded around its perimeter. In another embodiment, it is also possible to braze the top anchoring portion 54 of the cutting control structure 31 within the recess 109 as illustrated in FIG. 8 and FIG. 11. Other mechanisms that secure the releasable anchorage 56 of the cutting control structure 31 shown in FIG. 8 include the implementation of threaded engagements, locking mechanisms, studs, friction fitting, shrunk fitting and the like.

[0045] The methods and systems herein disclosed of releasably securing a cutting control structure 31 are not limited to fixed-cutter rotary drill-bits. The methods and systems herein disclosed can be extended to releasably securing cutting control structures 31 to any down-hole tool that generates cuttings during operation including but not limited to fixed-cutter drag-type rotary tools such as rotary drill bits, casing bits, reamers, bi-center rotary drill bits, reamer wings, down-hole milling tools and bi-center drill bits. Furthermore, the systems and methods herein disclosed are not limited to drilling subterranean formations. The methods and systems herein disclosed can be extended to drilling or cutting any subterranean structure, composition of matter or formation that generates cuttings during downhole operations.

[0046] The embodiments disclosed herein exhibit significant advantages over the prior art. The embodiments disclosed herein permit rapid removal and replacement of cutting control structures that become worn or broken during drilling of subterranean material without degradation to the tool body. The embodiments disclosed herein also enable easy modification of the location of cutting control structures during field operations thereby optimizing the position of cutting control structures depending on the drilling conditions and conditions of the wellbore. Furthermore, a variety of cutting control structures such as splitters, breakers, diverters and wedges can be configured on a single tool body for optimal break-up and dispersion of cuttings during drilling operations, thereby optimizing rate of penetration of the drill bit and alleviating bit balling.

[0047] Example embodiments have been described herein above regarding a method and apparatus for repairing or refurbishing fixed-cutter drag-type rotary tools for drilling subterranean material and having cutting control structures releasably secured to the tool body. Various modifications to and departures from the disclosed example embodiments will occur to those having skill in the art. The subject matter that is intended to be within the spirit of this disclosure is set forth in the following claims.

1. A rotary tool for drilling subterranean material comprising:
   a tool body having a distal crown end comprising a circumferential series of raised cutting blades with recessed junk slots therebetween;
   cutting elements located proximate a leading peripheral edge of one of said raised cutting blades and cutting control structures located interiorly of said cutting element at a leading surface of an adjacent junk slot; and
   said cutting control structures being releasably secured to said tool body in said adjacent junk slot whereby a used rotary tool is refurbishable by removing worn cutting control structures without degradation to said tool body and replacing said worn cutting control structures by installing new cutting control structures in said worn cutting control structures’ locations.

2. The rotary tool as recited in claim 1, wherein a longitudinal axis of at least one of said cutting control structures is substantially aligned with a central axis of a cutting face of one of said cutting elements.

3. The rotary tool as recited in claim 1, further comprising:
   a carrier having an exposed end on which said cutting control structures are mounted and an anchoring end comprising a releasable anchorage releasably secured to said tool body.

4. The rotary tool as recited in claim 3, wherein said releasable anchorage is at least partially concealed within said tool body.

5. The rotary tool as recited in claim 4, wherein at least a portion of said releasable anchorage extends into an adjacent junk slot on an opposite side of said raised cutting blade.

6. The rotary tool as recited in claim 4, wherein at least a portion of said releasable anchorage is substantially cylindrically shaped and threaded about an exterior surface thereof.

7. The rotary tool as recited in claim 3, wherein said cutting control structures are spaced apart on said carrier at a distance substantially equal to a spacing distance between said cutting elements on said raised cutting blade.

8. The rotary tool as recited in claim 7, wherein at least one of said cutting control structures is located adjacent to one of said cutting elements on said raised cutting blade.

9. The rotary tool as recited in claim 7, wherein at least one of said cutting control structures is positioned relative to at least one of said cutting elements so that said at least one of said cutting control structures lies in a flow path of cuttings generated by at least one operating cutting element.

10. The rotary tool as recited in claim 7, wherein two cutting control structures are fixed to said carrier at a top surface of said exposed end thereof.
11. The rotary tool as recited in claim 7, wherein three cutting control structures are fixed to said carrier at a top surface of said exposed end thereof.

12. The rotary tool as recited in claim 3, wherein said exposed end of said carrier comprises an upper surface upon which the plurality of cutting control structures are mounted, said upper surface being flush-oriented with the leading surface of the adjacent junk slot.

13. The rotary tool as recited in claim 3, wherein said exposed end of said carrier comprises an upper surface upon which said cutting control structures are mounted, said upper surface being elevated above the leading surface of said adjacent junk slot.

14. The rotary tool as recited in claim 1, wherein at least a portion of at least one of said cutting control structures projects over a cutting face of an adjacent cutting element.

15. A method for manufacturing a rotary tool for drilling subterranean material comprising:

   providing a tool body having a distal crown end comprising a circumferential series of raised cutting blades with recessed junk slots therebetween;

   affixing a plurality of cutting elements proximate a leading peripheral edge of one of said raised cutting blades;

   providing a retention recess into said tool body and located interiorly of said cutting elements at a leading surface of an adjacent junk slot;

   installing a carrier with a plurality of cutting control structures in said retention recess; and

   releasably securing said carrier within said retention recess.

16. The method of claim 15, wherein releasably securing said carrier comprises welding said carrier into said retention recess.

17. The method of claim 15, wherein releasably securing said carrier comprises brazing said carrier into said retention recess.

18. The method of claim 15, wherein providing a retention recess into said tool body further comprises forming a cylindrical passage into said tool body at the leading surface of said adjacent junk slot.

19. The method of claim 18, wherein releasably securing said carrier within said retention recess comprises press-fitting a releasable anchorage of said carrier into said cylindrical passage.

20. The method of claim 18, wherein releasably securing said carrier within said retention recess comprises shrink-fitting a releasable anchorage of said carrier into said cylindrical passage.

21. The method of claim 18, further comprising forming threads in said cylindrical passage.

22. The method of claim 21, wherein releasably securing said carrier within said retention recess comprises screwing a releasable anchorage of said carrier into said cylindrical passage.

23. The method of claim 18, wherein releasably securing said carrier within said retention recess comprises passing a releasable anchorage of said carrier through said cylindrical passage and securing a distal end of said releasable anchorage at a near surface of said raised cutting blade.

24. The method of claim 15, wherein said plurality of cutting control structures are formed from at least one of the group comprising polycrystalline diamond compact (PDC), thermally stable polycrystalline diamond (TSP), cubic boron nitride (CBN), polycrystalline cubic boron nitride (PCBN), carbide and ceramics.

25. The method of claim 15, wherein said plurality of cutting control structures are formed from at least one of the group comprising copper, aluminum and plastic.

26. The method of claim 15, wherein said plurality of cutting control structures have a shape chosen from one of the following shapes: semi-cylindrical shaped, conical, elliptical, substantially rectangular, polygonal and diamond shapes.

27. A method for manufacturing a rotary tool for drilling subterranean material comprising:

   providing a tool body having a distal crown end comprising a circumferential series of raised cutting blades with recessed junk slots therebetween;

   affixing a plurality of cutting elements proximate a leading peripheral edge of one of said raised cutting blades;

   providing a retention recess into said tool body and located interiorly of said cutting elements at a leading surface of an adjacent junk slot; and

   releasably securing a cutting control structure within said retention recess.

28. The method of claim 27, wherein releasably securing said cutting control structure within said retention recess comprises one of welding, brazing, press fitting and shrink fitting said cutting control structure within said retention recess.

29. A method of refurbishing a rotary tool for drilling subterranean material comprising:

   obtaining a rotary tool that has been used to drill subterranean material, said rotary tool comprising a tool body having a distal crown end comprising a circumferential series of raised cutting blades with recessed junk slots therebetween, a plurality of cutting elements affixed proximate a leading peripheral edge of one of said raised cutting blades and a plurality of cutting control structures releasably secured interiorly of said cutting elements at a leading surface of an adjacent junk slot;

   removing at least one of said plurality of cutting control structures; and

   replacing said at least one cutting control structure with a new cutting control structure and thereby refurbishing said rotary tool.

30. A method of drilling subterranean material with a rotary tool, comprising:

   rotating a rotary tool into subterranean material, said rotary tool comprising a tool body having a distal crown end comprising a circumferential series of raised cutting blades with recessed junk slots therebetween, a plurality of cutting elements affixed proximate a leading peripheral edge of one of said raised cutting blades and a plurality of cutting control structures releasably secured interiorly of said cutting elements at a leading surface of an adjacent junk slot;

   engaging the formation with said plurality of cutting elements to generate a plurality of formation cuttings; and

   modifying an attribute of at least one of said plurality of formation cuttings generated by at least one of said plurality of cutting elements engaging said formation with at least one of said plurality of cutting control structures.

31. The method of claim 30, wherein modifying said attribute of said at least one of said plurality of formation
32. The method of claim 30, wherein modifying said attribute of said at least one of said plurality of formation cuttings comprises modifying the shape of said at least one of said plurality of formation cuttings.

33. The method of claim 30, wherein modifying said attribute of said at least one of said plurality of formation cuttings comprises modifying a directional path of said at least one of said plurality of formation cuttings.

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