

CASING END TOOL

TECHNICAL FIELD

The present invention relates generally to drilling a wellbore, and more particularly to the drilling tools used at the end of a casing or liner within the wellbore. The present invention
5 concerns drilling tools (and methods for forming drilling tools) that are attachable to a casing or liner string. In the context of the present invention, the terms casing and liner are used interchangeably.

BACKGROUND

In conventional drilling techniques, a longitudinally extending string comprising sections
10 of drill pipe is secured to a drill bit of a larger diameter than the drill pipe. After a selected portion of the wellbore has been drilled, the drill string is removed and a string of tubular members of lesser diameter than the wellbore, known as a casing string, is placed in the wellbore. The annulus between the wall of the wellbore and the outside of the casing string is then filled with cement by pumping the cement down through a casing shoe or reamer shoe
15 disposed at the end of the casing string. Because the drill bit is removed intact from the wellbore after drilling, it may be made of strong abrasive and erosion resistant material, such as tungsten carbide.

In an alternative technique, designed to address the inefficiencies associated with making multiple wellbore trips in the conventional drilling technique discussed above, it is now known
20 to drill with casing. In this technique, the drilling operation employs a drill bit, termed a casing bit, which is attached to the end of the casing string. The casing bit functions not only to drill the earth formation, but also to guide the casing string into the wellbore. The casing bit remains in place during subsequent cementing of the casing in place. The casing string is thus run into the wellbore as the wellbore is being formed by the casing bit. This eliminates the need for one or
25 more extra trips to retrieve a drill string and drill bit after reaching a target depth where cementing is desired.

In either technique, additional drilling beyond the end depth of the casing string may be required. If so, the operator must drill out the casing end tool (shoe or bit) to reach the underlying formation. This is typically accomplished with a mill bit that is specifically designed to cut through the material from which the shoe or bit is made. This has led to the development of casing end tools that are more readily drilled out. Primarily, such end tools use an aluminum alloy as the parent body material for the reamer nose or the cutting structure carrying face of the end tool. More recently, casing end tools made of alloyed steel have been commercialized and are run on casing prior to being drilled out with specially designed drill out polycrystalline diamond compact (PDC) bits that carry an additional, standalone, overexposed tungsten carbide cutting structure to accomplish the drill out. Each of the aluminum and steel casing end tools are fabricated by processes other than infiltration casting, such as machining a billet of steel.

Prior art efforts relating to casing operations are set forth below. All references discussed herein are incorporated by reference.

U.S. Patent No. 5,373,907 to Weaver discloses a fabrication method for rotary drill bits. The rotary drill bit is fabricated using an infiltration matrix casting method that is known in the art. Hard matrix powder, which is primarily tungsten carbide, is loaded into the mold. This powder will ultimately form the body of the bit. A soft matrix powder is also loaded into the mold, such that when the drill bit is formed, the soft matrix powder provides a chamfer at the gage of the bit. This soft matrix powder may be machined in a subsequent operation.

U.S. Patent No. 6,062,326 to Strong et al discloses a casing shoe/reamer with cutting means. The shoe/reamer has flutes (blades) that in one embodiment carry PDC cutters along the gage and across the nose of the tool. The tool is disclosed as being made either from drillable aluminum or non-drillable material. In one embodiment the nose section is designed to be segmented with the segments being hinged to the outer portion of the tool so the nose segments can be pushed out and forward prior to cementing or as part of the cementing process.

U.S. Patent Nos. 6,401,820 and 6,659,173 to Kirk et al describe a shoe with reaming members and a nose portion of aluminum or zinc alloy to allow the nose to be drilled out.

U.S. Patent No. 6,443,247 to Wardley describes a casing drilling shoe with an outer drilling section constructed of a hard material such as steel and an inner section constructed of a readily drillable material such as aluminum. It further includes a device for displacing the outer drilling section radially outwardly.

U.S. Patent No. 6,848,517 to Wardley describes a drillable drill bit nozzle for use in a drill bit that is going to be drilled out.

U.S. Patent No. 7,066,253 to Baker describes a casing shoe or reamer shoe with an outer body of relatively hard material and a nose of relatively soft material which are interlocked. A following drill bit is used to drill out the majority of the soft material leaving a sheath of the soft material in the internal circumference of the hard material.

U.S. Patent No. 7,096,982 to McKay et al discloses a drill shoe with a body constructed of a relatively soft material which is set with blades of a relatively hard material. The blades, typically steel, are further set with PDC cutters. Once the desired depth of drilling has been achieved, a displacement element is activated to push out the soft material and bend the blades to the sidewalls of the annulus. The displacement element can then be drilled out with a following bit. McKay wants to provide a cutting structure support mechanism with the steel blades strong enough to handle drilling loads.

U.S. Patent No. 7,117,960 to Wheeler et al describes a bit for drilling with a completion string that incorporates an integrated female non-shouldered oilfield completion string thread. The specification describes the bit as being manufactured from a material which does not allow the bit to be readily drilled.

U.S. Patent No. 7,216,727 to Wardley discloses a casing drilling bit constructed from a relatively soft material such as aluminum, copper, or brass alloy and is coated with relatively

hard material. The cutting means of the cutting members consist of fine layers or cutting elements formed from hard material.

U.S. Patent No. 7,395,882 to Oldham et al is for “Casing and Liner Drilling Bits”. This patent teaches making such tools with an axisymmetric inner profile to be evenly addressed by a
5 subsequent drilling bit having a corresponding axisymmetric outer profile. It also teaches using nozzles deployed with sleeves, and gage sections that extend over the casing to which the tool is attached.

U.S. Patent Application Publication No. 2007/028972 to Clark et al is for “Reaming Tool Suitable for Running on Casing or Liner and Method of Reaming”. This published application
10 also teaches an axisymmetric inner profile and further states “....the absence of blades in the nose area projecting above the face of the nose allows for an uninterrupted cut of material of the body shell in the nose, making the reaming tool PDC bit-drillable.”

U.S. Patent No. 6,845,816 to Kirk et al teaches the use of an austempered ductile iron (ADI) material for a centralizer. This material is more robust than aluminum and lighter than
15 and more machinable than steel. See also, for example, ADI materials provided for sale by THDick.

Reference is also made to the Baker Hughes (Hughes Christensen) EZ Case Casing Bit System and the Weatherford International DrillShoe tools used for drilling with casing prior art devices (the disclosures of which are hereby incorporated by reference).

20 Various materials have been used to craft the body of the casing bit to facilitate the drill out operation. Aluminum is readily drilled out but is generally a softer material and may become gummy under the high drill out forces resulting in difficulty removing the drilled out aluminum from the wellbore. It also has a low resistance to erosion and abrasion, and cannot take the level of loading that steel is able to absorb. Alternatively, steel is more robust than aluminum, but it is
25 much more difficult to drill out, and it is prone to damage the cutting elements of the mill bit making additional drilling with the same tool after drill out more difficult.

SUMMARY

Casing end tools used for casing drilling and reaming or liner drill in or reaming are presented which overcome many of the previously noted shortfalls of the prior art. These tools
5 employ advanced design and manufacturing techniques not previously practiced on casing end tools. A preferred, but non-limiting, embodiment of a casing bit is described.

In an embodiment, the casing end tool body is cast from crystalline tungsten infiltrated with a brass binder. A steel cylinder may act as a blank or casting mandrel as is known in the art. Typically a blank makes up the central body of an infiltrated drill bit. The mold is loaded
10 with crystalline tungsten powder and an infiltration metal, typically a nickel brass alloy. The mold is then placed into a furnace with temperatures sufficient to melt the infiltration metal or binder material down into the crystalline tungsten powder. The great advantage of this embodiment is that it can take advantage of existing materials, design software, casting methods, and machine tools used in infiltration casting of drill bits.

In an embodiment, the casing end tool does not have a regular axisymmetric inner profile, but rather a non-axisymmetric pattern of raised bosses or lands creating an uneven, undulating and irregular surface (it being understood that “axisymmetric” means “exhibiting symmetry around an axis; or exhibiting cylindrical symmetry”). The point here is to increase the amount of interrupted cut during drill out (by an axisymmetric mill/drill bit) to stress the center part of the
20 bit body and improve fragmentation during drill out. At least some of the raised bosses or lands are meant to provide increased contact and support area if highly extended port sleeves are used. During drill out the lands are contacted first by a drill out or mill bit, and thus the likelihood of break up and fragmentation of the casing bit is increased.

In certain embodiments, blade channels and/or cutter channels may be cast or cut into
25 each exterior blade surface to increase fragmentation during drill out. Also, blind holes may be drilled or cast into the face of the casing end tool. These holes do not break into the plenum of

the tool. The purpose of the channels and holes is to create interrupted cuts and fracture points across the casing end tool face to accelerate the break up and fragmentation of the end tool face during drill out. For example, the cutter channels formed on the blades of the casing end tool may enhance fragmentation such that each cutter is more likely to be broken into an individual
5 fragment.

In an embodiment the casing end tool uses cutter back up structures. These cutter back up structures may be cast from the parent body material or may be manufactured separately and pressed, glued or brazed in. These structures may be made of steel, tungsten carbide, vanadium carbide, tungsten carbide matrix, domed superabrasive, or may be diamond impregnated
10 segments. The cutter back up structures may be slightly overexposed, equally exposed, or underexposed in comparison to their corresponding primary cutter. The cutter back up structures may be at the same radial distance, or at a slightly greater distance, or at a slightly lesser distance from bit centerline than their corresponding primary cutter.

In an embodiment, the casing end tool includes one or more ports or sleeved ports. If
15 sleeves are used they may be made of thin walled tungsten carbide, vanadium carbide, ceramic, or steel and may be brazed in holes formed in the casing bit body during casting. The flow through these sleeved ports may improve cleaning and drilling efficiency while reducing the incidence of bit body erosion. In an embodiment, the port sleeves may extend into the inner plenum of the casing end tool to move the active area of erosive flow away from the inner
20 concave surface of the tool.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an isometric view of a casing end tool in the form of a casing bit;

Figure 2 is a cross-section of the casing bit of Figure 1 illustrating cutter channels according to the present disclosure;

5 Figure 3 is a cross-section of the casing bit of Figure 1 taken through a different portion of the casing bit than shown in Figure 2;

Figure 4A is a side view of one embodiment of a cutter for use with the casing bit of Figure 1;

10 Figure 4B is a side view of another embodiment of a cutter for use with the casing bit of Figure 1;

Figure 5 is a plan view of the internal surfaces of a casing bit of Figure 1;

Figure 6 is a plan view of the face of the casing bit of Figure 1; and

15 Figure 7 is a side view of a cutter showing a cutter cap in accordance with the present disclosure.

DETAILED DESCRIPTION OF THE DRAWINGS

Reference is now made to Figure 1 which shows an isometric view of a casing end tool in the form of a casing bit 100 in accordance with an embodiment of the present disclosure. The casing bit 100 has a bit body 101 generally defining a bowl-like or cup-like configuration.

5 Formed on the outer surface of the casing bit 100 are a number of blades 106. Each blade 106 supports a plurality of cutters 108. Each cutter may have its superabrasive surface facing in approximately the same rotational direction to facilitate drilling as the casing bit 100 rotates counter-clockwise. The blades 106 extend outwardly from a central rotational axis of the casing bit 100 to define the gage of the bit. The portions of the casing bit 100 between the blades 106

10 are known as junk slots 118, but any suitable number of blades may be used depending on the particular drilling application. The illustrated embodiment shows four blades 106 and four junk slots 118. The earth removed by the cutters 108 may be directed by the junk slots 118 to flow up the wellbore.

A typical infiltration process for casting the casing bit 100 as a matrix body drill bit

15 begins by centering a cylinder blank 103 in a casting mold. The cylinder blank 103 of the bit is typically made of steel. This steel cylinder blank 103 acts as the blank or casting mandrel as is known in the art. Typically, a blank makes up the central body of an infiltrated drill bit. Matrix powder is then loaded into the mold. According to an embodiment of the present disclosure, the matrix powder may be crystalline tungsten powder. To enable subsequent processing to add

20 superabrasive cutters, graphite inserts are placed in the mold as cutter displacements to create voids in which PDC cutters will be subsequently brazed to the bit body after the bit body 101 is formed.

A binder alloy is placed on top of the crystalline tungsten powder and topped with flux. The binder may be a nickel brass alloy. A lid then covers the finished mold. The entire mold is

25 first preheated and then placed in a furnace. When the furnace reaches the melting point of the binder alloy, the binder infiltrates the crystalline tungsten powder. This creates a matrix cast of the bit body 101 that bonds with and becomes integral with the cylinder blank 103. The casting

is then removed and quenched at a controlled rate. Once cooled, the mold is broken away from the casting and the casing bit 100 is subsequently processed. For example, the cutter displacements are removed and prefabricated tungsten carbide PDC cutters are brazed to the blades 106.

5 In this embodiment, the matrix of the binder and the crystalline tungsten may enhance the erosion resistance of the nose or face of the tool, and the bit may still be machinable and will fragment and break apart when drilled out.

Reference is made to Figures 2 and 3, each of which show different cross sections of the casing bit 100 shown in Figure 1. The inner surface 102 and outer surface 104 of the bit body
10 101 define opposed sides of a wall which surrounds the central plenum region 132. The inner surface 102 may be generally concave in shape, while the outer surface 104 may be generally convex. The casing bit 100 also includes ports 130. If desired, each port may comprise a sleeved port 132. If a port sleeve 132 is used for a given port 130, the sleeve may be made of thin walled tungsten carbide, vanadium carbide, ceramic, or steel. Fluid flow through the ports
15 130 (sleeved ports 132) may allow for cleaning and drilling efficiency while reducing the incidence of bit body 101 erosion. In an embodiment, the port sleeves 132 may extend into the inner plenum 134 of the casing end tool to move the active area of erosive flow away from the inner surface 102 of the tool.

In an embodiment, the casing bit 100 does not have a regular or symmetric inner surface
20 102 profile but rather has an inner surface 102 with a non-axisymmetric pattern of raised bosses 140 or lands. This creates an uneven, undulating inner surface and thus an irregular inner profile. The point of this feature is to increase the amount of interrupted cut in the total bit body 101 during drill out by a mill/drill bit which may present an axisymmetric face in contact with the inner surface 102. The non-axisymmetric inner surface 102 will allow the drill out forces to
25 stress smaller portions of the tool bit body 101, and thus improve fragmentation of the casing bit 100 during drill out. The outer surface 104 of the tool, on the contrary may define an axisymmetric shape.

In an alternative embodiment, the inner surface 102 of the casing end tool may have an axisymmetric inner profile which preferably does not match the axisymmetric face of the mill/drill bit.

At least some of the raised bosses 140 or lands provide an additional function in that they
5 increase the thickness of the bit body 101 at and around the ports 130. This may provide increased contact and support area if extended port sleeves 132 are used. The port sleeves 132 may extend, for example, at least $\frac{1}{4}$ inch from the surrounding raised boss 140 or land.

The outer surface 104 of the casing bit 100 also includes channels to enhance fragmentation of the casing bit 100 during drill out. In certain embodiments, blade channels 191
10 may generally follow each blade 106 radially. Cutter channels 190 may run generally circumferentially and may generally correspond to each cutter 108 on the blade 106. The cutter channels 190 may cause each cutter 108 to break away from other fragments of the bit body 101 individually. The cutter channels 190 and/or the blade channels 191 may be cut or cast in the blades 106. The cutter channels may be cast in the blade 106 behind a cutter 108, in order to
15 increase the fragmentation of the casing bit 100 during drill out.

Each blade 106 may have a blade thickness extending beyond the main portion of the bit body 101. In certain embodiments, the depth of the blade thickness may be approximately $\frac{1}{2}$ inch. In certain embodiments, the depth of blade channels 191 and/or the cutter channels 190 may not extend to the full depth of the blade thickness. Rather, the channels may extend only
20 partially through the blade 106. In certain embodiments, the channels may extend approximately half the thickness of the blade 106. This may leave approximately $\frac{1}{4}$ inch of the blade thickness at the valley of the channels. By extending the channel only partially through the thickness of the blade 106, during the drilling operation, incidences of unintentional shearing of the blade from the remainder of the bit body 101 may be reduced or eliminated.

25 Several approaches are incorporated in the construction of the superabrasive cutting elements for the casing bit 100 of Figures 1-3. For example, polycrystalline diamond

(PCD/PDC) cutting elements may be subsequently attached to the cast bit body 101. Typical superabrasive cutting elements are 13mm in diameter and 13mm in length. The vast majority of the 13mm length is of tungsten carbide.

Figure 4A shows a side view of one embodiment of a cutter 108 for use the tool of Figure 1. This cutter, for example with a diameter ranging from 8mm and 19mm, uses a short tungsten carbide substrate 200 (for example, resulting in a total cutter length of 8mm, or 5mm, or 3mm). The cutter further includes a diamond layer (table) 202.

Figure 4B shows a side view of another embodiment of a cutter 108 for use in the tool of Figure 1. This cutter also has a short tungsten carbide substrate 200. However, if a longer cutter is needed, the short tungsten carbide substrate 200 is bonded to an additional length of alternative substrate material 204 such as steel or vanadium carbide. This allows for casing end tools that are designed around cutters of a traditional total length to use cutters which reduce the total amount of hard cemented tungsten carbide material to be encountered during drill out.

The cutters of Figures 4A and 4B may employ diamond layers 202 that are partially shallow leached or partially deep leached (see, for example, U.S. Patent Nos. 6,861,098, 6,861,137, 6,878,447, 6,601,662, 6,544,308, 6,562,462, 6,585,064, 6,589,640, 6,592,985, 6,739,214, 6,749,033, and 6,797,326, the disclosures of which are hereby incorporated by reference). In an alternative embodiment, the cutters of Figures 4A and 4B employ fully leached diamond tables 202 that have been reattached to the substrate 200 through a second high pressure/high temperature (HP/HT) press cycle (see, for example, U.S. Patent No. 5,127,923, the disclosure of which is hereby incorporated by reference).

Reference is now made to Figure 5 which shows a plan view of the casing bit 100 of Figure 1. The view in Figure 5 is looking into the bowl-like or cup-like configuration towards the inner surface 102. The raised bosses 140 are generally shown with a circular/oval shape as a matter of convenience and not limitation as the bosses can take on any desired shape which supports the formation of a non-axisymmetric pattern on the inner surface 102. Figure 5 further

shows how a boss 140 has been associated with the location of each extended port sleeve 132. As illustrated, the inner surface 102 may also have one or more raised bosses 140 that do not coincide with a port 130.

Reference is now made to Figure 6 which shows a plan view of the casing bit 100 Figure 1. The view in Figure 6 is looking at the face 105 of the bit 100. The face 105 includes a plurality of blades 106, each having a spiral configuration. It will be noted that the blades 106 could, alternatively, be straight blades as known in the art. The layout of the blades 106 is symmetric, but it will be understood that an asymmetric blade configuration could alternatively be used.

In an embodiment, as shown in Figure 6, the casing bit 100 includes on at least one blade a set of cutter back up structures 170. See, for example, U.S. Patent Nos. 5,090,492, 5,244,039, 4,889,017, and 4,823,892, the disclosures of which are incorporated by reference. The cutter back up structures 170 may be cast as part of the crystalline tungsten bit body 101, or in alternate embodiments, the backup structures 170 may be manufactured separately or from a different material and pressed, glued or brazed in. These structures may be made of steel, ADI, tungsten carbide, vanadium carbide, tungsten carbide matrix, crystalline tungsten matrix, domed superabrasive, or may be diamond impregnated segments. The cutter back up structures 170 may be slightly overexposed, equally exposed, or underexposed in comparison to their corresponding primary cutter. The cutter back up structures 170 may be at the same radial distance, or at a slightly greater distance, or at a slightly lesser distance from bit centerline than their corresponding primary cutter 108.

In any of the embodiments described above, one or more holes 200 may be drilled or cast into the face of the casing bit 100. These may be blind holes which do not extend to break into the plenum 134 of the tool. These blind holes 200 may create interrupted cuts and fracture points across the end tool face to accelerate the break up and fragmentation of the end tool face during drill out. Alternatively, the blind holes 200 may be provided on the inner surface. The sleeved

ports are also shown in Figure 6. In certain embodiments, the port sleeve 132 may be slightly recessed.

Reference is now made to Figure 7, which shows a side view of a cutter 500. The cutter 500 of Figure 7 can be used at any one or more of the cutter locations for casing end tools such as the casing bit 100 shown herein. The cutter 500 is fitted with a protective cap 502 made of a material better suited for milling operations (such as tungsten carbide or CBN). In this instance, the casing end tool has an enhanced capability of performing drill out through float equipment or a previously run and cemented casing end tool, or both.

In Figure 7, the PDC cutter 500 comprises a diamond table layer 504 (or diamond face) and an underlying substrate 506 which may be made of a tungsten carbide material. The underlying substrate 506 may alternatively have the form shown in Figures 4A and 4B. The diamond table layer 504 may be non-leached, shallow leached, deep leached, or resubstrated fully leached, as desired.

It will be understood that the cap 502 can, in a first implementation, be installed on the PDC cutter 500 after the PDC cutter has been secured to the cutter pocket of the bit body. Alternatively, in a second implementation, the cap 502 is installed on the PDC cutter 500 before securing the combined cutter-cap assembly to the cutter pocket of the bit body 101. Thus, the first implementation represents, for example, a retrofitting of a manufactured PDC casing bit to include a cap on desired ones of the included PDC cutters. Conversely, the second implementation represents, for example, the fabrication of a new PDC casing bit to include a capped PDC cutter at selected locations.

Figure 7 specifically illustrates the use of a tungsten carbide cap 502 (i.e., a cap made from tungsten carbide material). The material for the cap 502 may comprise a high toughness, low abrasion resistant tungsten carbide material, for example, a tungsten carbide material containing cobalt percentages in the 14-18% range. The cap 502 may have any desired shape, and several different shapes and configurations are discussed herein. Alternatively, as will be

discussed in more detail herein, the cap 502 may alternatively be made of a metal (or metal alloy) material. Still further, that metal/metal alloy cap 502 may include a tungsten carbide or CBN tip. The cap 502 may alternatively be made of another suitable material of choice (non-limiting examples of materials for the cap include: steel, titanium, nickel and molybdenum).

5 The cap 502 is held in place on the PDC cutter through a bonding action between the cap and the substrate 506 of the PDC cutter 500. More specifically, a portion of the cap is bonded to a portion of, or a majority of, the substrate 506 of the installed PDC cutter that is exposed outside of the casing bit body (i.e., outside of the cutter pocket). The cap 502 is attached to the PDC
10 cutter, in one implementation, using brazing 508 to (tungsten carbide, for example) substrate 506. The thickness of the braze material 508 illustrated in Figure 7 is shown over-scale in order to make its location and presence clear.

 Preferably, the cap 502 is not brazed (i.e., is not attached) to the diamond table layer 504 of the PDC cutter 500. Rather, a first portion 510 of the cap over the front face of the diamond
15 table layer 504 of the PDC cutter 500 simply rests adjacent to that face, while a second portion 512 of the cap over the substrate 506 is secured to that substrate by bonding. In this context, it is recognized that PDC diamond is not wettable with standard braze material. It is important that the diamond table 504 face of the PDC cutter 500 be protected by the cap 502 without the cap
20 being directly bonded to the face. The second portion 512 of the cap 502 adjacent the substrate 506 of the PDC, which is brazed and attached to the substrate material, may further be attached through brazing to the bit body 101 in an area at the back of the cutter pocket. The first portion
25 510 of the cap 502 may also be attached through brazing to the cutter pocket (more specifically, the base of the cutter pocket below the face of the PDC cutter). In some embodiments shorter substrate PDC cutters are used to increase the bond area of the cap at the base of the cutter pocket. In some embodiments the pocket base is configured to increase the bonding area
 available to the cap at the same location.

 Some braze material 508 may advantageously be present between the cap 502 and the front face of the diamond table layer 504 of the PDC cutter, but this material does not serve to

secure the cap to the diamond table layer. In a preferred embodiment, the braze material used to braze the cap to the cutter substrate adheres to the inner surfaces of the cap that are adjacent to the diamond table face and periphery of the PDC diamond layer. This braze material provides a thin cushioning layer to limit the transfer of impact loads to the diamond layer while the caps are
5 in use for milling casing or casing-associated equipment. The preferred configuration which does not adhere the cap to the diamond table face is preferred as this allows the cap to break free from the cutter when no longer needed (for example, once a milling operation is completed).

In an alternative embodiment the cap can be pre-mounted on the PDC cutter using a high temperature braze material in an LS bonder as is known in the art. The pre-capped PDC cutter
10 can then be brazed into the cutter pocket of a drill bit using known brazing methods and temperatures for brazing cutters into bits.

The casing bit of the present invention is designed to balance the requirements of drillability with the desired drilling performance characteristics needed for efficient and economical drilling with casing. To this end, the current invention incorporates new technology
15 and technology adapted from other drilling tools but modified and enhanced to meet the challenges presented by the unique geometry, clearances, and requirements of mounting a drilling tool on casing. The casing end tool of the present invention includes features to improve casing drilling performance, improve reaming, improve drillability, reduce body erosion, and increase break up and flushing of drilled out debris.

20 Embodiments of the invention have been described and illustrated above. The invention is not limited to the disclosed embodiments.

WHAT IS CLAIMED IS:

1. A casing bit, comprising:

a mandrel; and

a bit body bonded to the mandrel, the bit body having an inner surface and an outer surface opposite the inner surface, the bit body consisting essentially of a matrix material of crystalline tungsten and a binder material.
2. The casing bit of claim 1 wherein the bit body includes at least one blade.
3. The casing bit of claim 2 wherein the blade includes at least one channel having a channel depth less than a thickness of the blade.
4. The casing bit of claim 3 wherein the at least one channel is a blade channel radially following the blade.
5. The casing bit of claim 3 wherein the blade includes a plurality of cutters, each cutter being bonded to the blade.
6. The casing bit of claim 5 wherein each cutter is a polycrystalline diamond cutter.

7. The casing bit of claim 5 wherein each cutter comprises a diamond table mounted to a substrate of a first material.

8. The casing bit of claim 5 wherein the blade further includes a plurality of cutter channels, each cutter channel running circumferentially and having a depth less than the blade thickness.

9. The casing bit of claim 8 wherein the blade further comprises a plurality of cutter backup structures, and wherein one of the cutter channels is formed between adjacent ones of the cutter backup structures.

10. The casing bit of claim 8 further including a cap mounted to the substrate of the first material, wherein the cap at least partially overlies, but is not attached to, the diamond table.

11. The casing bit of claim 10 wherein the cap is made of or tipped with tungsten carbide.

12. The casing bit of claim 1 further including a plurality of blind openings formed in either the inner surface or the outer surface.

13. The casing bit of claim 1 wherein the binder material comprises brass.

14. The casing bit of claim 13 wherein the binder material comprises a nickel-brass alloy.

15. The casing bit of claim 1 wherein the inner surface includes a plurality of non-axisymmetric regions defined by raised portions of the inner surface.

16. The casing bit of claim 15 wherein the raised portions comprise a raised boss structure or a raised land structure.

17. The casing bit of claim 16 wherein the inner surface is configured such that during a drill out operation, drill out forces on the inner surface are first received by the raised boss structure or the raised land structure.

18. A casing end tool, comprising:

a tool body bonded to a mandrel, the tool body including a face portion having an inner surface, the face portion comprising a crystalline tungsten matrix material.

19. The tool of claim 18 wherein the tool body includes a plurality of blades.

20. The tool of claim 18 wherein the inner surface includes a plurality of non-axisymmetric regions defined by raised portions of the inner surface.

21. The tool of claim 20 wherein the raised portions comprise a raised boss structure or a raised land structure.

22. The tool of claim 21 wherein the inner surface is configured such that during a drill out operation, drill out forces on the inner surface are first received by the raised boss structure or the raised land structure.

23. The tool of claim 18 further including a plurality of blades, each blade supporting a plurality of cutter elements and further including at least one cutter channel having a depth less than a thickness of the blade.

24. The tool of claim 23 wherein one of the blades further comprises a plurality of cutter backup structures, and wherein the cutter channel is formed between adjacent ones of the cutter backup structures.

25. The tool of claim 18 wherein the tool is one of a casing bit or a casing reamer.

26. A casing end tool, comprising:

a body bonded to a mandrel, the body having a plurality of blades, each blade having at least one channel having a channel depth less than a thickness of the blade.

27. The tool of claim 26 wherein each blade supports a plurality of cutter elements, and the at least one channel running circumferentially along the blade.

28. The tool of claim 26 wherein the body includes an inner surface and an outer surface opposite the inner surface, the inner surface having a non-axisymmetric region being defined by a raised region of the inner surface.

29. The tool of claim 26 wherein the raised region comprises a raised boss or raised land structure.

30. The tool of claim 26 wherein the body further comprises:

a wall defining an inner surface and an outer surface opposite the inner surface; and

a plurality of ports formed through the inner surface and the outer surface, each port having a surrounding thicker region of the wall interior to the bit body.

31. The tool of claim 30 further including a port sleeve for each port, the port sleeve extending above the surrounding thicker region.

32. The tool of claim 26 wherein the at least one channel is a blade channel radially following the blade.

33. The tool of claim 26 wherein the body includes a face portion formed of a crystalline tungsten matrix material.