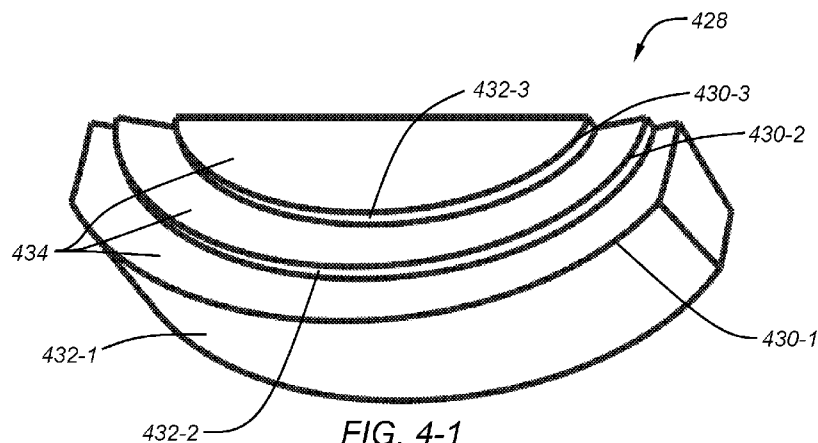


(43) International Publication Date
5 October 2017 (05.10.2017)

- (51) **International Patent Classification:**
E21B 29/00 (2006.01) *E21B 17/00* (2006.01)
- (21) **International Application Number:**
PCT/US2016/058965
- (22) **International Filing Date:**
27 October 2016 (27.10.2016)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
62/316,548 31 March 2016 (31.03.2016) US
- (71) **Applicant (for US only):** **SCHLUMBERGER TECHNOLOGY CORPORATION** [US/US]; 300 Schlumberger Drive, Sugar Land, Texas 77478 (US).
- (71) **Applicant (for CA only):** **SCHLUMBERGER CANADA LIMITED** [CA/CA]; 125 - 9 Avenue SE, Calgary, Alberta T2G 0P6 (CA).
- (71) **Applicant (for FR only):** **SERVICES PETROLIERS SCHLUMBERGER** [FR/FR]; 42 rue Saint Dominique, 75007 Paris (FR).
- (71) **Applicant (for all designated States except CA, DJ, FR, KW, US):** **SCHLUMBERGER TECHNOLOGY B.V.** [NL/NL]; Parkstraat 83-89m, NL-2514 JG The Hague (NL).
- (72) **Inventors:** **XIA, Sike**; 2507 Rock Shoals Way, Pearland, Texas 77584 (US). **BALASUBRAMANIAN, Nagarajan**; 19807 Pence Hills Court, Cypress, Texas 77433 (US). **DODGE, Jeffrey N.**; 4923 Maple Brook Lane, Kingwood,

Texas 77345 (US). **STOKES, David Alexander**; 186 West Stedhill Loop, The Woodlands, Texas 77374 (US).(74) **Agents:** **NUTTALL, Colby C.** et al.; 10001 Richmond Avenue, IP Administration Center of Excellence, Room 4720, Houston, Texas 77042 (US).(81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).**Published:**

— with international search report (Art. 21(3))

(54) **Title:** CUTTING INSERT FOR A MILLING TOOL

(57) **Abstract:** A milling tool includes a cutting insert coupled to a blade. The blade may change from a retracted to an expanded state to engage and cut downhole casing. The cutting insert may include a semi-elliptical body having major and minor diameters. The length may be about equal to half a minor diameter of the semi-elliptical body, and the width may be greater than 85% of the major diameter of the semi-elliptical body. A front cutting edge may follow an elliptical curve. One or more back-up cutting edges or chip-breakers may also follow elliptical curves. The milling tool may include multiple blades. One or more of the blades may have different arrangements of cutting inserts. Different arrangements may include varying the position of similar cutting inserts or using different types/geometries of cutting inserts on different blades.

TITLE

CUTTING INSERT FOR A MILLING TOOL

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application claims the benefit of, and priority to, U.S. Application No. 62/316,548 filed March 31, 2016. This application is also related to U.S. Patent Application No. 62/248,207 filed October 29, 2015 and U.S. Patent Application No. 15/017,918, filed on February 8, 2016. Each of the foregoing applications is expressly incorporated herein by this reference in its entirety.

BACKGROUND

10 When drilling an oil and gas well, one or more casing strings are installed and cemented in a wellbore as drilling progresses to increasing depths. The casing strings may provide stability to limit cave-ins in unstable formations, and may isolate the wellbore from the surrounding formation. As a result, the casing strings can seal off high-pressure zones from the surface and prevent fluid loss or
15 contamination of production zones. The casing strings may also provide a smooth internal surface for installing production equipment.

Once the oil and gas well is no longer commercially viable, the well may be abandoned, or slot recovery may be performed to use the wellbore as a kickoff point for sidetracking and the formation of a lateral borehole. Removal of a portion of a casing string for well abandonment or slot recovery
20 operations may include performing a section milling operation. Section mill blades are in a retracted or inactive state when the milling tool is tripped into the wellbore. Upon reaching a desired depth, the section mill blades are expanded into a radially outward, active state that engages the casing. As the milling tool and milling blades are rotated in the wellbore, the blades make a circumferential cut in the casing string. The tool string is then urged downhole while rotation continues so as to axially mill away
25 a desired length of the casing string.

SUMMARY

According to one or more embodiments, a cutting element includes a semi-elliptical body having major and minor diameters. A length of the body is up to half a minor diameter of the semi-elliptical
30 body, and a width of the body is at least 85% of a major diameter of the semi-elliptical body. A front cutting edge follows an elliptical curve, and one or more back-up cutting edges follow elliptical curves.

According to other embodiments, a milling tool, such as a section mill, may include a body and a blade coupled to the blade. The blade may include at least one semi-elliptical cutting insert coupled thereto.

35 In still other embodiments, a downhole cutting tool includes a body and at least two blades coupled to the body. Cutting elements are coupled to each of the blades, and the blades have different arrangements of cutting elements.

Methods of milling casing may, in some embodiments, include inserting a mill into a wellbore while a plurality of selectively expandable blades of the mill are in a retracted position. The selectively expandable blades may have cutting elements coupled thereto. The mill may be activated and the selectively expandable blade expanded radially outward, which may cause the cutting elements to contact casing lining the wellbore. A radial cut-out may be formed in the casing. The cut-out may be extended axially by using the cutting elements to cut axially along the casing.

A method of producing blades of a milling tool is also disclosed according to one or more embodiments. A first milling blade may be formed by coupling cutting inserts thereto. A second milling blade may be formed by coupling cutting inserts thereto. The first and second milling blades may have the same or different arrangements of cutting inserts. The cutting inserts on one or both of the first and second milling blades may be semi-elliptical, may have a curved cut-out, or may have some other configuration.

This summary is provided to introduce some features and concepts that are further developed in the detailed description. Other features and aspects of the present disclosure will become apparent to those persons having ordinary skill in the art through consideration of the ensuing description, the accompanying drawings, and the appended claims. This summary is therefore 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 claims.

BRIEF DESCRIPTION OF DRAWINGS

In order to describe various features and concepts of the present disclosure, a more particular description of certain subject matter will be rendered by reference to specific embodiments illustrated in the appended drawings. Understanding that these drawings depict just some example embodiments and are not to be considered to be limiting in scope, nor drawn to scale for each embodiment contemplated hereby, various embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

FIG. 1 is a schematic illustration of an example downhole milling system, in accordance with one or more embodiments of the present disclosure;

FIG. 2 is a partial side view of a bottomhole assembly for performing section milling, in accordance with one or more embodiments of the present disclosure;

FIG. 3 is a cross-sectional view of an example section mill, in accordance with one or more embodiments of the present disclosure;

FIGS. 4-1 and 4-2 are perspective views of an example cutting insert, in accordance with one or more embodiments of the present disclosure;

FIGS. 4-3 is a top view of the cutting insert of FIGS. 4-1 and 4-2, in accordance with one or more embodiments of the present disclosure;

FIGS. 4-4 is a cross-sectional view of the cutting insert of FIG. 4-3, in accordance with one or more embodiments of the present disclosure;

FIG. 5 is a cross-sectional view of another example cutting insert, in accordance with one or more embodiments of the present disclosure;

5 FIG. 6 is a top view of another example of a cutting insert, in accordance with one or more embodiments of the present disclosure;

FIGS. 7-1 to 7-3 are top views of partial cutting inserts, in accordance with one or more embodiments of the present disclosure;

10 FIGS. 8-1 and 8-2 are top views of milling blades with cutting inserts coupled thereto, in accordance with one or more embodiments of the present disclosure;

FIGS. 9-1 to 9-4 are top views of portions of milling blades with cutting inserts coupled thereto, in accordance with one or more embodiments of the present disclosure;

FIGS. 10-1 to 10-3 illustrate profiles of cutting inserts for cutting a workpiece, in accordance with one or more embodiments of the present disclosure;

15 FIG. 11-1 is a top view of another example cutting insert, in accordance with one or more embodiments of the present disclosure;

FIG. 11-2 is a top view of a portion of a milling blade having the cutting insert of FIG. 11-1 coupled thereto, in accordance with one or more embodiments of the present disclosure;

20 FIGS. 12-1 and 12-2 are top views of milling blades with cutting inserts coupled thereto, in accordance with one or more embodiments of the present disclosure.

FIG. 13 is a perspective view of a cutting insert, according to one or more embodiments of the present disclosure; and

FIG. 14 is a perspective view of another cutting insert, according to one or more embodiments of the present disclosure.

25

DETAILED DESCRIPTION

In accordance with some aspects of the present disclosure, embodiments herein relate to downhole tools. More particularly, embodiments disclosed herein may relate to downhole tools and bottomhole assemblies (“BHA”) that include a mill. An example BHA may include a mill for cutting casing for
30 use in wellbore abandonment, slot recovery, or other downhole operations. In still other aspects, embodiments of the present disclosure may relate to milling inserts, cutting inserts, or other cutting elements that may be used on a section mill blade or other mill to mill the casing.

Referring now to FIG. 1, a schematic diagram is provided of an example downhole system 100 that may utilize milling systems, assemblies, devices, and methods in accordance with embodiments
35 of the present disclosure. FIG. 1 shows an example wellbore 101 formed in a formation 102. In this particular embodiment the wellbore 101 includes a casing 103 installed therein. The casing 103 may extend along a full length of the wellbore 101; however, in other embodiments, the wellbore 101 may

be an openhole wellbore that is uncased. In still other embodiments, the wellbore 101 may include both cased and openhole portions.

In the particular embodiment illustrated in FIG. 1, a BHA 104 may be used to mill the casing 103 and expose one or more outer layers of casing, the formation 102, or the like. The BHA 104 may be connected to a drill string 105. In FIG. 1, the drill string 105 is illustrated as extending from the surface and having the BHA 104 suspended therefrom. The drill string 105 may include one or more tubular members. The tubular members of the drill string 105 may themselves have any number of configurations. As an example, the drill string 105 may include segmented/jointed drill pipe, wired drill pipe, coiled tubing, a wireline, or the like. In some embodiments, the drill string 105 may include other components (e.g., a tractor for applying weight when coiled tubing or a wireline is used).

The BHA 104 may include any number of components that may be used to perform one or more downhole operations. As an example, the BHA 104 may include one or more stabilizers 106, a bit 107, other components 108, one or more mills 109, or any combination of the foregoing. In some embodiments, the stabilizers 106 may be used to maintain the BHA 104 in a centered position within the wellbore 101. In at least some embodiments, such centralization may reduce or minimize vibrations within the BHA 104 and the drill string 105 during a downhole operation, may center the bit 107, mill 109, or other components during a remedial or other operation, or perform other functions.

The bit 107 may be a drill bit for drilling into the formation 102 surrounding the wellbore 101 and expanding the length of the primary wellbore. In other embodiments, however, the bit 107 may have other structures or uses. For instance, the bit 107 may be a milling bit for milling the casing 103 (e.g., during a sidetracking or wellbore departure operation), grinding up downhole tools or swarf during a remedial operation, or the like. In still other embodiments, the bit 107 may include a reamer for expanding the diameter of the wellbore 101.

In the particular embodiment shown in FIG. 1, one or more mills 109 may be provided. The mills 109 may take any number of forms, and may include, by way of example, casing mills, section mills, junk mills, other types of mills, or some combination of the foregoing. In at least some embodiments, the one or more mills 109 may include one or more blades that may be used to mill the casing 103, downhole tools, or junk within the wellbore 101. In at least some embodiments, the mill 109 may include blades that can be selectively expanded and retracted. For instance, when the BHA 104 is inserted into the wellbore 101, the blades may be in a retracted state. Upon reaching a desired depth, formation structure, or the like, a signal may be sent from the surface (e.g., through wireless, mud pulse, fluid pressure, ball drop, string rotation, RFID tag, or other activation techniques) to expand the blades so that they engage and cut the casing 103 or other components within or around the wellbore 101.

The BHA 104 may include additional or other components 108 for use in any number of manners. By way of example, the other components 108 of the BHA 104 may include one or more logging-while-drilling or measurement-while-drilling components (e.g., sensors, measurement devices, logging

devices, rotational velocity sensors, pressure sensors, cameras or visibility devices, proximity sensors, direction sensors, inclination sensors, survey sensors, resistivity sensors, density sensors, porosity sensors, torque sensors, weight-on-bit sensors, or other sensors or instrumentation), memory or data storage devices, motors (e.g., mud motors, turbine motors, positive displacement motors, etc.), rotary steerable and directional drilling equipment (e.g., point-the-bit components, push-the-bit components, pad-in-bit components), wellbore departure equipment (e.g., whipstocks), activation equipment (e.g., activation/deactivation subs), disconnect subs or equipment, circulation subs, communication equipment (e.g., pulsers, a signal processor, acoustic processors, wireless processors, signal boosters, fiber optic components, mud pulse telemetry receivers/transmitters), fishing/retrieval equipment, cleaning nozzles, reentry components, perforation or fracking equipment, plugs, anchors, packers, isolation/sealing devices, plugs, liner hangers, other devices or tools, or some combination of the foregoing.

As shown in FIG. 1, a drilling rig 110 may be used to convey the drill string 105 and BHA 104 into the wellbore 101. In an example embodiment, the drilling rig 110 may include a derrick and hoisting system 111, a rotating system, a mud circulation system, or other components. The derrick and hoisting system 111 may suspend the drill string 105, and the drill string 105 may pass through a wellhead 112 and into the wellbore 101. In some embodiments, the drilling rig 110 or derrick and hoisting system 111 may include a draw works, a fast line, a crown block, drilling line, a traveling block and hook, a swivel, a deadline, or other components. An example rotating system may be used, for instance, to rotate the drill string 105 and thereby also rotate one or more components of the BHA 104. In the illustrated embodiment, the rotating system may include a top drive 113; however, other embodiments may contemplate the use of a kelly, rotary table, or other components. Although the downhole system 100 is shown in FIG. 1 as being on land, those of skill in the art will recognize that embodiments of the present disclosure are also equally applicable to offshore and marine environments.

As discussed herein, the mill 109 of the BHA 104 may be a section mill. In operation, one or more blades of a section mill may be selectively retracted or expanded. For instance, the one or more blades may be in a retracted state as the section mill is inserted into the wellbore 101. Upon reaching a desired depth, the mill 109 may be activated and the one or more blades may be expanded using mechanical actuation, hydraulic actuation, hydro-mechanical actuation, electromechanical actuation, other techniques, or combinations of the foregoing.. The blades may expand radially outward and contact the casing 103 lining the wellbore 101. As the one or more blades expand radially outward, rotation of the mill may then be used to initially cut radially outward from the inside surface of the casing 103 to the outside surface of the casing 103. During or after initiation of the cut-out in the casing, the expanded blades may also be moved axially upward/uphole or downward/downhole to increase the axial length of the opening in the casing 103. When milling occurs by moving the BHA in a downward/downhole direction, the rotation of the expanded blades and the weight-on-mill of the

section mill may be used to mill the casing 103. When milling occurs by moving the BHA 104 in an upward/uphole direction, the rotation of the expanded blades and the axially directed, upward force may be used to mill the casing 103. The milled-out, and potentially openhole, portion of the wellbore 101 may then be suitable for rock-to-rock plugging, slot recovery, sidetracking, or other operations.

FIG. 2 illustrates an example BHA 204 in more detail, in accordance with another embodiment of the present disclosure. The BHA 204 may be used in a wellbore within an earthen formation and used in a milling operation occurring, for instance, in a cased wellbore. The BHA 204 may include various components, including one or more mills, which in this embodiment includes at least one section mill 209 for milling a casing or liner (e.g., casing 203) within a wellbore. In some embodiments, the section mill 209 may be used to create a rock-to-rock opening within the casing. Such an opening may be used to facilitate setting a rock-to-rock cement plug for a well abandonment operation, to create a rock interface for drilling of a sidetracked lateral borehole, or for other operations. In other embodiments, the section mill 209 may be used to mill out an interior casing and expose an outer casing. Regardless of the particular use of the section mill 209, it may include one or more blades or knives, which may be selectively expanded and retracted. In the retracted position, the cutter arms may be in a radially inward position that allows run-in of the section mill 209 within the wellbore. Upon reaching a desired depth and milling location, the blades may be selectively expanded by moving them radially outwardly in response to hydraulic, electronic, wireless, mechanical, other actuation control, or any combination of the foregoing. The blades and any cutting inserts or other cutting elements thereon may engage the casing 203 to initiate a cut-out, and at the same time or thereafter be moved in an upward or downward direction to mill the casing 203. Upon completion of a milling operation, the blades can be retracted to allow for withdrawal of the section mill 209 from the wellbore.

The BHA 204 of FIG. 2 may also include any number of other components. For instance, the section mill 209 or another component of the BHA 204 may include a position indicator that provides a surface signal to notify an operator when the cutter arms are fully expanded. Other components of the BHA 204 of FIG. 2 may include, by way of illustration, stabilizers/centralizers 206 or a taper mill 207. The stabilizers/centralizers 206, taper mill 207, or both, may be run below the section mill 209 in some embodiments. In the same or other embodiments, one or more stabilizers/centralizers 206 may be located above the section mill 209, below the section mill 209, or both above and below the section mill 209. A taper or lead mill 207 may be positioned at the downhole end portion of the BHA 204, and may include a tapered mill head that can be used as a guide mill within the wellbore or casing 203. Still other components of the BHA 204 may include drill collars 214, heavyweight drill pipe 215, other components, or combinations of the foregoing. In some embodiments, one or more jars 216 or other shock tools may be used. Float subs 217 may also be used (e.g., above the section mill 209) and used to limit or prevent cuttings from entering the section mill 209 or blocking a piston orifice or port. As will be appreciated by those of ordinary skill in the art in view of the disclosure herein, the BHA 204 may also include still other or additional components. Indeed, in some embodiments, the BHA

204 may include multiple section mills 209. As an example, to extend the length of the casing 203 that may be milled, two or more section mills 209 may be included and may be separately and individually activated to allow a first one of the section mills 209 (e.g., a lower section mill) to mill a first portion of the casing 203. The first section mill may then be deactivated and the second section
5 mill (e.g., an upper section mill) may be lowered or otherwise moved to the milled-out region and activated to continue milling the casing 203, or expanded to a greater radial position to mill an outer casing around the casing 203.

Turning now to FIG. 3, a particular example of a section mill 309 is shown and described in additional detail. The section mill 309 may have a body 318 having a bore 319 extending fully or
10 partially along an axial length thereof. The body 318 may be tubular; however, the body 318 may have other structures, cross-sectional shapes of the bore 319, or other configurations. Optionally, the upper end portion of the body 318, the lower end portion of the body 318, or both, may have a connector 320 for connecting the body 318 to a drill string or components of a BHA or other downhole tool. In some embodiments, the connector 320 may include a threaded connector with a box or pin connection.
15 Optionally, the connector 320 may have different configurations at the top and bottom end portions of the body 318 (e.g., box connection and one end portion and a pin connection at the other end portion).

In accordance with some embodiments, one or more longitudinal slots 321 or other openings may be formed in, and extend axially along, a portion of the outer circumference or perimeter of the body 318. The number of slots 321 or other openings may be different for various embodiments. For
20 instance, the body 318 may have between 1 and 20 slots 321 in some embodiments, and more particularly may have between 2 and 12 slots 321 in some embodiments. For instance, there may be 3, 6, or 8 slots 321 in some embodiments. Of course, in other embodiments, a range of a number of slots 321 in the body 318 may begin and end anywhere between 1 and 20, although in other embodiments there may be more than 20 slots 321.

Each slot 321 may be aligned with a movable blade 322, 323 that is coupled to the body 318. In
25 the illustrated embodiment, the movable blades 322 may be axially longer than the movable blades 323. In some embodiments, the movable blades 322, 323 may alternate in a circumferential direction around the body 318. For instance, 3 axially longer movable blades 322 may be interspaced by 3 axially shorter movable blades 323. Each of the movable blades 322, 323 may be mounted on a
30 respective pivot 324 in each of the slots 321. In some embodiments, a cam 325 may be carried or otherwise operated by a piston 326 that may move in response to fluid circulating within the body 318. The cam 325 (or each of multiple cams 325) may act on the movable blades 322, 323 so that the movable blade 322, 323 is pivotally and radially movable outward from a central axis of the body 318 to a cutting position. In FIG. 3, the movable blade 322 is shown in the radially extended, cutting
35 position. The piston 326 may be biased by a compression spring 327. In operation, the section mill 309 may rotate about a longitudinal axis of the body 318.

The movable blades 322, 323 may include or be coupled to cutting inserts 328, 329 of any suitable type for use in a section milling operation. As shown in FIG. 3, the cutting inserts 328, 329 may be mounted on the front face of each movable blade 322, 323. In some embodiments, a bottom surface or face of each cutting insert 328, 329 may be welded or brazed to the front face or surface of each movable blade 322, 323. According to at least some embodiments, the cutting inserts 328, 329 may be arranged in an array extending radially and axially on the movable blades 322, 323. Each cutting insert 328, 329 may be adjacent one or more other cutting inserts 328, 329, and may optionally abut or contact adjacent cutting inserts 328, 329 along one or more front, rear, or side edges or faces.

In FIG. 3, the array may include the cutting inserts 328, 329 arranged at least partially in offset or staggered rows. For instance, the cutting inserts 328 may be arranged and aligned in radial rows of generally uniform height. Each row may be at a different axial or longitudinal position. The cutting inserts 328 may then have different lengths, or be otherwise positioned so that the edge of one cutting insert 328 may be out of alignment with, and radially offset or staggered from, an edge of a cutting insert 328 in an axially adjacent row. Such an arrangement is, however, merely illustrative. In other embodiments, for instance, cutting inserts may be arranged in rows of differing heights, in columns, or in both columns and rows (i.e., without offsets or staggering). Moreover, in some embodiments, each cutting insert may be of a uniform size, although in other embodiments some cutting inserts may have different widths, heights, lengths, or other sizes. Additionally, while the cutting inserts 328 are shown as being arranged in a generally regular, repeating pattern along about the full front face of the movable blade 322, other embodiments contemplate positioning the cutting inserts 328, 329 along less than a full portion of the front face or other cutting portion of the movable blade 322, or arranging the cutting inserts 328, 329 in a non-uniform or even random or pseudo-random pattern.

According to at least one embodiment, two or more different cutting inserts 328, 329 may be coupled to the movable blades 322, 323. In particular, first cutting inserts 328 may be a first cutting insert, or a first type of cutting insert and may have one or more of a different shape, structure, material, form, or other configuration relative to second cutting inserts 329, which may be a second type of cutting insert. As shown in FIG. 3, for instance, the second cutting inserts 329 may be aligned along the outer radial edge of the movable blade 322 (and potentially on blade 323, although the face of blade 323 is not shown). The second cutting inserts 329 may be different than the first cutting inserts 328 that may extend radially inward from the second cutting inserts 329. Accordingly, as the movable blades 322, 323 extend radially outwardly, the second cutting inserts 329 may initially make contact with a casing or other workpiece to be cut or milled by the section mill 309. In at least some embodiments, the second cutting inserts 329 may be used to initiate a radial cut-out in the casing. For instance, the second cutting inserts 329 may include features that initiate a radial cut-out better than features of the first cutting inserts 329. In some embodiments, one or both of the first and second cutting inserts 328, 329 may include features configured or otherwise designed for face milling. Face milling features may be to specifically designed, arranged, or otherwise configured to cut or mill

primarily in an axial or longitudinal direction. Thus, in at least some embodiments, a second cutting insert 329 may be used and configured to initiate a cut-out in a casing (or simply may be better suited for such operation) by cutting/milling radially outward through a thickness of the casing, while a first cutting insert 328 may be used and configured to extend a length of the cut-out in the casing by cutting/milling along an axial or longitudinal length of the casing. In some embodiments, the second cutting inserts 329 may have a generally rectangular shape, or may have parallel or concentric front and trailing edges. The front edge, the trailing edge, or both, may be linear in some embodiments. In the same or other embodiments, the first cutting inserts 328 may be curved. For instance, a front edge may be curved and may be non-parallel relative to the trailing edge of the first cutting insert 328. Front or trailing edges may be curved, or the front edge may be curved and the trailing edge may be linear. In some embodiments, front and trailing edges are both curved but are not concentric.

FIG. 3 illustrates an example in which the second cutting inserts 329 are in multiple axial rows and extend along a portion of the outer radial edge of the movable blade 322. Other embodiments contemplate placing the second cutting inserts 329 along lesser or greater portions of the movable blade 322. Also, some embodiments contemplate at least a portion of the second cutting inserts 329 extending radially outwardly from an outer radial edge of the movable blade 322. In other embodiments, however, the second cutting inserts 329 may be aligned with, or even radially inward relative to, an outer radial edge of the movable blades 322, 323.

The cutting inserts 328, 329 may be referred to herein as, or may include, milling/cutting inserts or other cutting elements formed of any material suitable for milling casing within a wellbore. In an example embodiment, the casing may be made of steel and the cutting inserts 328, 329 may be formed of a material that can cut steel. Examples of suitable materials useful for cutting steel or other casing may include, by way of illustration, tungsten, titanium, ceramics, metal carbides (e.g., niobium carbide, tungsten carbide, cobalt-cemented tungsten carbide, titanium carbide, cemented titanium carbide, tantalum carbide, cemented tantalum carbide, vanadium carbide, molybdenum carbide), diamond (e.g., polycrystalline diamond), cubic boron nitride (e.g., polycrystalline cubic boron nitride), other so-called “superhard” or “super-abrasive” materials, or any combination of the foregoing.

An example of a cutting insert 428 that may be used on a milling tool is illustrated in FIGS. 4-1 to 4-4. The cutting insert 428 may include features configured or otherwise designed to allow the cutting insert 428 to be used in a face milling operation. For instance, the cutting insert 428 may include one or more cutting edges 430-1, 430-2, 430-3 (collectively cutting edges 430). In particular, the cutting insert 428 may include a front cutting edge 430-1. The front cutting edge 430-1 may be formed at an intersection of a front face 432-1 and a top face 434. When the cutting insert 428 is installed on a tool (e.g., movable blade 322 of FIG. 3), the cutting insert 428 may be oriented such that the front cutting edge 430-1 may act as a primary cutting edge face mill a workpiece (e.g., casing) when the cutting insert 428 is rotated (e.g., about a longitudinal axis of the tool).

The cutting insert 428 may also include one or more back-up cutting edges 430-2, 430-3. The back-up cutting edges 430-2, 430-3 may be formed at an intersection of the top face 434 and corresponding secondary front faces 432-2, 432-3. The back-up cutting edges 430-2, 430-3 may act as a secondary cutting edges. In at least some embodiments, the contact between the cutting insert 428 and a workpiece at the front cutting edge 430-1 may cause the cutting insert 428 to wear, and the front cutting edge 430-1 may gradually move toward the back-up cutting edges 430-2, 430-3. Eventually, such wear may reach the back-up cutting edge 430-2, at which time the back-up cutting edge 430-2 may become the primary cutting edge used in milling a workpiece. Increased wear may continue until the back-up cutting edge 430-3 becomes the primary cutting edge. The use of multiple cutting edges is optional. In embodiments where multiple cutting edges 430 are provided, however, the secondary cutting edge (e.g., back-up cutting edge 430-2) may provide a new cutting edge when the primary cutting edge (e.g., front cutting edge 430-1) cracks or wears. Additionally, in combination with other features of the cutting insert 428 (e.g., a back rake angle), the back-up cutting edges 430-2, 430-3 or other features may operate as a chip breaker. In particular, as casing or another workpiece is cut by the front cutting edges 430-1, tailing swarf from the workpiece may be broken up to form chips of a consistently small size and shape that can be efficiently handled and conveyed to the surface. In some cases, larger chips or swarf may wrap around tools or objects downhole and create a mass or “bird nest” which may obstruct the wellbore and be difficult to convey to the surface. The rate of penetration of the tool using the cutting insert 428 may also be rendered more consistent as a result of breaking swarf into smaller chips.

As discussed herein, the geometry of the cutting insert 428 may be structured or otherwise configured to facilitate use of the cutting insert 428 in a face milling operation and potentially to generate swarf that can be efficiently handled within a wellbore. The geometry of the cutting insert 428 may be varied or structured as desired to facilitate such an operation. FIG. 4-2 to FIG. 4-4 provide additional views of the cutting insert 428 of FIG. 4-1 to facilitate a discussion of examples of geometries that may be used by the cutting insert 428.

More particularly, FIG. 4-2 is a rear perspective view of the cutting insert 428, FIG. 4-3 is a top view of the cutting insert 428, and FIG. 4-4 is a side cross-sectional view of the cutting insert 428. As discussed herein, the front cutting edge 430-1 of the cutting insert 428 may be configured to engage the workpiece and mill axially along a length of the workpiece. In at least some embodiments, the back-up cutting edges 430-2, 430-3 may be located on ridges protruding from a body of the cutting insert 428. The cutting edges 430 and any corresponding ridges may extend along a full or partial length of the cutting insert 428, and may be spaced apart from each adjacent cutting edge 430 or ridge. In some embodiments, the ridges and cutting edges 430 may form a series of teeth. A portion of the top face 434 between a cutting edge 430 and the following front face 432 may be referred to herein as a rake face. In FIG. 4-4, three rake faces 434-1, 434-2, 434-3 of the top face 434 are shown to

correspond to each of the cutting edges 430. In other embodiments, different numbers of ridges, rake faces, or other features may be provided.

As seen in the side cross-sectional view of FIG. 4-4, the trailing portions of the top face 434 (i.e., rake faces 434-1 to 434-3) may be oriented at an axial rake angles 431 relative to a line parallel to the bottom face 444. In some embodiments, the axial rake angle 431 may be between 0° and 30°. In still other embodiments, the axial rake angle 431 may be within a range having a lower limit, upper limit, or both upper and lower limits that include any of 0°, 5°, 10°, 15°, 20°, 25°, 30°, and any values therebetween. For instance, the axial rake angle 431 may be between 0° and 20°, between 5° and 20°, between 10° and 20°, between 7.5° and 25°, between 5° and 30°, between 5° and 15°, between 17.5° and 22.5°, between 18° and 20°, or between 2.5° and 25°. In still other embodiments, the axial rake angle 431 may be larger than 30° or less than 0° (i.e., negative). In some embodiments, the trailing portions of the top face 434 may define one or more different axial rake angles 431. For instance, although the axial rake angle 431 is shown as corresponding to the second rake face 434-2 (and the first back-up cutting edge 430-2), the same axial rake angle may be defined by at least one of the first rake face 434-1 (and the front cutting edge 430-1) or the third rake face 434-3 (and the second back-up cutting edge 430-3). In particular, in FIG. 4-4, the first and second rake faces 434-1, 434-2 may define the same axial rake angle 431. Also in this figure, the third rake face 434-3 may have a different axial rake angle. For instance, the third rake face 434-3 may define an axial rake angle of 0°, although such embodiment is merely illustrative. In other embodiments, the third rake face 434-3 may define an axial rake angle equal to the axial rake angle 431 of the first rake face 434-1, the second rake face 432-2, or both first and second rake faces 434-1, 434-2 (e.g., when the rake face 434-4 follows the dashed line in FIG. 4-4).

Where the rake faces 434 have a positive angle, there may be an offset in the height between the corresponding cutting edge 430 and a lower most portion of the front faces 432-2, 432-3. Such offset may be referred to as a drop distance. The drop distance may be different in various embodiments and, in at least some embodiments, may be based on the dimensions of the cutting insert 428, including the height 433 of the cutting insert 428, the axial rake angle 431, the number of cutting edges 430, the shape of top face 434, the length 435 of the cutting insert 428, the width 437 of the cutting insert 428, and the like. The drop distance may, for instance, be larger where the axial rake angle 431 is larger, where there are fewer cutting edges 430, or where the cutting insert 428 has a greater length 435 or height 433. In some embodiments, the drop distance may be between 0% and 60% of the height of the cutting insert 428. In still other embodiments, the drop distance as a percentage of the height 433 of the cutting insert 428 may be within a range having a lower limit, an upper limit, or both upper and lower limits that include any of 0%, 5%, 15%, 25%, 35%, 45%, 60%, and any values therebetween. For instance, the drop distance as a percentage of the height 433 of the cutting insert 428 may be between 7.5% and 10%, between 10% and 12.5%, between 15% and 17.5%, between 22.5% and 25%,

or between 5% and 30%. In still other embodiments, the drop distance of any one or more rake faces 434 may be greater than 60% of the height 433 of the cutting insert 428.

The dimensions and shape of a cutting insert 428 may be different in various embodiments. For example, the width 437 of the cutting insert 428 may be between 1/8 inch (3.2 mm) and 3 inches (76.2 mm), a height 433 or thickness of the cutting insert 528 may be between 1/16 inch (1.6 mm) and 1 inch (25.4 mm), or a length 435 of the cutting insert 528 may be between 1/16 inch (1.6 mm) and 1 inch (25.4 mm). For instance, the width 437 of the cutting insert 428 may be between 0.75 inch (19.1 mm) and 1.25 inch (31.8 mm), the height 433 may be between 0.2 inch (5.1 mm) and 0.4 inch (10.2 mm), and the length 435 may be between 0.325 inch (8.3 mm) and 0.425 inch (10.8 mm).

The front face 432-1 and a rear face 442 of the cutting insert 428 may be parallel to each other or may have other configurations. Optionally, one or more of the front face 432-1 or the rear face 442 may be perpendicular to the bottom face 444. In FIG. 4-4, for instance, the rear face 442 is shown as being perpendicular to the bottom face 444, while the front face 432-1 is non-parallel and non-perpendicular relative to each of the rear race 442 and the bottom face 444.

More particularly, the front face 432-1 may extend between the front cutting edge 430-1 and the bottom face 444, while the rear face 442 may extend between a trailing edge 439 and the bottom face 444. The height 433 of the cutting insert 428 may, in this embodiment, be measured as a perpendicular distance between the bottom face 444 and the cutting edge 430-1, or optionally between the bottom face 444 and the trailing edge 439. The cutting insert 428 may also define a front flank angle 441. In some embodiments, the front flank angle 441 may be measured between the front face 432-1 and a reference line perpendicular to the bottom face 444 of the cutting insert 428, although in the same or other embodiments the reference line may be measured relative to other components (e.g., parallel to rear face 442; parallel to the height 433; perpendicular to a longitudinal axis of a downhole cutting or milling tool, a wellbore, etc.). In some embodiments, the cutting insert 428 may also define a rear flank angle (not shown) between the rear face 442 and a reference line parallel to the reference line used to measure the front flank angle 441.

In accordance with embodiments of the present disclosure, the front flank angle 441 and rear flank angle may be different, or they may be the same. The particular measurements of one or more of the front flank angle 441 and the rear flank angles may, in some embodiments, range from 0° to 25°. For instance, the front flank angle 441 may be within a range having a lower limit, an upper limit, or both upper and lower limits that include any of 0°, 1°, 2.5°, 5°, 7.5°, 10°, 15°, 20°, 25°, and any values therebetween. For instance, the front flank angle 441 may be between 2.5° and 12.5°, between 5° and 10°, between 3° and 6°, or between 7.5° and 15°. In other embodiments, a cutting insert 428 may have a front flank angle 441 greater than 25° or less than 0° (i.e., a negative front flank angle). The rear flank angle may have similar or the same values. As will be appreciated by a person having ordinary skill in the art in view of the disclosure herein, the front flank angle 441 may be equal to, less than, or greater than the rear flank angle.

As also shown in FIG. 4-4, in some embodiments, one or more of the secondary front faces 432-2, 432-3 may be oriented at back-up flank angle 443. In some embodiments, the back-up flank angle 443 may be measured between respective secondary front faces 432-2, 432-3 and a reference line perpendicular to the bottom face 444 of the cutting insert 428, although in the same or other
5 embodiments the reference line may be measured relative to other components (e.g., parallel to rear face 442; parallel to the height 433; perpendicular to a longitudinal axis of a downhole cutting or milling tool, a wellbore, etc.).

In accordance with embodiments of the present disclosure, the back-up flank angles 443 of the secondary front faces 432-2, 432-3 may be different, or they may be the same. The back-up flank
10 angles 443 may also be the same as, or different from, the front flank angle 441. The particular magnitude of the back-up flank angles 443 may, in some embodiments, range from 0° to 25°. For instance, one or more of the back-up flank angles 443 may be within a range having a lower limit, an upper limit, or both upper and lower limits that include any of 0°, 1°, 2.5°, 5°, 7.5°, 10°, 15°, 20°, 25°, and any values therebetween. For instance, the back-up flank angles 443 may be between 2.5° and
15 12.5°, between 5° and 10°, between 3° and 6°, or between 7.5° and 15°. In other embodiments, a cutting insert 428 may have a back-up flank angle 443 greater than 25° or less than 0° (i.e., a negative front flank angle). Optionally, the back-up flank angles 443 may be in a different direction when compared to the front flank angle 441. For instance, in FIG. 4-4, the front face 432-1 is shown as sloping from the front cutting edge 430-1 toward the rear face 442. In contrast, the secondary front
20 faces 432-2, 432-3 are shown as sloping away from the rear face 442. In this embodiment, the front flank angle 441 may be considered positive and the back-up flank angles 443 may be considered to be negative. In other embodiments, the relationship may be reversed with the front face 432-1 sloping away from the rear face 442 and the secondary front faces 432-2, 432-3 sloping toward the rear face 442. In still other embodiments the front faces 432 may each slope in the same direction.

As will be appreciated in view of the disclosure herein, the shape of the cutting insert 428, including
25 any components thereof, may be different in any of various embodiments. For instance, in at least some embodiments, one or more of the cutting edges 430 may be curved rather than linear. In some embodiments, the curve of the one or more cutting edges 430 may be constant or varied. For instance, the one or more cutting edges 430 may follow a full or partial portion of a circle, ellipse, or other shape.
30 With particular reference to FIG. 4-3, it can be seen that the cutting insert 428 may have one or more cutting edges 430 following a portion of an elliptical curve.

In particular, in FIG. 3-3, the front cutting edge 430-1 is shown as extending between opposing
side faces 446. The side faces 446 are optional, and may be omitted in some embodiments, in which case the front cutting edge 430 interface with the trailing edge 439 and may extend in an elliptical or
35 other curved path from opposing ends of the trailing edge 439 of the cutting insert 428 (see FIG. 6). Where side faces 446 are included, a length 445 of the side faces 446 may be less than the length 435 of the cutting insert 428. In some embodiments, the length 445 of the side faces 446 may be between

0% and 75% of the length 435 of the cutting insert 428. In still other embodiments, the length 445 as a percentage of the length 435 of the cutting insert 428 may be within a range having a lower limit, an upper limit, or both upper and lower limits that include any of 0%, 5%, 15%, 25%, 35%, 45%, 60%, 75% and any values therebetween. For instance, the length 445 as a percentage of the length 435 of the cutting insert 428 may be between 25% and 75%, between 35% and 50%, between 40% and 45%, between 45% and 50%, or between 5% and 45%. In still other embodiments, the length 445 may be greater than 75% of the length 435 of the cutting insert 428. In some embodiments, the width 437 of the cutting insert 428 may be reduced relative to a cutting insert in which the front cutting edge 430-1 extends to the trailing edge 439. For instance, the width 437 may be between 10% and 100% of the width of a cutting insert that doesn't include the side faces 446. More particularly, in some embodiments, the width of the cutting insert 428 may be between 50% and 95%, or between 85% and 95% of the width of a cutting insert that doesn't include the side faces 446.

One or more of the back-up cutting edges 430-2, 430-3 may also extend to the side faces 446, although in the embodiment shown in FIG. 4-3, the back-up cutting edges 430-2, 430-3 are shown as intersecting the trailing edge 439 rather than the side faces 446. In this particular embodiment, the cutting edges 430 are shown as being concentric and evenly spaced part, although in other embodiments, the cutting edges 430 may be non-concentric (e.g., shifted), spaced at unequal intervals, have other configurations, or combinations of the foregoing.

In this particular example, the cutting edges 430 follow a generally elliptical path having major and minor diameters. In some embodiments, the front cutting edge 430-1 may have the largest major diameter, minor diameter, or major and minor diameters, and the second back-up cutting edge 430-3 may have the smallest major diameter, minor diameter, or major and minor diameters. For instance, in at least one embodiment, the front cutting edge 430-1 may have a major diameter of 1.1 inches (27.9 mm) and a minor diameter of 0.75 inch (19.1 mm). The first back-up cutting edge 430-2 may have major and minor diameters of 0.9 inch (22.9 mm) and 0.55 inch (14.0 mm), respectively. The second back-up cutting edge 430-2 may have major and minor diameters of 0.7 inch (17.8 mm) and 0.35 inch (8.9 mm), respectively. In such embodiment, the difference between the major and minor diameters for each cutting edge 430 may be about equal (i.e., 0.35 inch (8.9 mm)). In other embodiments, however, the difference between major and minor diameters may differ for one or more cutting edges, or the particular dimensions of the major and minor diameters may otherwise be different. In FIG. 4-3, for instance, the major diameter extends across the width 437 of the cutting insert 428 while the minor diameter extends across the length 435. As the cutting insert 428 may be semi-elliptical, however, the minor diameter may be halved (i.e., the length 435 of the cutting insert 428 may be half the minor diameter of the front cutting edge 430-1). In other embodiments, however, the major diameter may be halved, the major and minor diameter may be full (i.e., full elliptical cutting insert rather than semi-elliptical), the length 435 may be greater than 50% of the minor diameter (e.g., 75%

of the minor diameter of the front cutting edge 430-1) or less than 50% of the minor diameter (e.g., 35% of the minor diameter of the front cutting edge 430-1).

Turning now to FIG. 5, a cross-sectional view of another example cutting insert 528 is shown in accordance with further example embodiments. The cutting insert 528 may be generally similar to the cutting insert 428 of FIG. 4-4, and the discussion herein related to the cutting insert 428 may therefore also apply to the cutting insert 528. In this particular embodiment, however, the cutting insert 528 is shown with a front flank angle 541 and a rear flank angle 549. In some embodiments, the front flank angle 541 may be measured between the front face 532-1 and a reference line perpendicular to the bottom face 544 of the cutting insert 528, although in the same or other embodiments the reference line may be measured relative to other components (e.g., parallel to a height of the cutting insert 528, perpendicular to a longitudinal axis of a downhole cutting or milling tool or a wellbore, etc.). In some embodiments, the cutting insert 528 may also define a rear flank angle 549 between the rear face 542 and a reference line parallel to the reference line used to measure the front flank angle 541.

The front flank angle 541 and the rear flank angle 549 may be the same, or they may be different. In FIG. 5, the flank angles 541, 549 are shown as being in the same direction (i.e., the front face 532-1 and the rear face 542 are inclined in the same direction). In other embodiments, however, one of the flank angles 541, 549 may be positive while the other may be negative. The magnitude of the flank angles 541, 549 may also be varied in different embodiments, and examples of flank angle magnitudes are discussed herein in reference to the cutting insert 428 of FIGS. 4-1 to 4-4.

As also shown in FIG. 5, three rake faces 534-1, 534-2, 534-3 are shown as extending from corresponding cutting edges. The first and second rake faces 534-1, 534-2 are shown, in cross-section, as being linear. The first and second rake faces 534-1, 534-2 may therefore define a straight taper. In contrast, the third rake face 534-3 is shown as having a curved profile and a curved (e., parabolic) taper.

FIG. 6 illustrates still another example embodiment of a cutting insert 628 in accordance with some embodiments of the present disclosure. The cutting insert 628 may have a plurality of ridges, teeth, recesses, or other geometries, features, or the like. The ridges illustrated in FIG. 6 may define a front cutting edge 630-1 and four back-up cutting edges 630-2 to 630-5. Each of the back-up cutting edges 630-2 to 630-5 may extend a full or partial width of the cutting insert 628. In particular, in FIG. FIG. 6, the front cutting edge 630-1 extends a full width of the cutting insert 628, while each of the back-up cutting edges 630-2 to 630-5 extends a partial width of the cutting insert 628. More particularly, the back-up cutting edges 630-2 to 630-5 are shown as being nested and potentially concentric, and as starting and ending on at a trailing edge 639 of the cutting insert 628.

As shown, the cutting insert 628 may have a generally semi-elliptical shape, and each cutting edge 630 may also have a semi-elliptical shape, albeit of progressively smaller dimension. In other embodiments, the cutting edges 630 may have a different general shape than a body of the cutting

insert 628. Further, while FIG. 6 illustrates five teeth or cutting edges 630, in other embodiments, there may be more than five or fewer than five cutting edges 630.

As discussed herein, cutting inserts or other cutting elements of the present disclosure may have various shapes and configurations. FIGS. 7-1 to 7-3, for instance, are top views of cutting inserts 728 similar to the cutting insert 428 of FIGS. 4-1 to 4-4, but with different widths 737. In FIG. 7-1, for instance, the cutting insert 728-1 may be a quarter semi-elliptical cutting insert that has a width 737-1 that is about 25% the width 437 of the cutting insert of FIG. 4-3. The width 737-1 may be measured between a side surface 746-1 and a side surface 747-1. In this particular example, the side surface 747-1 may have a greater length than the side surface 746-1, as the cutting edges of the cutting insert 728-1 may follow an elliptical path and increase in diameter from the first side 746-1.

FIG. 7-2 may be a half semi-elliptical cutting insert that has a width 737-2 that is about 50% the width 437 of the cutting insert 428 of FIG. 4-3. The width 737-2 may be measured between a side surface 746-2 and a side surface 747-2. In this particular example, the side surface 747-2 may have a greater length than the side surface 746-2, as the cutting edges of the cutting insert 728-2 may follow an elliptical path and increase in diameter from the first side 746-2. In some embodiments, the half semi-elliptical cutting insert 728-1 of FIG. 7-2 may have a length about equal to the length 435 of the full semi-elliptical cutting insert 428 of FIG. 4-3.

FIG. 7-3 may be a three-quarter semi-elliptical cutting insert that has a width 737-3 that is about 75% the width 437 of the cutting insert 428 of FIG. 4-3. The width 737-3 may be measured between a side surface 746-3 and a side surface 747-3. In this particular example, the side surface 747-3 may have a greater length than the side surface 746-3, as the cutting edges of the cutting insert 728-2 may follow an elliptical path and increase in diameter from the first side 746-2. In some embodiments, the length of the side surface 747-3 may be about equal to the length of the side surface 747-1 of FIG. 7-1.

Using partial width cutting inserts such as those shown in FIGS. 7-1 to 7-3 may assist in aligning cutting inserts on a mill blade, according to some embodiments of the present disclosure. FIGS. 8-1 to 9-4, for instance illustrate example mill blades that have cutting inserts coupled thereto. The cutting inserts may be arranged in one or more patterns to allow the cutting inserts to perform a milling operation (e.g., face milling operation).

With particular reference to FIGS. 8-1 and 8-2, two milling blades 822-1, 822-2 are shown, with each having a different configuration or arrangement of cutting inserts 828. In some embodiments, a milling tool (e.g., a section mill) may include multiple blades, each of which include the same arrangement of cutting inserts 828. The arrangement may be that shown in FIG. 8-1, in FIG. 8-2, or there may be some other arrangement. In other embodiments, different blades may have different arrangements of cutting inserts. For instance, a six-bladed section mill may include three milling blades 822-1 interspersed with (or followed by) three milling blades 822-2.

In the particular embodiment shown in FIG. 8-1, the blade 822-1 is shown as having an offset or tiled arrangement of cutting inserts 828. The cutting inserts may include full semi-elliptical cutting inserts 828-1 and half semi-elliptical cutting inserts 828-2. Cutting inserts 828 coupled to the blade 822-1 at the outer radial edge 847 may be full semi-elliptical cutting inserts 828-1, although such inserts may be shown as having different shapes, sizes, and configurations as they may be ground down to match the profile of the outer radial edge 847.

In some embodiments, including both full and half semi-elliptical cutting inserts 828-1, 828-2 may allow the blade 822-2 to be efficiently arranged with cutting inserts 828 in a desired pattern. For instance, a first row 827-1 of cutting inserts 828 may include a half semi-elliptical cutting insert 828-2 along a ridge, notch, groove, or other alignment guide 848. One or more full semi-elliptical cutting inserts 828-1 may then be positioned in the row against the half semi-elliptical cutting insert 828-2.

The adjacent row 827-2 (above row 827-1 in FIG. 8-1) may then include a full semi-elliptical cutting insert 828-1 adjacent the alignment guide 848, followed by one or more additional full semi-elliptical cutting inserts 828-1. By virtue of the full semi-elliptical cutting insert 828-1 being 50% wider than the half semi-elliptical cutting insert 828-2, the full cutting inserts 828-1 in the first row 827-1 may be offset by half a width relative to the full cutting inserts 828-1 in the second row 827-2.

FIG. 8-2 illustrates a similar offset between full cutting inserts 828-1 in the first and second rows 827-1, 827-2; however, the offset is obtained by using quarter semi-elliptical cutting inserts 828-3 and three-quarter semi-elliptical cutting inserts 828-4. In particular, in this embodiment, a quarter semi-elliptical cutting inserts 828-3 is positioned against the alignment guide 848 and is followed in a radial direction within the first row 827-1 by full semi-elliptical cutting inserts 828-1. The second row 827-2 includes a three-quarter semi-elliptical cutting insert 828-4 followed by full semi-elliptical cutting inserts 828-1. As the quarter semi-elliptical cutting insert 828-3 are 25% of the width of a full semi-elliptical cutting insert 828-1 and the three-quarter semi-elliptical cutting insert 828-4 are 75% of the width of a full semi-elliptical cutting insert 828-1, the full cutting inserts 828-1 in the first row 827-1 may be offset by half a width relative to the full cutting inserts 828-1 in the second row 827-2.

As should be appreciated in view of the disclosure herein, the use of full, half, quarter, and three-quarter cutting inserts 828 is merely illustrative, and other embodiments may utilize other sizes of cutting inserts, or other mechanisms for arranging the cutting inserts to obtain a desired alignment or pattern. Further, while FIGS. 8-1 and 8-2 also show the cutting inserts 828 as aligned in rows with side faces of the same length abutting each other, in other embodiments the cutting inserts 828 may be aligned in columns in addition to, or instead of, rows. Additionally, side faces of different sizes may be abutting or adjacent each other.

FIGS. 8-1 and 8-2 illustrate two blades with different cutting insert arrangements and which may be used on the same section mill or other milling tool; however, in other embodiments there may be three or more different cutting insert arrangements used on various blades of a milling tool. FIGS. 9-1 to 9-4, for instance, illustrated portions of 4 different blades 922-1 to 922-4 (collectively blades 922)

including full, half, quarter, and three-quarter cutting inserts. As shown in FIG. 9-1, for instance, the first row 927 of cutting inserts may include a full cutting insert aligned at an inner portion 948, followed by one or more additional full cutting inserts. FIG. 9-2, in contrast, shows a blade 922-2 including a first row 927 with a half cutting insert aligned at the inner portion 948, followed by one or more full cutting inserts. FIGS. 9-3 and 9-4 show similar blades 922-3, 922-4, respectively. In FIG. 9-3, the first row 927 of cutting inserts includes a quarter cutting insert aligned at the inner portion 948, followed by one or more full cutting inserts. In FIG. 9-4, the first row 927 of cutting inserts includes a three-quarter cutting insert aligned at the inner portion 948, followed by one or more full cutting inserts. When comparing the blades 922, it can be seen that the full cutting inserts in the first row 927 of FIG. 9-2 are offset a half-width of a full cutting insert relative to the cutting inserts in the first row 927 of FIG. 9-1. The cutting inserts in the first row of 927 of FIG. 9-3 are offset by a quarter-width of a full cutting insert relative to the cutting inserts in the first row 927 of FIG. 9-1. The cutting inserts in the first row 927 of FIG. 9-4 are offset by three-quarters of a width of a full cutting insert relative to the cutting inserts in the first row 927 of FIG. 9-1 (and a half width of a full cutting insert relative to the first row 927 of FIG. 9-3).

A milling tool including multiple blades may include any of the blades illustrated in FIGS. 9-1 to 9-4, and in some embodiments, each blade may have the same configuration (e.g., each blade may have cutting inserts arranged as shown in FIG. 9-1). In other embodiments, however, the some or even each of the blades may have a different configuration. When the cutting inserts have a curved or variable profile as shown in FIG. 9-1 to 9-4, varying the arrangements of cutting inserts may be used to provide, in some embodiments, a more even cutting profile for a milling operation.

FIG. 10-1, for instance, illustrates a profile of cutting inserts 1028 when each of multiple blades have the same arrangement of cutting inserts 1028. A casing 1003 or other workpiece that is being milled may be located along a portion of the width of the cutting profile. In some examples, the particular location of the casing 1003 may be difficult to determine in advance, so the casing 1003 may be aligned with a one or more cutting inserts 1028. More likely, and as shown in FIG. 10-1, the casing 1003 may be at least partially offset from the cutting inserts 1028. The curved cutting edge of the cutting inserts 1028 may therefore not fully engage the casing 1003 during milling, which can reduce rate of milling, increase vibration, or have other effects.

FIG 10-2 illustrates a profile of cutting inserts 1028 when there are multiple blades that define two arrangements of cutting inserts 1028. In particular, one blade may have cutting inserts 1028 offset by a half-width relative to cutting inserts 1028 of the other blade. As shown, when the casing 1003 is milled by the cutting inserts 1028, there may be an increased likelihood of the casing 1003 being aligned with a cutting insert 1028 (or with multiple cutting inserts). Further, the cutting profile itself may have smaller peaks and valleys relative to the cutting profile of FIG. 10-1, which may lead to reduced vibration/chatter, increased contact, and increased rate of milling.

FIG. 10-3 shows a further profile of cutting inserts 1028 when four arrangements of cutting inserts 1028 are used on multiple blades of a milling tool. In particular, the blades are offset from each other in quarter-width increments. As shown, in such an embodiment, the cutting profile includes still smaller peaks and valleys, and has been considerably flattened relative to the cutting profile of FIG. 10-1. This flatter profile may provide for further reduced vibration/chatter, and increased contact and rate of milling. The embodiments shown in FIGS. 10-1 to 10-3 are illustrative, and in other embodiments, other offsets, arrangements of cutting inserts, and the like may be used to provide other cutting profiles.

In some embodiments of the present disclosure, a cutting insert may be circular, elliptical, semi-circular, or semi-elliptical, but may be configured to reduce spaces or gaps between cutting inserts. For instance, as can be seen in FIG. 9-4, there may be gaps between semi-elliptical cutting inserts. In FIG. 11-1, however, semi-elliptical cutting inserts 1128-1 may be configured to reduce or potentially even eliminate the gaps between cutting inserts. In particular, in this embodiment, a semi-elliptical cutting insert 1128-1 may be a full cutting insert having a same length and width as cutting insert 428 of FIG. 4-3. In other embodiments, however, the semi-elliptical cutting insert 1128-1 may have a reduced dimension in one or more directions (e.g., length, width, etc.). For instance, the length may be the same as for the cutting insert 428, but the width may be less (e.g., between 50% and 100% of the length of the cutting insert 428). In other embodiments, the width may be the same and the length may be less, or both the length and the width may be less.

In this embodiment, the trailing edge 1139 may not be linear along a full portion thereof, but may instead follow an at least partially curved path. In particular, as shown in FIG. 11-1, the trailing edge 1139 may be partially linear (i.e., linear at a portion centered within the width of the cutting insert 1128-1), but may then be concavely curved toward the outer radial ends and the front cutting edge 1130 of the cutting insert 1128-1. Relative to the cutting insert 428 of FIG. 4-3, the curved portion of the trailing edge 1139 may define cut-out portions 1161.

The curvature of the curved portions of the trailing edge 1139 may generally correspond to a portion of the front cutting edge 1130. In such an embodiment, and as shown in FIG. 11-2, a cutting insert 1128 may be positioned within the cut-out portion 1161 and coupled to a blade 1122 of a milling tool. The trailing cutting insert 1128 may substantially fill gaps between cutting inserts 1128.

As also shown in FIG. 11-2, partial cutting inserts may also be used on the blade 1122. For instance, half-sized cutting inserts 1128-2 may be used, although in other embodiments, quarter, three-quarter, or other cutting inserts 1128-2 of reduced width may be used. In some embodiments, cutting inserts of reduced length may be used. Cutting inserts 1128-3, for instance, may have a reduced length relative to the cutting inserts 1128-1. In particular, in this embodiment, the cutting inserts 1128-3 may include two cutting edges (i.e., a front cutting edge and one back-up cutting edge), whereas the cutting inserts 1128-1 may include three cutting edges (i.e., a front cutting edge 1130 and two back-up cutting

edges). By removing one of the cutting edges, the length or width of the cutting insert 1128-3 may be less than that of the cutting insert 1128-1.

While some embodiments of the present disclosure relate to cutting tools using cutting elements with similar configurations for each cutting edge (even if on differently sized cutting elements), other embodiments contemplate the use of multiple types of cutting elements, in which different types of cutting edge configurations are used. For instance, FIGS. 12-1 and 12-2 illustrate two example milling blades 1222, 1223. Each milling blade 1222, 1223 may have a different type of cutting insert 1228, 1229 coupled thereto. In particular, the milling blade 1222 is shown as having a plurality of semi-elliptical cutting inserts 1228 (which optionally includes some combination of full, half, quarter, three-quarter, or otherwise configured semi-elliptical cutting inserts). In contrast, the milling blade 1223 is shown as having a plurality of rectangular cutting inserts 1229 coupled thereto. In some embodiments, the cutting inserts 1229 may be similar to those described in U.S. Patent No. 5,070,952, which is incorporated herein by reference. In some embodiments, the cutting insert 1228, the cutting inserts 1229, or both, may include multiple teeth defining back-up cutting edges (whether elliptical or linear) may be formed. Additionally, while blades 1222, 1223 are shown as including a single type of cutting insert (i.e., cutting insert 1228 or 1229), in other embodiments the blades 1222, 1223 may include multiple types of cutting inserts. In some embodiments, the blades 1222, 1223 may include multiple types of cutting inserts, but may primarily include a single type of cutting insert (e.g., semi-elliptical cutting insert with multiple back-up ridges such as cutting insert 1228 or a rectangular cutting insert with multiple back-up ridges such as cutting insert 1229).

A milling tool, such as a section mill, may include multiple blades. According to at least some embodiments, each blade may include the same type of cutting inserts 1228, 1229 (or combinations of multiple types on the same blade, as shown in FIG. 3). In other embodiments, different blades may have different types of cutting inserts (or different combinations of multiple types of cutting inserts). For instance, a six-bladed section mill may include three milling blades 1222 with cutting inserts 1228 interspersed with (or followed by) three milling blades 1223 with cutting inserts 1229. Similarly, an eight-bladed section mill may include four milling blades 1222 interspersed with (or followed by) four milling blades 1223. In some embodiments, the numbers of blades including different types or arrangements of cutting inserts 1228, 1229 may be varied. For instance, rather than having equal numbers of blades with cutting inserts 1228, 1229, there may be different numbers of blades with each cutting inserts. For instance, a six-bladed section mill may include four or five blades having cutting inserts 1228 and one or two blades having cutting inserts 1229.

Various features may be provided by using different types/geometries of cutting inserts on different blades. For instance, one type/geometry of cutting inserts may have a cutting action and be used to generate swarf, while another could grind to create a surface that can be efficiently cut by a following knife. Similarly, blades including one type/geometry of cutting insert may be used to initiate a radial cut (e.g., a cut-out) in the casing or other workpiece, while blades with another type/geometry of cutting

insert may primarily be used for axially cutting (e.g., face-milling). In some embodiments, both types of cutting inserts may be used for axially cutting, but one may be more efficient at initiating a radial cut-out. Additionally, where multiple blades have the same type of cutting insert, the configuration/arrangement of cutting inserts may be the same on each blade. In other embodiments, and as described herein particularly with reference to FIGS. 8-1 to 10-3, different blades may have different arrangements of the same type of cutting insert. While the blades 1222, 1223 of FIGS. 12-1 and 12-2 are different (e.g., blade 1222 is longer) in other embodiments, the blades 1222, 1223 may have the same size and shape. In other embodiments, the cutting inserts 1228 may be on a smaller blade and the cutting insert 1229 may be on the longer blade 1222 and the cutting inserts 1228 may be on the shorter blade 1223.

The blades 1228, 1229 may also use other cutting inserts instead of, or in addition to, the semi-elliptical cutting inserts 1228 or the rectangular cutting inserts 1229 of FIGS. 12-1 and 12-2. For instance, in some embodiments, the cutting inserts 1228 may be replaced by rectangular cutting inserts that have a different configuration from that of cutting inserts 1229. By way of example, FIGS. 13 and 14 illustrate example cutting inserts 1328, 1428 that may have a rectangular plan shape, but which may have a different configuration than the cutting inserts 1229 that may include linear back-up cutting edges. In FIG. 13, for instance, the cutting insert 1328 includes a monolithic body formed of tungsten carbide or another superhard or superabrasive material. For example, the body may include or be made of tungsten carbide (including cemented tungsten carbide), tungsten carbide doped with titanium carbide, tantalum carbide and/or niobium carbide, silicon carbide, alumina, cubic boron nitride, polycrystalline diamond, boron carbide, boron carbon nitride, materials having a hardness greater than 80 HRA (Rockwell Hardness A), or combinations of the foregoing.

In some embodiments, the body may have a front face 1342, a back face 1344, a top face 1434, a bottom face 1342, and side faces 1346. The back face 1344 may be coupled to the blade or other component of a milling tool. A cut-out 1336 may be formed in the otherwise generally rectangular body, and may define a cutting edge 1330, a cutting face 1338-1, and a chip-breaking face 1338-2. The cutting edge 1330 and the cutting face 1338-1 may be configured to cut into and remove material from a wellbore casing or other workpiece. Swarf generated by the cutting face 1338-1 may be urged toward the chip-breaking face 1338-2. Optionally, a transition face may be located between the cutting face 1338-1 and the chip-breaking face 1338-2. In some embodiments, the transition face may form a continuous curve or surface with the cutting face 1338-1 and the chip-breaking face 1338-2, although in other embodiments an abrupt angle may cause a transition face to be discontinuous with the cutting face 1338-1, the chip-breaking face 1338-2, or both. Swarf generated during cutting of a workpiece may be urged to move along the cutting face 1338-1, toward and along the optional transition face, and to the chip-breaking face 1338-2, which may facilitate breaking the swarf into individual chips. The individual chips of swarf, in contrast to the longer ribbons of swarf that can form entwined balls of swarf known as bird's nests.

The bottom face 1342 may be adjacent to and at angle relative to the cutting face 1338-1. The bottom face 1342 and the cutting face 1338-1 may be joined or otherwise interface along the cutting edge 1330. The cutting edge 1330 may form a substantially abrupt, discontinuous transition or junction between the bottom face 1342 and the cutting face 1338-1, and may be used to cut into the wellbore casing or other workpiece. The cutting edge 1330 may allow the cutting face 1338-1 to also cut into the wellbore casing while the bottom face 1342 is substantially aligned with or even in contact with the wellbore casing.

The cut-out 1336, cutting face 1338-1, and the cutting edge 1340 may extend between the sides 1346 of the cutting insert 1328, and potentially a full width 1347 of the cutting insert 1328. It should be understood that while the cutting insert 1328 of FIG. 13 is thus shown with a uniform profile across a full width 1347 of the cutting insert 1328, in other embodiments, a cutting insert may have a variable or non-uniform profile across the width. For example, a cutting insert 1428 of FIG. 14 may have one or more of a cutting face 1438-1, a chip-breaking face 1438-2, or a transition face that extends partially along a width 1447 of the cutting insert 1428. For instance, in this embodiment, the cutting face 1438-1, chip-breaking face 1438-2, and a transition face may be formed within a spherical or elliptical (e.g., quarter spherical or quarter elliptical) cut-out 1436 formed in an otherwise generally rectangular cutting insert 1428. Although described as a cut-out, the cut-out 1436 (and cut-out 1336) may not be formed by removing material, but may instead be formed by casting or otherwise forming the cutting insert 1428 using a mold defining the cut-out.

The cutting insert 1328 of FIG. 13 or the cutting insert 1428 of FIG. 14 may also be used in connection with embodiments of the present disclosure. For instance, the cutting insert 1328 or 1428 may be used on the blade 1222 of FIG. 12-1 instead of (or in combination with) the cutting insert 1228. The blade 1223 of FIG. 12-2 may continue to use cutting inserts 1229. In the same or other embodiments, the blade 1223 may use the cutting inserts 1328 or 1428 instead of (or in combination with) the cutting insert 1229. Additional or other combinations may also be used (e.g., a different blade may be used for each of three, four, or more types/geometries of cutting inserts). Further examples of additional or other cutting elements that may be used in combination with aspects described herein can be found in United States Patent Application Serial No. 15/0179,918, filed on February 8, 2016, which application is expressly incorporated herein by this reference in its entirety.

In the description herein, various relational terms are provided to facilitate an understanding of various aspects of some embodiments of the present disclosure. Relational terms such as “bottom,” “below,” “top,” “above,” “back,” “front,” “left,” “right,” “rear,” “forward,” “up,” “down,” “horizontal,” “vertical,” “clockwise,” “counterclockwise,” “upper,” “lower,” and the like, may be used to describe various components, including their operation (or illustrated position) relative to one or more other components. Relational terms do not indicate a particular orientation for each embodiment within the scope of the description or claims. For example, a component of a BHA that is described as “below” another component may be farther from the surface while within a vertical wellbore, but

may have a different orientation during assembly, when removed from the wellbore, or in a deviated borehole. Accordingly, relational descriptions are intended solely for convenience in facilitating reference to various components, but such relational aspects may be reversed, flipped, rotated, moved in space, placed in a diagonal orientation or position, placed horizontally or vertically, or similarly modified. Certain descriptions or designations of components as “first,” “second,” “third,” and the like may also be used to differentiate between similar components. Such language is not intended to limit a component to a singular designation. As such, a component referenced in the specification as the “first” component may be the same or different than a component that is referenced in the claims as a “first” component.

Furthermore, while the description or claims may refer to “an additional” or “other” element, feature, aspect, component, or the like, it does not preclude there being a single element, or more than one, of the additional element. Where the claims or description refer to “a” or “an” element, such reference is not be construed that there is just one of that element, but is instead to be inclusive of other components and understood as “at least one” of the element. It is to be understood that where the specification states that a component, feature, structure, function, or characteristic “may,” “might,” “can,” or “could” be included, that particular component, feature, structure, or characteristic is provided in some embodiments, but is optional for other embodiments of the present disclosure. 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.” Components that are “integral” or “integrally” formed include components made from the same piece of material, or sets of materials, such as by being commonly molded or cast from the same material, or commonly machined from the same piece of material stock. Components that are “integral” should also be understood to be “coupled” to each other.

Although various example embodiments have been described in detail herein, those skilled in the art will appreciate in view of the present disclosure that many modifications are possible in the example embodiments without materially departing from the present disclosure. Accordingly, any such modifications are intended to be included in the scope of this disclosure. Likewise, while the disclosure herein contains many specifics, these specifics should not be construed as limiting the scope of the disclosure or of any of the appended claims, but merely as providing information pertinent to one or more specific embodiments that may fall within the scope of the disclosure and the appended claims. Any described features from the various embodiments disclosed may be employed in combination.

A person having ordinary skill in the art should realize in view of the present disclosure that equivalent constructions do not depart from the spirit and scope of the present disclosure, and that various changes, substitutions, and alterations may be made to embodiments disclosed herein without departing from the spirit and scope of the present disclosure. Equivalent constructions, including functional “means-plus-function” clauses are intended to cover the structures described herein as performing the recited function, including both structural equivalents that operate in the same manner,

and equivalent structures that provide the same function. It is the express intention of the applicant not to invoke means-plus-function or other functional claiming for any claim except for those in which the words ‘means for’ appear together with an associated function. Each addition, deletion, and modification to the embodiments that falls within the meaning and scope of the claims is to be embraced by the claims.

While embodiments disclosed herein may be used in an oil, gas, or other hydrocarbon exploration nor production environment, such environment is merely illustrative. Systems, tools, assemblies, cutting inserts, methods, and other components of the present disclosure, or which would be appreciated in view of the disclosure herein, may be used in other applications and environments. In other embodiments, cutting inserts, cutting tools, milling tools, methods of milling, methods of cutting, methods of initiating a cut-out, or other embodiments discussed herein, or which would be appreciated in view of the disclosure herein, may be used outside of a downhole environment, including in connection with other systems, including within automotive, aquatic, aerospace, hydroelectric, manufacturing, other industries, or even in other downhole environments. The terms “well,” “wellbore,” “borehole,” and the like are therefore also not intended to limit embodiments of the present disclosure to a particular industry. A wellbore or borehole may, for instance, be used for oil and gas production and exploration, water production and exploration, mining, utility line placement, or myriad other applications.

Certain embodiments and features may have been described using a set of numerical values that may provide lower or upper limits. It should be appreciated that any particular value may be used alone to define a particular value or an open-ended range (e.g., 7.5 mm, at least 7.5 mm, up to 7.5 mm), or ranges may include the combination of any two values (e.g., between 2.5 mm and 7.5 mm). Any numerical value is “about” or “approximately” the indicated value, and takes into account experimental error and variations that would be expected by a person having ordinary skill in the art. Any numbers, percentages, ratios, measurements, or other values stated herein are therefore intended to include the stated value as well as other values that are about or approximately the stated value, as would be appreciated by one of ordinary skill in the art encompassed by embodiments of the present disclosure. A stated value should therefore be interpreted broadly enough to encompass values that are at least close enough to the stated value to perform a desired function or achieve a desired result. The stated values include at least experimental error and variations that would be expected by a person having ordinary skill in the art, as well as the variation to be expected in a suitable manufacturing or production process. A value that is about or approximately the stated value and is therefore encompassed by the stated value may further include values that are within 5%, within 1%, within 0.1%, or within 0.01% of a stated value.

The abstract included with this disclosure is provided to allow the reader to quickly ascertain the general nature of some embodiments of the present disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims.

CLAIMS

What is claimed is:

1. A cutting insert, comprising:

a semi-elliptical body, the body having:

a length of half a minor diameter of the semi-elliptical body; and

a width of at least 85% of a major diameter of the semi-elliptical body;

a front cutting edge following an elliptical curve; and

one or more back-up cutting edges following elliptical curves.

2. The cutting insert of claim 1, the one or more back-up cutting edges being concentric with the front cutting edge.

3. The cutting insert of claim 1 or claim 2, the front cutting edge having a trailing flank face at an axial flank angle between 15° and 25° .

4. The cutting insert of claim 3, at least one of the one or more back-up cutting edges having a trailing flank face at an axial flank angle between 15° and 25° .

5. The cutting insert of claim 1 or claim 2, the front cutting edge being on an edge of a front face oriented at a front flank angle between 0° and 10° .

6. The cutting insert of any one of claim 1, claim 2, claim 3, or claim 5, the one or more back-up cutting edges being on an edge of a secondary front face oriented at a back-up flank angle of between 0° and 10° .

7. The cutting insert of any one or claim 1 to claim 6, the length of the semi-elliptical body being between 0.325 inch (8.3 mm) and 0.425 inch (10.8 mm).

8. The cutting insert of claim 7, the width of the semi-elliptical body being between 0.75 inch (19.1 mm) and 1.25 inch (31.8 mm).

9. The cutting insert of claim 8, the height of the semi-elliptical body being between 0.2 inch (5.1 mm) and 0.4 inch (10.2 mm).

10. The cutting insert of any one or claim 1 to claim 9, the semi-elliptical body including a trailing edge that is linear along a full length thereof.

11. The cutting insert of any one of claim 1 to claim 9, the semi-elliptical body including a trailing edge that is curved along at least a portion thereof.

12. The cutting insert of claim 11, the trailing edge having a curvature corresponding to at least a portion of the curvature of the front cutting edge.

13. The cutting insert of any one of claim 1 to claim 12, the one or more back-up cutting edges being chip-breakers.

14. A downhole cutting tool, comprising:
a body; and
at least two blades coupled to the body, each of the at least two blades including cutting elements coupled thereto, and a first blade of the at least two blades including a different arrangement of cutting elements than a second blade of the at least two blades.

15. The downhole cutting tool of claim 14, the first blade including a first geometry of cutting elements and the second blade including a second geometry of cutting elements.

16. The downhole cutting tool of claim 15, each of the cutting elements of the first blade sharing the first geometry, and each of the cutting elements of the second blade sharing the second geometry.

17. The downhole cutting tool of any one of claim 14 to claim 16, the different arrangements of the first and second blades including cutting elements of differing radial offsets.

18. The downhole cutting tool of any one of claim 14 to claim 17, the first blade including cutting elements having a curved cutting face, and the second cutting elements having a planar cutting face.

19. The downhole cutting tool of claim 18, the cutting elements of the first blade including at least one of an elliptical cutting edge or a cut-out defining a curved cutting face.

20. A method of milling casing, comprising:
inserting a mill into a wellbore while at least one movable blade of the mill is in a retracted position, the at least one movable blade including at least one cutting insert of any of claims 1–13;
initiating a radial cut-out in a casing within the wellbore; and
extending the cut-out in the casing by using the at least one cutting insert to cut axially along the casing.

1 / 13

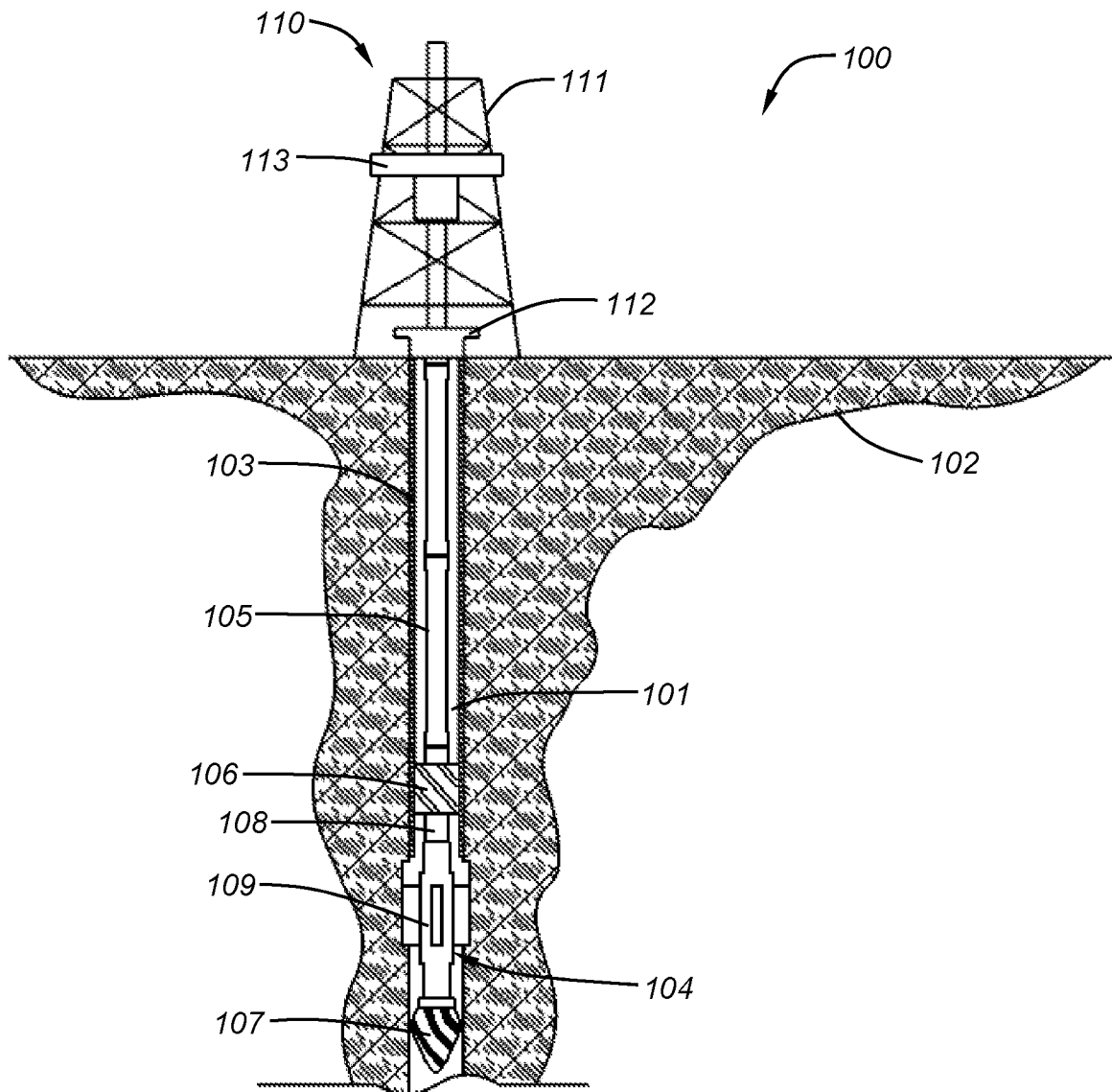


FIG. 1

2 / 13

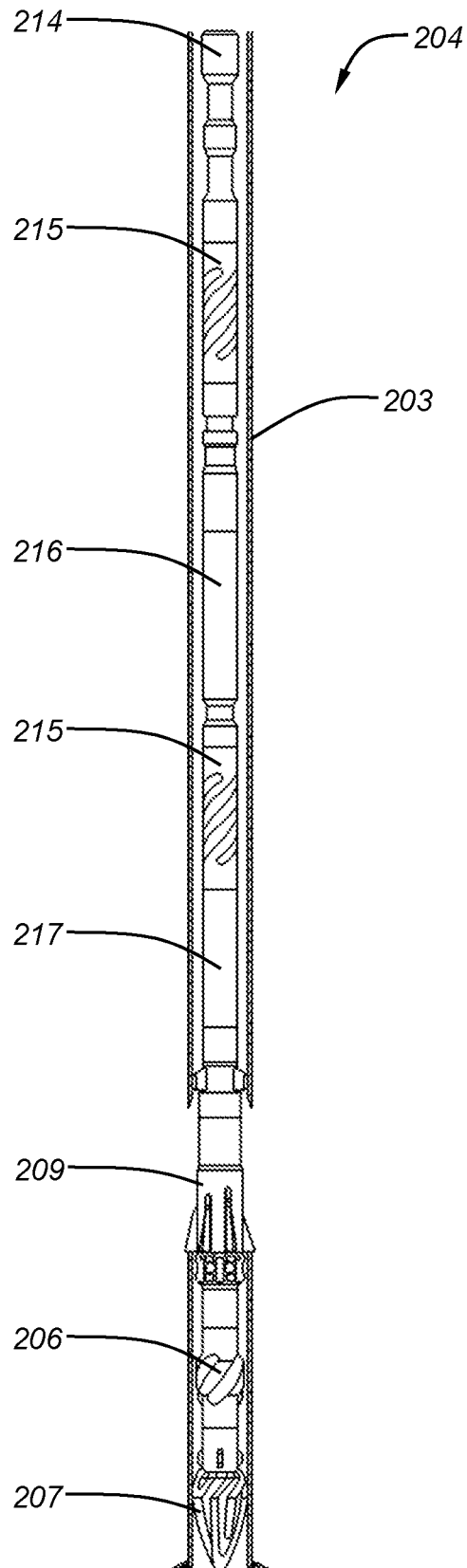


FIG. 2

3 / 13

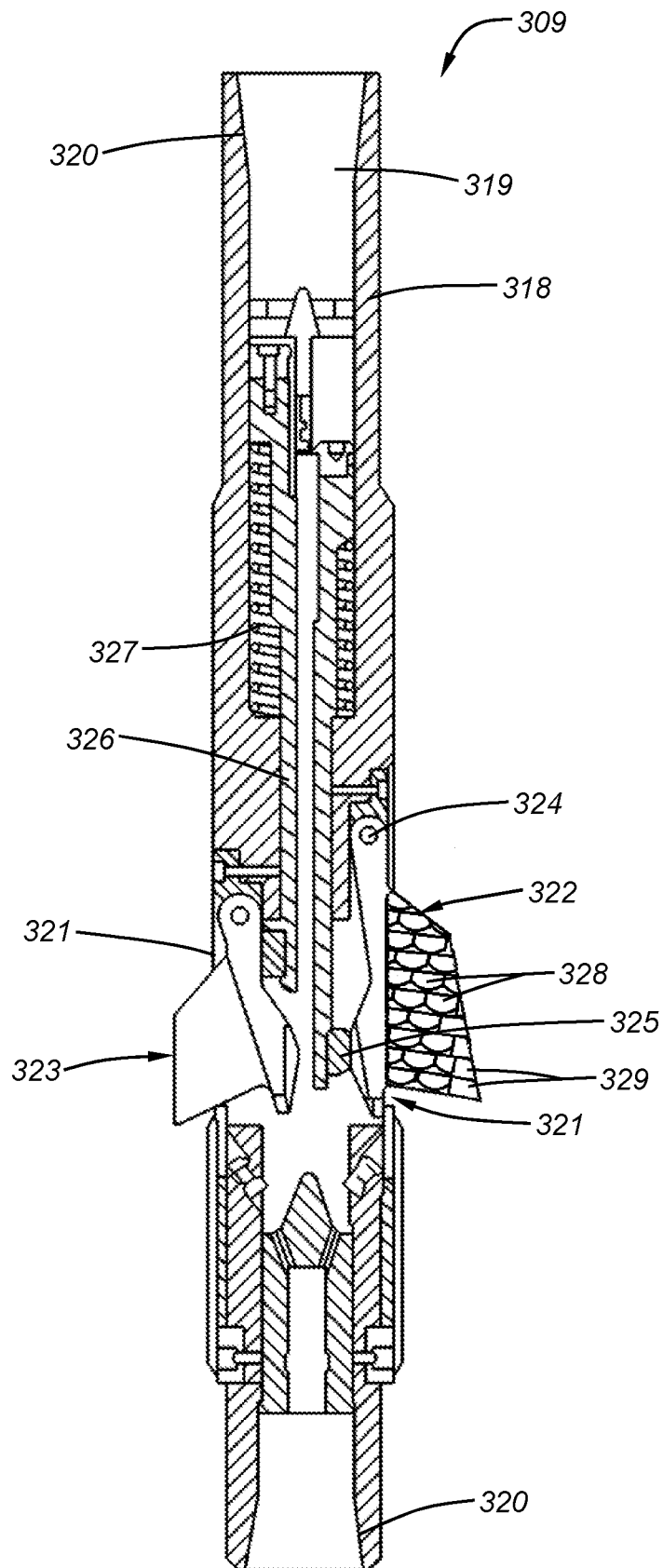
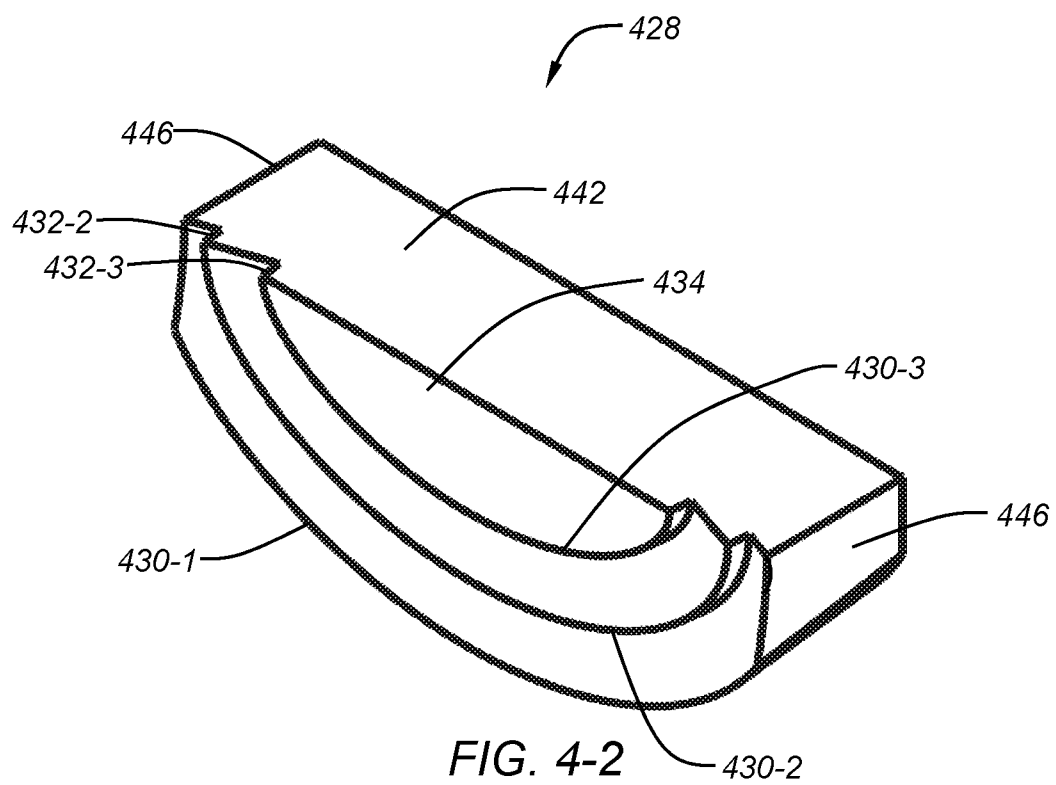
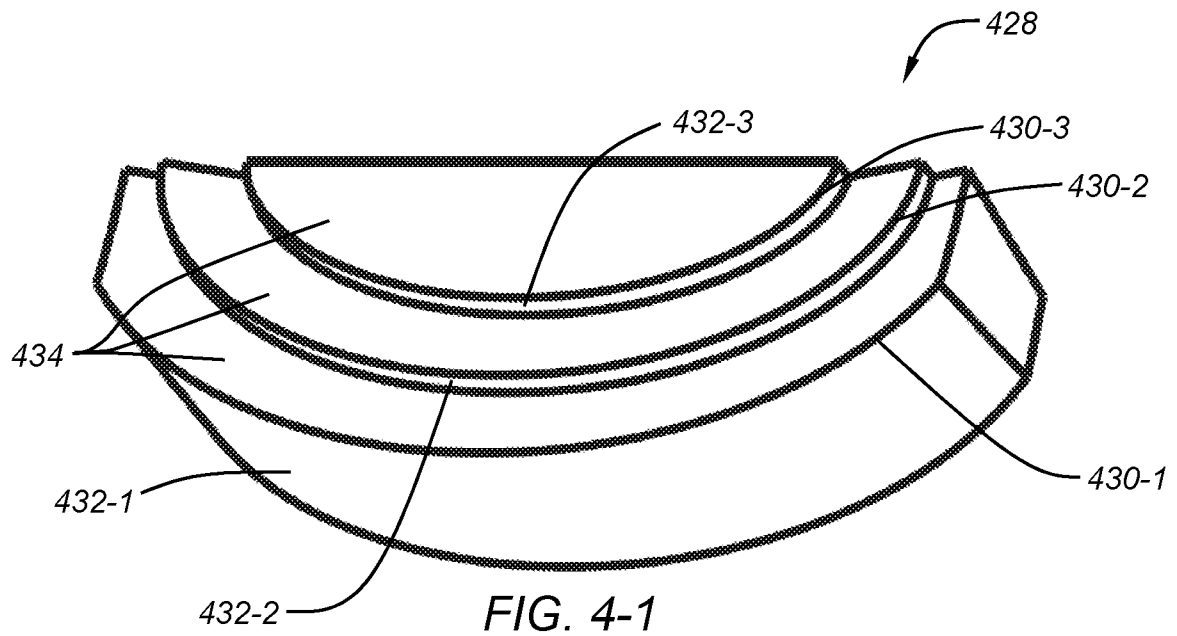
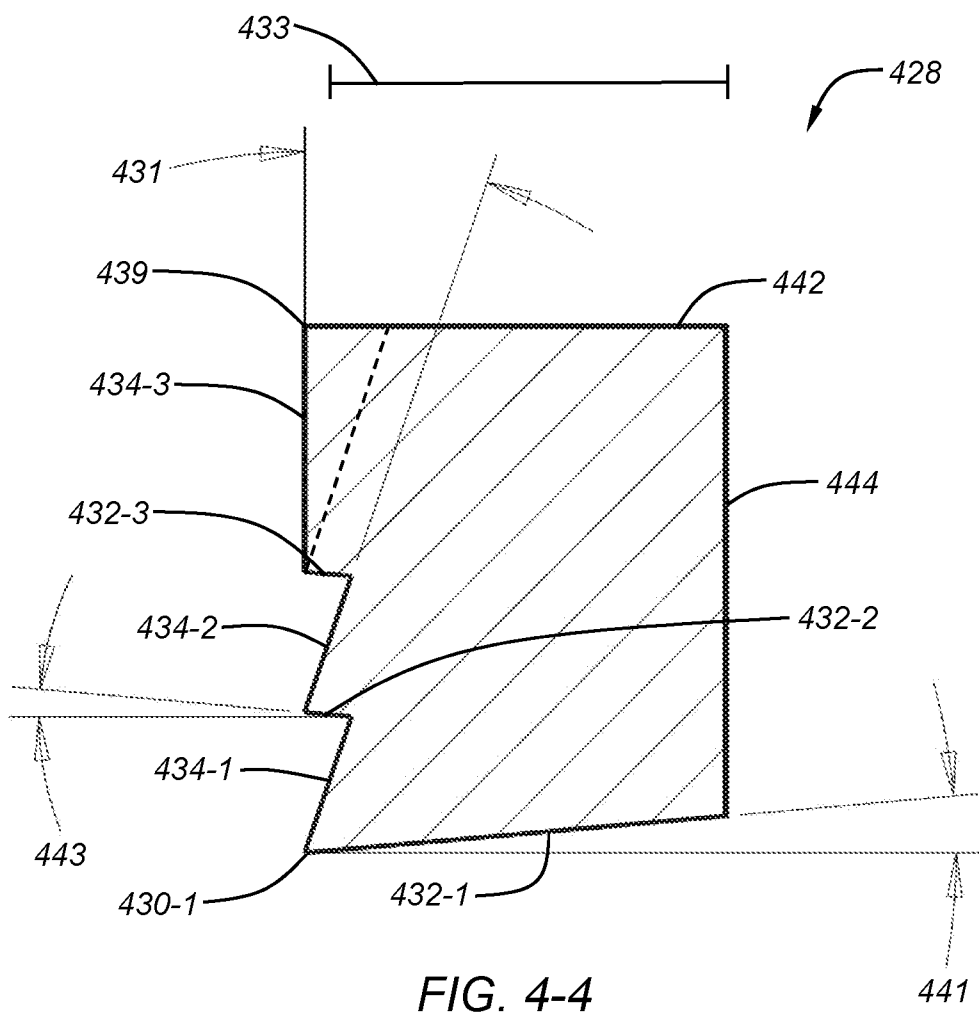
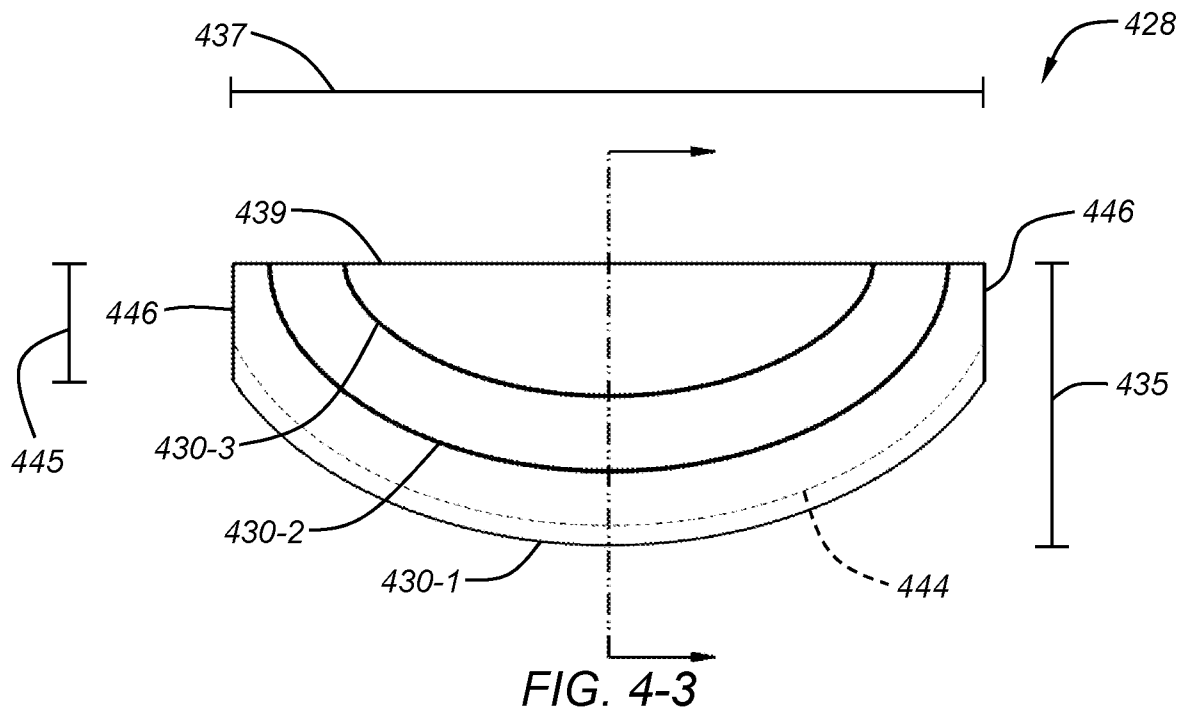


FIG. 3

4 / 13



5 / 13



6/13

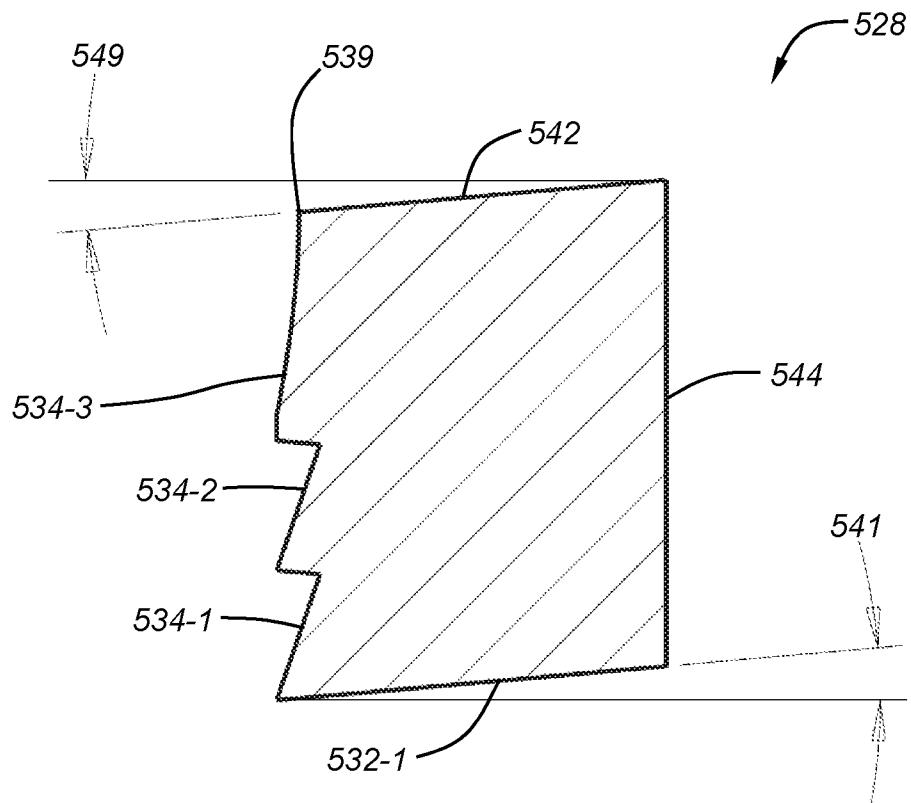


FIG. 5

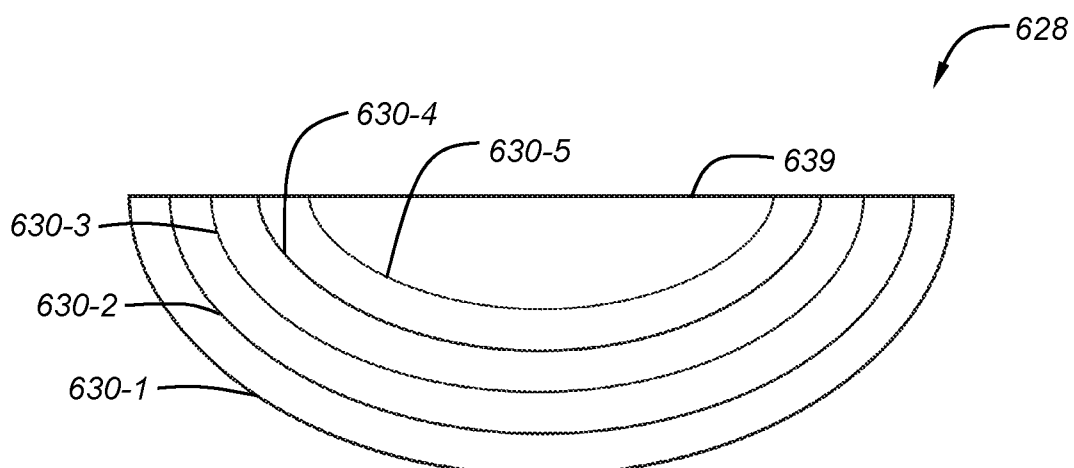


FIG. 6

7/13

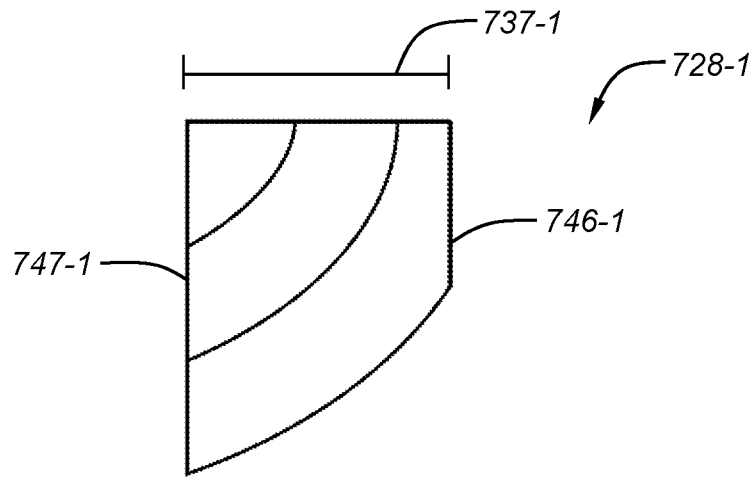


FIG. 7-1

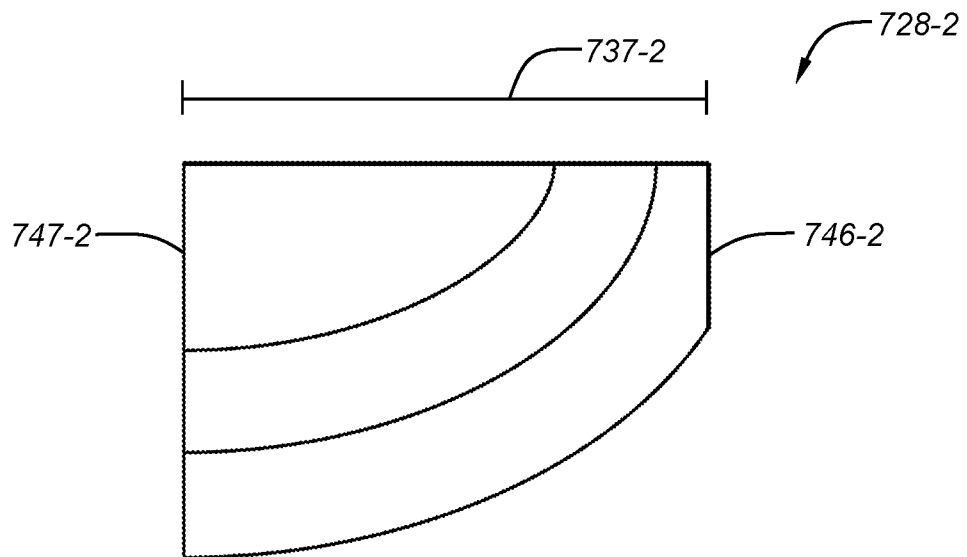


FIG. 7-2

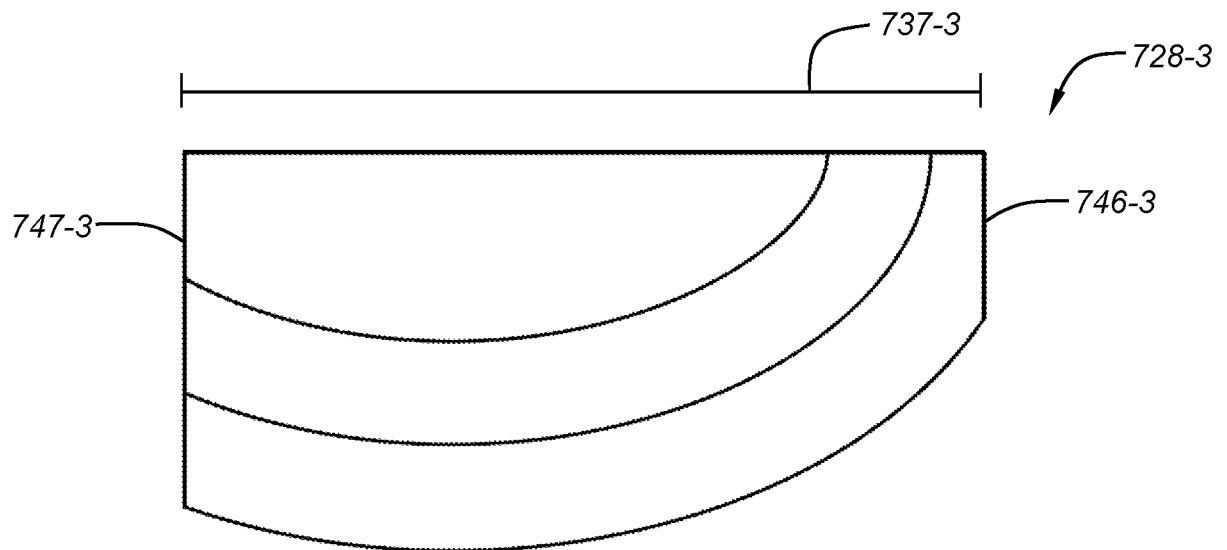
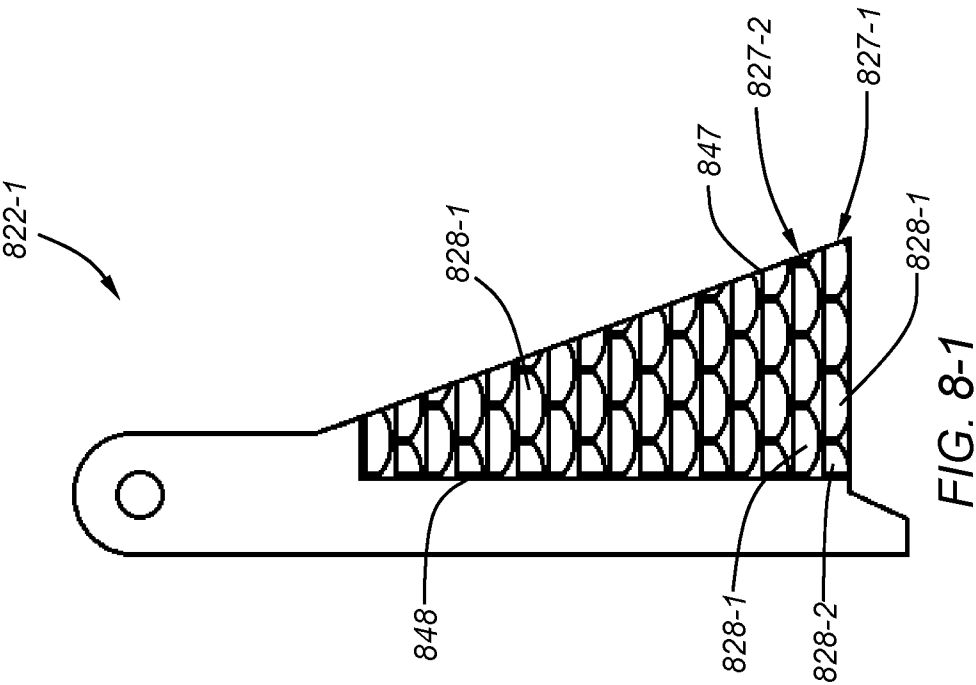
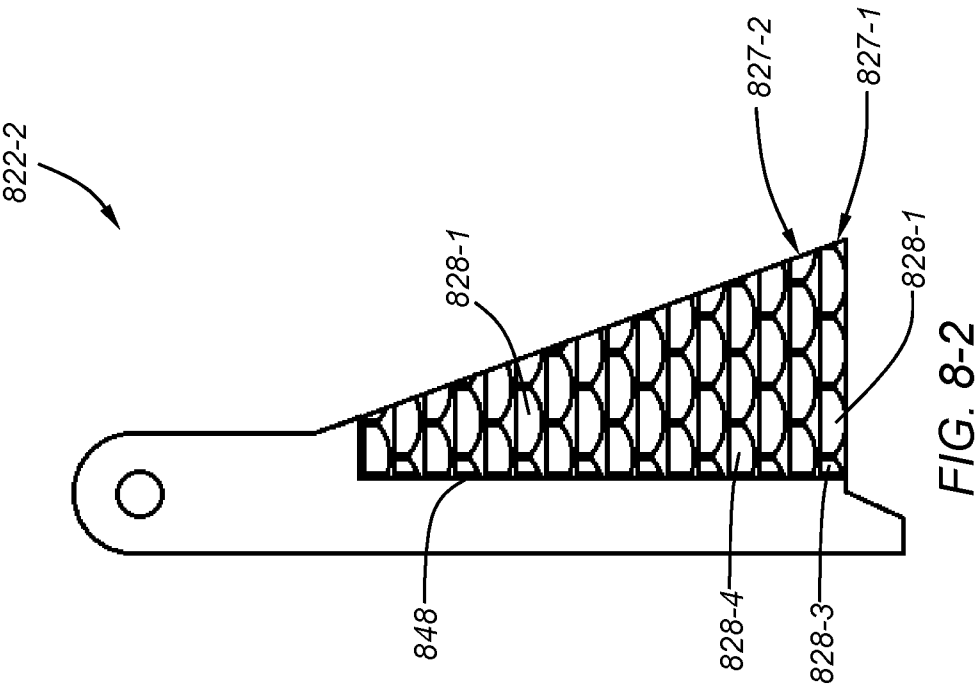
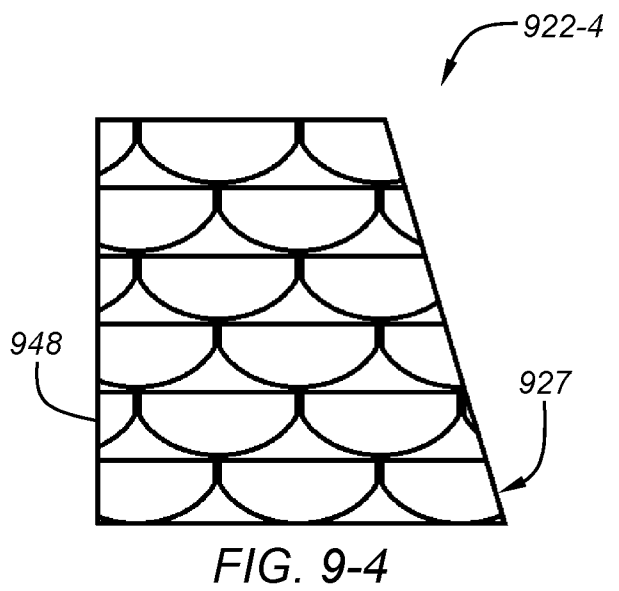
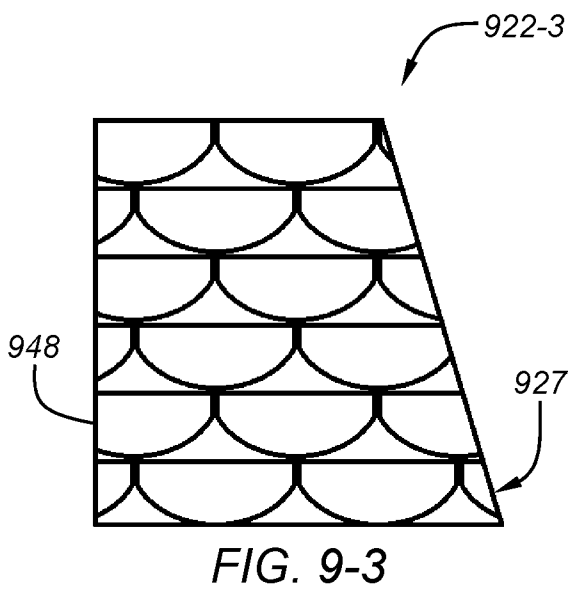
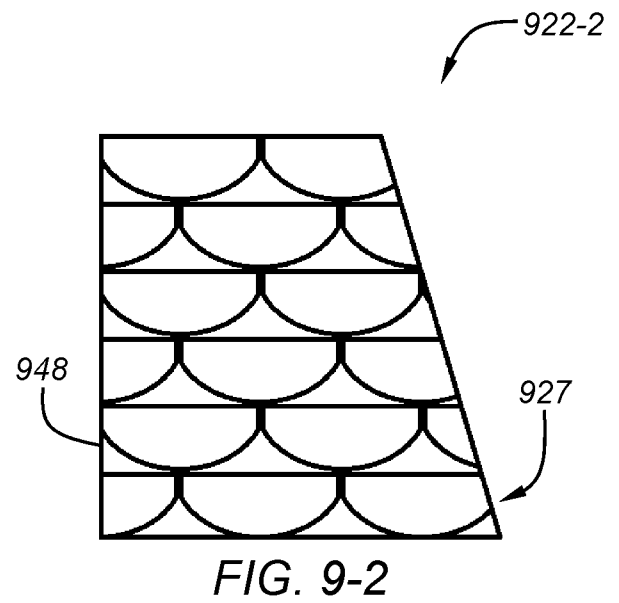
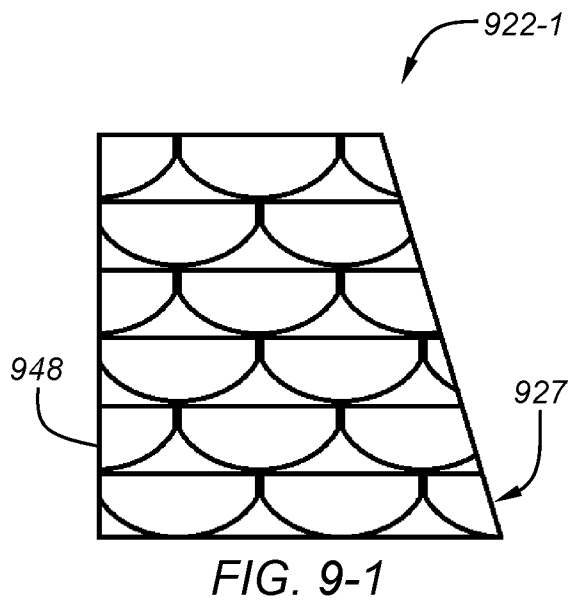
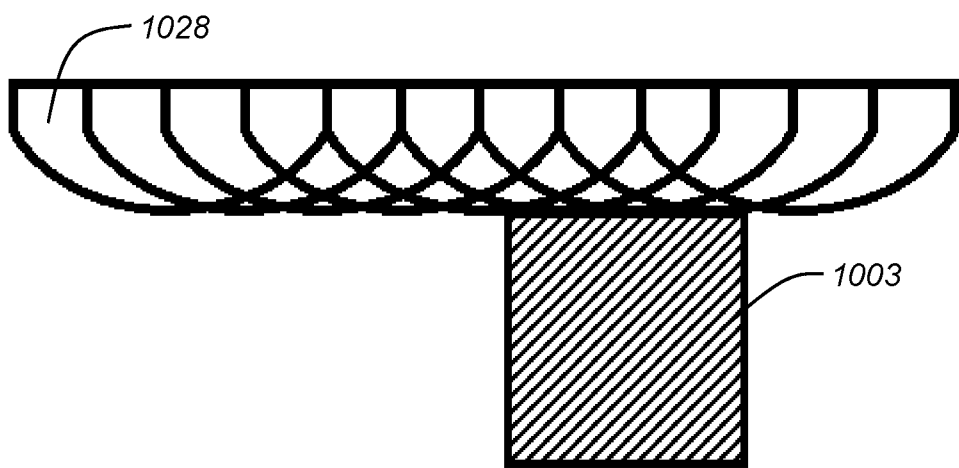
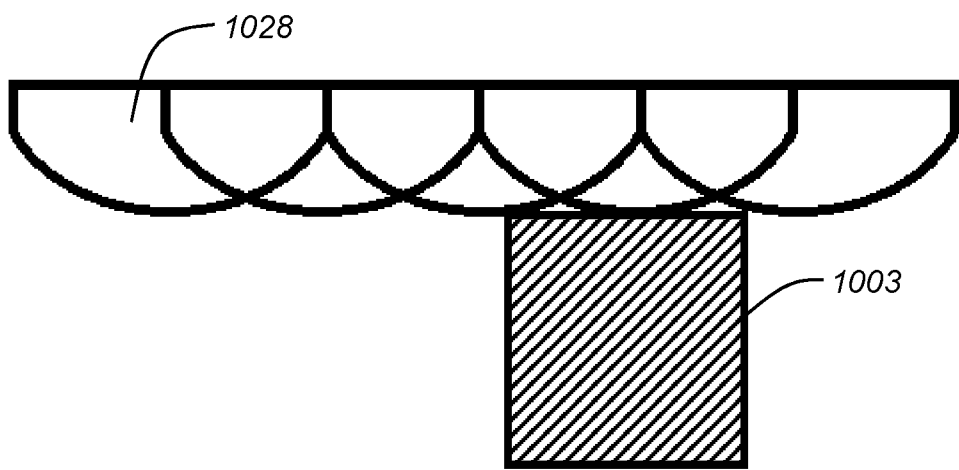
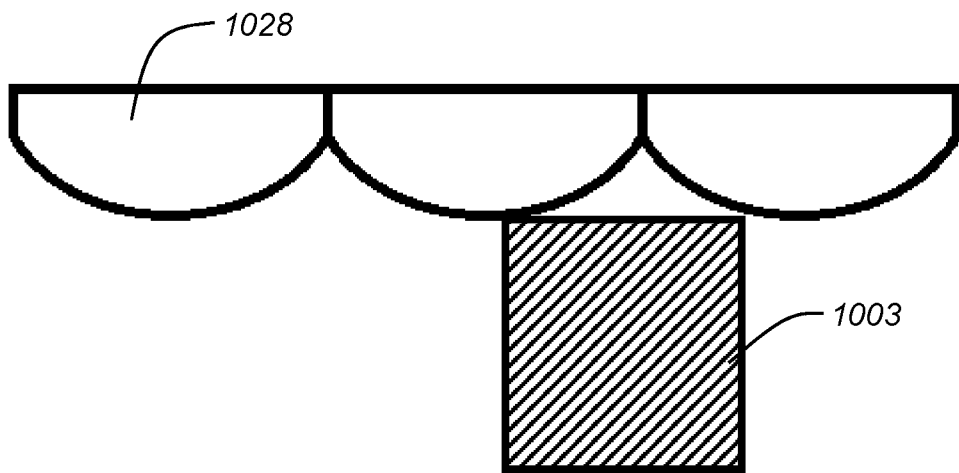


FIG. 7-3





10 / 13



11 / 13

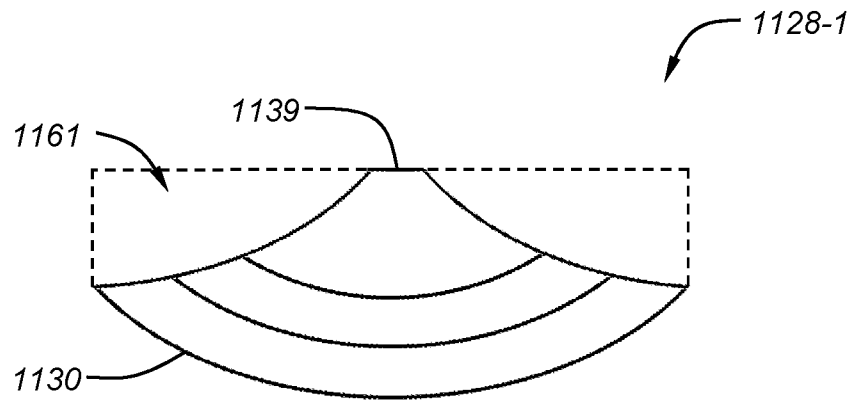


FIG. 11-1

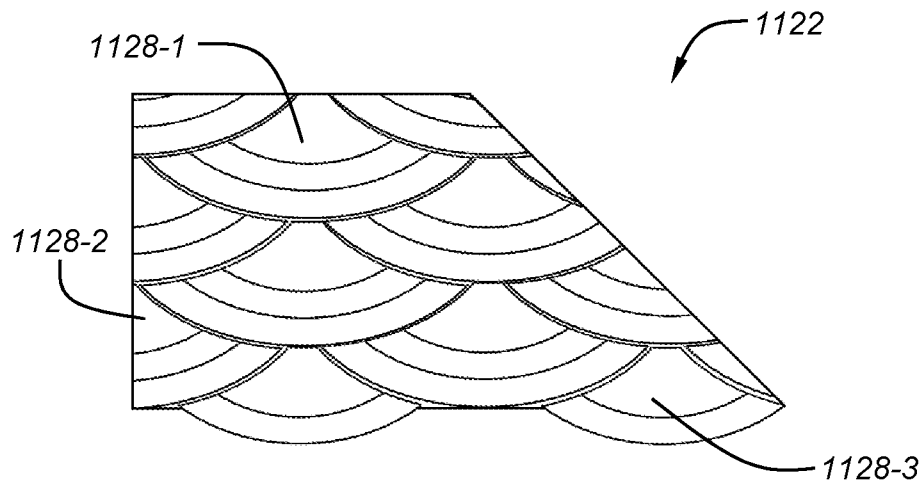


FIG. 11-2

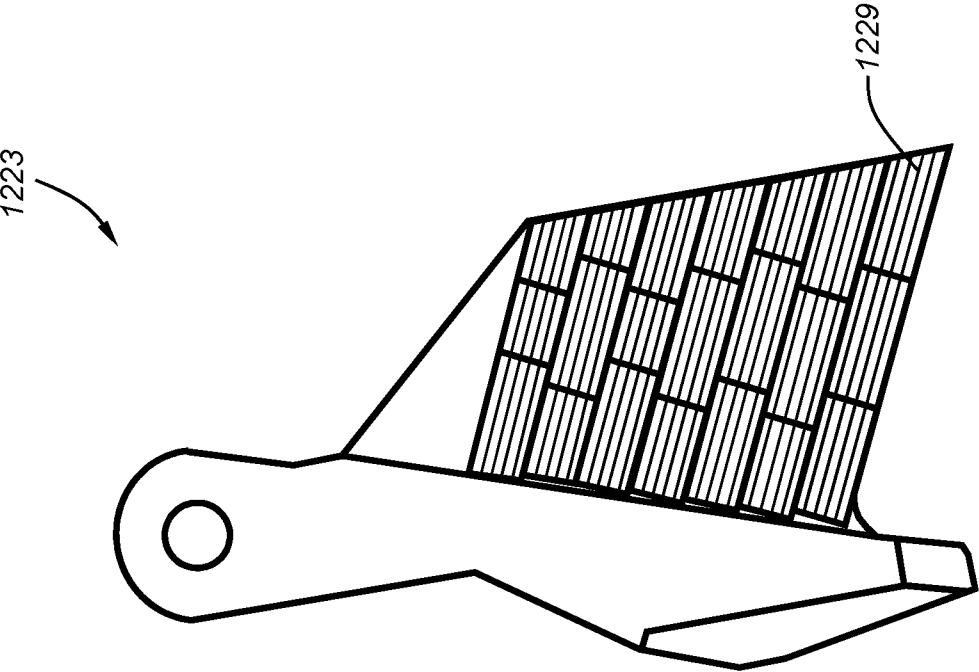


FIG. 12-2

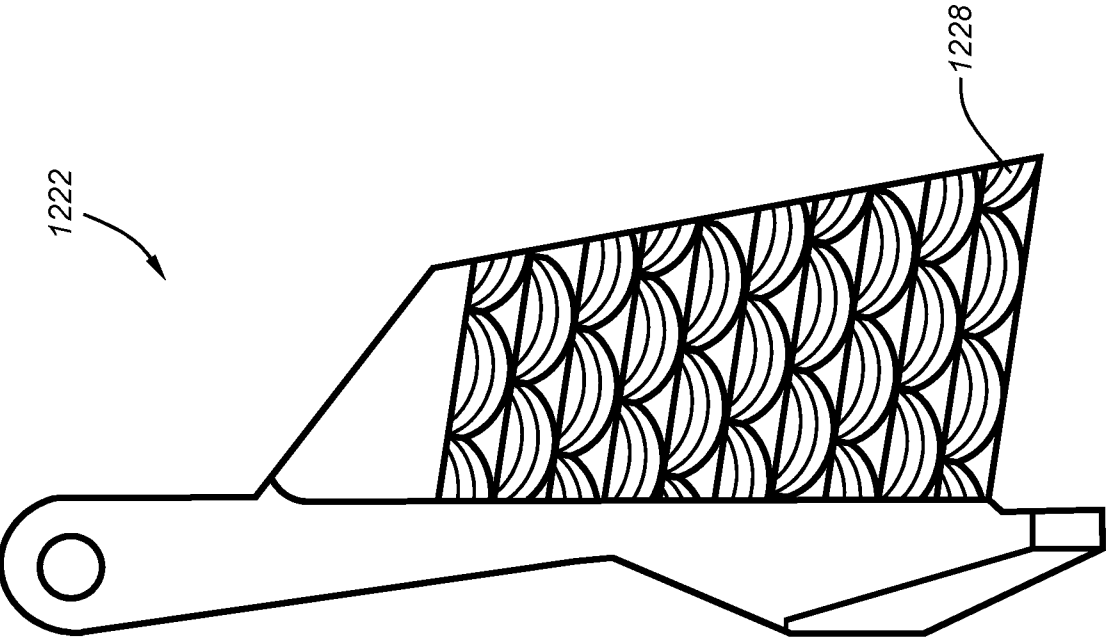


FIG. 12-1

13 / 13

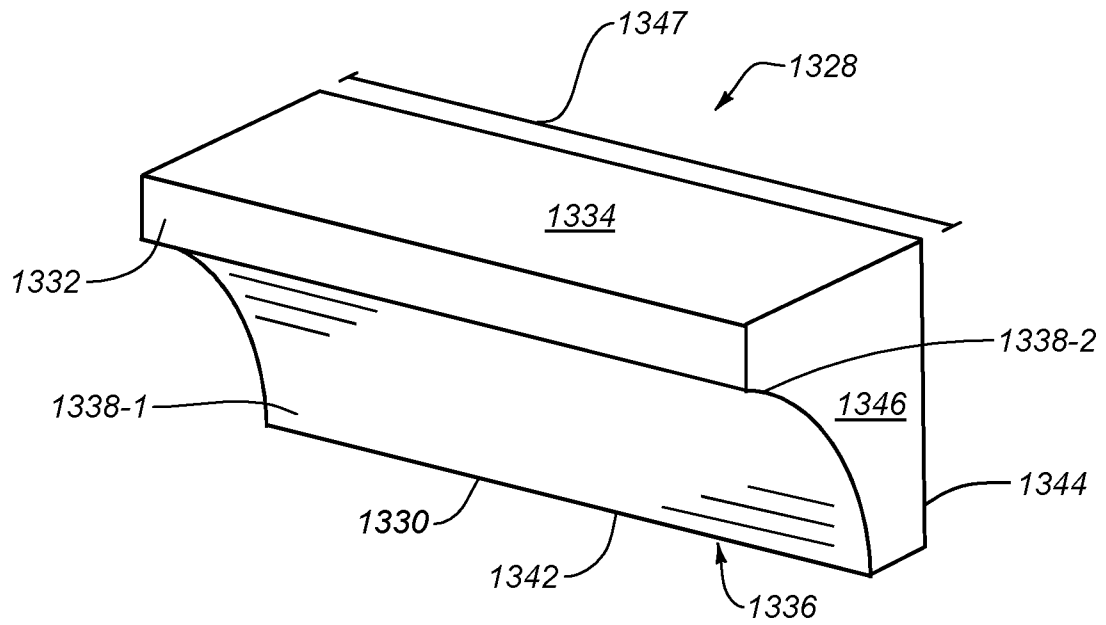


FIG. 13

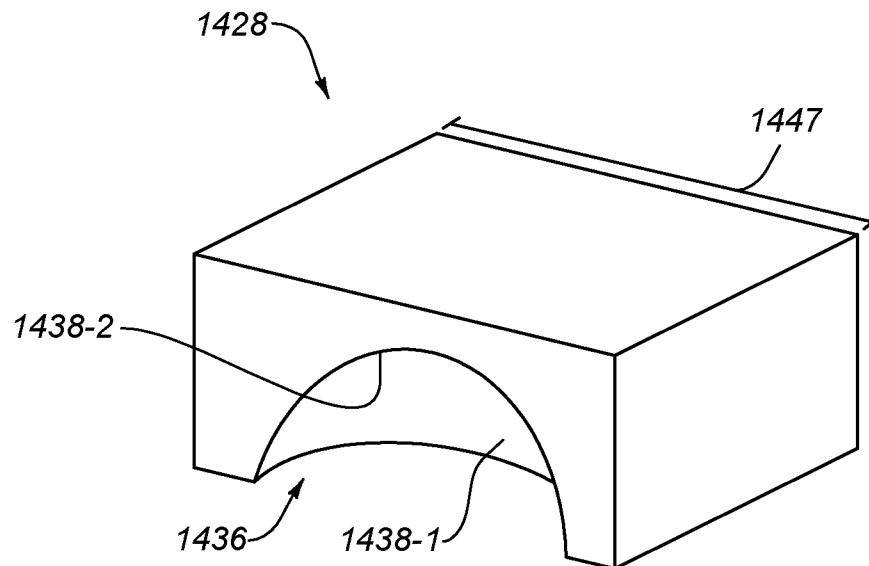


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/058965**A. CLASSIFICATION OF SUBJECT MATTER****E21B 29/00(2006.01)i, E21B 17/00(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 29/00; E21B 10/46; E21B 10/00; E21B 17/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: milling tool, cutting insert, semi-elliptical, front cutting edge, back-up cutting edge, flank

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5984005 A (HART et al.) 16 November 1999 See column 10, lines 49-54, column 16, lines 12-36 and figures 6A-6B, 31-34.	1-5, 14-17
Y	US 2014-0166305 A1 (SMITH INTERNATIONAL, INC.) 19 June 2014 See paragraphs [0028], [0036], claim 13, and figures 2-5.	1-5, 14-17
A	US 2015-0167394 A1 (SMITH INTERNATIONAL, INC.) 18 June 2015 See paragraphs [0041]-[0050] and figures 2-4.	1-5, 14-17
A	EP 0712993 B1 (SMITH INTERNATIONAL, LIMITED.) 16 April 2003 See claim 1, and figures 1-4.	1-5, 14-17
A	US 2015-0376966 A1 (SMITH INTERNATIONAL, INC.) 31 December 2015 See paragraphs [0067]-[0070] and figures 3-8.	1-5, 14-17



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

14 February 2017 (14.02.2017)

Date of mailing of the international search report

16 February 2017 (16.02.2017)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea



Facsimile No. +82-42-481-8578

Authorized officer

LEE, Dal Kyong

Telephone No. +82-42-481-8440



International application No.
PCT/US2016/058965

PCT/US2016/058965

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 8-9,12,19
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claims 8-9,12,19 are regarded to be unclear because the claims refer to multiple dependent claims which do not comply with PCT Rule 6.4(a).
3. ☒ Claims Nos.: 6-7,10-11,13,18,20
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/058965

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5984005 A	16/11/1999	AU 1996-71367 B2	25/05/2000
		AU 2000-26839 A1	14/09/2000
		CA 2230985 C	25/07/2006
		CA 2287949 A1	12/11/1998
		CA 2287949 C	06/12/2005
		CA 2300834 A1	04/03/1999
		CA 2300834 C	11/10/2005
		CA 2361928 A1	31/08/2000
		CA 2361928 C	21/11/2006
		EP 0851964 A1	20/10/1999
		EP 0851964 B1	02/07/2003
		EP 0979344 A1	16/02/2000
		EP 0979344 B1	28/08/2002
		EP 1015731 A1	05/07/2000
		EP 1015731 B1	23/10/2002
		EP 1155215 A2	21/11/2001
		EP 1155215 B1	08/09/2004
		US 5626189 A	06/05/1997
		US 5908071 A	01/06/1999
		US 6170576 B1	09/01/2001
		WO 00-50729 A2	31/08/2000
		WO 00-50729 A3	07/12/2000
		WO 97-11251 A1	27/03/1997
		WO 98-50671 A1	12/11/1998
		WO 99-10621 A1	04/03/1999
US 2014-0166305 A1	19/06/2014	GB 2524915 A	07/10/2015
		US 9512690 B2	06/12/2016
		WO 2014-099868 A1	26/06/2014
US 2015-0167394 A1	18/06/2015	WO 2015-094659 A1	25/06/2015
EP 0712993 B1	16/04/2003	AU 5198096 A	06/11/1997
		EP 0712993 A2	22/05/1996
		EP 0712993 A3	07/01/1998
		GB 2295172 A	22/05/1996
		GB 2295172 B	19/08/1998
		US 5778995 A	14/07/1998
US 2015-0376966 A1	31/12/2015	CN 105269047 A	27/01/2016
		EP 2960428 A2	30/12/2015