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ASYMMETRIC ANCHORING RIDGE DESIGN FOR EXPANDABLE LINER HANGER**CROSS-REFERENCE TO RELATED APPLICATION**

[0001] This application claims priority to U.S. Application Serial No. 18/306,467, filed on April 25, 2023, entitled “ASYMMETRIC ANCHORING RIDGE DESIGN FOR EXPANDABLE LINER HANGER,” which claims the benefit of U.S. Provisional Application Serial No. 63/337,528, filed on May 2, 2022, entitled “ASYMMETRIC ANCHORING RIDGE DESIGN FOR EXPANDABLE LINER HANGER,” commonly assigned with this application and incorporated herein by reference in their entirety.

BACKGROUND

[0002] During wellbore operations, it is typical to “hang” a liner onto a casing such that the liner supports an extended string of tubular below it. As used herein, “tubing string” refers to a series of connected pipe sections, casing sections, joints, screens, blanks, cross-over tools, downhole tools, and the like, inserted into a wellbore, whether used for drilling, work-over, production, injection, completion, or other processes. A tubing string may be run in and out of the casing, and similarly, tubing string can be run in an uncased wellbore or section of wellbore. Further, in many cases a tool may be run on a wireline or coiled tubing instead of a tubing string, as those of skill in the art will recognize.

[0003] Expandable liner hangers may generally be used to secure the liner within a previously set casing or liner string. Expandable liner hangers may be “set” by expanding the liner hanger radially outward into gripping and sealing contact with the casing or liner string. For example, expandable liner hangers may be expanded by use of hydraulic pressure to drive an expanding cone, wedge, or “pig,” through the liner hanger. Other methods may be used, such as mechanical swaging, explosive expansion, memory metal expansion, swellable material expansion, electromagnetic force-driven expansion, etc.

[0004] The expansion process may typically be performed by means of a setting tool used to convey the liner hanger into the wellbore. The setting tool may be interconnected between a work string (e.g., a tubular string made up of drill pipe or other segmented or continuous tubular elements) and the liner hanger. The setting tool may expand the liner hanger into anchoring and sealing engagement with the casing.

BRIEF DESCRIPTION

[0005] Reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0006] TABLE 1 illustrates an FEA of an improved anchoring ridge design;

[0007] FIG. 1 illustrates an example of a liner hanger system designed according to one or more embodiments of the disclosure;

[0008] FIG. 2 illustrates an elevational view, with cut-away and partial cross-section, of an embodiment of axial load bearing assembly on an expandable liner hanger;

[0009] FIG. 3 illustrates a perspective view of expandable liner hanger assembly with the plurality of anchoring ridges;

[0010] FIGs. 4A and 4B illustrate various different embodiments of an expandable liner hanger designed according to the disclosure;

[0011] FIGs. 5A through 5G illustrate various embodiments of a liner hanger having an anchoring ridge designed, manufactured, and placed according to one or more embodiments of the disclosure; and

[0012] FIG. 6 illustrates an alternative embodiment of an expandable liner hanger assembly designed, manufactured and/or operated according to one or more embodiments of the disclosure.

DETAILED DESCRIPTION

[0013] In the drawings and descriptions that follow, like parts are typically marked throughout the specification and drawings with the same reference numerals, respectively. The drawn figures are not necessarily, but may be, to scale. Certain features of the disclosure may be shown exaggerated in scale or in somewhat schematic form and some details of certain elements may not be shown in the interest of clarity and conciseness. The present disclosure may be implemented in embodiments of different forms. Specific embodiments are described in detail and are shown in the drawings, with the understanding that the present disclosure is to be considered an exemplification of the principles of the disclosure, and is not intended to limit the disclosure to that illustrated and described herein. It is to be fully recognized that the different teachings of the embodiments discussed herein may be employed separately or in any suitable combination to produce desired results. Moreover, all statements herein reciting principles and aspects of the disclosure, as well as specific examples thereof, are intended to encompass

equivalents thereof. Additionally, the term, "or," as used herein, refers to a non-exclusive or, unless otherwise indicated.

[0014] Unless otherwise specified, use of the terms "connect," "engage," "couple," "attach," or any other like term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described.

[0015] Unless otherwise specified, use of the terms "up," "upper," "upward," "uphole," "upstream," or other like terms shall be construed as generally away from the bottom, terminal end of a well, regardless of the wellbore orientation; likewise, use of the terms "down," "lower," "downward," "downhole," or other like terms shall be construed as generally toward the bottom, terminal end of a well, regardless of the wellbore orientation. Use of any one or more of the foregoing terms shall not be construed as denoting positions along a perfectly vertical or horizontal axis. Unless otherwise specified, use of the term "subterranean formation" shall be construed as encompassing both areas below exposed earth and areas below earth covered by water, such as ocean or fresh water.

[0016] As can be appreciated, liner hangers (e.g., expanded liner hangers) should support the substantial weight of the attached tubing string below. For deep and extra-deep wells, subsea wells, etc., the tubing string places substantial axial load on the hanging mechanism engaging the liner hanger to the casing. There is a need for improved methods and apparatus providing a liner hanger having an anchoring mechanism and sealing mechanism capable of supporting the substantial axial loads imparted by longer and heavier liner strings. Furthermore, there is a need in certain situations to improve performance of liner hanger designs that have failed to achieve adequate axial load holding in an uphole direction when placed in collapse by pressure from downhole.

[0017] Additionally, the industry is requiring increasingly higher axial load capacities from our expandable liner hangers. Additionally, casing hardness is also increasing. When the casing is harder than the liner hanger, the anchoring ridges tend to brinell when the liner hanger is expanded. This brinelling of the anchoring ridges reduces the anchor capacity of the liner hanger.

[0018] The present disclosure has recognized, for the first time, that axial load performance of liner hangers can be improved by altering the geometry of the anchoring ridge. Conventional anchoring ridges are symmetric with a flat at their apex. The present disclosure has recognized

that by adding a bevel to the apex, essentially removing the flat, the interaction between the anchoring ridge and the casing may be changed when the liner hanger is expanded, which results in higher axial load capacity. In at least one embodiment, the improved anchoring ridge geometry is asymmetric (e.g., an asymmetric trapezoid) and includes a compound angle, which creates a sharp edge at its apex. This sharp edge allows the anchoring ridge to bite into the casing better than the existing flat-top anchoring ridges, due to higher contact force between the anchoring ridge and casing ID. Hanger axial load capacity is directly related to its contact force with the casing ID. This improved anchoring ridge design has been proven out through FEA, as shown in Table 1.

[0019] In at least one embodiment, one or more of the anchoring ridges have an entry angle (θ_1), an exit angle (θ_2), and a bevel angle (α) greater than zero degrees. In certain embodiment, the entry angle (θ_1) and the exit angle (θ_2) are similar. In yet other embodiments, the entry angle (θ_1) and the exit angle (θ_2) are different. Often, the entry angle (θ_1) and the exit angle (θ_2) are chosen such that after expansion, the anchoring ridges remain substantially normal to the liner hanger body. For example, in certain instances, the entry angle (θ_1) and the exit angle (θ_2) range from 30 degrees to 70 degrees.

[0020] In contrast, the bevel angle (α) is created between the bevel radially exterior point (e.g., apex) and bevel radially interior point, and is typically at least 1 degree. In yet another embodiment, the bevel angle (α) is greater than 5 degrees, if not greater than 10 degrees, if not greater than 25 degrees or even greater than 35 degrees. In yet another embodiment, the bevel angle (α) ranges from 10 degrees to 30 degrees, if not between 12 degrees and 17 degrees. In certain embodiments, the bevel radial exterior point (e.g., apex) is a very narrow thin flat surface. For example, in at least one embodiment, the very narrow thin flat surface has a length (L) less than 20 mm. In yet another embodiment, the very narrow thin flat surface is smaller and has a length (L) less than 2 mm, if not less than 1 mm, or even less than .5 mm. In yet another embodiment, the very narrow thin flat surface has a length (L) that ranges from 1.5 mm to .2 mm.

[0021] In certain embodiments, one or more of the beveled surfaces are arranged such that the bevel radially exterior point is located uphole of the bevel radially interior point. In yet another embodiment, one or more of the beveled surfaces are arranged such that the bevel radially interior point is located uphole of the bevel radially exterior point. In yet another embodiment,

certain of the one or more beveled surfaces are arranged such that the bevel radially exterior point is located uphole of the bevel radially interior point and others of the one or more beveled surfaces are arranged such that the bevel radially interior point is located uphole of the bevel radially exterior point. In yet other embodiments, the anchor ridge design includes one or more of the beveled surfaces that are arranged such that the bevel radially exterior point is located uphole of the bevel radially interior point, include one or more anchor ridges with one or more flat (e.g., non-beveled) surfaces, and include one or more of the beveled surface that are arranged such that the bevel radially interior point is located uphole of the bevel radially exterior point. For example, the one or more flat surfaces could be positioned on either side of the sealing elements, when used.

[0022] The number of anchoring ridges having the beveled surface for a given design may vary. In at least one embodiment, one or more of the anchoring ridges have the beveled surface. In yet another embodiment, at least 20 percent of the anchoring ridges have the beveled surface, if not at least 50 percent of the anchoring ridges. In yet another embodiment, at least 75 percent of the anchoring ridges have the beveled surface, if not 100 percent.

[0023] FIG. 1 illustrates an example of a liner hanger system 10 (e.g., expandable liner hanger system). In liner hanger system 10, a casing string 12 has been installed and cemented within a wellbore 14. An expandable liner 16 may be hung, extending downhole from a lower end of casing string 12. An annulus 24 may be created between casing string 12 and a work string 22. In embodiments, an expandable liner hanger 18 can support additional wellbore casing, operational tubulars or tubing strings, completion strings, downhole tools, etc., for positioning at greater depths.

[0024] As used herein, the terms “liner,” “casing,” and “tubular” are used generally to describe tubular wellbore items, used for various purposes in wellbore operations. Liners, casings, and tubulars can be made from various materials (metal, plastic, composite, etc.), can be expanded or unexpanded as part of an installation procedure, and can be segmented or continuous. It is not necessary for a liner or casing to be cemented into position. Any type of liner, casing, or tubular may be used in keeping with the principles of the present invention.

[0025] As further illustrated in FIG. 1, expandable liner hanger 18 may seal and secure an upper end of expandable liner 16 near a lower end of casing string 12. Alternatively, expandable liner hanger 18 may seal and secure the upper end of expandable liner 16 above a window (not

shown) formed through a sidewall of casing string 12, with expandable liner 16 extending outwardly through the window into a branch or lateral wellbore. Thus, it will be appreciated that many different configurations and relative positions of casing string 12 and expandable liner 16 are possible.

[0026] In embodiments, as also shown in FIG. 1, a setting tool 20 may be connected proximate the expandable liner hanger 18 on the work string 22. Work string 22 may convey setting tool 20, expandable liner hanger 18, and expandable liner 16 into wellbore 14, conduct fluid pressure and flow tests, transmit torque, tensile and compressive force, etc. Setting tool 20 may facilitate conveyance and installation of expandable liner 16 and expandable liner hanger 18, in part by using the torque, tensile and compressive forces, fluid pressure and flow, etc., as delivered by work string 22.

[0027] In FIG. 1, expandable liner hanger 18 is illustrated with a plurality of sealing members 25 and a plurality of anchoring ridges 26 positioned on and attached to expandable liner hanger 18. In embodiments, when expandable liner hanger 18 is expanded, such as with an expansion cone, into anchoring and sealing engagement with casing string 12, the plurality of anchoring ridges 26 and the plurality of sealing members 25 engage the interior of casing string 12. These elements are discussed more fully below.

[0028] Reliance upon rubber elements for both sealing and anchoring may lead to variations in predicted anchoring values. In high-pressure, high-temperature (HPHT) applications, the sealing ability of a liner hanger varies. In operation, it may be difficult to determine how the sealing elements and anchoring elements are influencing each other, which complicates the prediction of the performance of a particular design. Several different arrangements may be possible as to the number and axial location, with one or more sealing members 25 located at a downhole end 15, and one or more anchoring ridges 26 located at an uphole end 17.

[0029] FIG. 2 illustrates an elevational view, with cut-away and partial cross-section, of an embodiment of axial load bearing assembly 28 on expandable liner hanger 18. In embodiments, axial load bearing assembly 28 is shown on expandable liner hanger 18 having a sealing sub-assembly 30 and an anchoring sub-assembly 32. This arrangement may increase axial loading capacity of the expandable liner hanger 18. The functions of anchoring and sealing may be performed largely by the separate sub-assemblies.

[0030] Sealing sub-assembly 30 may include plurality of sealing members 25, which may be elastomeric, such as a bonded elastomeric material. A plurality of sealing members 25 may be positioned around the expandable liner hanger 18. The inner diameters of the plurality of sealing members 25 may abut the outer surface of expandable liner hanger 18. The plurality of sealing members 25 may be spaced longitudinally along the expandable liner hanger 18. Alternatively, the plurality of sealing members 25 may be replaced by a single sealing member 25, which may extend longitudinally ranging from about 8 inches (20.3 cm) to about 14 inches (35.5 cm) and, more particularly about twelve inches (30.5 cm), for example. The plurality of sealing members 25 may perform a sealing function, once radially expanded, and provide an annular seal between expandable liner hanger 18 and adjacent casing string 12 (e.g., shown on FIG. 1).

[0031] Anchoring sub-assembly 32, as shown in FIG. 2, may include one or more circumferential, radially extending anchoring ridges 26, which may also provide sealing capabilities. One or more of the anchoring ridges 26 may be circumferentially continuous; however, other arrangements will be apparent to those of skill in the art. As discussed above, one or more of the anchoring ridges 26 may include a beveled surface, for example having a bevel angle (α). The anchoring ridges 26 may comprise many different materials. In at least one embodiment, the anchoring ridges 26 comprise metal. In yet another embodiment, the anchoring ridges 26 may be made of any suitable steel grade, aluminum, any other ductile material, and a combination thereof. In certain implementations, the anchoring ridges 26 may be made from a combination of one or more of the recited materials. In certain embodiments, the anchoring ridges 26 may be made from AISI4140 steel or AISI4340 steel.

[0032] FIG. 3 illustrates a perspective view of expandable liner hanger assembly 18 with the plurality of anchoring ridges 26. As shown in FIGs. 2 and 3, one or more of the anchoring ridges 26 may be in the shape of an asymmetric trapezoid.

[0033] Generally, in the downhole setting, elements with pressure from above (uphole) are typically “boosted” or enhanced because of the pressure on the inner diameter of the liner hanger. Elements with pressure from below (downhole) are typically placed in collapse, thus reducing the contact stress and liner hanger performance when reacting to load from below (downhole). The pressure from below (downhole) may be sealed off by placing one or more sealing members 25 on the bottom of expandable liner hanger 18—thus limiting the influence of collapse pressure—as illustrated in FIG. 4A. This may be due to fluid being able to communicate

through stress-relief features in the one or more anchoring ridges 26. Therefore, stress-relief features may provide stress relief and fluid communication. In another embodiment, as illustrated in Figure 4B another sealing sub-assembly 30, including additional sealing members 25, may be placed above the one or more anchoring ridges 26 as well, thereby limiting the ability of pressure to reduce contact stress against casing string 12. In certain scenarios, pressures may be directed from below (downhole) or above (uphole) and/or combined with varying internal pressures—all of which may impact the contact stress that expandable liner hanger 18 has against the inner diameter of casing string 12.

[0034] Turning to FIG. 5A, illustrated is one embodiment of a liner hanger 500a having an anchoring ridge 510a designed, manufactured, and placed according to one or more embodiments of the disclosure. In the embodiment of FIG. 5A, the anchoring ridge 510a includes an entry angle (θ_1), an exit angle (θ_2), and a bevel angle (α). In the illustrated embodiment, the entry angle (θ_1) and the exit angle (θ_2) are substantially similar. Furthermore, the bevel angle (α) is positioned such that a bevel radially exterior point 520a is uphole of a bevel radially interior point 530a.

[0035] Turning to FIG. 5B, illustrated is one embodiment of a liner hanger 500b having an anchoring ridge 510b designed, manufactured, and placed according to one or more embodiments of the disclosure. In the embodiment of FIG. 5B, the anchoring ridge 510b includes an entry angle (θ_1), an exit angle (θ_2), and a bevel angle (α). In the illustrated embodiment, the entry angle (θ_1) and the exit angle (θ_2) are substantially similar. Furthermore, the bevel angle (α) is positioned such that a bevel radially exterior point 520b is downhole of the bevel radially interior point 530b.

[0036] Turning to FIG. 5C, illustrated is one embodiment of a liner hanger 500b having an anchoring ridge 510b designed, manufactured, and placed according to one or more embodiments of the disclosure. In the embodiment of FIG. 5C, the anchoring ridge 510b includes an entry angle (θ_1), an exit angle (θ_2), and a bevel angle (α), for example similar to FIG. 5A, but also includes a very narrow thin flat surface. For example, in at least one embodiment, the very narrow thin flat surface has a length (L) less than 20 mm. In yet another embodiment, the very narrow thin flat surface is smaller and has a length (L) less than 2 mm, if not less than 1 mm, or even less than .5 mm. In yet another embodiment, the very narrow thin flat surface has a length (L) that ranges from 1.5 mm to .2 mm.

[0037] Turning to FIG. 5D, illustrated is one embodiment of a liner hanger 500d having two or more anchoring ridges 510d, 510d' designed, manufactured, and placed according to one or more embodiments of the disclosure. In the illustrated embodiment of FIG. 5D, the anchoring ridge 510d is similar in design to the anchoring ridge 510a of FIG. 5A, and the anchoring ridge 510d' includes an entry angle (θ_1'), an exit angle (θ_2'), and a bevel angle (α'), which may or may not be similar to the entry angle (θ_1), the exit angle (θ_2), and the bevel angle (α) of anchoring ridge 510d.

[0038] Turning to FIG. 5E, illustrated is one embodiment of a liner hanger 500e having one or more anchoring ridges 510e and one or more anchoring ridges 515e designed, manufactured, and placed according to one or more embodiments of the disclosure. In the illustrated embodiment of FIG. 5E, the anchoring ridge 510e is similar in design to the anchoring ridge 510a of FIG. 5A, and the anchoring ridge 515e is similar in design to the anchoring ridge 510b of FIG. 5B.

[0039] Turning to FIG. 5F, illustrated is one embodiment of a liner hanger 500f having one or more anchoring ridges 510f designed, manufactured, and placed according to one or more embodiments of the disclosure, as well as one or more traditional anchoring ridges 515f (e.g., a non-beveled anchoring ridge having a bevel angle (α) of zero degrees). In the illustrated embodiment of FIG. 5F, the anchoring ridge 510f is similar in design to the anchoring ridge 510a of FIG. 5A or anchoring ridge 510b of FIG. 5B, and the anchoring ridge 515f is similar in design to existing flat top anchoring ridges.

[0040] Turning to FIG. 5G, illustrated is one embodiment of a liner hanger 500g having one or more anchoring ridges 510g and one or more anchoring ridges 515g designed, manufactured, and placed according to one or more embodiments of the disclosure, as well as one or more traditional anchoring ridges 520g. In the illustrated embodiment of FIG. 5G, the anchoring ridge 510g is similar in design to the anchoring ridge 510a of FIG. 5A, the anchoring ridge 515g is similar in design to the anchoring ridge 510b of FIG. 5B, and the anchoring ridge 520g is similar in design to existing flat top anchoring ridges. In the illustrated embodiment of FIG. 5G, the anchoring ridge 520g is located between the anchoring ridge 510g and anchoring ridge 515g.

[0041] Turning to FIG. 6, illustrated is an alternative embodiment of an expandable liner hanger assembly 600 designed, manufactured and/or operated according to one or more embodiments of the disclosure. The expandable liner hanger assembly 600 is similar in many respects to the expandable liner hanger assembly 18 of FIG. 2. Accordingly, like reference

numbers have been used to indicate similar, if not identical, features. The expandable liner hanger assembly 600 differs, for the most part, from the expandable liner hanger assembly 18, in that the expandable liner hanger assembly 600 includes one or more hardened external surfaces 610. In at least one embodiment, the one or more hardened external surfaces 610 of the one or more anchoring ridges 26 may be hardened using laser transformation hardening. Laser transformation hardening is an example of a suitable steel surface hardener. Laser transformation hardening produces thin surface zones that are heated and cooled very rapidly, resulting in very fine martensitic microstructures, even in steels with relatively low hardenability. While laser hardening has been discussed, other methods for hardening (e.g., chemical hardening, such as QPQ or gas carburization, flame hardening, or additive hardening techniques, such as thermal spraying or any other additive manufacturing process) could be used. Accordingly, one or more hardened external surfaces 610 may be of a different hardness than the base of the anchoring ridges 26, but the one or more hardened external surfaces 610 are of the same chemical composition as the base of the anchoring ridges 26.

[0042] Further, the relative hardness of the one or more hardened external surfaces 610 compared to casing string 12 may be in the HRC 60+ range. HRC is an abbreviation for Rockwell C Hardness. As used herein, Rockwell C Hardness is measured in accordance with ASTM E18-17e1: Standard Test Methods for Rockwell Hardness of Metallic Materials. This feature of hardening external surface may be added to each existing anchoring ridge 26. The depth of the hardness after laser transformation hardening can be controlled by process parameters including power, pulse, and duration. In embodiments, case depths for the external surface of one or more anchoring ridges 26 may be 0.1 to 0.3 inch (0.25 to 0.76 cm). In other embodiments, case depths for the external surface of one or more anchoring ridges 26 may be 0.010 to 0.095 inch (0.025 to 0.24 cm). While a range is not specifically stated, in embodiments a separation of 10 HRC between a hardened anchoring ridge and casing is effective to allow the ridge to anchor in adjacent casing thereby preventing relative movement between the liner hanger and parent casing.

[0043] Alternatively, other methods of hardening external surface may be employed. For example, diffusion hardening methods include, but are not limited to, carburizing, nitriding, carbonitriding, nitrocarburizing, boriding, titanium-carbon diffusion, and Toyota diffusion process. However, it may be difficult to selectively apply the diffusion methods without the risk

of altering the material of the base of the anchoring ridges 26. Further, selective hardening methods include flame hardening, induction hardening, electron beam (EB) hardening, ion implant, selective carburizing and nitriding, and use of arc lamps.

[0044] As further illustrated in FIG. 6, one or more anchoring ridges 26 may each have a plurality of stress-relief features 620 defined thereon. In embodiments, a stress-relief groove or similar feature may be provided to support plastic expansion. Stress-relief features 620 may be notches or cut-outs spaced circumferentially on one or more anchoring ridges 26, as shown. Further, stress-relief features 620 may be created through milling. Those of skill in the art will recognize other stress-relief features and geometries as well. Stress-relief features 620 may also allow for fluid communication between one or more anchoring ridges 26.

[0045] Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions, and alterations may be made herein without departing from the spirit and scope of the invention as defined by the appended claims.

[0046] In embodiments, the following methods are disclosed; the steps are not exclusive and can be combined in various ways. Further, additional steps and limitations are listed here, which can be performed in various order, omitted, or repeated. A method of placing expandable liner hanger 18 having axial load bearing capability, once expanded, in a downhole casing string 12 positioned in a subterranean wellbore, the method comprising the steps of: running-in a radially expandable tool having an anchoring sub-assembly and a sealing sub-assembly; radially expanding the radially expandable tool, thereby engaging the downhole tubular with a plurality of radially extending ridges positioned on the exterior surface of the radially expandable tool by penetrating the downhole tubular with at least one hardened ridge with anchoring corners; engaging the sealing sub-assembly with the downhole tubular and sealing the annulus defined between the expandable tool and downhole tubular; and bearing an axial load placed on the expanded downhole tool.

[0047] The method can further comprise steps such as: radially expanding the radially expandable tool using a hydraulically powered expansion cone; and/or wherein the plurality of ridges extend circumferentially around the radially expandable tubular; and/or further comprising at least one radial expansion stress relief feature; and/or wherein the at least one radial expansion stress relief feature comprises at least one longitudinally extending groove defined in at least one ridge. Other steps and orders of steps are apparent to one of skill in the art. Those of skill in the

art will recognize additional steps, different order of steps, and that not all steps need be performed to practice the inventive methods described.

[0048] Aspects disclosed herein include:

A. An expandable liner hanger assembly, the expandable liner hanger assembly including: 1) a radially expandable tubular defining an interior passageway and an exterior surface; and 2) an anchoring ridge extending radially outward from the radially expandable tubular, the anchoring ridge having an entry angle (θ_1), an exit angle (θ_2), and a bevel angle (α) greater than zero degrees.

B. A well system, the well system including: 1) a wellbore extending through one or more subterranean formations; and 2) an expandable liner hanger assembly positioned within the wellbore, the expandable liner hanger assembly including: a) a radially expandable tubular defining an interior passageway and an exterior surface; and b) an anchoring ridge extending radially outward from the radially expandable tubular, the anchoring ridge having an entry angle (θ_1), an exit angle (θ_2), and a bevel angle (α) greater than zero degrees.

C. A method, the method including: 1) forming a wellbore through one or more subterranean formations; and 2) positioning an expandable liner hanger assembly within the wellbore, the expandable liner hanger assembly including: a) a radially expandable tubular defining an interior passageway and an exterior surface; and b) an anchoring ridge extending radially outward from the radially expandable tubular, the anchoring ridge having an entry angle (θ_1), an exit angle (θ_2), and a bevel angle (α) greater than zero degrees.

[0049] Aspects A, B, and C may have one or more of the following additional elements in combination: Element 1: wherein the bevel angle (α) is at least 1 degree. Element 2: wherein the bevel angle (α) is greater than 5 degrees. Element 3: wherein the bevel angle (α) is greater than 10 degrees. Element 4: wherein the bevel angle (α) is greater than 25 degrees. Element 5: wherein the bevel angle (α) ranges from 10 degrees to 30 degrees. Element 6: wherein the bevel angle (α) ranges from 12 degrees to 17 degrees. Element 7: wherein a bevel radial exterior point of the anchoring ridge is a thin flat surface having a length (L) less than 20 mm. Element 8: wherein a bevel radial exterior point of the anchoring ridge is a thin flat surface having a length (L) less than 2 mm. Element 9: wherein a bevel radial exterior point of the anchoring ridge is a thin flat surface having a length (L) less than 1 mm. Element 10: wherein the radially expandable tubular has an uphole end and a downhole end, and further wherein a bevel radially

exterior point of the anchoring ridge is located more proximate the uphole end than a bevel radially interior point of the anchoring ridge. Element 11: wherein the radially expandable tubular has an uphole end and a downhole end, and further wherein a bevel radially interior point of the anchoring ridge is located more proximate the uphole end than a bevel radially exterior point of the anchoring ridge. Element 12: wherein the anchoring ridge is a first anchoring ridge, and further including a second anchoring ridge extending radially outward from the radially expandable tubular. Element 13: wherein the second anchoring ridge has an entry angle (θ_1), an exit angle (θ_2), and a bevel angle (α') greater than zero degrees. Element 14: wherein the radially expandable tubular has an uphole end and a downhole end, and further wherein a first bevel radially exterior point of the first anchoring ridge is located more proximate the uphole end than a first bevel radially interior point of the first anchoring ridge, and a second bevel radially interior point of the second anchoring ridge is located more proximate the uphole end than a second bevel radially exterior point of the second anchoring ridge. Element 15: further including a third anchoring ridge positioned between the first and second anchoring ridges. Element 16: wherein the third anchoring ridge is a non-beveled anchoring ridge having a bevel angle (α) of zero degrees. Element 17: wherein the second anchoring ridge is a non-beveled anchoring ridge having a bevel angle (α) of zero degrees. Element 18: further including a sealing member positioned radially outside of the radially expandable tubular. Element 19: wherein the sealing member is positioned between the first and second anchoring ridges. Element 20: further including radially expanding the radially expandable tubular to engage the anchoring ridge with the wellbore. Element 21: further including wellbore casing located radially inside of the wellbore, the radially expanding the radially expandable tubular engaging the anchoring ridge with the wellbore casing.

[0050] Those skilled in the art to which this application relates will appreciate that other and further additions, deletions, substitutions, and modifications may be made to the described embodiments.

WHAT IS CLAIMED IS:

1. An expandable liner hanger assembly, comprising:
a radially expandable tubular defining an interior passageway and an exterior surface; and
an anchoring ridge extending radially outward from the radially expandable tubular, the anchoring ridge having an entry angle (θ_1), an exit angle (θ_2), and a bevel angle (α) greater than zero degrees.
2. The expandable liner hanger assembly as recited in Claim 1, wherein the bevel angle (α) is at least 1 degree.
3. The expandable liner hanger assembly as recited in Claim 1, wherein the bevel angle (α) is greater than 5 degrees.
4. The expandable liner hanger assembly as recited in Claim 1, wherein the bevel angle (α) is greater than 10 degrees.
5. The expandable liner hanger assembly as recited in Claim 1, wherein the bevel angle (α) is greater than 25 degrees.
6. The expandable liner hanger assembly as recited in Claim 1, wherein the bevel angle (α) ranges from 10 degrees to 30 degrees.
7. The expandable liner hanger assembly as recited in Claim 1, wherein the bevel angle (α) ranges from 12 degrees to 17 degrees.
8. The expandable liner hanger assembly as recited in Claim 1, wherein a bevel radial exterior point of the anchoring ridge is a thin flat surface having a length (L) less than 20 mm.
9. The expandable liner hanger assembly as recited in Claim 1, wherein a bevel radial exterior point of the anchoring ridge is a thin flat surface having a length (L) less than 2 mm.

10. The expandable liner hanger assembly as recited in Claim 1, wherein a bevel radial exterior point of the anchoring ridge is a thin flat surface having a length (L) less than 1 mm.

11. The expandable liner hanger assembly as recited in Claim 1, wherein the radially expandable tubular has an uphole end and a downhole end, and further wherein a bevel radially exterior point of the anchoring ridge is located more proximate the uphole end than a bevel radially interior point of the anchoring ridge.

12. The expandable liner hanger assembly as recited in Claim 1, wherein the radially expandable tubular has an uphole end and a downhole end, and further wherein a bevel radially interior point of the anchoring ridge is located more proximate the uphole end than a bevel radially exterior point of the anchoring ridge.

13. The expandable liner hanger assembly as recited in Claim 1, wherein the anchoring ridge is a first anchoring ridge, and further including a second anchoring ridge extending radially outward from the radially expandable tubular.

14. The expandable liner hanger assembly as recited in Claim 13, wherein the second anchoring ridge has an entry angle (θ_1'), an exit angle (θ_2'), and a bevel angle (α') greater than zero degrees.

15. The expandable liner hanger assembly as recited in Claim 13, wherein the radially expandable tubular has an uphole end and a downhole end, and further wherein a first bevel radially exterior point of the first anchoring ridge is located more proximate the uphole end than a first bevel radially interior point of the first anchoring ridge, and a second bevel radially interior point of the second anchoring ridge is located more proximate the uphole end than a second bevel radially exterior point of the second anchoring ridge.

16. The expandable liner hanger assembly as recited in Claim 15, further including a third anchoring ridge positioned between the first and second anchoring ridges.

17. The expandable liner hanger assembly as recited in Claim 16, wherein the third anchoring ridge is a non-beveled anchoring ridge having a bevel angle (α) of zero degrees.

18. The expandable liner hanger assembly as recited in Claim 13, wherein the second anchoring ridge is a non-beveled anchoring ridge having a bevel angle (α) of zero degrees.

19. The expandable liner hanger assembly as recited in Claim 13, further including a sealing member positioned radially outside of the radially expandable tubular.

20. The expandable liner hanger assembly as recited in Claim 19, wherein the sealing member is positioned between the first and second anchoring ridges.

21. A well system, comprising:
a wellbore extending through one or more subterranean formations; and
an expandable liner hanger assembly positioned within the wellbore, the expandable liner hanger assembly including:

a radially expandable tubular defining an interior passageway and an exterior surface; and

an anchoring ridge extending radially outward from the radially expandable tubular, the anchoring ridge having an entry angle (θ_1), an exit angle (θ_2), and a bevel angle (α) greater than zero degrees.

22. The well system as recited in Claim 21, wherein the bevel angle (α) is at least 1 degree.

23. The well system as recited in Claim 21, wherein the bevel angle (α) is greater than 5 degrees.

24. The well system as recited in Claim 21, wherein the bevel angle (α) is greater than 10 degrees.

25. The well system as recited in Claim 21, wherein the bevel angle (α) is greater than 25 degrees.

26. The well system as recited in Claim 21, wherein the bevel angle (α) ranges from 10 degrees to 30 degrees.

27. The well system as recited in Claim 21, wherein the bevel angle (α) ranges from 12 degrees to 17 degrees.

28. The well system as recited in Claim 21, wherein a bevel radial exterior point of the anchoring ridge is a thin flat surface having a length (L) less than 20 mm.

29. The well system as recited in Claim 21, wherein a bevel radial exterior point of the anchoring ridge is a thin flat surface having a length (L) less than 2 mm.

30. The well system as recited in Claim 21, wherein a bevel radial exterior point of the anchoring ridge is a thin flat surface having a length (L) less than 1 mm.

31. The well system as recited in Claim 21, wherein the radially expandable tubular has an uphole end and a downhole end, and further wherein a bevel radially exterior point of the anchoring ridge is located more proximate the uphole end than a bevel radially interior point of the anchoring ridge.

32. The well system as recited in Claim 21, wherein the radially expandable tubular has an uphole end and a downhole end, and further wherein a bevel radially interior point of the anchoring ridge is located more proximate the uphole end than a bevel radially exterior point of the anchoring ridge.

33. The well system as recited in Claim 21, wherein the anchoring ridge is a first anchoring ridge, and further including a second anchoring ridge extending radially outward from the radially expandable tubular.

34. The well system as recited in Claim 33, wherein the second anchoring ridge has an entry angle (θ_1'), an exit angle (θ_2'), and a bevel angle (α') greater than zero degrees.

35. The well system as recited in Claim 33, wherein the radially expandable tubular has an uphole end and a downhole end, and further wherein a first bevel radially exterior point of the first anchoring ridge is located more proximate the uphole end than a first bevel radially interior point of the first anchoring ridge, and a second bevel radially interior point of the second anchoring ridge is located more proximate the uphole end than a second bevel radially exterior point of the second anchoring ridge.

36. The well system as recited in Claim 35, further including a third anchoring ridge positioned between the first and second anchoring ridges.

37. The well system as recited in Claim 36, wherein the third anchoring ridge is a non-beveled anchoring ridge having a bevel angle (α) of zero degrees.

38. The well system as recited in Claim 33, wherein the second anchoring ridge is a non-beveled anchoring ridge having a bevel angle (α) of zero degrees.

39. The well system as recited in Claim 33, further including a sealing member positioned radially outside of the radially expandable tubular.

40. The well system as recited in Claim 39, wherein the sealing member is positioned between the first and second anchoring ridges.

41. A method, comprising:
forming a wellbore through one or more subterranean formations; and
positioning an expandable liner hanger assembly within the wellbore, the expandable liner hanger assembly including:

a radially expandable tubular defining an interior passageway and an exterior surface; and

an anchoring ridge extending radially outward from the radially expandable tubular, the anchoring ridge having an entry angle (θ_1), an exit angle (θ_2), and a bevel angle (α) greater than zero degrees.

42. The method as recited in Claim 41, further including radially expanding the radially expandable tubular to engage the anchoring ridge with the wellbore.

43. The method as recited in Claim 42, further including wellbore casing located radially inside of the wellbore, the radially expanding the radially expandable tubular engaging the anchoring ridge with the wellbore casing.