US 20170183920A1

(19) **United States**

(12) **Patent Application Publication**

Ribble et al.

(10) **Pub. No.: US 2017/0183920 A1**

(43) **Pub. Date: Jun. 29, 2017**

(54) **COLLAR SWAGING OF SINGLE-PIECE CENTRALIZERS**

(71) Applicant: **Antelope Oil Tool & Mfg. Co., LLC**, Houston, TX (US)

(72) Inventors: **George W. Ribble**, Spring, TX (US); **Michael L. Betik**, Tomball, TX (US); **David Harris Stewart**, Seabrook, TX (US); **Eugene Edward Miller**, Weatherford, TX (US)

(21) Appl. No.: **15/308,619**

(22) PCT Filed: **May 6, 2015**

(86) PCT No.: **PCT/US2015/029462**

§ 371 (c)(1),
(2) Date: **Nov. 3, 2016**

Related U.S. Application Data

(60) Provisional application No. 61/989,699, filed on May 7, 2014, provisional application No. 62/012,129, filed on Jun. 13, 2014.

Publication Classification

(51) **Int. Cl.**

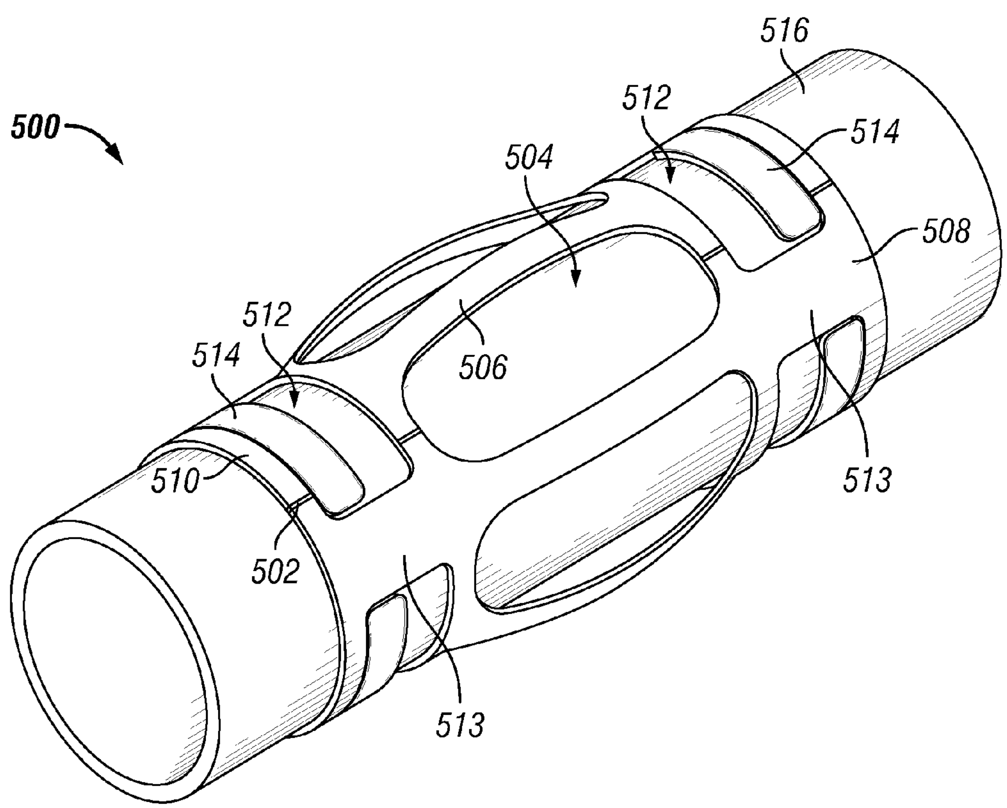
E21B 17/10	(2006.01)
B21D 41/04	(2006.01)
B21D 39/20	(2006.01)
B21D 41/02	(2006.01)
B21D 28/28	(2006.01)
B21D 39/18	(2006.01)

(52) **U.S. Cl.**

CPC ***E21B 17/1078*** (2013.01); ***B21D 28/28*** (2013.01); ***B21D 39/18*** (2013.01); ***B21D 39/20*** (2013.01); ***B21D 41/023*** (2013.01); ***B21D 41/028*** (2013.01); ***B21D 41/04*** (2013.01)

(57) **ABSTRACT**

A method for manufacturing a centralizer. The method includes selecting a tubular having a first inner diameter, cutting the tubular to form a blank including at least one end collar and ribs integrally-formed therewith, and swaging the at least one end collar such that the first inner diameter is modified to a second inner diameter.



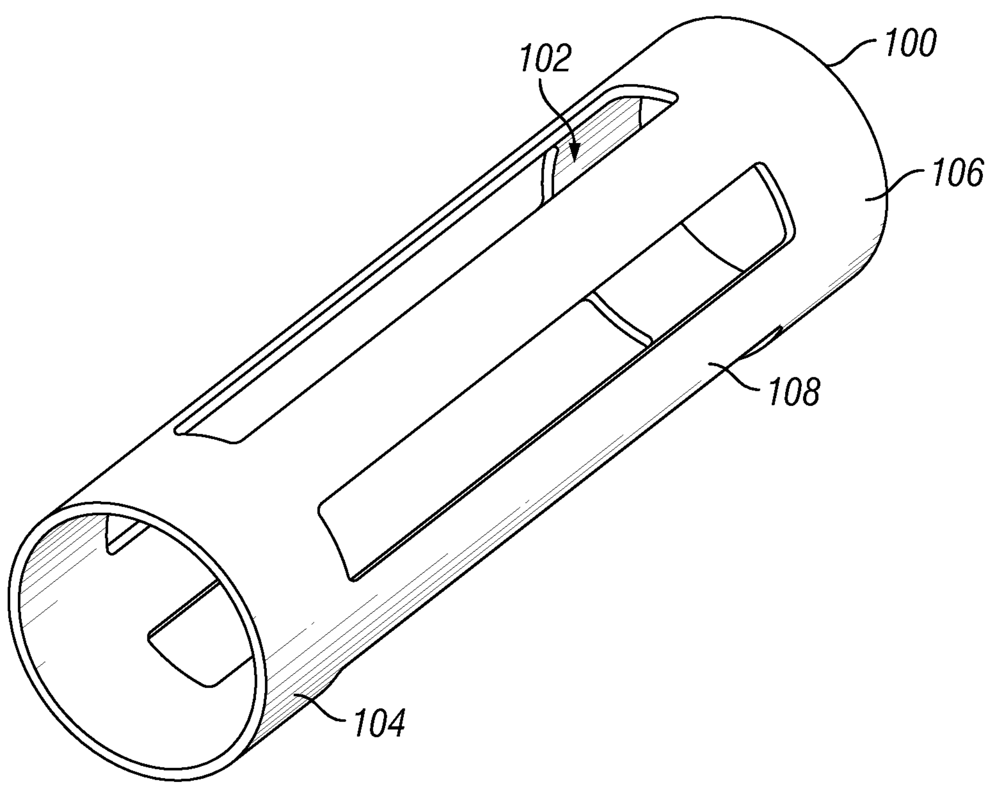


FIG. 1

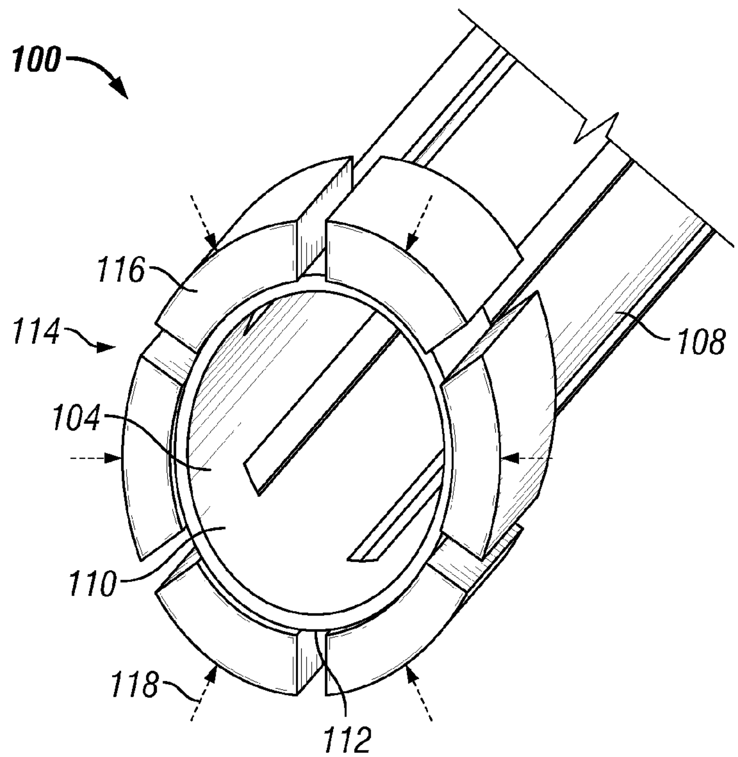

100
116
114
104
110
118
112
108

FIG. 2

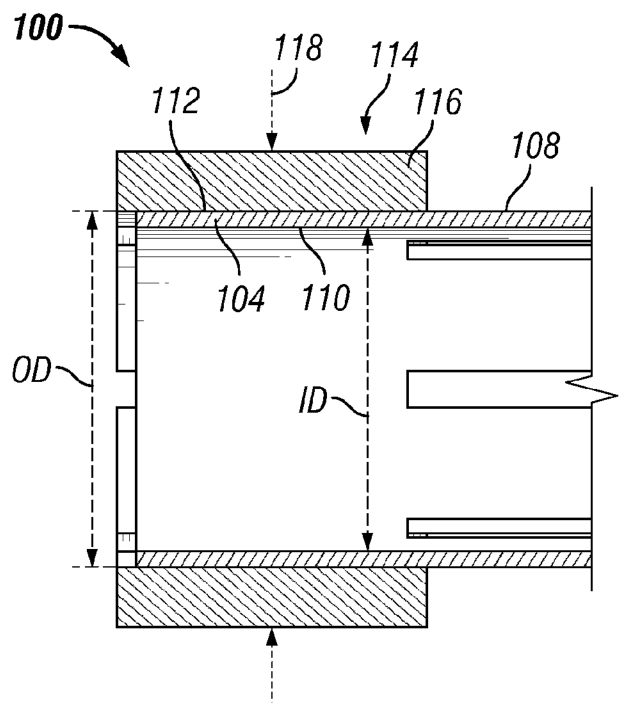

100
118
114
112
116
108
104
110
OD
ID

FIG. 3

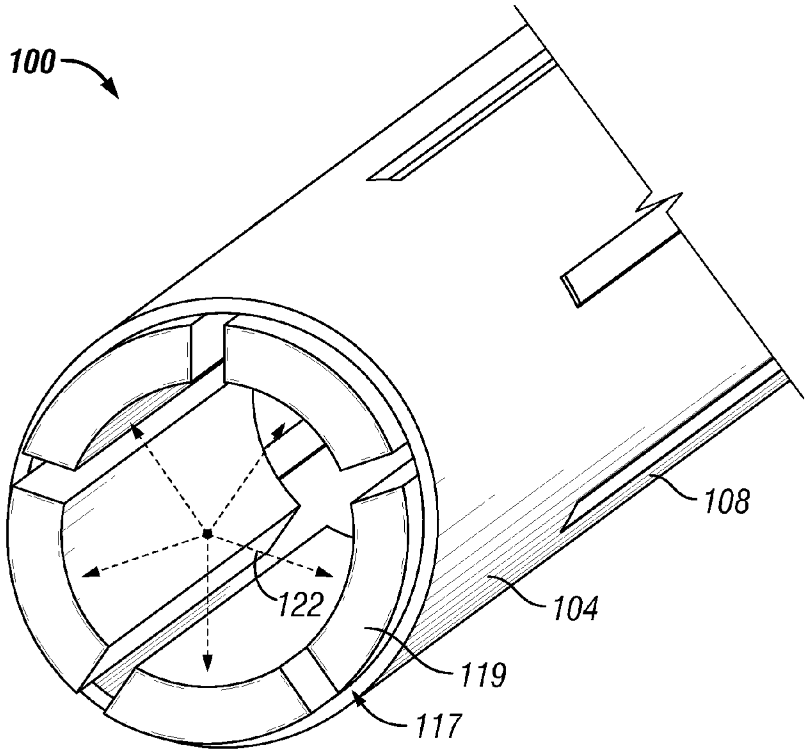


FIG. 4

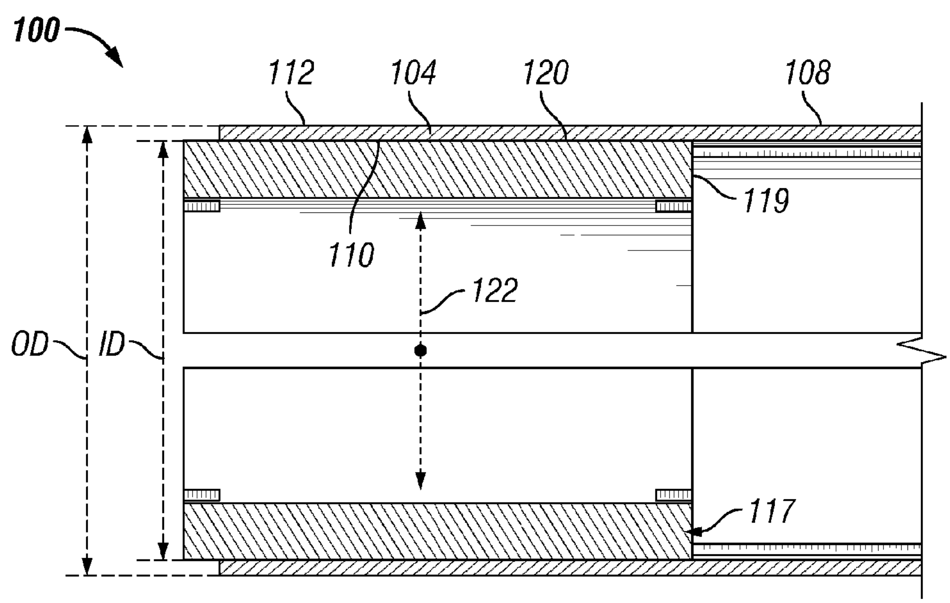


FIG. 5

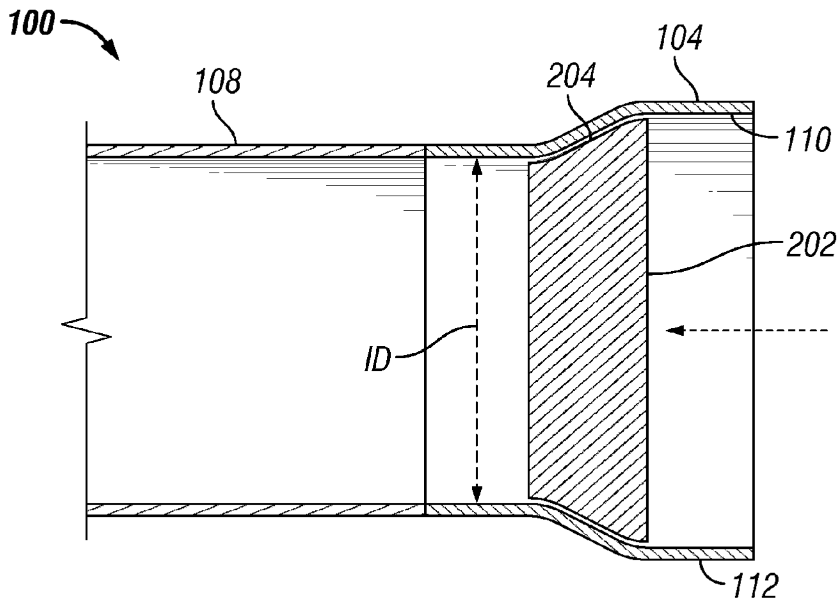


FIG. 6

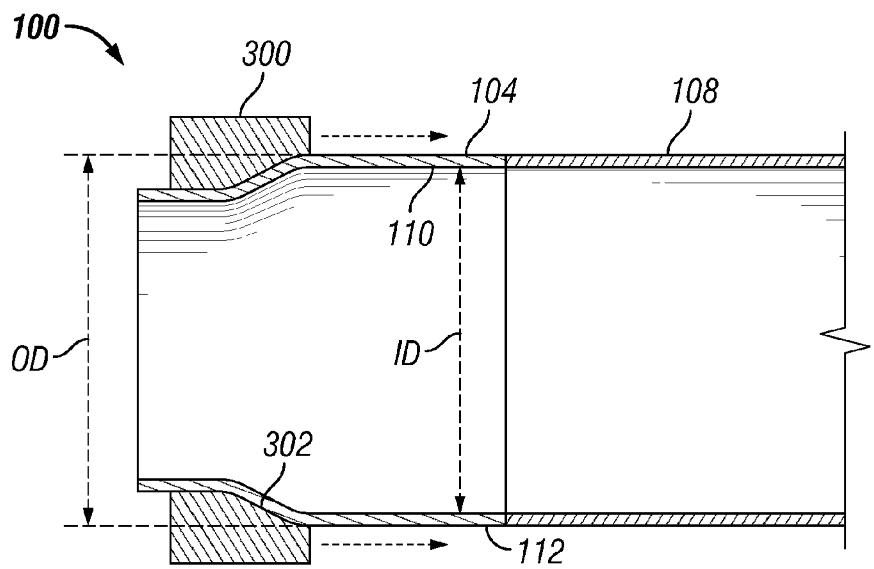


FIG. 7

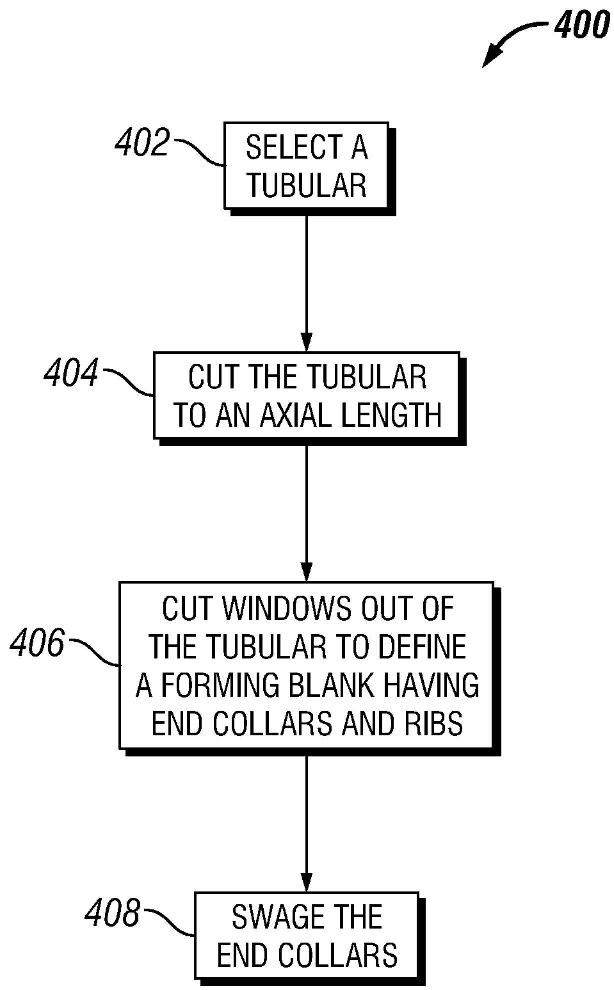

400
402
SELECT A TUBULAR
404
CUT THE TUBULAR TO AN AXIAL LENGTH
406
CUT WINDOWS OUT OF THE TUBULAR TO DEFINE A FORMING BLANK HAVING END COLLARS AND RIBS
408
SWAGE THE END COLLARS

FIG. 8

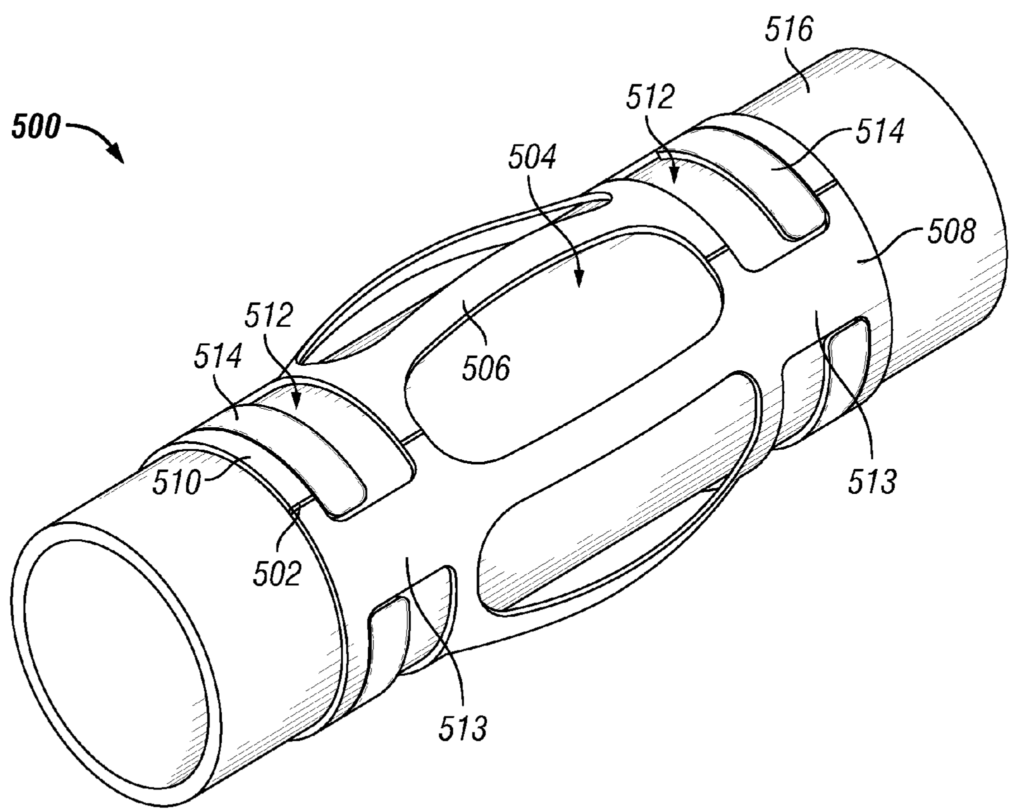


FIG. 9

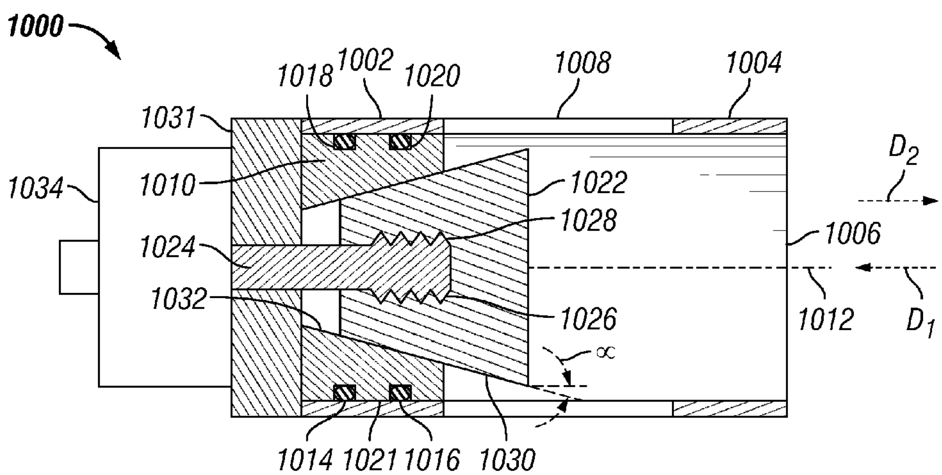

1000
1002
1004
1006
1008
1010
1012
1014
1016
1018
1020
1021
1022
1024
1026
1028
1030
1031
1032
1034
D_1
D_2
∝

FIG. 10

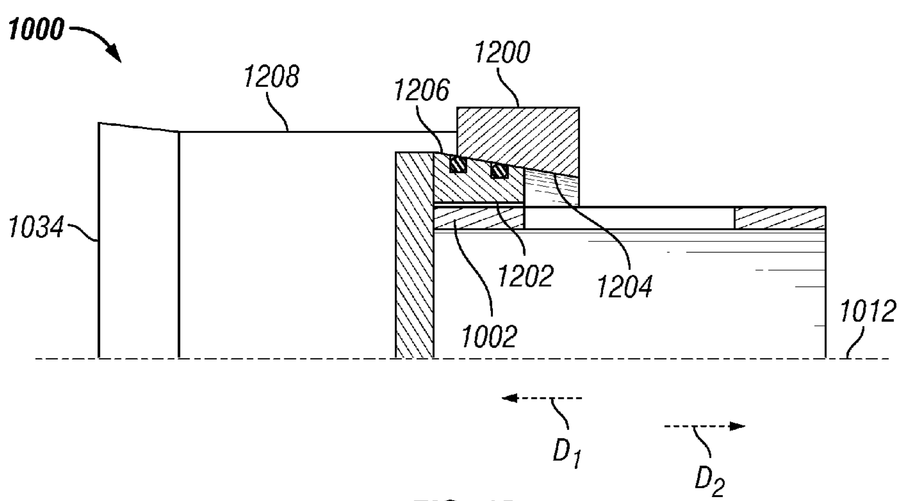

1000
1200
1202
1204
1206
1208
1002
1012
1034
D_1
D_2

FIG. 12

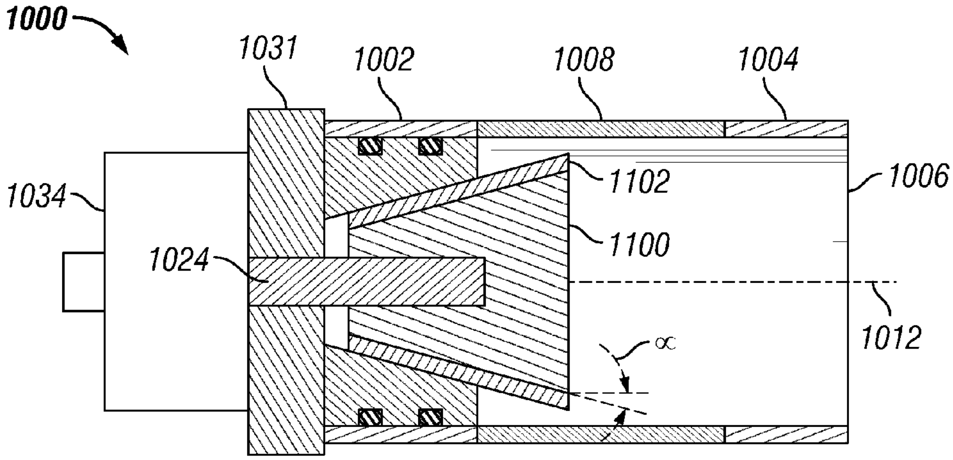


FIG. 11A

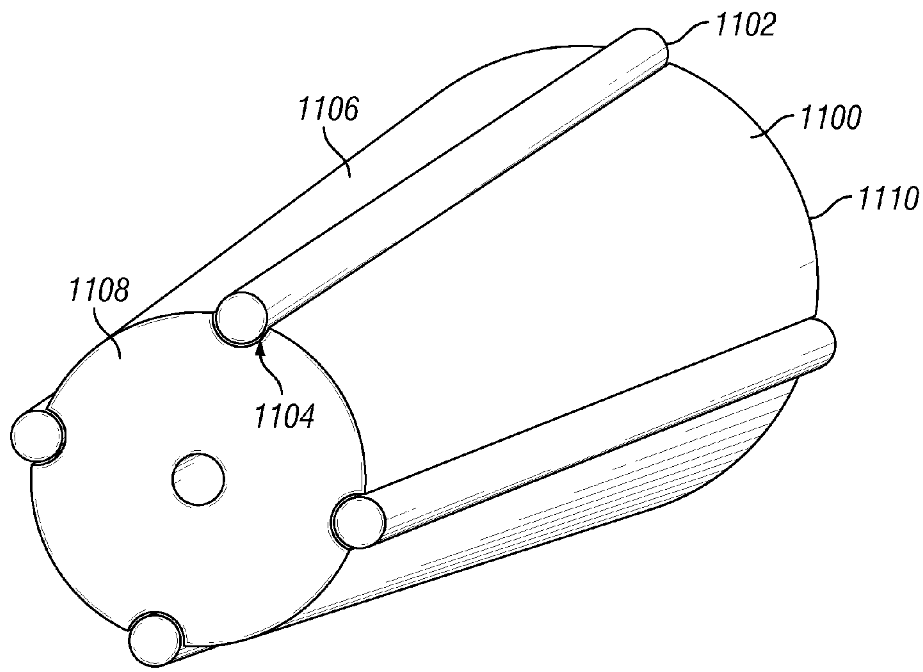


FIG. 11B

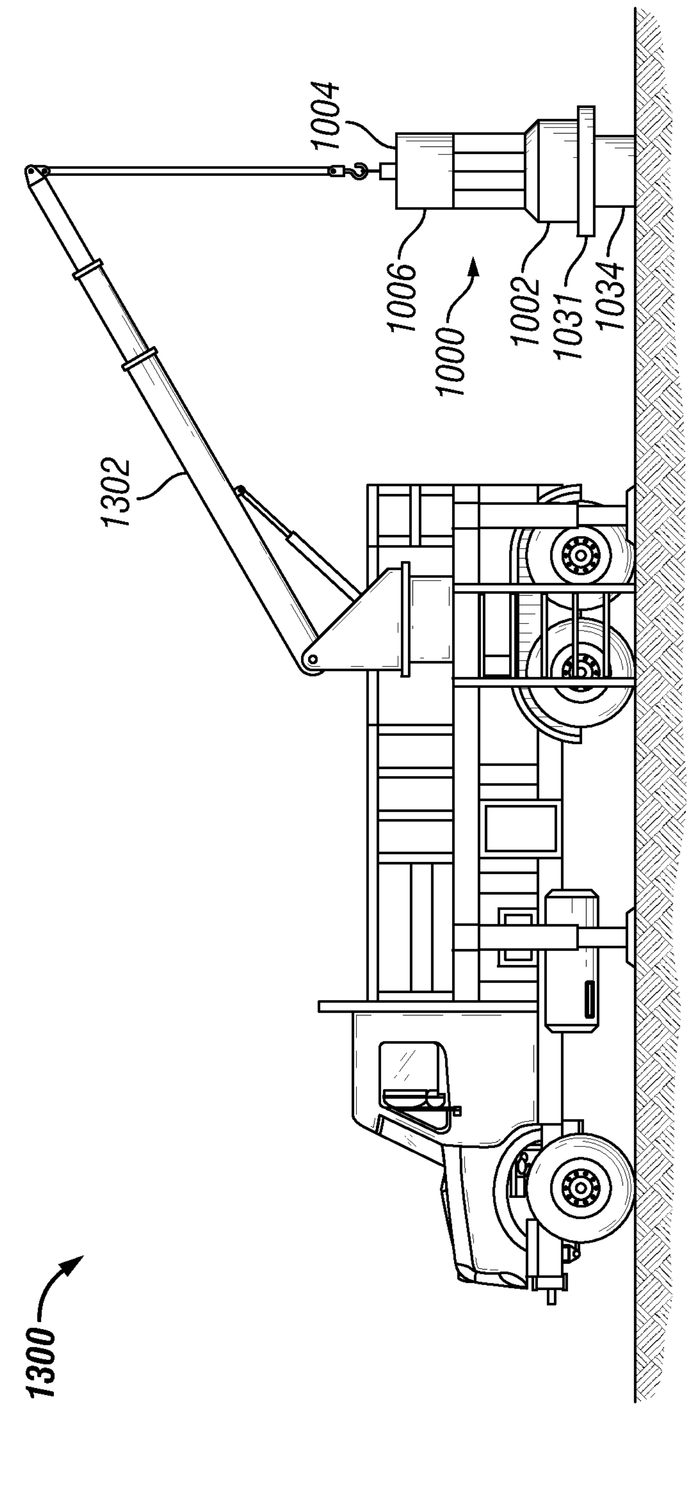


FIG. 13

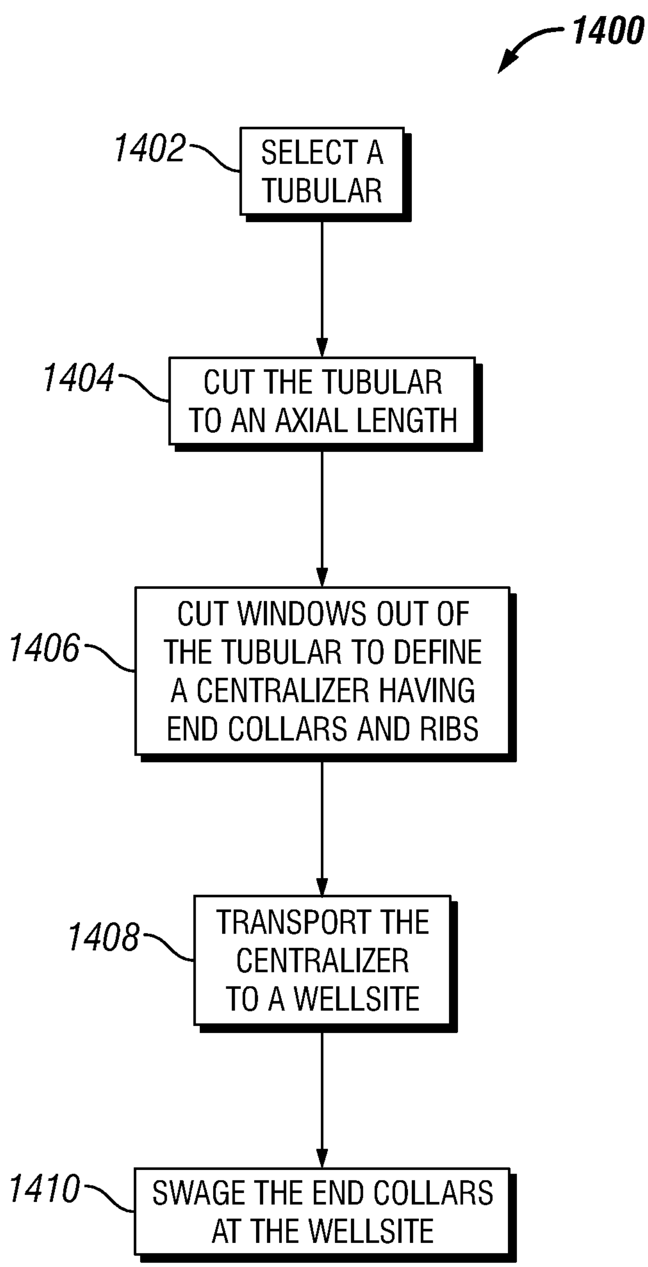

1400
1402
SELECT A TUBULAR
1404
CUT THE TUBULAR TO AN AXIAL LENGTH
1406
CUT WINDOWS OUT OF THE TUBULAR TO DEFINE A CENTRALIZER HAVING END COLLARS AND RIBS
1408
TRANSPORT THE CENTRALIZER TO A WELLSITE
1410
SWAGE THE END COLLARS AT THE WELLSITE

FIG. 14

COLLAR SWAGING OF SINGLE-PIECE CENTRALIZERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application having Ser. No. 61/989,699, which was filed on May 7, 2014. This application also claims priority to U.S. Provisional Patent Application having Ser. No. 62/012,129, which was filed on Jun. 13, 2014. The entirety of these provisional applications is incorporated herein by reference.

BACKGROUND

[0002] A centralizer may be installed on a tubular (e.g., a drill string or casing string) in an oilfield context, to provide an annular standoff between the tubular and a surrounding tubular (e.g., a wellbore wall). The centralizers may provide this standoff using blades or ribs that extend radially-outward from the tubular and axially between two end collars. One type of centralizer employs flexible, bow-shaped ribs or “bow springs,” which resiliently engage the surrounding tubular. Such bow-spring centralizers may be capable of providing a standoff across a range of diameters in the wellbore, and may collapse radially to pass through restrictions or obstructions (i.e., areas of reduced diameter in the wellbore). Other types of centralizers may use rigid or semi-rigid ribs, or may define shapes that are not bowed.

[0003] Centralizers may be formed using a variety of manufacturing processes. For example, the end collars of the centralizers may be formed from rolled sheet metal. The rolled sheet metal may, for example, form the end collars, and strips of metal may be attached to the end collars to form the ribs. Another way to manufacturer the centralizers is a “one-piece” process, which may start with a sheet or a segment of pipe. When starting with a sheet, the sheet may be cut to length, and material may be cut away from sheet to yield the appropriate geometries for the end collars and ribs. Before or after such cutting, the sheet may be rolled and seam welded. The process for forming from a segment of pipe may involve cutting the material from the pipe to result in the appropriate geometries. In either case, portions of the centralizer may be heat-treated, etc. to yield the desired characteristics.

[0004] One-piece centralizer manufacturing processes may reduce the number of steps needed to form the centralizer; however, a challenge in the one-piece centralizer manufacturing processes is seen in the tolerance requirements of the pipe from which the centralizer is made and the tubular (e.g., drill string or casing string) over which the centralizer is installed. In particular, sizing the inner diameter of the centralizer such that it may slide over the tubular during installation without binding, while minimizing the total outer diameter of the finished assembly, may be a challenge in view of such tolerances.

[0005] Accordingly, the rolled, one-piece embodiment may be more readily implemented, since it allows for custom sizing of the sheet, whereas the pipe may come in standard sizes, subject to relatively wide tolerances. On the other hand, the rolling process may be more expensive and may exhibit wide variations in wall thickness, whereas beginning with already-formed pipe may obviate some of these challenges.

SUMMARY

[0006] Embodiments of the present disclosure may provide a method for manufacturing a centralizer. The method may include selecting a tubular having a first inner diameter. The tubular may be cut to form a blank including at least one end collar and ribs integrally-formed therewith. The at least one end collar may be swaged such that the first inner diameter is modified to a second inner diameter.

[0007] Embodiments of the present disclosure may also provide a centralizer. The centralizer may include a rolled tubular having a seam. At least one rib may be formed in the rolled tubular. At least one end collar may also be formed in the rolled tubular. The at least one end collar has a first inner diameter prior to a swaging process and a second inner diameter after the swaging process.

[0008] Embodiments of the present disclosure may further provide a swaging device for a centralizer. The swaging device may include a body having a tapered surface and a plurality of dies. The dies may include a reverse-tapered surface that is reverse tapered with respect to the tapered surface of the body. The dies may also include an engagement surface that is opposite to the reverse-tapered surface. The body is configured to slide relative to the plurality of dies so as to swage an end collar of the centralizer.

[0009] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the present teachings, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The accompanying drawing, which is incorporated in and constitutes a part of this specification, illustrates an embodiment of the present teachings and together with the description, serves to explain the principles of the present teachings. In the figures:

[0011] FIG. **1** illustrates a perspective view of a forming blank, according to an embodiment.

[0012] FIG. **2** illustrates a perspective view of a portion of the forming blank, depicting an end collar of the forming blank undergoing a diameter-reducing swaging process, according to an embodiment.

[0013] FIG. **3** illustrates a side, cross-sectional view of the portion of the forming blank of FIG. **2**.

[0014] FIG. **4** illustrates a perspective view of a portion of the forming blank, depicting the end collar thereof undergoing a diameter-increasing swaging process, according to an embodiment.

[0015] FIG. **5** illustrates a side, cross-sectional view of the portion of the forming blank of FIG. **4**.

[0016] FIG. **6** illustrates a side, cross-sectional view of a portion of the forming blank undergoing another embodiment of the diameter-increasing swaging process.

[0017] FIG. **7** illustrates a side, cross-sectional view of a portion of the forming blank undergoing another embodiment of the diameter-reducing swaging process.

[0018] FIG. **8** illustrates a flowchart of a method for manufacturing a centralizer, according to an embodiment.

[0019] FIG. **9** illustrates a perspective view of a centralizer, according to an embodiment.

[0020] FIG. **10** illustrates a side, cross-sectional view of a swaging assembly for a centralizer, according to an embodiment.

[0021] FIG. **11**A illustrates a side, cross-sectional view of another embodiment of the swaging assembly.

[0022] FIG. **11**B illustrates a perspective view of a roller die of the swaging assembly of FIG. **11**A.

[0023] FIG. **12** illustrates a side, cross-sectional view of yet another embodiment of the swaging assembly.

[0024] FIG. **13** illustrates a conceptual view of a mobile unit including the swaging assembly, according to an embodiment.

[0025] FIG. **14** illustrates a flowchart of a method for providing a centralizer at a wellsite, according to an embodiment

[0026] It should be noted that some details of the figure have been simplified and are drawn to facilitate understanding of the embodiments rather than to maintain strict structural accuracy, detail, and scale.

DETAILED DESCRIPTION

[0027] Reference will now be made in detail to embodiments of the present teachings, examples of which are illustrated in the accompanying drawing. In the drawings, like reference numerals have been used throughout to designate identical elements, where convenient. In the following description, reference is made to the accompanying drawing that forms a part thereof, and in which is shown by way of illustration a specific exemplary embodiment in which the present teachings may be practiced. The following description is, therefore, merely exemplary.

[0028] Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the disclosure are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. Moreover, all ranges disclosed herein are to be understood to encompass any and all sub-ranges subsumed therein.

[0029] FIG. **1** illustrates a perspective view of a forming blank **100**, which may be formed into a centralizer, according to an embodiment. It will be appreciated that, in at least one embodiment, the forming blank **100** may not require further operations to be performed thereon to result in the centralizer; that is, the forming blank **100** itself may be a centralizer, e.g., for relatively small clearance applications.

[0030] The forming blank **100** may be formed from a segment of a tubular, such as casing pipe, drill pipe, etc. The tubular for the forming blank may be fabricated in any suitable manner, such as roll forming and seam welding in a pipe production facility or mill. The tubular may be selected based on its inner diameter being near (e.g., nearest of a set of available stock sizes) to a target inner diameter, as will be discussed in greater detail below. Further, the forming blank **100** may include cut-out windows **102**, which may represent areas of the tubular that have been removed via a cutting process applied to the segment of tubing. The cut-out windows **102** may be cut using water jet cutting, laser cutting, milling, or any other suitable process. Further, the cut-out windows **102** may be positioned so as to define end collars **104**, **106** and ribs **108** extending axially-between the end collars **104**, **106**. Accordingly, the cut-out windows **102** may be generally elongated rectangular shapes, leaving sections defining the two, axially-offset end collars **104**, **106** and the relatively thin ribs **108** extending axially-therebetween. Moreover, any number of cut-out windows **102** may be created, e.g., according to the desired number of ribs **108**. Further, the cut-out windows **102** (and thus the ribs **108**) may be defined at generally uniform angular intervals and sizes, but, in other cases, may be non-uniform in terms of location, size, etc. The ribs **108** may be heat-treated, expanded, and/or otherwise formed to provide an appropriate shape and resiliency (e.g., to provide bow-springs), but in other embodiments may be rigid, semi-rigid, etc. Examples of a one-piece centralizer may be found in U.S. Pat. No. 7,845,061 and U.S. Patent Publication No. 2014/0096888, the contents of which are incorporated herein.

[0031] FIG. **2** illustrates a perspective view of a portion of the forming blank **100**, showing the end collar **104** undergoing a diameter-reducing swaging process, according to an embodiment. The end collar **106** may be generally similar to the end collar **104**, and similar processes, as will be described below, may be applied thereto. Accordingly, a duplicative description of the structure and formation of the end collar **106** is omitted. With continuing reference to FIG. **2**, FIG. **3** illustrates a side, cross-sectional view of the portion of the forming blank **100** shown in FIG. **2**, according to an embodiment.

[0032] In some cases, the tubular from which the forming blank **100** is cut may have an inner diameter ID that is larger than a target inner diameter. Thus, the end collar **104** may also have the inner diameter ID larger than a target inner diameter, and a swaging process may be applied to reduce the inner diameter ID to a predefined tolerance of the target inner diameter.

[0033] Briefly, swaging is a process by which the dimensions of a part are altered by forcing the part into a set of forming dies, or (additionally) by progressively engaging rolling dies with the part to form it into a new shape. Die swaging, for example, may be performed using a crimping die set **114**, which may include arcuate die segments **116** that are arranged around the outer diameter surface **112** of the end collar **104**. The die segments **116** may be forced radially-inwards (compressed), as indicated by arrows **118**, to reduce the outer diameter OD (and the inner diameter ID) of the end collar **104** to the desired size or range of sizes.

[0034] The axial length of one, some, or all of the die segments **116** may be smaller, equal to, or larger than the axial length of the end collar **104**. For illustrative purposes only, the die set **114** is illustrated as being slightly larger in axial dimension than the end collar **104**. In some embodiments, the diameter-reducing swaging process may affect the shape of the ribs **108** proximal to the end collar **104**, since the ribs **108** may be integrally-formed with the end collar **104**. This change in the shape of the ribs **108** may be mitigated or removed during subsequent working or treating of the ribs **108**, but in other embodiments, it may be ignored.

[0035] The extent to which the inner diameter ID and/or outer diameter OD may be decreased may depend at least partially on the strain capacity of the material and the desired final structural properties of the centralizer. To name a specific example, thin-walled tubes made from steel with elongations of 10% or more may be decreased by 10% of their diameter or more, which may be an amount that bridges the range between standard mill size tubulars and standard centralizer sizes. Moreover, the arcuate die segments **116** may be forced radially-inwards using any suitable device, such as, to name just a few examples, a crimping device, clamp, hydraulics, or by moving a tapered sleeve across the radial die set **114**.

[0036] FIG. **4** illustrates another perspective view of a portion of the forming blank **100**, depicting the end collar **104** undergoing a diameter-increasing swaging process, according to an embodiment. FIG. **5** illustrates a side, cross-sectional view of the portion of the forming blank **100** shown in FIG. **4**, according to an embodiment. Referring to FIGS. **4** and **5**, the inner diameter ID (and/or the outer diameter OD) of the end collar **104** may be expanded to achieve a target size and/or tolerance.

[0037] In an embodiment, a set of expandable dies **117** may be employed. The set of expandable dies **117** may include a plurality of arcuate die segments **119**. Outer surfaces **120** of the die segments **119** may be configured to engage the inner diameter surface **110** of the end collar **104** and expand, as indicated by arrows **122**, so as to increase the inner diameter ID of the end collar **104**. For example, a tapered body may be progressively received through the set of expandable dies **117**, thereby forcing the individual die segments **119** radially-outwards. In various embodiments, the arcuate die segments **119** may have an axial dimension that is shorter, equal to, or longer than the axial dimension of the end collar **104**. The illustrated embodiment of FIG. **5**, with the axial dimension of the die segments **119** being greater than the axial dimension of the end collar **104**, is thus merely one example among several contemplated. As with the diameter-reducing swaging process, the diameter-increasing swaging process may alter the geometry of the ribs **108** proximal to the end collar **104**, since the ribs **108** are connected thereto (e.g., integrally formed therewith). Such alterations may be mitigated or removed during subsequent working or treatment of the ribs **108** or, in some embodiments, may be acceptable in the centralizer.

[0038] As with the diameter-reducing swaging operation discussed above, the extent to which the inner diameter ID may be increased may depend at least partially on the strain capacity of the material and the desired final structural properties of the centralizer. To name a specific example, thin-walled tubes made from steel with elongations of 10% or more may be increased by 10% of their diameter or more, which may be an amount that bridges the range between standard mill size tubular goods and standard centralizer sizes.

[0039] Instead of, or in addition to, using the set of expandable dies **117** to expand the end collar **104**, the diameter-increasing swaging process may include roller forming. In this process, a series of tapered rollers may be rotated inside the tube, and a tapered body may be pulled against the rollers, forcing them gradually outwards. A similar process may also be employed as a diameter-reducing swaging process. Roller forming may be a relatively gentle swaging process, compared with die swaging, and may deliver precise inner diameter ID tolerances, circularity, and a good surface finish; accordingly, this process may be used as a second swaging process, so as to finish the end collar **104**, or may be used in lieu of the die-swaging process.

[0040] FIG. **6** illustrates a schematic, side, cross-sectional view of the end collar **104** and a portion of the ribs **108** of the forming blank **100** undergoing another diameter-increasing swaging process, according to an embodiment. In this embodiment, a die **202** with a tapered outer diameter surface **204** may be employed. The die **202** may be formed from a single piece, or may include several segments that are connected together, either movably or not. The die **202** may be received into the end collar **104** and may be pulled therethrough, or the forming blank **100** may be pushed or pulled across the die **202**, or both, such that the die **202** is drawn through the end collar **104**. The die **202** may have a maximum outer diameter that exceeds the inner diameter ID of the un-swaged end collar **104**, and thus moving (pulling, pushing, etc.) the die **202** through the end collar **104** may cause the end collar **104** (e.g., at least the inner diameter ID thereof) to expand.

[0041] Similarly, FIG. **7** illustrates a schematic, side, cross-sectional view of the end collar **104** and a portion of the ribs **108** of the forming blank **100**, undergoing another diameter-decreasing swaging process, according to an embodiment. In this embodiment, a die **300** with a tapered inner diameter surface **302** may be employed. The die **300** may be a single-piece, but in other embodiments, may include two or more pieces, which may be movably secured together or fixed together. The end collar **104** may be received into the die **300**, e.g., pulled or pushed therethrough, or the end collar **104** may be held stationary as the die **300** is pushed or pulled therethrough. The die **300** may thus be drawn across the end collar **104**. The minimum inner diameter defined by the tapered inner diameter surface **302** may be less than the outer diameter OD of the end collar **104**, and thus the end collar **104** may be reduced in outer diameter OD and, in at least some embodiments, in inner diameter ID, by the end collar **104** passing over the end collar **104**. The tapered inner diameter surface **302** may be conical in profile, curved, etc. Moreover, in an embodiment, the die **300** may include or be replaced with rollers, hydraulics, pneumatics, may include multiple pieces fixedly or movably secured together, etc.

[0042] The swaging processes, whether diameter-increasing or diameter-reducing, may be performed as cold-forming processes, or may be practiced on hot material (e.g., one or more steel alloys). Swaging the hot material may lower the forces required, but may also reduce the accuracy of the final ID tolerance as the material (e.g., steel) cools and transforms its microstructure. Additionally, the swaging processes may use hydraulic dies or any other tools suitable for increasing or decreasing the diameter of the end collar **104**.

[0043] FIG. **8** illustrates a flowchart of a method **400** for manufacturing a single-piece centralizer, according to an embodiment. The method **400** may include selecting a tubular, e.g., of a standard size from a mill, having an inner diameter ID, an outer diameter OD, or both that are near to, but outside of a determined, acceptable tolerance of a determined target inner diameter or outer diameter, as at **402**. In an embodiment, the tubular may be a heat-treatable alloy steel tube of the nearest mill size to (e.g., under or over) the desired inner diameter ID of the finished centralizer. Example casing sizes over which the centralizer may be installed and/or fabricated from range from about 4½" to about 13⅝".

[0044] The method **400** may then include cutting the tubular to a specified axial length, as at **404**. Before, after, or while cutting the tubular to the specified axial length at **404**, the method **400** may also include cutting windows **102** out of the tubular, thereby defining ribs **108** circumferentially between the windows **102**, and end collars **104**, **106** on opposite axial ends of the windows **102** and ribs **108**, as at **406**. Such cutting may be accomplished using a variety of machines configured to cut cylindrical structures, e.g., by water jet cutting, laser cutting, milling, etc. It will be appreciated that two or more such machines may be employed, e.g., one to cut the tubular to the axial length at **404** and one to cut out the windows **102** at **406**, and in other cases, a single machine may perform both operations.

[0045] The cutting operations may yield a starting or "forming" blank **100** with continuous sections at either end (the end collars **104**, **106**) connected by ribs **108**, which may, in some embodiments, be formed into a bowed, spring profile. The method **400** may then proceed to swaging the end collars **104**, **106** of the blank **100**, as at **408**. When starting with a tubular with an inner diameter ID smaller than the desired final collar inner diameter ID, the two end collars **104**, **106** may be expanded (e.g., using a die or rollers as part of the swaging operation). When starting with a tubular with an inner diameter that is larger than the desired final collar outer diameter OD, the end collar **104**, **106** may be compressed (e.g., using a die or rollers as part of a swaging operation).

[0046] In addition to changing the inner and/or outer diameter ID, OD, the swaging process may also reduce ellipticity (i.e., make more circular or "circularize") in the end collars **104**, **106**. Accordingly, the shape of starting tubulars that have a slight ovality may be corrected in the swaging operation, at the same time the inner diameter ID thereof is being adjusted. Further, in some embodiments, one or both of the end collars **104**, **106** may include a peak, e.g., along the seam where the tubular is welded together. The swaging process may be employed to remove this peak, while also increasing or decreasing the diameter, and increasing the circularity of the end collar **104**.

[0047] FIG. **9** illustrates a perspective view of a centralizer **500**, according to an embodiment. The centralizer **500** may be formed as a single piece (e.g., from a sheet of metal that is rolled and welded along a seam **502**). The rolling and/or welding may be conducted at a pipe mill (e.g., to standard size and tolerance specifications). The centralizer **500** may have one or more first windows **504** cut (or otherwise formed or defined) therein, which are spaced apart circumferentially so as to define ribs **506** therebetween. The first windows **504** may be rectangular, ovular, or any other suitable shape. Further, the first windows **504** may generally be centered at the axial center of the centralizer **500**, and may have an axial dimension that is shorter than the overall axial dimension of the centralizer **500**. Accordingly, the centralizer **500** may include one or more end collars **508**, **510** at either or both axial ends of the centralizer **500**, with the ribs **506** and the first windows **504** extending therebetween.

[0048] The ribs **506** may be integrally-formed with the end collars **508**, **510**. Further, the ribs **506** may be radially-extended and/or heat-treated (e.g., to provide resilient bow-springs). In other embodiments, the ribs **506** may be otherwise shaped and/or formed as rigid or semi-rigid ribs or blades.

[0049] One or more second windows **512** may optionally be cut from (or otherwise formed or defined in) the centralizer **500**, e.g., in the end collars **508**, **510**. The second windows **512** may be spaced circumferentially apart, defining axial bridges **513** therebetween, which may maintain the integrity of the end collars **508**, **510**. Further, the second windows **512** may be sized and configured to engage a stop-feature **514** coupled with a tubular (e.g., casing or drill pipe) **516** on which the centralizer **500** may be installed. In a specific embodiment, the stop-feature **514** may be a spray-deposited metal, such as WEARSOX® (commercially-available from Antelope Oil Tool & Mfg. Co., LLC). In other embodiments, the stop-feature **514** may be any structure that is welded, adhered, fastened, or otherwise attached to the tubular **516**. In still other embodiments, the stop-feature **514** may be integrally-formed with the tubular **516**. Further, the stop-features **514** may have an axial length that is less than an axial length of the second windows **512**, thereby providing an axial range of motion for the end collars **508**, **510**, e.g., allowing the ribs **506**, in a bow-spring embodiment, to flex.

[0050] The end collars **508**, **510** may have an inner diameter ID and an outer diameter OD. As described above with respect to the forming blank **100** of FIGS. **1-7**, the inner and/or outer diameters may be larger or smaller than desired. For example, it may be advantageous for the end collars **508**, **510** to have an inner diameter ID that is slightly larger than the outer diameter OD of the tubular **516** around which the centralizer **500** is to be installed. Accordingly, and as also discussed above with respect to the end collars **104**, **106**, the end collars **508**, **510** may be swaged, either to increase or decrease the inner and/or outer diameter thereof, to thereby modify the inner and/or outer diameter to a target dimension within a target tolerance.

[0051] The first and second windows **504**, **512** may be formed in the centralizer **500** at the same time or at different times, using the same or different machines, processes, etc. Further, the first and/or second windows **504**, **512** may be formed before or after welding the sheet of metal together to form the seam **502** and/or before or after swaging one or both of the end collars **508**, **510**.

[0052] Accordingly, it will be seen that a single-piece centralizer with a precise inner diameter ID and circularity tolerance may be formed from an inexpensive, high-volume starting tubular stock of arbitrary intermediate diameter near, but outside of a tolerance for, the desired final product dimensions and tolerances. This may obviate the process of rolling individual tube sections or accounting for variable-wall thickness tolerances of seamless tubulars as the starting point for the production process.

[0053] FIG. **10** illustrates a side, cross-sectional view of a swaging device **1000**, according to an embodiment, which may be employed for swaging end collars **1002**, **1004** of a centralizer **1006**. The centralizer **1006** may be formed and/or otherwise share a similar structure as an embodiment of the centralizer **100** or **500**. Accordingly, ribs **1008** may extend between the end collars **1002**, **1004**.

[0054] The swaging device **1000** may include a plurality of dies **1010**, which may be arcuate segments that are disposed circumferentially-around a central axis **1012** (e.g., as described above with reference to the arcuate die segments **119** shown in FIG. **4**). Any number of dies **1010** may be employed. Further, the dies **1010** may be held together using one or more elastic bands (two shown: **1014**, **1016**), which may be disposed in one or more grooves (two shown: **1018**, **1020**). In a specific embodiment, the elastic bands **1014**, **1016** may be O-rings; however, in other embodiments, other types of elastic bands or springs may be employed. Moreover, in some cases, the elastic bands **1014**, **1016** may not be disposed in a groove, but may ride freely on an outer surface **1021** of the dies **1010** or may be otherwise positionally-constrained with respect thereto. Further, in some cases, the bands **1014**, **1016** may be segmented, with each segment extending between two of the dies **1010**, either along the outer surface **1021** of the dies **1010**, or at a radial position inwards therefrom.

[0055] The dies **1010** may be received within the end collar **1002** of the centralizer **1006**, such that the outer surfaces **1021** of the dies **1010** are generally at about the same distance from the central axis **1012** as the inner surface of the end collar **1002** (i.e., the outer surface **1021** of the dies **1010** touches the end collar **1002**, or nearly does). In some embodiments, however, the dies **1010** may be substantially smaller than the end collar **1002** and spaced radially-apart therefrom, at least initially. In either example, the outer surface **1021** may be configured to bear upon the end collar **1002** and may thus be considered to provide an engagement surface of the dies **1010**.

[0056] The swaging device **1000** may also include a body **1022** and a shaft **1024**. The body **1022** may be a mandrel, which may be coupled with the shaft **1024** (e.g., by meshing threads **1026**, **1028** thereof, respectively, as shown). In other embodiments, any connection capable of providing a least a linear transmission of force along the central axis **1012** in at least one of a first axial direction D_1 and a second axial direction D_2, from the shaft **1024** to the body **1022**, may be employed.

[0057] Further, the body **1022** may have a tapered outer surface **1030**, which may be configured to slide along a reverse-tapered inner surface **1032** of the dies **1010**. The reverse-tapered inner surface **1032** of the dies **1010** may be defined radially-opposite to the outer, engaging surface **1021** thereof. Further, the tapered outer surface **1030** may be tapered (e.g., angled with respect to the central axis **1012**) by a taper angle a ranging from about 1°, about 2°, about 3°, about 4°, or about 5° to about 20°, about 15°, about 10°, or about 7°.

[0058] The swaging device **1000** may also include a driver **1034**, which may be a hydraulic, pneumatic, magnetic, mechanical, or any other type of driver **1034**. Accordingly, one or more power sources (e.g., gas, electric, hydraulic, pneumatic) may be provided, to operate the driver **1034**. Further, the driver **1034** may be configured to move the shaft **1024** and thus the body **1022** linearly. Moreover, the driver **1034** may be configured to support a weight of the swaging device **1000** against a support surface. For example, the central axis **1012** may extend vertically, or at an acute angle to vertical, such that the body **1022** is above the driver **1034**.

[0059] In some embodiments, a retaining plate **1031** may be provided to restrain the position of the dies **1010** and/or the centralizer **1006**. For example, the retaining plate **1031** may be disposed between the driver **1034** and the body **1022**, with the shaft **1024** extending movably therethrough.

[0060] In operation, according to an example, the centralizer **1006** may be loaded onto the swaging device **1000**, e.g., with the end collar **1002** abutting the retaining plate **1031**. The driver **1034** may then be energized, so as to move the shaft **1024** linearly in the first axial direction D_1. Moving the shaft **1024** may also move the body **1022**. The dies **1010** may be restrained from moving by engagement with the retaining plate **1031**. Accordingly, the body **1022** may move in the first axial direction D_1 with respect to the dies **1010**, and thus the tapered outer surface **1030** may slide relative to the reverse-tapered inner surface **1032**. In this way, the dies **1010** may be forced to expand radially-outward, proportional to the distance moved by the body **1022** and the taper angle α. When the body **1022** is moved in the second direction D_2 (e.g., away from the driver **1034**, as shown), the body **1022** may allow the dies **1010** to move radially-inward, e.g., by the elasticity of the bands **1014**, **1016**.

[0061] Driving the dies **1010** outwards may cause the end collar **1002** to be expanded and thus plastically deformed outwardly. Accordingly, the end collar **1002** may begin at a first diameter, which may be expanded to a second, target diameter by the dies **1010**. Further, the second, target diameter may be within a target tolerance, and may have a target cylindricity. Moreover, the expansion (e.g., deformation) may be controlled in a number of ways, for example, by varying the size of the retaining plate **1031** so as to control the stroke of the body **1022**, by determining a force necessary to move the body **1022** by a certain amount and limiting the force applied to the body **1022** to that amount, by providing a stop block for the shaft **1024** movement, or in any other manner. Additionally, the end collar **1002** may retain some amount of elasticity during the radially-outward deformation. Accordingly, the body **1022** may be moved sufficiently to account for the end collar **1002** springing back after the dies **1010** are disengaged therefrom.

[0062] Once the end collar **1002** is expanded, the driver **1034** may reverse the direction of the force on the shaft **1024**, and may drive the body **1022** in the second axial direction D_2, allowing the dies **1010** to move radially-inwards. The centralizer **1006** may then be removed from the swaging device **1000**. Then, the other end collar **1004** may be swaged, or another centralizer **1006** may be loaded onto the swaging device **1000**.

[0063] FIG. **11**A illustrates a side, cross-sectional view of another embodiment of the swaging device **1000**. FIG. **11**B illustrates a perspective view of a roller body **1100** for use with the swaging device **1000** of FIG. **11**A. As shown, the roller body **1100** may be tapered, similar to the body **1022** (FIG. **10**), but may also include a plurality of rollers **1102** which may be disposed in cutouts **1104** defined in an outer surface **1106** of the roller body **1100**. Although four rollers **1102** and four cutouts **1104** are shown, it will be appreciated that any number of rollers **1102** and cutouts **1104** may be employed. Further, in some embodiments, the rollers **1102** may extend along an entirety of the roller body **1100**, e.g. between a first axial end **1108** and a second axial end **1110** of the roller body **1100**, but in other embodiments, may be spaced apart from the axial ends **1108**, **1110** (e.g., by retaining walls configured to maintain or assist in maintaining the position of the rollers **1102**).

[0064] In some embodiments, the cutouts **1104** may have a generally uniform depth (e.g., the distance from the outer surface **1106** to the bottom of the cutouts **1104**). Moreover, the rollers **1102** may be generally cylindrical, and thus the tapering of the outer surface **1106** may result in the rollers **1102** being oriented at the taper angle a. In some embodiments, the rollers **1102** may be tapered, rather than cylindrical. Further, the rollers **1102** may be restrained in the cutouts **1104** by shafts or any other suitable connectors that may allow the rollers **1102** to roll with respect to the outer surface **1106** of the roller body **1100**. In other embodiments, the rollers **1102** may be or include one or more (e.g., rows of) spherical rolling elements disposed in the cutouts **1104**.

[0065] Referring specifically to FIG. **11**A, the roller body **1100** may be coupled with the driver **1034** via the shaft **1024**. The shaft **1024** may be coupled with the roller body **1100** such that linear and torque (rotational) forces may be applied to the roller body **1100** via the shaft **1024**. The retaining plate

1031 may remain stationary, and may serve to restrain the position, axially and/or rotationally, of the dies 1010. The roller body 1100 may be received within the dies 1010, and the end collar 1002 received therearound (e.g., as discussed above with respect to the body 1022).

[0066] In operation, in addition to being moved along the central axis 1012, the driver 1034 may rotate the shaft 1024, and thus the body 1022, about the central axis 1012. This may cause the rollers 1102 to roll against the dies 1010 as the body 1022 moves, which may reduce friction forces, and thus reduce loading forces that may be required to expand the end collar 1002 of the centralizer 1006. Although described above and illustrated as employing the dies 1010, it will be appreciated that, in some cases, the roller body 1100 may bear directly on the end collar 1002, with the dies 1010 being omitted.

[0067] FIG. 12 illustrates a partial cross-section of another embodiment of the swaging device 1000. In this embodiment, the swaging device 1000 includes an outer body 1200, which may be generally annular and received around the end collar 1002 of the centralizer 1006. The swaging device 1000 of FIG. 12 may also include an outer die 1202, which may include a plurality of arcuate segments. The outer body 1200 may include a tapered inner surface 1204, and the outer dies 1202 may include a reverse-tapered outer surface 1206. The inner and outer surfaces 1204, 1206 may engage one another, such that movement of the outer body 1200 in the first axial direction may cause the outer dies 1202 to be driven radially-inwards.

[0068] The outer body 1200 may be coupled with the driver 1034 via an elongate member 1208. The elongate member 1208 may, for example, be a cable, with the driver 1034 including a reel to take up the cable. In another embodiment, the elongate member 1208 may be or include a hydraulic arm, which may be extended or retracted by energizing the driver 1034. In another embodiment, the elongate member 1208 may be at least partially threaded, and the driver 1034 may include a screw or pinion, so as to linearly translate the elongate member 1208.

[0069] In operation, the end collar 1002 may be loaded into the swaging device 1000, with the end collar 1002 disposed radially-within the outer dies 1202 and the outer body 1200. The body 1200 may then be driven (e.g., pushed and/or pulled) in the first direction D_1 (e.g., toward the driver 1034 in the illustrated embodiment), such that the tapered inner surface 1204 slides against the reverse-tapered outer surface 1206 of the dies 1202, thereby driving the dies 1202 inward, so as to reduce the diameter of the end collar 1002 to a target diameter, tolerance, cylindricity, etc. Once the dies 1202 have reached the prescribed position, the driver 1034 may reverse or, at least, remove the force on the outer body 1200, allowing the swaged, larger end collar 1003 to be removed from the swaging device 1000.

[0070] FIG. 13 illustrates a conceptual view of a mobile swaging unit 1300, according to an embodiment, including one or more embodiments of the swaging device 1000. The mobile swaging unit 1300 may be a truck, as illustrated, such as a flat-bed truck. In other embodiments, however, other types of vehicles may be used. Further, the mobile swaging unit 1300 may be deployed to or proximal to a wellsite, which may include casing-running and/or drilling equipment with which the centralizer 1006 may be employed and deployed into a wellbore at the wellsite.

[0071] The mobile swaging unit 1300 may, in some embodiments, include a hoisting device 1302, such as a crane. The hoisting device 1302 is merely optional however, and may be employed, for example, when relatively large-diameter, or otherwise heavy, centralizers 1006 are to be swaged. For many sizes of centralizers 1006, however, one or two human users may be able to load the centralizer 1006 into the swaging device 1000, without needing a hoisting device 1302.

[0072] As shown, the swaging device 1000 may be disposed in a vertical orientation (e.g., with the driver 1034 supported directly on the ground). In some embodiments, however, a table, stand, brackets, etc. may be provided. In such a vertical configuration, the centralizer 1006 may be carried (or hoisted) by the end collar 1004 and slid down onto the body 1022 (e.g., FIG. 10). In situations where a human worker is responsible for moving the centralizer 1006 onto the swaging device 1000, the vertical orientation of the swaging device 1000 may minimize or avoid the worker having to bend to load the centralizer 1006 onto the swaging device 1000, which may enhance ergonomics. Moreover, in still other cases, the swaging device 1000 may be horizontally-oriented and supported (e.g., on a stand). Once the end collar 1002 of the centralizer 1006 is loaded onto the swaging device 1000, the driver 1034 may be energized to swage (either expand, as shown, or contract) the end collar 1002.

[0073] The mobile swaging unit 1300 may include a lift or another device that may facilitate moving the swaging device 1000 to the illustrated position. For example, the hoisting device 1302 may be employed to move the swaging device 1000 into position. In other embodiments, other lifting devices may be employed. In still other embodiments, however, the swaging device 1000 may be generally fixed in position in the mobile swaging unit 1300 (e.g., attached to the truck or a moving platform thereof), or may be moved by one or more human workers without the assistance of a lifting device.

[0074] FIG. 14 illustrates a flowchart of a method 1400 for providing a centralizer (e.g., a single-piece centralizer) at a wellsite, according to an embodiment. For purposes of illustration, the method 1400 is described herein with reference to the swaging device 1000 and the centralizer 1006 (e.g., FIG. 10); however, it will be appreciated that the method 1400 is not limited to any particular structure, unless otherwise stated herein, and may be employed with any of the centralizer embodiments and/or swaging devices disclosed herein and/or others.

[0075] The method 1400 may include selecting a tubular, as at 1402. The tubular selected may be fabricated in a stock size at a pipe mill, for example. In some cases, the stock sizes may have a tolerance range. Further, the stock size may define an inner diameter that is smaller or larger than a desired, second inner diameter. The desired, second inner diameter may be selected such that the centralizer 1008, with the end collars 1002, 1004 of the second inner diameter, may slide along a casing, drill pipe, or any other tubular, with little or no interference and a minimized outer diameter. Further, a cylindricity of the stock pipe may be outside of an acceptable tolerance.

[0076] The tubular may be cut to a desired axial length, as at 1404. Before, during, or after such cutting at 1404, windows may be cut from the tubular, so as to define the centralizer 1006 having the end collars 1002, 1004 and ribs

1008, as at 1406. In some embodiments, heat treatment operations, rib expansion, and/or any other process may be conducted, so as to give the centralizer 1006 any desired metallurgical or other types of properties.

[0077] Before, during, or after cutting at 1404 and/or 1406, the centralizer 1006 (or tubular, in the case that the tubular is uncut) may be transported to a wellsite, as at 1408. The wellsite may be an area that is proximal to a wellhead of a subterranean well, such as a natural gas well, oil well, and/or the like. One or more tubulars, such as, for example, base pipe, drill pipe, casing, lining, etc. may be configured to be run into the well. In some embodiments, the tubulars may be centralized within a surrounding tubular using the centralizer 1006, so as to provide an annular standoff between the tubulars and the surrounding tubular.

[0078] However, as noted above, in some embodiments, the tubulars may have an outer diameter that is larger than the inner diameter of the centralizer 1006. Accordingly, the method 1400 may include swaging the end collars 1002, 1004 of the centralizer 1006 at the wellsite, as at 1410. This may be conducted using an embodiment of the mobile unit 1300 and/or the swaging device 1000. For example, a user may hoist, either by hand or using a lifting device, such as lifting device 1302, the centralizer 1008 and load the end collar 1002 onto the swaging device 1000. The user may then energize the driver 1034 of swaging device 1000, causing the swaging device 1000 to swage the end collar 1002, such that the inner diameter of the end collar 1002 reaches a predetermined size that exceeds the outer diameter of the tubular to be centralized by a predetermined amount. Thereafter, the swaging may be repeated for the other end collar 1004. The centralizer 1006 may then be received around (e.g., slid over the end of) the tubular, and the tubular may be deployed, e.g., as part of a tube string, into the well along with the centralizer 1006.

[0079] In other embodiments, the outer diameter of the tubulars may be smaller than the inner diameter of the centralizer 1006, prior to swaging at 1410. For example, the inner diameter of the un-swaged centralizers 1006 may be larger than needed to slide the end collars 1002, 1004 over the tubular. Accordingly, the swaging at 1410 may include reducing the inner diameter thereof, so as to reduce the positive outer diameter added by using the centralizer 1006 on the tubular. Whether increasing the diameter or decreasing the diameter of the centralizer 1006, swaging at 1410 may, in at least one embodiment, also increase a cylindricity of the end collars 1002, 1004, e.g., to within a desired tolerance of a desired target cylindricity.

[0080] While the present teachings have been illustrated with respect to one or more implementations, alterations and/or modifications may be made to the illustrated examples without departing from the spirit and scope of the appended claims. In addition, while a particular feature of the present teachings may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular function. Furthermore, to the extent that the terms "including," "includes," "having," "has," "with," or variants thereof are used in either the detailed description and the claims, such terms are intended to be inclusive in a manner similar to the term "comprising." Further, in the discussion and claims herein, the term "about" indicates that the value listed may be somewhat altered, as long as the alteration does not result in nonconformance of the process or structure to the illustrated embodiment. Finally, "exemplary" indicates the description is used as an example, rather than implying that it is an ideal.

[0081] Other embodiments of the present teachings will be apparent to those skilled in the art from consideration of the specification and practice of the present teachings disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the present teachings being indicated by the following claims.

What is claimed is:

1. A method for manufacturing a centralizer, comprising:
selecting a tubular having a first inner diameter;
cutting the tubular to form a blank comprising at least one end collar and ribs integrally-formed therewith; and
swaging the at least one end collar such that the first inner diameter is modified to a second inner diameter.

2. The method of claim 1, wherein swaging the at least one end collar comprises expanding the first inner diameter, the second inner diameter being larger than the first inner diameter.

3. The method of claim 2, wherein expanding the first inner diameter comprises:
receiving a die into engagement with an inner diameter surface of the at least one end collar; and
expanding the die.

4. The method of claim 2, wherein expanding the first inner diameter comprises moving a die through the at least one end collar, the die having a maximum outer diameter that is greater than the first inner diameter.

5. The method of claim 1, wherein swaging the at least one end collar comprises decreasing the first inner diameter, the second inner diameter being less than the first inner diameter.

6. The method of claim 5, wherein decreasing the first inner diameter comprises:
positioning a set of crimping dies around an outer diameter surface of the at least one end collar; and
forcing the set of crimping dies radially-inwards.

7. The method of claim 5, wherein decreasing the first inner diameter comprises moving a die having an inner diameter that is less than an outer diameter of the at least one end collar over an outer diameter surface of the at least one end collar.

8. The method of claim 1, further comprising heating at least a portion of the blank before swaging the at least one end collar.

9. The method of claim 1, wherein cutting the tubular comprises defining a window in the at least one end collar, the window being sized and configured to receive a stop-feature.

10. A centralizer comprising:
a rolled tubular having a seam;
at least one rib formed in the rolled tubular; and
at least one end collar formed in the rolled tubular, wherein the at least one end collar has a first inner diameter prior to a swaging process and a second inner diameter after the swaging process.

11. The centralizer of claim 10, wherein the second inner diameter is larger than the first inner diameter.

12. The centralizer of claim 10, wherein the second inner diameter is smaller than the first inner diameter.

13. The centralizer of claim **10**, wherein a first window is defined radially-through the rolled tubular and circumferentially-offset from the at least one rib, and wherein a second window is defined radially-through the at least one end collar.

14. A swaging device for a centralizer, comprising:
a body having a tapered surface; and
a plurality of dies each having:
a reverse-tapered surface that is reverse tapered with respect to the tapered surface of the body; and
an engagement surface that is opposite to the reverse-tapered surface, wherein the body is configured to slide relative to the plurality of dies so as to swage an end collar of the centralizer.

15. The swaging device of claim **14**, wherein the body and the plurality of dies are configured to be disposed radially-inside of the end collar of the centralizer.

16. The swaging device of claim **15**, wherein the tapered surface of the body is an outer surface thereof, and the reverse-tapered surface of the plurality of dies is an inner surface thereof, and wherein, when the body is moved in a first axial direction, the body causes the plurality of dies to expand radially-outward.

17. The swaging device of claim **14**, further comprising:
a driver coupled with the body to move the body with respect to the plurality of dies;
a retaining plate disposed between the driver and the body; and
a shaft connecting the driver and the body,
wherein the shaft is received through the retaining plate, and the retaining plate is configured to maintain a position of the plurality of dies when the body is moved by the driver.

18. The swaging device of claim **14**, wherein the body comprises a plurality of rollers.

19. The swaging device of claim **18**, wherein the plurality of rollers are cylindrical and disposed in cutouts defined in the tapered surface of the body.

20. The swaging device of claim **14**, further comprising:
a vehicle configured to be moved into proximity of a wellsite; and
a hoisting device coupled with the vehicle and configured to move the centralizer such that the end collar of the centralizer is received around or within the plurality of dies.

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