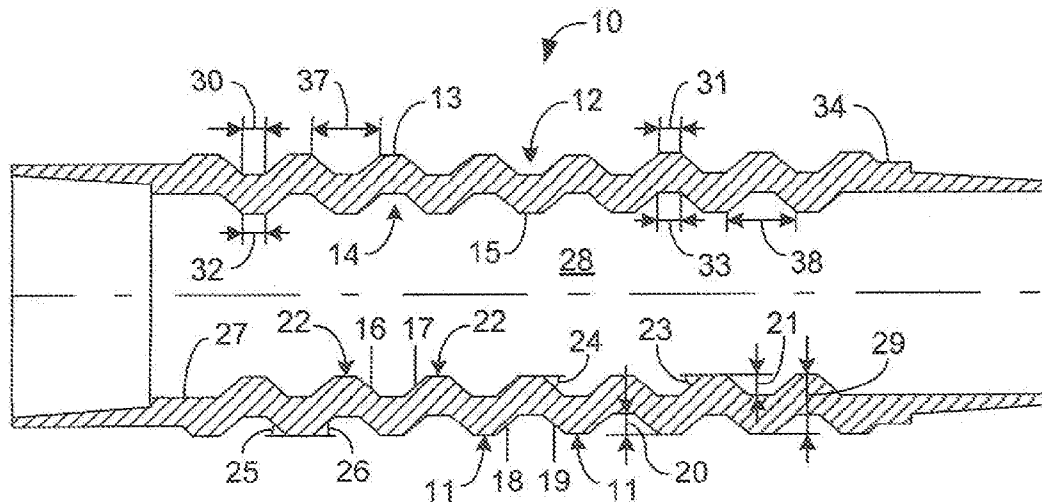




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(19) **United States**(12) **Patent Application Publication**
Benzie et al.(10) **Pub. No.: US 2012/0193088 A1**(43) **Pub. Date: Aug. 2, 2012**(54) **EXPANDABLE COMPLIANT ANCHOR/SEAL**(52) **U.S. Cl. 166/206; 277/322**(75) **Inventors:** **Scott A. Benzie**, Houston, TX (US);
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Filippov, Houston, TX (US)(73) **Assignee:** **MOHAWK ENERGY LTD.**,
Houston, TX (US)(21) **Appl. No.: 13/250,847**(22) **Filed: Sep. 30, 2011****Related U.S. Application Data**(60) Provisional application No. 61/462,190, filed on Jan.
31, 2011.**Publication Classification**(51) **Int. Cl.**
E21B 23/01 (2006.01)
E21B 33/00 (2006.01)(57) **ABSTRACT**

A tubular is an expandable compliant anchoring and sealing tubular. In one embodiment, the expandable compliant anchoring and sealing tubular is located on a cladding string, a liner hanger, a packer or a bridge plug. The expandable compliant anchoring and sealing tubular has grooves and protrusions both on external and internal surfaces of the tubular with external protrusions positioned against internal grooves and internal protrusions against external grooves in a radial direction. Upon radial expansion of the expandable compliant anchoring and sealing tubular, the external protrusions may be disposed in high interference contact with the surrounding casing or wellbore providing an anchoring and sealing relationship. This tubular configuration may be used when precise internal diameter of the surrounding casing or wellbore is unknown. The expandable compliant anchoring and sealing tubular may provide dimensional adjustability by bending of the groove spans in a radial direction.



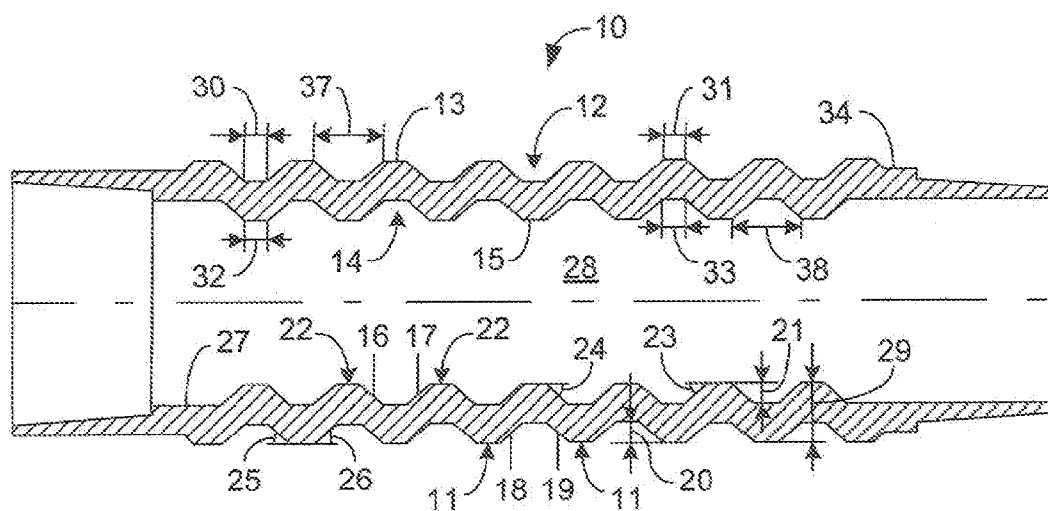


Fig. 1

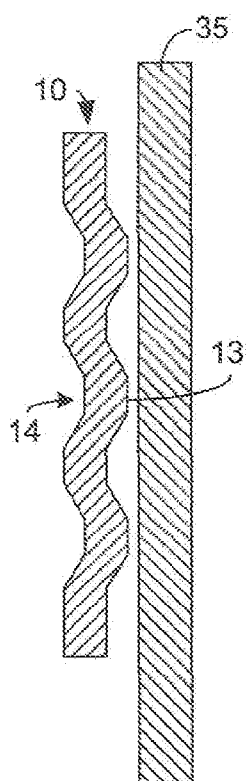


Fig. 2A

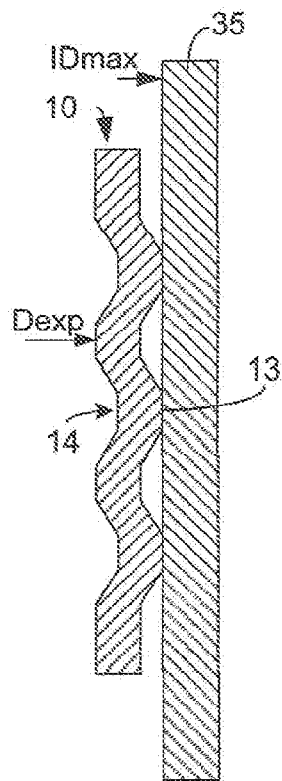


Fig. 2B

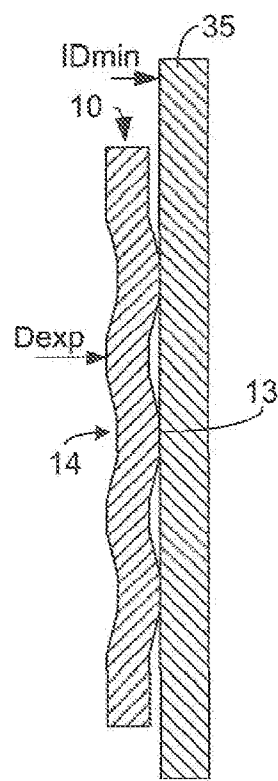


Fig. 2C

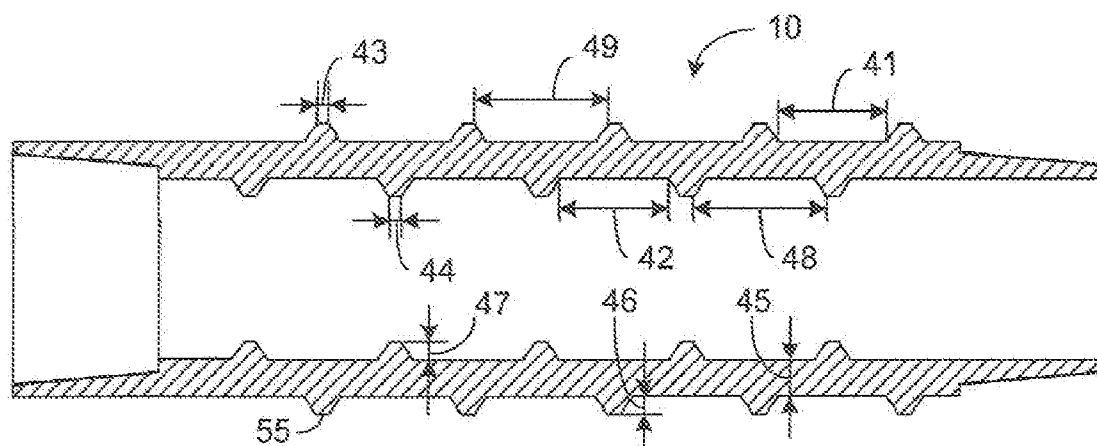


Fig. 3

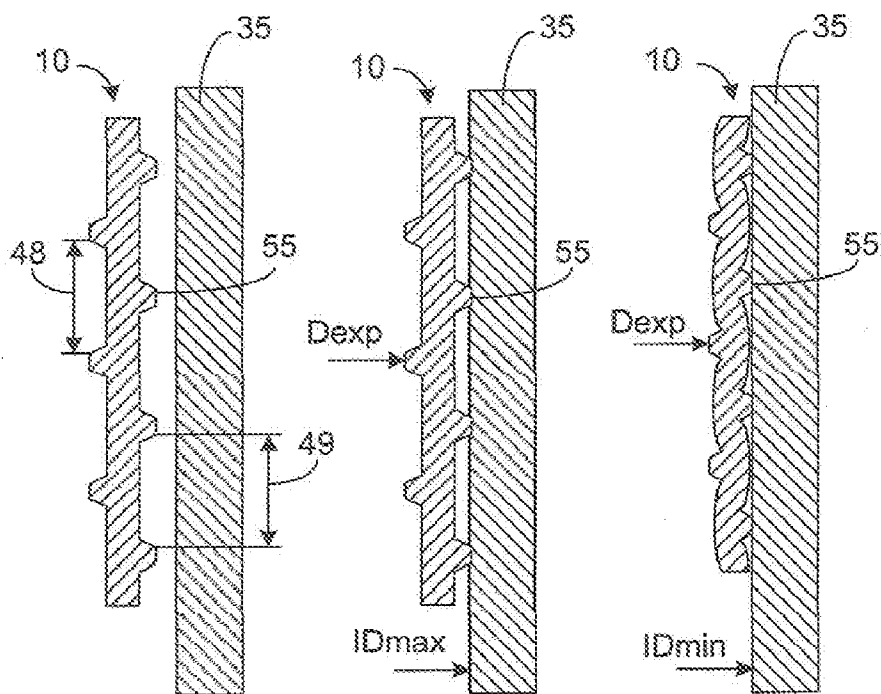


Fig. 4A

Fig. 4B

Fig. 4C

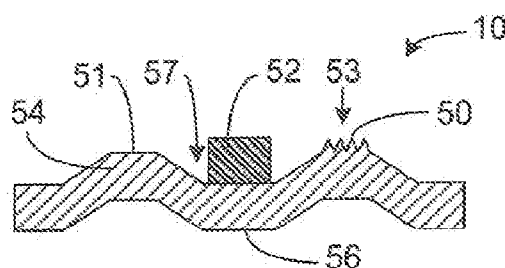


Fig. 5

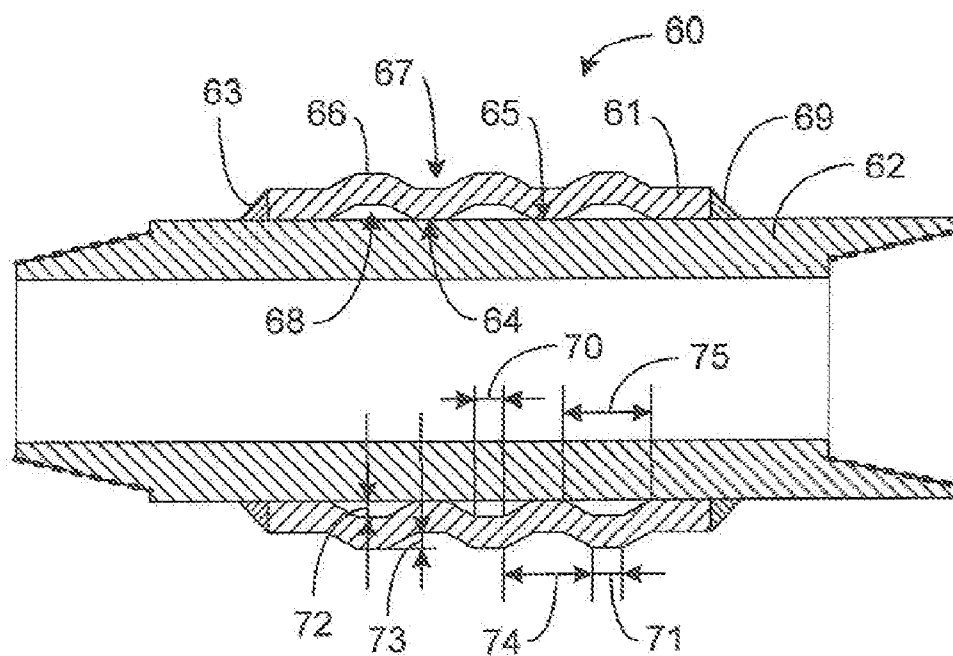


Fig. 6

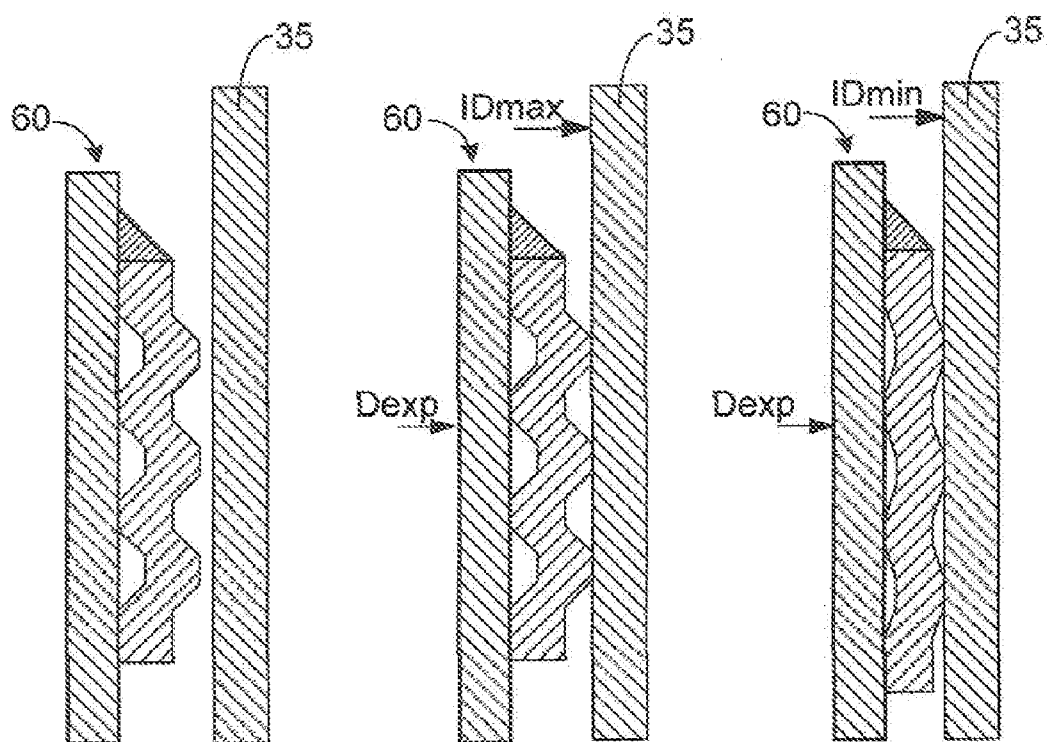


Fig. 7A

Fig. 7B

Fig. 7C

EXPANDABLE COMPLIANT ANCHOR/SEAL**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application is a non-provisional application that claims the benefit of U.S. Application Ser. No. 61/462,190 filed on Jan. 31, 2011, which is incorporated by reference herein in its entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

BACKGROUND OF THE INVENTION

[0003] 1. Field of the Invention

[0004] This invention relates to the field of tubular systems, and more specifically to tubular systems that can be expanded against surrounding casing or wellbore to provide an anchoring and sealing relationships.

[0005] 2. Background of the Invention

[0006] Frequently an anchoring/sealing tubular, which may be inserted in casing or an open hole and expanded into a sealing and supporting relationship with the surrounding casing or open hole, is needed to act as a liner hanger, a packer, or to isolate worn casing, or to provide a zonal isolation in a wellbore. Drawbacks to conventional designs include a compliance to adjust to the variability in inside dimensions to be encountered with the surrounding casing or wellbore while at the same time to provide adequate support for loads and/or sealing relationships.

[0007] Consequently, there is a need for improved tubular systems. Additional needs include an expandable, compliant, integrated anchoring and sealing tubular system.

BRIEF SUMMARY OF SOME OF THE PREFERRED EMBODIMENTS

[0008] An expandable, compliant, integrated, anchoring and sealing tubular system located on a cladding string, a liner hanger, a packer or a bridge plug. The expandable, compliant, integrated, anchoring and sealing tubular system comprises grooves and protrusions both on external and internal surfaces of the tubular with external protrusions positioned against internal grooves and internal protrusions against external grooves in a radial direction. Upon radial expansion of the tubular, the external protrusions may be disposed in high interference contact with the surrounding casing or wellbore and may provide an anchoring and sealing relationship. Without limitation, this tubular configuration may be particularly useful when a precise internal diameter of the surrounding casing or wellbore is unknown. In embodiments, the system provides dimensional adjustability by bending of the groove spans in the radial direction.

[0009] These and other needs in the art are addressed in one embodiment by an expandable tubular defining an internal wall and an external wall. The tubular includes a plurality of external grooves and external protrusions on the external wall and a plurality of internal grooves and internal protrusions on the internal wall. The external grooves are positioned against internal protrusions, and internal grooves positioned against external protrusions in a radial direction. The external grooves providing support and/or sealing relationship with the surrounding casing or wellbore upon expansion of said tubular.

[0010] These and other needs in the art are addressed in another embodiment by an expandable tubular system that includes a first expandable tubular and a second expandable tubular. The tubular system having said first expandable tubular defining an internal wall and an external wall. Said first tubular having a plurality of external grooves and external protrusions on the exterior wall and a plurality of internal grooves and internal protrusions on the interior wall. Said external grooves are positioned against internal protrusions, and internal grooves positioned against external protrusions in a radial direction. The first expandable tubular positioned as a sleeve over the second expandable tubular and attached by at least one end to the second expandable tubular preventing sliding of the first expandable tubular over the second expandable tubular in a longitudinal direction. Said expandable tubular system providing sealing/anchoring relationships with the surrounding casing or wellbore upon radial expansion thereof against the surrounding casing or wellbore.

[0011] The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter that form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and the specific embodiments disclosed may be readily utilized as a basis for modifying or designing other embodiments for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent embodiments do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] For a detailed description of the preferred embodiments of the invention, reference will now be made to the accompanying drawings in which:

[0013] FIG. 1 illustrates a cross-sectional view of an embodiment of an expandable compliant anchoring and sealing tubular;

[0014] FIG. 2A illustrates a partial cross-sectional view of an embodiment of the expandable compliant anchoring and sealing tubular shown in FIG. 1 being inserted inside the surrounding casing before expansion;

[0015] FIG. 2B is a partial cross-sectional view of an embodiment of the expandable compliant anchoring and sealing tubular shown in FIG. 1 being expanded against surrounding casing having a maximum inside diameter;

[0016] FIG. 2C is a partial cross-sectional view of an embodiment of the expandable compliant anchoring and sealing tubular shown in FIG. 1 being expanded against surrounding casing having a minimum inside diameter;

[0017] FIG. 3 is a cross-sectional view of another embodiment of an expandable compliant anchoring and sealing tubular;

[0018] FIG. 4A is a partial cross-sectional view of an embodiment of the expandable compliant anchoring and sealing tubular shown in FIG. 3 being inserted inside the surrounding casing before expansion;

[0019] FIG. 4B is a partial cross-sectional view of an embodiment of the expandable compliant anchoring and sealing tubular shown in FIG. 3 being expanded against surrounding casing having a maximum inside diameter;

[0020] FIG. 4C is a partial cross-sectional view of the expandable compliant anchoring and sealing tubular shown in FIG. 3 being expanded against surrounding casing having a minimum inside diameter;

[0021] FIG. 5 is a partial cross-sectional view of an embodiment of an expandable compliant anchoring and sealing tubular with sealing and elastomeric elements;

[0022] FIG. 6 is a cross-sectional view of an embodiment of an expandable compliant anchoring and sealing tubular system;

[0023] FIG. 7A is a partial cross-sectional view of an embodiment of the expandable compliant anchoring and sealing tubular system shown in FIG. 6 being inserted inside the surrounding casing before expansion;

[0024] FIG. 7B is a partial cross-sectional view of an embodiment of the expandable compliant anchoring and sealing tubular system shown in FIG. 6 being expanded against surrounding casing having a maximum inside diameter; and

[0025] FIG. 7C is a partial cross-sectional view of an embodiment of the expandable compliant anchoring and sealing tubular shown in FIG. 6 being expanded against surrounding casing having a minimum inside diameter.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] FIG. 1 illustrates an embodiment of expandable compliant anchoring and sealing tubular 10 having a plurality of external grooves 12 and external protrusions 13 on exterior surface 34 and a plurality of internal grooves 14 and internal protrusions 15 on internal surface 27. In embodiments as shown, internal grooves 14 are positioned against external protrusions 13, and external grooves 12 are positioned against internal protrusions 15 in a radial direction. In embodiments, each external groove 12 is disposed between two external protrusions 13. In an embodiment, each internal groove 14 is disposed between two internal protrusions 15. In embodiments as shown, on opposing ends of each internal groove 14 are internal protrusion angled sides 16, 17, which extend to the corresponding internal protrusion apex 22. In other embodiments as shown, on opposing ends of each external groove 12 are external protrusion angled sides 18, 19, which extend to the corresponding external protrusion apex 11.

[0027] In an embodiment for cladding a casing or wellbore 35, which internal diameter may vary between ID_{max} and ID_{min}, the depths of external groove 12 and internal groove 14 are each not less than $0.5 \cdot (ID_{max} - ID_{min})$ (as shown in FIGS. 2B, 2C). Without limitation, the expected variations in internal diameter of casing may be estimated using API Specification 5CT, Specification for Casing and Tubing. For instance, the variation in internal diameter, (ID_{max}–ID_{min}), for 7½ inch, 39 lb/ft casing, according to API Specification, may be as much as 0.239 inches. Further, without limitation, the expected variations in wellbore diameter may be estimated using the caliper measurements, for instance as disclosed in SPE/IADC 67769 publication, which is incorporated herein by reference in its entirety.

[0028] Expansion of expandable compliant anchoring and sealing tubular 10 may be accomplished by any expansion means suitable for use with tubular systems. In an embodiment (not illustrated), a method of expansion of expandable compliant anchoring and sealing tubular 10 includes moving a solid or variable expansion mandrel (not illustrated) within passage 28 or by applying pressure in passage 28.

[0029] In an embodiment, after expandable compliant anchoring and sealing tubular 10 is positioned at a desired location inside surrounding casing or wellbore 35 as shown in FIG. 2A, free expansion of expandable compliant anchoring and sealing tubular 10 (i.e., before it comes in contact with the casing or wellbore 35) occurs without flattening of expandable compliant anchoring and sealing tubular 10. It is to be understood that without flattening refers to without plastic bending of groove spans 37 and 38, which for selected tubular wall thickness 29 and depth of grooves 20 and 21 defines the minimum value of groove shoulder angles 23, 24, 25 and 26. In an embodiment as shown in FIGS. 2B and 2C when external protrusions 13 come into contact with the surrounding casing or wellbore 35, the additional pressure is exerted on external protrusions 13, which may lead to an increase in the bending moments applied to groove spans 37, 38. In embodiments as shown in FIG. 2C, plastic bending may be the result. In embodiments, selecting the maximum value of pressure between external protrusions 13 and the surrounding casing or wellbore 35 may define the maximum value of groove shoulder angles 23, 24, 25, and 26 to allow plastic bending of internal protrusion angled sides 16, 17 and external protrusion angled sides 18, 19 to accommodate for differences in surrounding casing inner diameter (ID). In an embodiment as shown in FIG. 1, expandable compliant anchoring and sealing tubular 10 has substantially equal widths of external protrusions 13 and internal protrusions 15; external grooves 30 and internal apices 32; and internal grooves 33 and external apices 31. In such an embodiment, plastic bending of the groove spans 37, 38 may result in longitudinal elongation of the expandable compliant anchoring and sealing tubular 10.

[0030] In an embodiment as shown in FIG. 3, the widths of external groove 41 and internal groove 42 selected are significantly larger than the widths of external protrusion 43 and internal protrusion 44. In embodiments, the depths of internal and external grooves 46 and 47 are each not less than the expected radial variance of $0.5 \cdot (ID_{max} - ID_{min})$ of the surrounding casing or wellbore 35 (shown in FIGS. 4A–4C). For selected tubular wall thickness 45 and widths of external protrusion 43 and internal protrusion 44 of expandable compliant anchoring and sealing tubular 10, the widths of external groove 41 and internal groove 42 are defined from the condition that during free expansion of expandable compliant anchoring and sealing tubular 10 (i.e. before external protrusions 55 come into contact with the surrounding casing or wellbore 35), internal groove span 48 and external groove span 49 do not exhibit plastic bending. When external protrusions 55 come into contact with the surrounding casing or wellbore 35, the additional pressure is exerted on external protrusions 55, which may lead to an increase in the bending moments applied to internal groove span 48 and external groove span 49. In embodiments as shown in FIGS. 4A–4C, selecting the maximum value of the pressure between external protrusions 55 and the surrounding casing or wellbore 35 defines the minimum lengths of width of external groove 41 and internal groove 42 to allow plastic bending of the internal groove span 48 and external groove span 49 to accommodate for differences in surrounding casing or wellbore 35 inner diameter (ID). In such embodiments, plastic bending of the groove spans 48, 49 may result in longitudinal shrinkage of expandable compliant anchoring and sealing tubular 10.

[0031] Both minimum and maximum values of groove shoulder angles (i.e., groove shoulder angles 23, 24, 25, 26) for expandable compliant anchoring and sealing tubular 10

may be estimated based on boundary conditions described above using standard formulas of Strength of Materials, for instance as disclosed in *STRENGTH OF MATERIALS* by S. Timoshenko (which is incorporated by reference herein in its entirety), or using Finite Element Analysis.

[0032] In another embodiment as shown in FIG. 5, one or more advantages may be achieved through expandable compliant anchoring and sealing tubular 10 comprising some of the external protrusions 54 or both external protrusions 54 and internal protrusions 56 comprising sealing elements 50. Sealing elements 50 may include wickers or teeth of triangular or circular profile or any other suitable sealing profile 53. In an embodiment, at least one of the protrusions of expandable compliant anchoring and sealing tubular 10 does not include sealing elements. Instead, embodiments include this protrusion having a substantially smooth surface. In an embodiment, smooth surface protrusion 51 acts as a wear pad during run-in of expandable compliant anchoring and sealing tubular 10 to facilitate removal of debris or other materials that may interfere with the interface of sealing elements 50 with the inner wall surface of surrounding casing or wellbore 35.

[0033] In embodiments as shown in FIG. 5, one or more advantages may be achieved through incorporation of elastic elements 52 in some of the external grooves 57. Elastic elements 52 may include O-ring type elements of different cross-sectional profiles provided that upon radial expansion of expandable compliant anchoring and sealing tubular 10 elastic elements 52 are compressed between the surrounding casing or wellbore 35 and expandable compliant anchoring and sealing tubular 10. Without limitation, such elastic elements 52 may provide additional sealing capability (i.e., for instance, in the case of corroded or damaged internal surface surrounding casing or wellbore 35).

[0034] In an embodiment as shown in FIG. 6, one or more of the advantages may be achieved by utilizing expandable compliant anchoring and sealing tubular 10 as a seal/anchor between an expandable tubular and surrounding casing or wellbore 35. As shown in FIG. 6, an expandable compliant sealing/anchoring system 60 comprising a first expandable tubular 61 (i.e., expandable compliant anchoring and sealing tubular 10) and a second expandable tubular 62. First expandable tubular 61 is positioned over second expandable tubular 62 as a sleeve and attached at one end or at both ends 63, 69 to second expandable tubular 62 preventing sliding of first expandable tubular 61 over second expandable tubular 62 in a longitudinal direction. This may be achieved by any suitable method such as by welding, gluing, crimping, encapsulation or by threadable engagement. First expandable tubular 61 comprises a plurality of external protrusions 66 and external grooves 67 and a plurality of internal grooves 68 and internal protrusions 64. Internal grooves 68 are positioned against external protrusions 66, and external grooves 67 are positioned against internal protrusions 64 in a radial direction. In embodiments, internal protrusions 64 are positioned into contact or a near contact relationship with external surface 65 of second expandable tubular 62. The geometry of first expandable tubular 61 is selected using the same principles as for expandable compliant anchoring and sealing tubular 10 taught above. In an embodiment, the depths 73, 72 of external and internal grooves 67, 68, respectively, are not less than the half of the expected variance in diameter of the surrounding casing or wellbore 35. The widths 71, 70 of external protrusions 66 and internal grooves 68, respectively, may be

selected substantially equal or the widths 70 of internal grooves 68 may be selected substantially larger than the widths 71 of external protrusions 66, provided that upon radial expansion of the expandable compliant sealing/anchoring system 60 the groove spans 74, 75 do not exhibit plastic bending until the external protrusions 66 come into contact with the surrounding casing or wellbore 35.

[0035] FIG. 7A shows schematically an embodiment of expandable compliant sealing/anchoring system 60 being deployed at the desirable location inside the surrounding casing or wellbore 35. The expansion swage diameter (not illustrated) is selected such that expansion to the diameter D_{exp} of the expandable compliant sealing/anchoring system 60 against the surrounding casing or wellbore 35 with maximum expected internal diameter, ID_{max} , may result in minimal plastic bending of groove spans 74, 75 (as shown in the embodiment of FIG. 7B), while when expanded against the minimal internal diameter, ID_{min} , the additional bending of groove spans 74, 75 may compensate for the variance in internal diameter of the surrounding casing or wellbore 35 (as shown in the embodiments of FIG. 7C).

[0036] First expandable tubular 61 and second expandable tubular 62 may be formed of any suitable material. In an embodiment, the material is a malleable metal. Without limitation, examples of suitable malleable metals include steel or alloys thereof.

[0037] It is to be understood that embodiments of expandable compliant anchoring and sealing tubular 10 may have protrusions and/or grooves of different widths. In other embodiments, the protrusions may be hardened or may be coated to increase friction with surrounding coating. Also, embodiments of the internal surface of the expandable tubular may be coated with a lubricant to reduce friction with an expansion swage. Moreover, embodiments of expandable compliant anchoring and sealing tubular 10 may have variable internal and external diameters. For instance, the diameter of the smooth external protrusions may be larger than the diameter of the external protrusions comprising sealing elements to protect sealing elements during deployment operation.

[0038] 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.

What is claimed is:

1. An expandable tubular defining an internal wall and an external wall, said tubular comprising:
 - a plurality of external grooves and external protrusions on the external wall and a plurality of internal grooves and internal protrusions on the internal wall, said external grooves are positioned against internal protrusions and internal grooves positioned against external protrusions in a radial direction;
 - said external grooves providing support and/or a sealing relationship with a surrounding casing or wellbore upon expansion of said tubular.
2. The expandable tubular of claim 1, wherein a depth of the internal grooves and a depth of the external grooves are not less than a half of the expected variance in a diameter of the surrounding casing or wellbore.
3. The expandable tubular of claim 1, further comprising groove spans, wherein the groove spans do not exhibit plastic

bending upon radial expansion of said tubular before the external protrusions come in to contact with the surrounding casing or wellbore.

4. The expandable tubular of claim 1, further comprising groove spans, wherein the groove spans exhibit plastic bending upon radial expansion of said tubular against the surrounding casing or wellbore with minimum expected internal diameter.

5. The expandable tubular of claim 1, comprising substantially equal widths of the grooves and the protrusions.

6. The tubular of claim 1, wherein widths of the grooves are larger than widths of the protrusions.

7. The expandable tubular of claim 1, wherein the external protrusions include sealing elements.

8. The expandable tubular of claim 7, wherein at least one external protrusion has a substantially smooth surface.

9. The expandable tubular of claim 1, wherein a portion of the external grooves include elastic elements.

10. The expandable tubular of claim 9, wherein the elastic elements become compressed between the surrounding casing or wellbore and said tubular upon radial expansion of said tubular.

11. An expandable tubular system comprising a first expandable tubular and a second expandable tubular, said tubular system comprising:

said first expandable tubular defining an internal wall and an external wall, said first tubular comprising:

a plurality of external grooves and external protrusions on the external wall and a plurality of internal grooves and internal protrusions on the internal wall, said external grooves are positioned against the internal protrusions and the internal grooves are positioned against the external protrusions in a radial direction;

the first expandable tubular positioned as a sleeve over the second expandable tubular and attached by at least one end to the second expandable tubular preventing sliding of the first expandable tubular over the second expandable tubular in a longitudinal direction;

said expandable tubular system providing sealing and/or anchoring relationships with the surrounding casing or

wellbore upon radial expansion thereof against the surrounding casing or wellbore.

12. The expandable tubular system of claim 11, wherein the first expandable tubular comprises a depth of grooves on the internal wall and a depth of the grooves on the external wall not less than half of the expected variance in a diameter of the surrounding casing or wellbore.

13. The expandable tubular system of claim 11, further comprising groove spans, wherein the groove spans do not exhibit plastic bending upon radial expansion of said expandable tubular system before the external protrusions come in to contact with the surrounding casing or wellbore.

14. The expandable tubular system of claim 11, further comprising groove spans, wherein the groove spans exhibit plastic bending upon radial expansion of said tubular against the surrounding casing or wellbore with minimum expected internal diameter.

15. The expandable tubular system of claim 11, comprising substantially equal widths of grooves and the protrusions.

16. The expandable tubular system of claim 11, wherein widths of the grooves are larger than widths of the protrusions.

17. The expandable tubular system of claim 11, comprising widths of the grooves substantially larger than the width of protrusions.

18. The expandable tubular system of claim 11, wherein the external protrusions include sealing elements.

19. The expandable tubular system of claim 11, wherein the internal protrusions include sealing elements.

20. The expandable tubular system of claim 19, wherein at least one external protrusion has a substantially smooth surface.

21. The expandable tubular system of claim 11, wherein a portion of the external grooves include elastic elements.

22. The expandable tubular system of claim 21, wherein the elastic elements become compressed between the surrounding casing or wellbore and the first expandable tubular upon radial expansion of said expandable tubular system.

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