(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 434 089 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
28.03.2012 Bulletin 2012/13

(51) Int Cl.:
E21B 33/12 *(2006.01)* ***E21B 33/129*** *(2006.01)*

(21) Application number: **11250823.9**

(22) Date of filing: **27.09.2011**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **28.09.2010 US 892084**

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(54) Friction bite with swellable elastomer elements

(57) A friction-enhancing material is applied to an outer surface of a swellable element of a downhole tool. The friction-enhancing material helps prevent axial extrusion of the elastomer of the swellable element. The friction-enhancing material may include particles, a mesh, and wickers, among other kinds of friction-enhancing material, and may be disposed on or embedded in all or a portion of an outer surface of the swellable element.

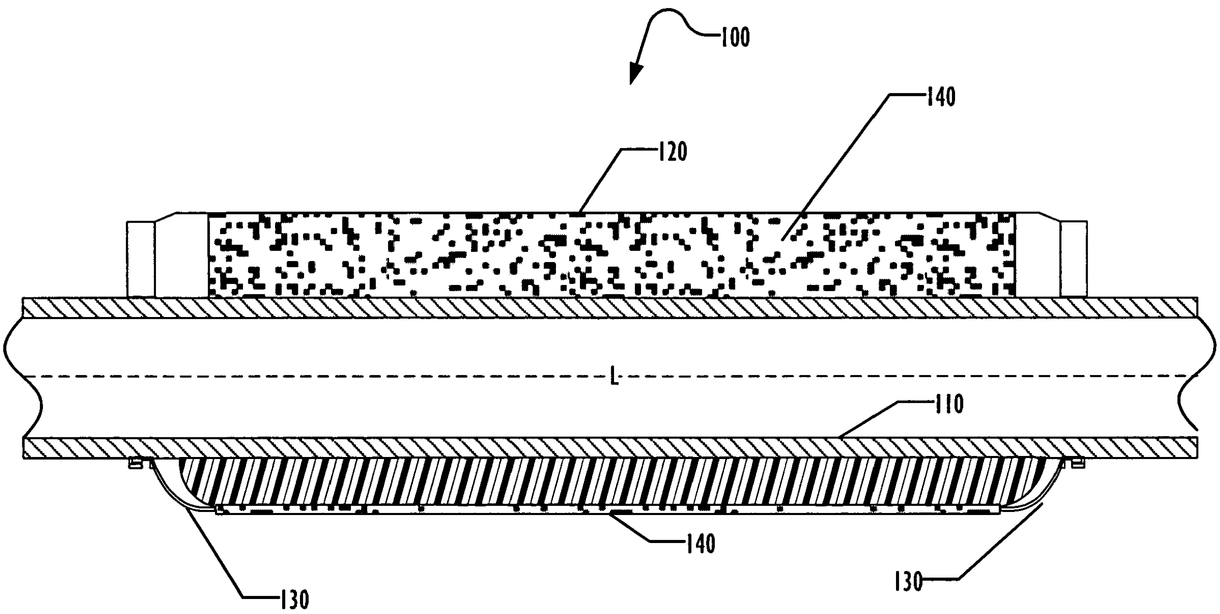

FIG. 1

EP 2 434 089 A2

Description

TECHNICAL FIELD

[0001] The present invention relates to the field of downhole tools, and in particular to swellable packers.

BACKGROUND ART

[0002] In the field of hydrocarbon exploration and production, various tools are used to provide fluid seals between two components in a wellbore. Annular barriers have been designed for preventing undesirable flow of wellbore fluids in the annulus between a wellbore tubular and the inner surface of a surrounding tubular or the borehole wall. In many cases, the annular barriers provide a fluid seal capable of holding a significant pressure differential across its length. In one application, a wellbore packer is formed on the outer surface of a completion string that is run into an outer casing in a first condition having a particular outer diameter. When the packer is in its desired downhole location, it is inflated or expanded into contact with the inner surface of the outer casing to create a seal in the annulus. Similar wellbore packers have been designed for use in openhole environments, to create a seal between a tubular and the surrounding wall of the wellbore.

[0003] Conventional packers are actuated by mechanical or hydraulic systems. A force or pressure is applied from the wellhead to move a mechanical packer element radially into contact with the surrounding surface. In an inflatable packer, fluid is delivered from the wellhead to inflate a chamber defined by a bladder around the tubular body.

[0004] More recently, wellbore packers have been developed which include a mantle of swellable material formed around the tubular. The swellable material is selected to increase in volume on exposure to at least one predetermined fluid, which may be a hydrocarbon fluid or an aqueous fluid or brine. The swellable packer may be run to a downhole location in its unexpanded state, where it is exposed to a wellbore fluid and caused to increase in volume. The design, dimensions, and swelling characteristics are selected such that the swellable packer element expands to create a fluid seal in the annulus to isolate one wellbore section from another. Swellable packers have several advantages over conventional packers, including passive actuation, simplicity of construction, and robustness in long-term isolation applications.

[0005] In addition, swellable packers may be designed for compliant expansion of the swellable mantle into contact with a surrounding surface, such that the force imparted on the surface prevents damage to a rock formation or sandface, while still creating an annular barrier or seal. Swellable packers therefore lend themselves well to openhole completions in loose or weak formations.

[0006] The materials selected to form a swellable element in a swellable packer vary depending on the specific application. Swellable materials are elastomeric (i.e. they display mechanical and physical properties of an elastomer or natural rubber). Where the swellable mantle is designed to swell in hydrocarbons, it may comprise a material such as an ethylene propylene diene monomer (EPDM) rubber. Where the swellable mantle is required to swell in aqueous fluids or brines, the material for example may comprise an N-vinyl carboxylic acid amide-based cross-linked resin and a water swellable urethane in an ethylene propylene rubber matrix. In addition, swellable elastomeric materials may be designed to increase in volume in both hydrocarbon fluids and aqueous fluids.

[0007] One failure mode of packing elements that seal in an annular space is extrusion. Mechanical backups have been used to bridge off the extrusion gap and help retain the swellable packing element, but these are not always practical or possible.

SUMMARY OF INVENTION

[0008] In one embodiment, a downhole apparatus is disclosed. The downhole tool comprises a swellable element. The swellable element comprises a swellable elastomeric material selected to increase in volume on exposure to at least one predetermined fluid; and a first area, disposed with the swellable element and operable to increase friction between the swellable element and a surrounding surface upon swelling of the swellable element.

[0009] In another embodiment, a swellable element for a downhole tool is disclosed. The swellable element comprises a swellable elastomeric material selected to increase in volume on exposure to at least one predetermined fluid; and a friction-enhancing material, disposed on a first annular area of an outer surface of the swellable elastomeric material.

[0010] In yet another embodiment, a method of reducing axial extrusion of a swellable element of a downhole tool is disclosed. The method comprises disposing a friction-enhancing material on a portion of an outer surface of the swellable element.

[0011] An aspect of the invention relates to a downhole apparatus, comprising:

> a swellable element comprising a swellable elastomeric material selected to increase involume on exposure to at least one predetermined fluid; and
> a first area, disposed with the swellable element and operable to increase friction between the swellable element and a surrounding surface upon swelling of the swellable element.

[0012] The downhole apparatus may be a swellable packer.

[0013] The first area may comprise a plurality of particles disposed on a surface of the first area, the particles selected for friction enhancement.

[0014] The plurality of particles may be dispersed randomly on the surface of the first area.

[0015] The plurality of particles may be patterned onto the surface of the first area.

[0016] The first area may comprise a mesh disposed about an outer diameter of the first area, the mesh selected for friction enhancement.

[0017] The mesh may be composed of stainless steel wire.

[0018] The first area may comprise a plurality of wickers, formed of material selected for friction enhancement.

[0019] The first area may comprise a plurality of wickers, formed of material selected to be harder than the surrounding surface.

[0020] The first area may comprise a roughened radially outward surface of a portion of the swellable element.

[0021] The first area may comprise the entire outer surface of the swellable element.

[0022] The downhole apparatus may further comprise a backup member, configured to resist axial extrusion of the swellable element, disposed at an end of the swellable element.

[0023] The first area may be proximal to the backup member.

[0024] Another aspect of the invention relates to a swellable element for a downhole tool, comprising:

a swellable elastomeric material selected to increase in volume on exposure to at least one predetermined fluid; and
a friction-enhancing material, disposed on a first annular area of an outer surface of the swellable elastomeric material.

[0025] The friction-enhancing material may comprise a plurality of particles disposed on the outer surface of the first annular area.

[0026] The plurality of particles may be formed from a material selected to have a hardness sufficient to bite into a surrounding surface when deployed in a casing or wellbore.

[0027] The plurality of particles may be randomly dispersed in the first annular area.

[0028] The plurality of particles may be patterned on the first annular area.

[0029] The friction-enhancing material may comprise a mesh, disposed about an outer diameter of the first annular area.

[0030] The friction-enhancing material may comprise a plurality of wickers, disposed about an outer diameter of the first annular area.

[0031] The predetermined fluid may be an aqueous solution.

[0032] A further aspect of the present invention relates to a method of reducing axial extrusion of a swellable element of a downhole tool, comprising:

disposing a friction-enhancing material on a portion of an outer surface of the swellable element.

[0033] The act of disposing a friction-enhancing material may comprise:

disposing particles of a substance harder than the swellable element on the portion of the outer surface of the swellable element.

[0034] The act of disposing a friction-enhancing material may comprise:

disposing a plurality of wickers about the portion of the outer surface of the swellable element.

[0035] The act of disposing a friction-enhancing material may comprise:

disposing a mesh formed of a substance harder than the swellable element about the portion of the outer surface of the swellable element.

[0036] The act of disposing a friction-enhancing material may comprise:

embedding the friction-enhancing material into the portion of the outer surface of the swellable element.

BRIEF DESCRIPTION OF DRAWINGS

[0037] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate an implementation of apparatus and methods consistent with the present invention and, together with the detailed description, serve to explain advantages and principles consistent with the invention. In the drawings,

Figure 1 is a cutaway view of a downhole tool according to one embodiment.

Figure 2 is a cutaway view of a downhole tool according to another embodiment.

Figure 3 is a cutaway view of a downhole tool according to yet another embodiment.

DESCRIPTION OF EMBODIMENTS

[0038] In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the invention. It will be apparent, however, to one skilled in the art that the invention may be practiced without these specific details. In other instances, structure and devices are shown in block diagram form in order to avoid obscuring the invention. References to numbers without subscripts or suffixes are understood to reference all instance of subscripts and suffixes corresponding to the referenced number. Moreover, the language used in this disclosure has been principally selected for readability and instructional purposes, and may not have been selected to delineate or circumscribe the inventive subject matter, resort to the claims being necessary to determine such inventive subject matter. Reference in the specification to "one embodiment" or to "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiments is included in at least one embodiment of the invention, and multiple references to "one embodiment" or "an embodiment" should not be understood as necessarily all referring to the same embodiment.

[0039] FIG. 1 is a cutaway view of a portion of a swellable packer 100 according to one embodiment. Some common features of the swellable packer known to the art are omitted for clarity of the drawing. The swellable packer **100** comprises a central body **110,** such as a tubular or mandrel, about which is disposed a swellable elastomer mantle **120.** The swellable mantle **120** may be formed of one or more sections as desired, using any known technique for forming a swellable mantle about a central body. In one embodiment, the swellable mantle **120** may be bonded or otherwise attached to the body **110.** The swellable mantle **120** is formed of an elastomer designed to swell when exposed to an aqueous solution, such as water or brine, or a hydrocarbon fluid.

[0040] Upon insertion into the well, the elastomer of the mantle **120** swells upon exposure to the fluid surrounding the packer **100** in the wellbore. As the elastomer of the mantle **120** swells, it expands radially outwardly, engaging a surrounding casing or open hole wellbore (not shown in FIG. **1)** sealing the packer **100** in an annular space around the packer **100,** typically to the casing or wellbore. The elastomer of the mantle **120** may also swell axially, and if not prevented from doing so, may extrude axially around the other elements disposed at the ends of the mantle **120,** reducing the pressure that is exerted by the expanded mantle **120** on the surrounding casing or wellbore.

[0041] To prevent this extrusion, mechanical backup units **130** may be provided. Axial expansion of the mantle **120** is limited by the backup units **130,** which typically expand under axial pressure, reducing extrusion around the expanded backup units. Although backup units **130** are disposed at both ends of the swellable mantle **120** as illustrated in FIG. **1,** in some embodiments, the backup unit **130** may be disposed at only one end of the mantle **120,** or a different technique for reducing extrusion may be employed at the end of the mantle 120 axially distal from the backup unit **130.** Although mechanical backups **130** have been used to bridge off the extrusion gap and help retain the swellable packing element, these are not always practical or possible. Furthermore, some extrusion may occur around the backup units **130.**

[0042] By increasing the friction factor between the mantle **120** and the bore, the extrusion resistance is increased, and thus the pressure holding capability of the packer **100.** Various embodiments disclosed herein use implanted mechanical components disposed on or embedded into the outer surface of the swellable mantle **120** to increase the friction or gripping capability of the mantle **120.** These mechanical components may include particles, slip segments, wire-mesh sheet, etc. that would either bite into the bore, or provide a rougher, stronger surface than the swellable rubber. These mechanical components may increase the tensile holding capability of the element, as well as increasing the pressure holding capability of the packer **100.**

[0043] There are different ways of increasing the friction coefficient of the surface of the mantle **120.** In FIG. **1,** the friction enhancement is achieved by disposing particles **140** onto the outer surface of the mantle **120,** or embedding the particles **140** into the outer surface. The particles **140** provide an increased friction coefficient for the entire surface of the mantle **120.** As illustrated in FIG. 1, the particles **140** are randomly distributed across the surface of the mantle **120.** In other embodiments, the particles **140** may be randomly distributed across one or more portions of the outer surface of the mantle **120,** preferably at least in areas proximal to the ends of the mantle **120,** where extrusion of the elastomer around the backup units **130** may occur.

[0044] In yet other embodiments, the friction-enhancing particles **140** may be patterned across the entire or portions of the outer surface of the mantle **120,** using any desired pattern.

[0045] The friction increasing particles **140** in one embodiment may comprise carbide particles, designed to bite into the surrounding surface of the casing or wellbore. Other friction-enhancing particles **140** may be used that are not hard enough to bite into the surrounding surface, but which add frictional improvement to the mantle **120,** such as elastomers or plastic particles that are harder than the elastomer forming the mantle 120.

[0046] The particles 140 may be of any desired size, and the density of distribution of the particles 140 may be any desired density. The particles 140 may be deposited on or embedded into the elastomer of the mantle **120** before disposition of the mantle **120** on the body **110,** or may be added after the mantle **120** is disposed on the downhole tool **100.**

[0047] In an alternate embodiment, instead of using particles **140** added to the outer surface of the mantle **120,** the outer surface of the mantle **120** may be scored or roughened mechanically producing random or patterned scorings or roughened areas to increase the friction coefficient of the surface of the mantle **120.**

[0048] FIG. **2** is a cutaway view of a downhole tool **200** according to one embodiment in which, instead of discrete particles 140, a mesh **240** is disposed about the mantle **120** to provide friction enhancement. The mesh **240** may be formed of wire, such as a stainless steel wire, or any other desired materials. As with the embodiment of FIG. **1,** the mesh **240** may be formed of the material hard enough to bite into the surrounding surface of the casing or wellbore, but may alternately simply be harder than the elastomer used to form the mantle **120.** The mesh **240** may be disposed on the outer surface of the mantle **120** or may be embedded into the surface of the mantle **120.**

[0049] FIG. **3** is a cutaway view of a downhole tool **300** according to yet another embodiment. In this embodiment, one or more areas of wickers **340** may be disposed annularly about the outer diameter of the mantle **120** to provide the desired friction enhancement. As illustrated in FIG. **3,** six areas of wickers **340** are provided, but the number and placement of the wicker areas **340** is illustrative and by way of example only. Any number of wicker areas **340** may be placed in any desired arrangement on the mantle **120.** Preferably, wicker areas **340** are placed proximal to the ends of the mantle **120** where extrusion around backup units **130** may occur.

[0050] The wickers may be formed of stainless steel or any other material. In one embodiment, the wickers may be formed of a material of sufficient hardness to bite into the surrounding surface. In another embodiment, the wickers do not need to be hard enough to bite into the surrounding surface, but simply are harder than the mantle 120, thus increase frictional drag on the mantle **120.**

[0051] The wickers may have any desired shape configured to increased friction, and do not need to be capable of anchoring the mantle **120** to completely prevent movement of the mantle **120** relative to the surrounding surface.

[0052] Although as described above the friction-enhancing material is disposed on the outer surface of the mantle **120,** and other embodiments the friction-enhancing elements, whether separate particles, meshes, wickers, or other forms, may be embedded into the elastomer of the mantle **120** below the outer surface. Under pressure from the expanded mantle 120 against the surrounding surface, the subsurface embedded friction-enhancing elements may, instead of directly engaging the surrounding surface to resist movement, pinch the elastomer of the mantle 120between the friction-enhancing elements **140, 240,** or **340,** enhancing friction between the mantle **120** and the surrounding surface.

[0053] By increasing friction between the mantle **120** and the surrounding surface, the friction-enhancing elements **140, 240,** and **340** reduce axial extrusion of the elastomer of the mantle **120** around the support assemblies or backup rings **130** disposed at the ends of the mantle **120.** By reducing extrusion, the pressure on the surrounding surface caused by the expansion of the elastomer radially outwardly may be increased.

[0054] It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments may be used in combination with each other. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention therefore should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein."

Claims

1. A downhole apparatus, comprising:

a swellable element comprising a swellable elastomeric material selected to increase in volume on exposure to at least one predetermined fluid; and
a first area, disposed with the swellable element and operable to increase friction between the swellable element and a surrounding surface upon swelling of the swellable element.

2. The downhole apparatus of claim 1, wherein the downhole apparatus is a swellable packer.

3. The downhole apparatus of claim 1 or 2, wherein the first area comprises a plurality of particles disposed on a surface of the first area, the particles selected for friction enhancement.

4. The downhole apparatus of claim 3, wherein the plurality of particles are dispersed randomly on the surface of the first area, or
wherein the plurality of particles are patterned onto the surface of the first area.

5. The downhole apparatus of any preceding claim, wherein the first area comprises a mesh disposed about an outer diameter of the first area, the mesh selected for friction enhancement, and optionally wherein the mesh is composed of stainless steel wire.

6. The downhole apparatus of any preceding claim, wherein the first area comprises
a plurality of wickers, formed of material selected for friction enhancement, or
wherein the first area comprises
a plurality of wickers, formed of material selected to be harder than the surrounding surface, or
wherein the first area comprises:
a roughened radially outward surface of a portion of the swellable element.

7. The downhole apparatus of any preceding claim, wherein the first area comprises the entire outer surface of the swellable element.

8. The downhole apparatus of any preceding claim, further comprising:

a backup member, configured to resist axial extrusion of the swellable element, disposed at an end of the swellable element, and optionally wherein the first area is proximal to the backup member.

9. The downhole apparatus of claim 1, wherein the first area comprises:

a friction-enhancing material, disposed on a first annular area of an outer surface of the swellable elastomeric material.

10. The downhole apparatus of claim 9, wherein the friction-enhancing material comprises a plurality of particles disposed on the outer surface of the first annular area, or
wherein the plurality of particles are formed from a material selected to have a hardness sufficient to bite into a surrounding surface when deployed in a casing or wellbore.

11. The downhole apparatus of claim 10, wherein the plurality of particles are randomly dispersed in the first annular area, or
wherein the plurality of particles are patterned on the first annular area.

12. The downhole apparatus of claim 9, 10 or 11, wherein the friction-enhancing material comprises a mesh, disposed about an outer diameter of the first annular area, or
wherein the friction-enhancing material comprises a plurality of wickers, disposed about an outer diameter of the first annular area.

13. The downhole apparatus of claim 9, 10, 11 or 12, wherein the predetermined fluid is an aqueous solution.

14. A method of reducing axial extrusion of a swellable element of a downhole tool, comprising:

disposing a friction-enhancing material on a portion of an outer surface of the swellable element.

15. The method of claim 14, wherein the act of disposing a friction-enhancing material comprises:

disposing particles of a substance harder than the swellable element on the portion of the outer surface of the swellable element, or

wherein the act of disposing a friction-enhancing material comprises:

disposing a plurality of wickers about the portion of the outer surface of the swellable element, or

wherein the act of disposing a friction-enhancing material comprises:

disposing a mesh formed of a substance harder than the swellable element about the portion of the outer surface of the swellable element, or

wherein the act of disposing a friction-enhancing material comprises:

embedding the friction-enhancing material into the portion of the outer surface of the swellable element.

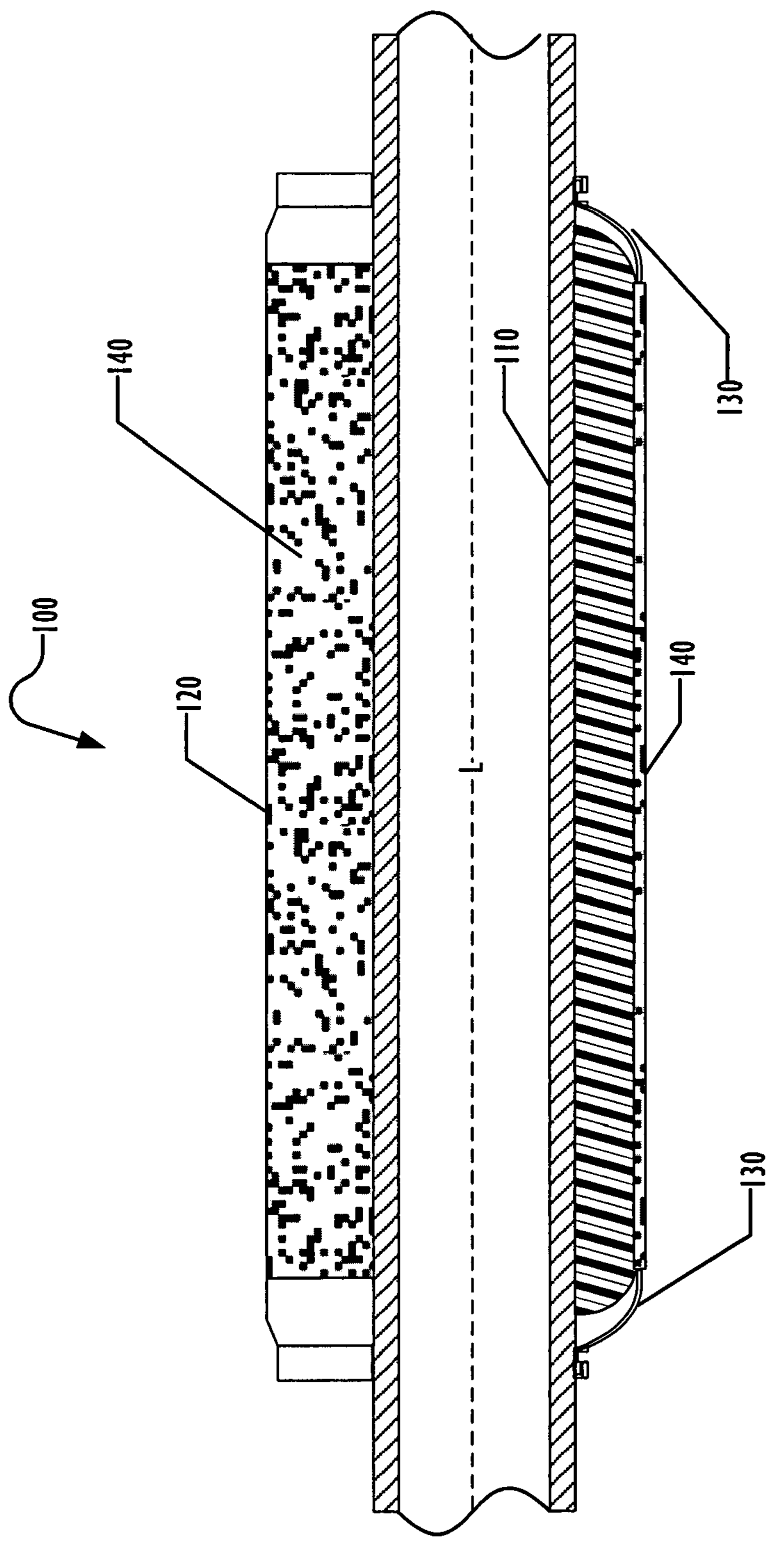

FIG. 1

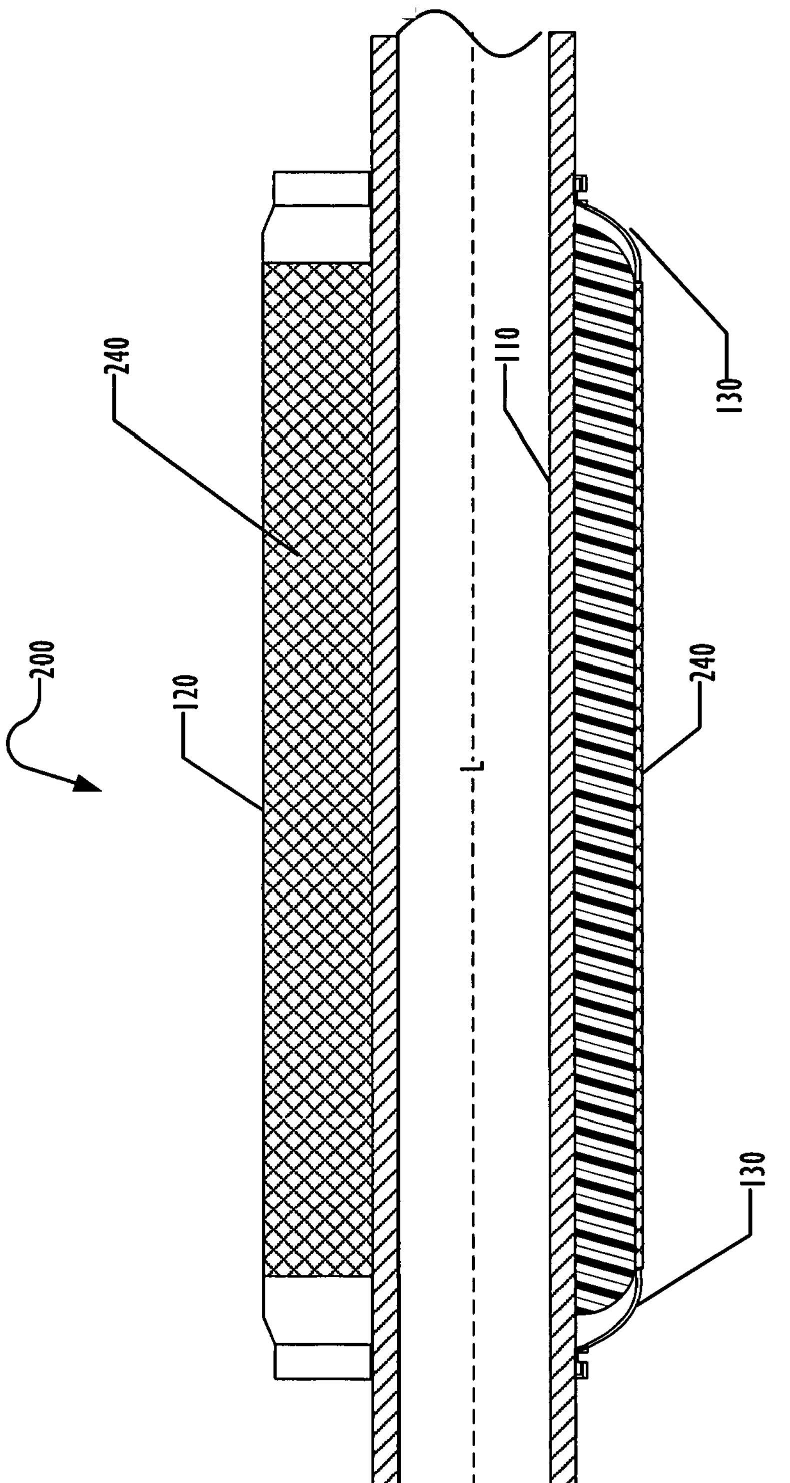

FIG. 2

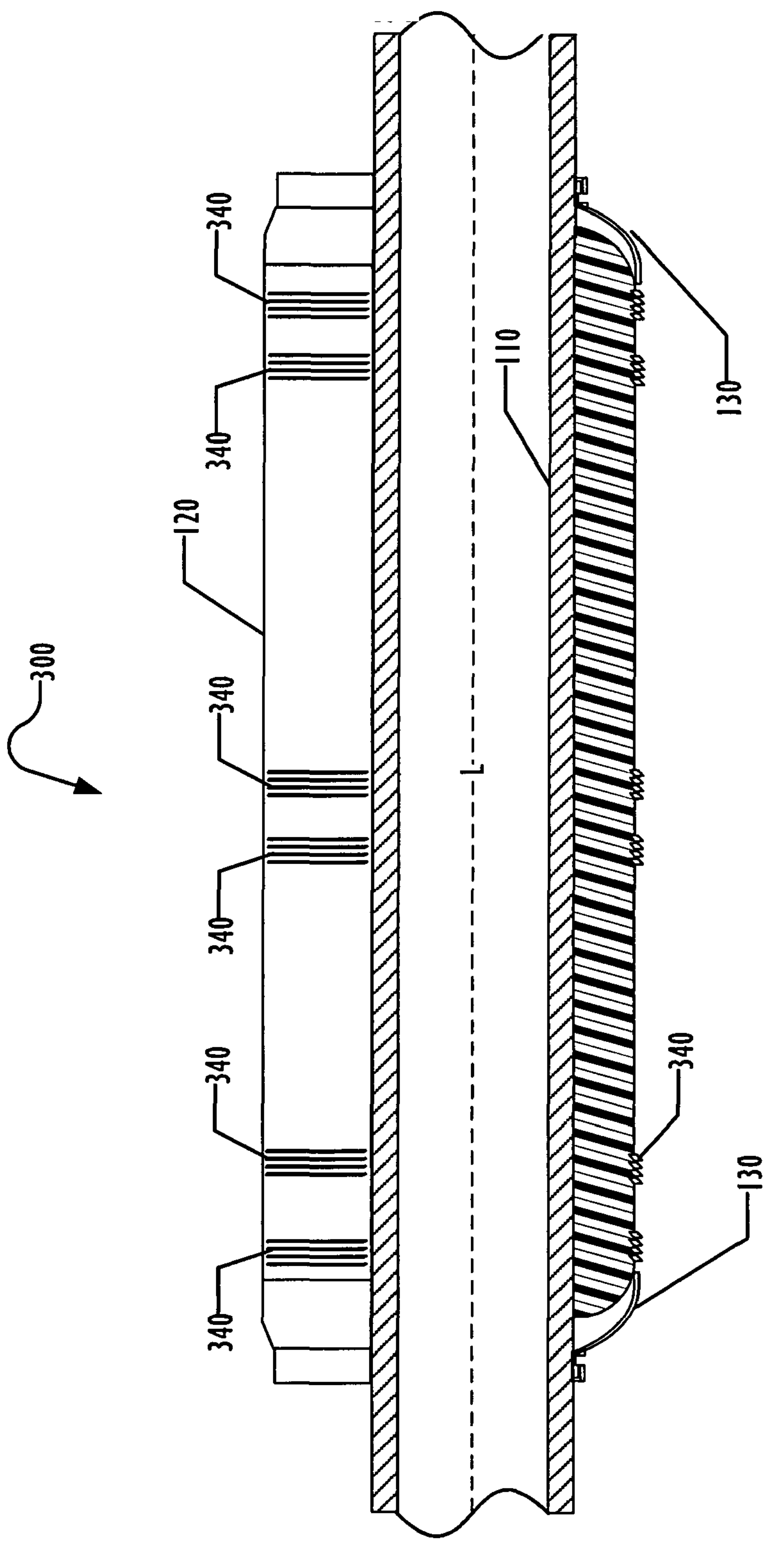

FIG. 3