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OPEN TIP DOWNHOLE EXPANSION TOOL

CROSS REFERENCE TO RELATED APPLICATIONS

5 [0001] This application claims the benefit of U.S. Application No. 17/132734, filed on December 23, 2020, which is incorporated herein by reference in its entirety.

BACKGROUND

10 [0002] In the resource recovery industry there is often reason to expand diametrically a tool. This may be to support a tubular or span an annulus, for example. One common tool that is frequently used will be characterized herein as an open tip downhole expansion tool. While there are a number of tools that fit within this characterization, one of them is a backup for an element of a seal. Such tools are deflected from a run in position to a deployed position based upon pressure in the element from inflation or compression thereof, for example. There are competing interests with respect to such tools. These are ease of setting and durability of holding once set. The simplest recitation of this is a thinner material tool 15 will set easily but also fail easily and a thicker material tool will be difficult to set but will likely not fail once set. It is important to the art to manage these competing interests.

20 [0003] In view of the above, the art will benefit from a new configuration for an open tip downhole expansion tool.

SUMMARY

25 [0004] An embodiment of an open tip downhole expansion tool including a frustoconical member having a base at a diametrically smaller portion of the frustoconical member and a tip at a diametrically larger portion of the frustoconical member, the member having a radially outer zone and a radially inner zone and having an axial length extending from the base to the tip; an outer compliance area in a material of the member along a length of the radially outer zone; and an inner compliance area in a material of the member along a length of the radially inner zone, the outer and inner compliance areas being located at different positions along the axial length of the frustoconical member, the outer and inner 30 compliance areas each causing the frustoconical member to present a first resistance to deformation when the compliance areas are in a first condition and a higher resistance to deformation of the frustoconical member when the compliance areas are in a second condition.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The following descriptions should not be considered limiting in any way.

With reference to the accompanying drawings, like elements are numbered alike:

[0006] Figure 1 is a schematic sectional view of an open tip downhole expansion tool
5 as disclosed herein;

[0007] Figure 2 is a schematic sectional view of an open tip downhole expansion tool that is relatively common in the art (prior art);

[0008] Figure 3 is a schematic sectional view of an open tip downhole expansion tool of greater thickness than would be used in the art but presented for comparison with
10 characteristics of the tool disclosed herein;

[0009] Figure 4 is a schematic view of all three above tools overlays and in a set position; and

[0010] Figure 5 is a graph of rubber pressure versus radial deflection of each of the open tip downhole expansion tools of Figures 1-3 used in a capacity as a seal element backup
15 ring; and

[0011] Figure 6 is a graph plotting rubber pressure versus axial deflection of each of the open tip downhole expansion tools of Figures 1-3 used in a capacity as a seal element backup ring after casing contact has occurred.

20 DETAILED DESCRIPTION

[0012] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0013] The terms “about”, “substantially” and “generally” are intended to include
25 the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application. For example, “about” and/or “substantially” and/or “generally” can include a range of $\pm 8\%$ or 5% , or 2% of a given value.

[0014] Referring to Figure 1 an open tip downhole expansion tool 10 is illustrated adjacent a gauge ring 12 on a mandrel 14 and within a tubular 16 in which the tool 10 is to be
30 set. The tool 10 as disclosed comprises a frustoconical member 18 whose structure demands only a relatively low pressure to set and yet provides a high resistance to failure through plastic deformation. The frustoconical member 18 includes a base 20 extending to an open tip 22 wherein the base presents a diametrically smaller structure than the tip 22. Frustoconical member 18 further features a radially outer zone 24 and a radially inner zone

26 that are delineated for illustrative purposes by a dashed line 28 along the member 18. It is to be understood that although, in Figure 1, the dashed line 28 roughly partitions the member 18 to be $\frac{1}{2}$ outer zone 24 and $\frac{1}{2}$ inner zone 26, it is contemplated that the radially inner zone 26 may be smaller or larger or the radially outer zone 24 may be smaller or larger including
5 the inner or outer zone being $\frac{1}{4}$ of the thickness of the material of the member 18 and the other of the radially inner or radially outer zone being $\frac{3}{4}$ of the thickness of the material of the member 18, for example. Further, the radially inner and radially outer zones need not together represent the entirety of the material thickness of the member 18. Rather, in
10 embodiments, there may also be one or more other zones through the thickness of the material; the radially inner and radially outer zone merely forming a portion of the whole. The frustoconical member 18 also presents an axial length 30 extending from the base to the base 20 to the tip 22.

[0015] An outer compliance area 32 is created in the material of the member along a length of the radially outer zone 24. The compliance area 32 may be in the form of a reduced material modulus. In one example such reduced modulus may be achieved by causing area 32 to have a reduced density. Density as a material property may be adjusted for the compliance area 32 such that the density of the material of the radially outer zone 24 in area 32 is less than the density of adjacent material of the radially outer zone 24. The material itself may be the same or a different material. Whether the material of the radially outer zone 24 is all the same and simply possesses a reduced density at the area 32 or is actually a distinct material at the area 32 having reduced density, or alternatively some other property that promotes deflection for a certain distance and then retards deflection beyond that distance, the purposes of the member 18 are achieved. The area 32 will compress more easily than surrounding areas until the density of the material in area 32 is raised by compressive forces thereon. After the material in area 32 is compressed, its strength and resistance to deflection increase. Reduced material modulus is easily achieved, for example, in an additive manufacturing process wherein same or different materials may be grown with same or different modulus. The art is well versed in how to achieve the material property differences employed in connection with the inventive structure as described herein. The depth of the compliance area 32, width of the compliance area 32, as well as the number of compliance areas 32 are adjustable parameters.

[0016] In Figure 1, compliance area 32 is illustrated. It is to be appreciated that in the embodiment of Figure 1, the compliance area 32 extends from the outside surface 33 of the

member 18 and into (and in some cases through) the radially outer zone 24 of the member 18. In an embodiment, the compliance area 32 is positioned to be where the member 18 will make contact with the gauge ring 12 or some other structure in the various embodiments. It is further to be appreciated, however, that other embodiments do not employ a gauge ring or similar at all but rather the compliance area 32 maximizes flexibility of the member 18 when setting. During the setting process, the compliance area 32 will start in a first condition where deflection is easier and become denser or work hardened, or experience some other material change that exhibits greater resistance to deflection or bending resistance in a second condition. The increase in bending resistance is valuable for containing higher element pressures that may be experienced after the setting process.

[0017] Similar to the compliance area 32, an inner compliance area 34 is also disclosed. The inner compliance area is placed in the material of the member 18 along a length of the radially inner zone 26. The compliance area 34 may be similar in form to that of compliance area 32 and extending into the material of the member 18 from a surface 35 of the member 18 or a chamber within the material of the member 18. The depth of the compliance area 34, width of the compliance area 34, as well as the number of compliance areas 34 are adjustable parameters. Depth of the compliance area 34 is related to overall member compliance with greater depth being proportional to greater compliance. In Figure 1, the compliance area 34 is illustrated. It is to be appreciated that in the embodiment of Figure 1, the compliance area 34 extends from the inside surface 35 of the member 18 and into (and in some cases through) the radially inner zone 26 of the member 18. The compliance area 34 is positioned as illustrated to be where the member 18 will need to bend in a direction to accommodate the tip 22 contacting an inside dimension of a tubular in which the tool is set. In some embodiments where a sealing element is employed, this maximizes flexibility of the member 18 about the element when setting. During the setting process, the compliance area 34 will become denser or work hardened, or experience some other material change that exhibits greater resistance to deflection or bending resistance. The increase in bending resistance is valuable for containing higher element pressures that may be experienced after the setting process.

[0018] Referring to Figure 4, each of a prior art open tip downhole expansion tool, a thicker open tip downhole expansion tool and the inventive open tip downhole expansion tool are overlayed to indicate the relative positions they would take during a setting process and at the same pressures. As one will appreciate, the inventive open tip downhole expansion tool is in a near perfect position while the prior art open tip downhole expansion tool is overly

deformed and ready to fail and the thick open tip downhole expansion tool has failed to be fully properly set. The prior art open tip downhole expansion tool will be inadequate for higher after setting pressures and the thick open tip downhole expansion tool will require excessive setting pressures. The inventive open tip downhole expansion tool maximizes usability and reliability.

[0019] With regard to the above assertion that resistance to deformation increases dramatically with compliance areas changing their bending resistance, the graphs identified as Figures 5 and 6 convey rubber pressure versus radial deflection of each of the open tip downhole expansion tools of Figures 1-3 used in a capacity as a seal element backup ring and rubber pressure versus axial deflection of each of the open tip downhole expansion tools of Figures 1-3 used in a capacity as a seal element backup ring after casing contact has occurred, respectively. It is readily apparent from these graphs that the inventive open tip downhole expansion tool performs significantly better than the others depicted. Similar benefits are reaped by using the inventive open tip downhole expansion tool for duties other than as a seal element backup ring. Considering Figure 6, the graph makes the superior properties of the disclosed tool evident.

[0020] Set forth below are some embodiments of the foregoing disclosure:

[0021] Embodiment 1: An open tip downhole expansion tool including a frustoconical member having a base at a diametrically smaller portion of the frustoconical member and a tip at a diametrically larger portion of the frustoconical member, the member having a radially outer zone and a radially inner zone and having an axial length extending from the base to the tip; an outer compliance area in a material of the member along a length of the radially outer zone; and an inner compliance area in a material of the member along a length of the radially inner zone, the outer and inner compliance areas being located at different positions along the axial length of the frustoconical member, the outer and inner compliance areas each causing the frustoconical member to present a first resistance to deformation when the compliance areas are in a first condition and a higher resistance to deformation of the frustoconical member when the compliance areas are in a second condition.

[0022] Embodiment 2: The tool as in any prior embodiment, wherein at least one of the radially inner zone and radially outer zone is about $\frac{1}{2}$ a radial thickness of a material of the frustoconical member.

[0023] Embodiment 3: The tool as in any prior embodiment, wherein one of the radially inner zone and radially outer zone is about $\frac{1}{4}$ of a radial thickness of a material of the frustoconical member.

[0024] Embodiment 4: The tool as in any prior embodiment, wherein at least one of the outer compliance area and the inner compliance area is of reduced modulus.

[0025] Embodiment 5: The tool as in any prior embodiment, wherein the reduced modulus is a function of material density.

[0026] Embodiment 6: The tool as in any prior embodiment, wherein the is a compliance area extends from an outer or inner radial surface respectively of the frustoconical member to a depth of between about $\frac{1}{4}$ and about $\frac{3}{4}$ of a radial thickness of a material of the frustoconical member.

[0027] Embodiment 7: The tool as in any prior embodiment, wherein the modulus of the compliance area changes during the setting of the tool.

[0028] Embodiment 8: The tool as in any prior embodiment, wherein at least one of the inner compliance area and the outer compliance area is a plurality of compliance areas.

[0029] Embodiment 9: The tool as in any prior embodiment, wherein the plurality of compliance areas each extend from a surface of the member into the material of the member

[0030] The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Further, it should be noted that the terms “first,” “second,” and the like herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another. The modifier “about” used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., it includes the degree of error associated with measurement of the particular quantity).

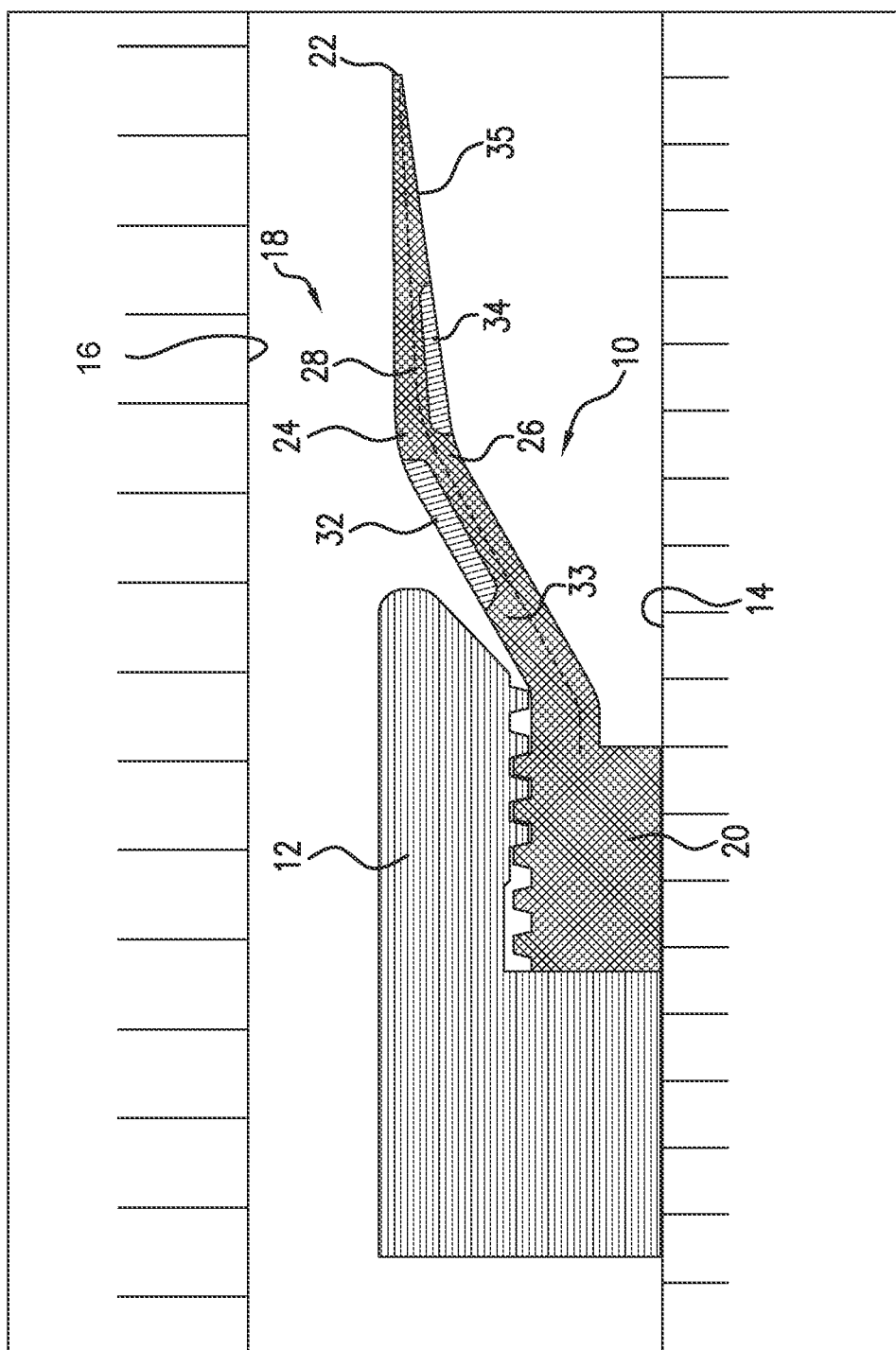
[0031] The teachings of the present disclosure may be used in a variety of well operations. These operations may involve using one or more treatment agents to treat a formation, the fluids resident in a formation, a wellbore, and / or equipment in the wellbore, such as production tubing. The treatment agents may be in the form of liquids, gases, solids, semi-solids, and mixtures thereof. Illustrative treatment agents include, but are not limited to, fracturing fluids, acids, steam, water, brine, anti-corrosion agents, cement, permeability modifiers, drilling muds, emulsifiers, demulsifiers, tracers, flow improvers etc. Illustrative well operations include, but are not limited to, hydraulic fracturing, stimulation, tracer injection, cleaning, acidizing, steam injection, water flooding, cementing, etc.

[0032] While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to
5 adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary
10 embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited.

What is claimed is:

1. An open tip (22) downhole expansion tool (10) characterized by:
a frustoconical member (18) having a base (20) at a diametrically smaller portion of the frustoconical member (18) and a tip (22) at a diametrically larger portion of the frustoconical member (18), the member (18) having a radially outer zone (24) and a radially inner zone (26) and having an axial length (30) extending from the base (20) to the tip (22);
an outer compliance area (32) in a material of the member (18) along a length (30) of the radially outer zone (24); and
an inner compliance area (34) in a material of the member (18) along a length (30) of the radially inner zone (26), the outer (32) and inner (34) compliance areas being located at different positions along the axial length (30) of the frustoconical member (18), the outer (32) and inner (34) compliance areas each causing the frustoconical member (18) to present a first resistance to deformation when the compliance areas (32, 34) are in a first condition and a higher resistance to deformation of the frustoconical member (18) when the compliance areas (32, 34) are in a second condition.
2. The tool (10) as claimed in claim 1 wherein at least one of the radially inner zone (26) and radially outer zone (24) is about $\frac{1}{2}$ a radial thickness of a material of the frustoconical member (18).
3. The tool (10) as claimed in claim 1 wherein one of the radially inner zone (26) and radially outer zone (24) is about $\frac{1}{4}$ of a radial thickness of a material of the frustoconical member (18).
4. The tool (10) as claimed in claim 1 wherein at least one of the outer compliance area (32) and the inner compliance area (34) is of reduced modulus.
5. The tool (10) as claimed in claim 4 wherein the reduced modulus is a function of material density.
6. The tool (10) as claimed in claim 3 wherein there is a compliance area (32, 34) extends from an outer (24) or inner (26) radial surface respectively of the frustoconical member (18) to a depth of between about $\frac{1}{4}$ and about $\frac{3}{4}$ of a radial thickness of a material of the frustoconical member (18).
7. The tool (10) as claimed in claim 4 wherein the modulus of the compliance area (32, 34) changes during the setting of the tool (10).
8. The tool (10) as claimed in claim 1 wherein at least one of the inner compliance area (34) and the outer compliance area (32) is a plurality of compliance areas.

9. The tool (10) as claimed in claim 8 wherein the plurality of compliance areas each extend from a surface of the member (18) into the material of the member (18)



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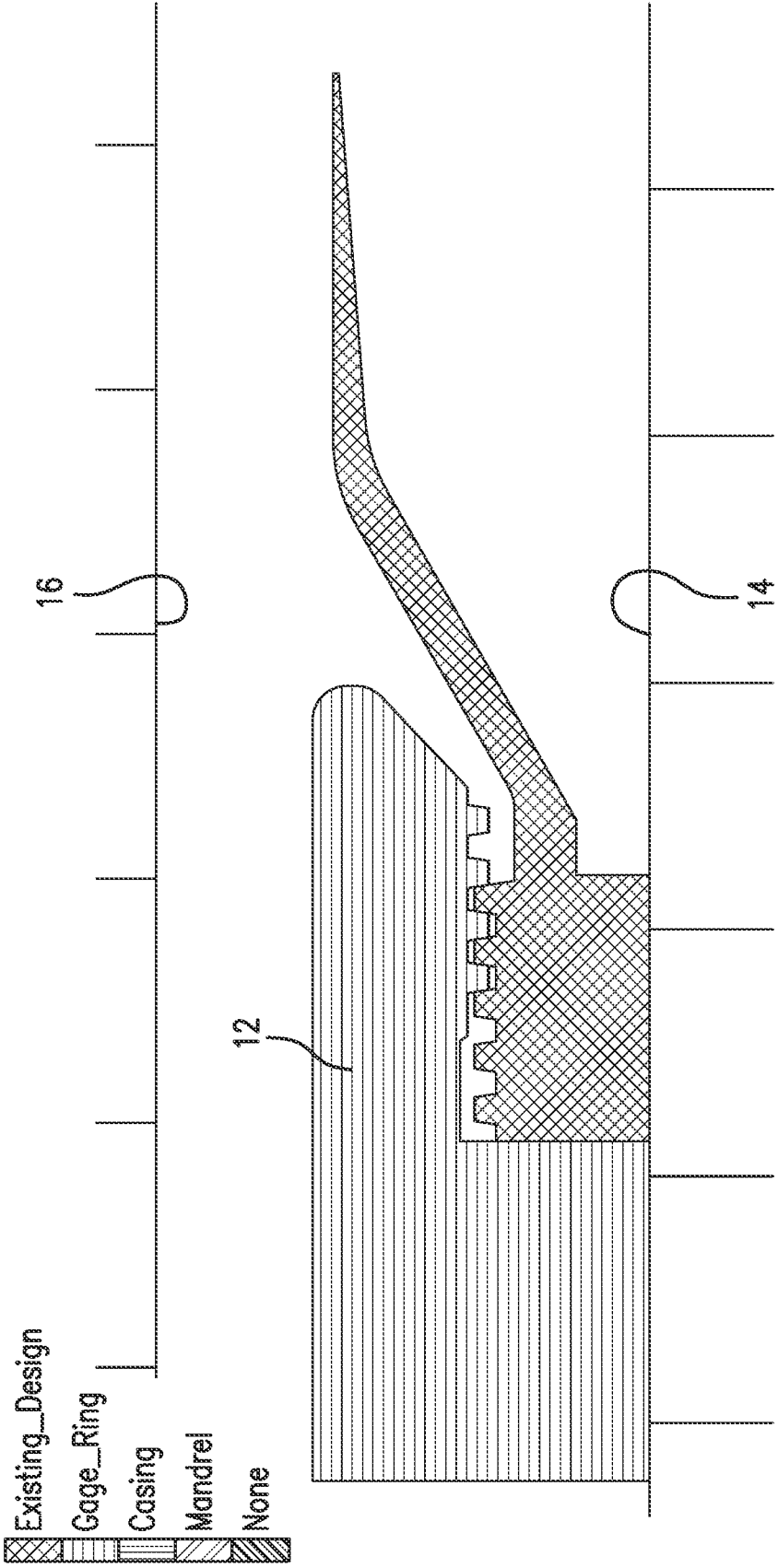


FIG.2 (Prior Art)

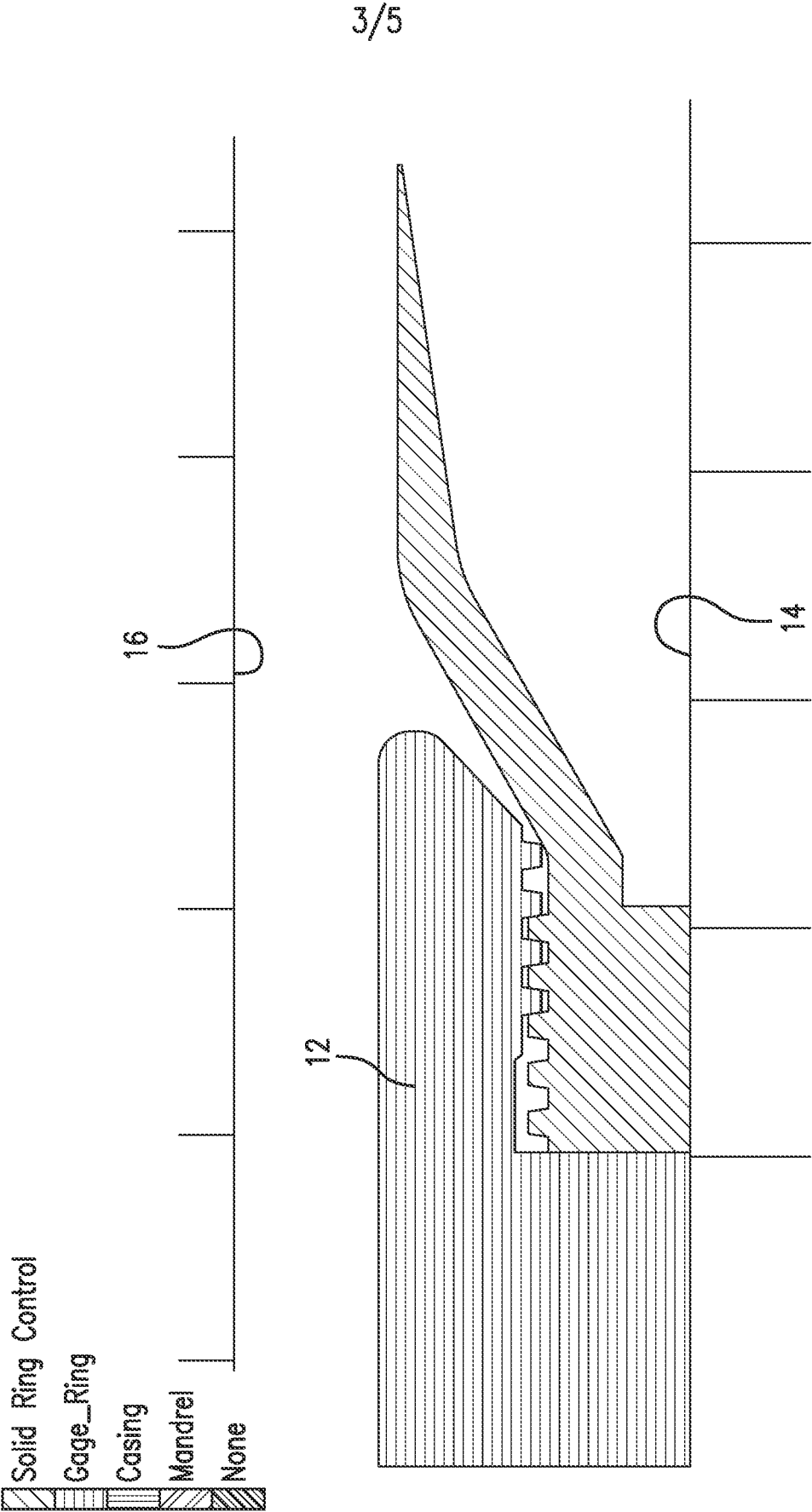


FIG.3

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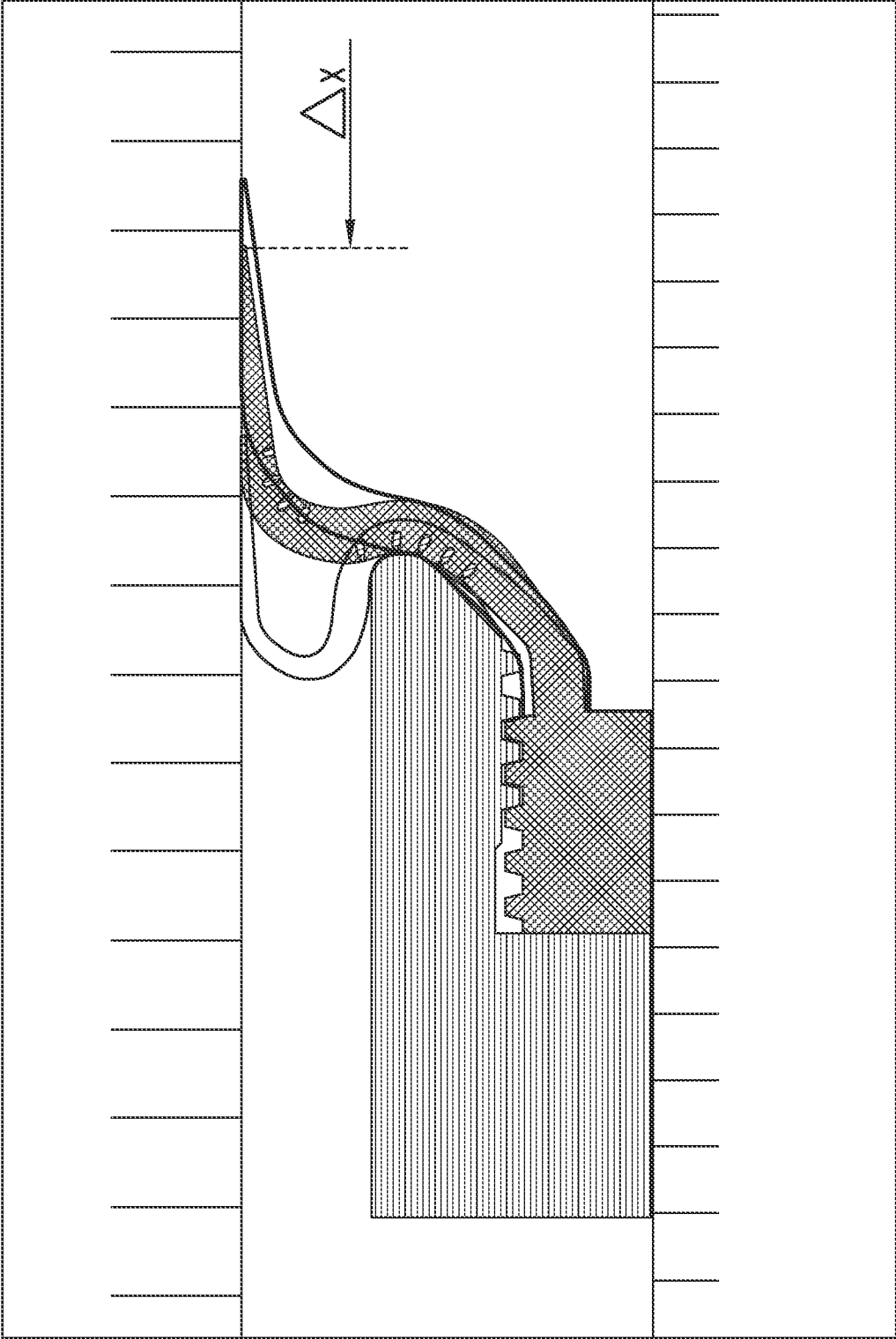


FIG.4

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Example Back-Up Ring Radial Deflection During Set
Expected Performance Based On FEA Simulation

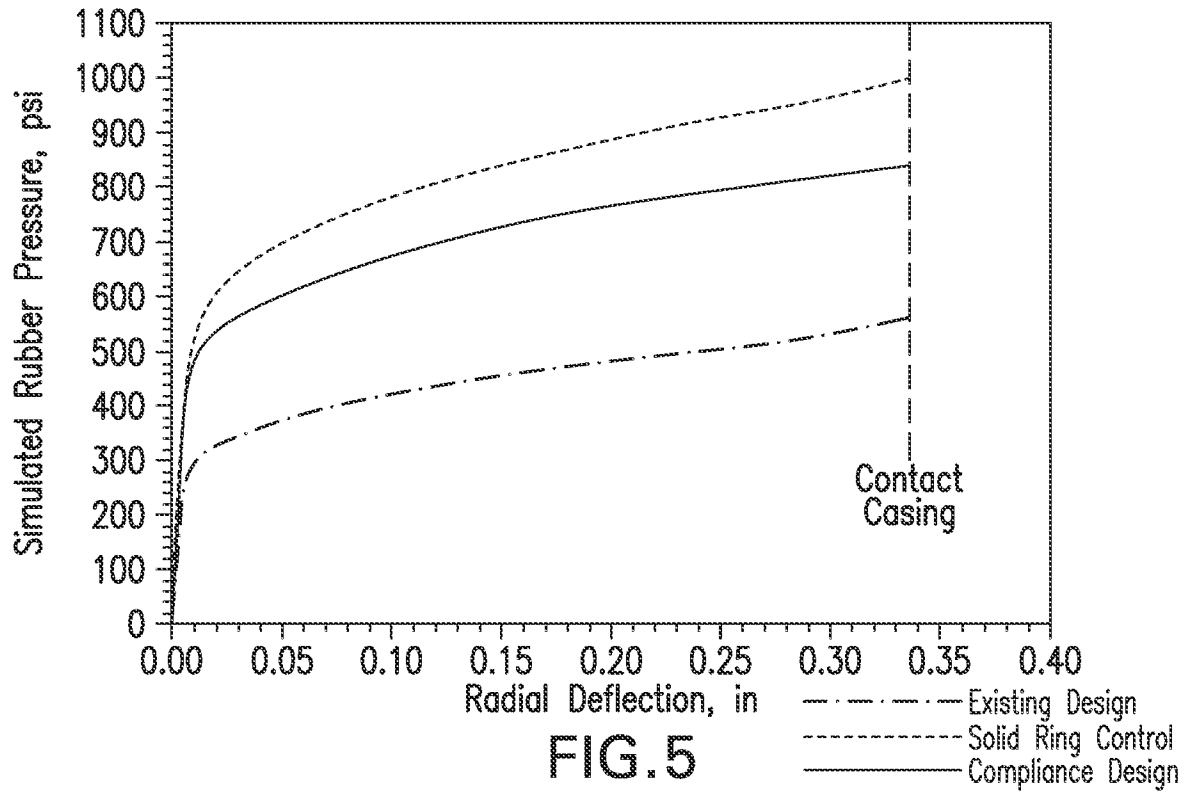


FIG. 5

Example Back-Up Ring Radial Deflection During Set
Expected Performance Based On FEA Simulation

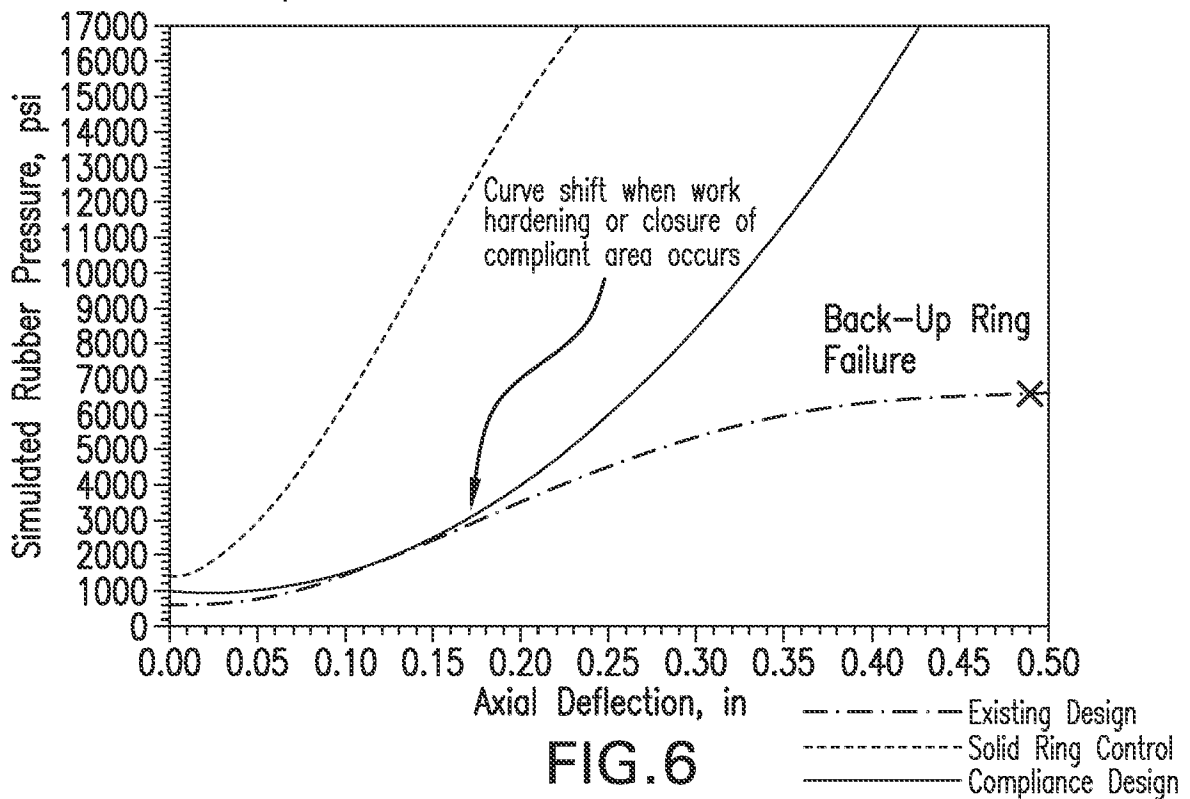


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2021/073011

A. CLASSIFICATION OF SUBJECT MATTER E21B 23/04(2006.01)i; E21B 23/01(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) E21B 23/04(2006.01); E21B 23/06(2006.01); E21B 33/12(2006.01); E21B 33/128(2006.01); F16J 15/16(2006.01); F16J 15/18(2006.01) Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models Japanese utility models and applications for utility models Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS(KIPO internal) & Keywords: open tip downhole expansion tool, frustoconical member, outer compliance area, inner compliance area, deformation, resistance		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2018-0172160 A1 (URBAN et al.) 21 June 2018 (2018-06-21) paragraphs [0001]-[0038]; and figures 1-2	1-9
Y	US 2019-0040710 A1 (DENG et al.) 07 February 2019 (2019-02-07) paragraphs [0019], [0044]; and figures 1-10	1-9
Y	US 2013-0147121 A1 (XU, YINGQING) 13 June 2013 (2013-06-13) paragraph [0024]; and figures 1-7	2-3,6
A	WO 2019-051468 A1 (BAKER HUGHES, A GE COMPANY, LLC.) 14 March 2019 (2019-03-14) claims 1-13; and figures 1-11	1-9
A	US 2012-0217025 A1 (SHKURTI et al.) 30 August 2012 (2012-08-30) claims 1-15; and figures 4-7C, 13-14	1-9
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "D" document cited by the applicant in the international application "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 15 April 2022		Date of mailing of the international search report 15 April 2022
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon 35208, Republic of Korea Facsimile No. +82-42-481-8578		Authorized officer LEE, Hun Gil Telephone No. +82-42-481-8525

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/US2021/073011

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				WO	2012-118772	A3	28 February 2013