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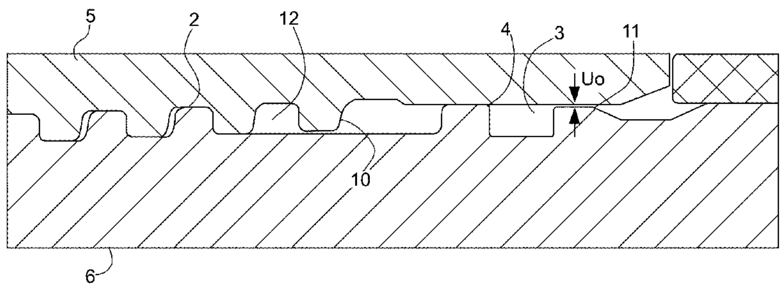
Fig.1C



(57) Abstract: A pin-box well tubular connector assembly having pin and box connector members (6, 5) with intermeshing external and internal screw thread profiles is optimized for expansion downhole in a wellbore by: A) inserting a swellable dope in the gap between the pin and box connector members (6, 5) and optionally B) configuring the pin and box connectors (6, 5) such that in axial direction a gap of at least 0.2 mm is present between the external and internal screw thread profiles; and/or C) configuring the box connector member (5) such that it has at least one thread (10) that does not engage a thread on the pin member (6).

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EXPANDING WELL TUBULARS INTERCONNECTED BY PIN-BOX ASSEMBLIES OPTIMIZED FOR EXPANSION

BACKGROUND OF THE INVENTION

The invention relates to a method and system for expanding well tubulars interconnected by pin-box assemblies that are optimized for expansion.

A known well tubular expansion system and method are disclosed in International patent application WO2012104257.

In this known method a well tubular is expanded downhole in a wellbore of an oil and/or gas production well by mechanically pulling or hydraulically pushing an expansion cone therethrough.

A problem with this known method is that if a pair of tubulars interconnected by a pin-box screw thread connector assembly is expanded this generates high stresses in the assembly when the expansion cone is pulled or pushed therethrough, which may cause the screw thread assembly to leak and/or fail.

There is a need for an improved method and system for expanding well tubulars interconnected by pin-box assemblies that are optimized for expansion.

SUMMARY OF THE INVENTION

In accordance with the invention there is provided a method for expanding a pair of well tubulars that are interconnected by a pin-box connector assembly comprising pin and box connector members with intermeshing external and internal screw thread profiles, the method comprising:

- inserting a swellable dope in the gap between the pin and box connector members;

- interconnecting the pair of well tubulars by means of the optimized pin-box connector assembly; and
- radially expanding the interconnected well tubulars by moving an expansion cone therethrough.

Optionally the pin and box connector members are further optimized for expansion by:

B: configuring the box connector member such that it has at least one thread that does not engage a thread on the pin connector member; and/or

C: configuring the pin and box connector members such that in axial direction a gap of at least 0.2 mm, optionally between 0.3 and 0.5 mm, is present between the external and internal screw thread profiles.

Optionally:
- the pin and box connector members each have base and tip sections that are configured such that a base section of the pin connector member engages a tip section of the box connector member and a tip section of the box member engages a base section of the pin member, and
- the box connector member has an extended tip section that comprises a ring-shaped sealing lip that engages a ring-shaped sealing shoulder at the base section of the pin member, wherein optionally the at least one thread of the box connector member that does not engage a thread on the pin connector member is an idle thread that forms part of the extended tip section of the box connector member and optionally a swellable pipe dope is inserted between the pin and box connector members, which pipe dope swells upon contact with a wellbore fluid and/or heating during the expansion process.

The well tubulars may be expanded to generate a MOnoDiameter(MOD) wellbore section with a substantially constant internal diameter of a hydrocarbon fluid production well, through which, after completion of the well, a larger flux of crude oil, natural gas and/or another hydrocarbon fluid can be produced than through conventional telescoping wells, and/or which can reach formation layers from which no hydrocarbon fluid can be economically produced with conventional telescoping wells.

Optionally, at least 10 adjacent pairs of well tubulars are each interconnected at a wellhead by the screw threaded pin-box assemblies to an elongate upper expandable tubular string having a length between 200 and 2000 meters and the elongate expandable tubular string is expanded downhole by moving an expansion cone therethough.

Subsequently:

- a subsequent lower wellbore section having a length between 200 and 2000 meters may be drilled below a lower end of the expanded tubular string;

- at least 10 adjacent pairs of lower well tubulars are each interconnected at the wellhead by the screw threaded pin-box assemblies to an additional lower expandable tubular string having a length between 200 and 2000 meters;

- the additional lower expandable tubular string is lowered through the expanded upper tubular string until an area of overlap between the upper and lower tubular strings has a length between 10 and 100 meters, optionally between 30 and 70 meters; and

- the lower expandable tubular string is expanded downhole by moving an expansion cone therethrough, thereby expanding the lower tubular string in the area of overlap against the upper tubular string such that the lower expandable tubular string has after expansion thereof, except in the area of overlap, an internal width substantially similar to an internal width of the expanded upper tubular string.

In accordance with the invention there is furthermore provided a well tubular assembly for use in the method according to the invention, the well tubular assembly comprising a screw threaded pin-box connector assembly wherein a swellable pipe dope is inserted between the pin and box connector members, which pipe dope swells upon contact with a wellbore fluid and/or heating during the expansion process which box connector member is optimized for expansion by.

Optionally the box connector member is further optimized for expansion by:

B: configuring the box connector member such that it has at least one thread that does not engage a thread on the intermeshing pin connector member; and/or

C: configuring the box connector connector member such that in axial direction a gap of at least 0.2 mm is present between the external and internal screw thread profiles.

These and other features, embodiments and advantages of the well tubular expansion method, expandable well tubular and well tubular assembly according to the invention are described in the accompanying claims, abstract and the following detailed description of non-limiting embodiments depicted in the accompanying drawings, in which description reference numerals are used which refer to corresponding reference numerals that are depicted in the drawings.

Similar reference numerals in different figures denote the same or similar objects. Objects and other features depicted in the figures and/or described in this specification, abstract and/or claims may be combined in different ways by a person skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1A-C show an expandable pin-box well tubular connection assembly according to the invention; and

Figure 2 shows how an pin-box well tubular connection assembly is deformed during the expansion process.

DETAILED DESCRIPTION OF THE DEPICTED EMBODIMENTS

The invention relates to an expandable pin-box well tubular connection assembly which is optimized for expansion within an oil and/or gas production well.

The tubulars may be expanded using an expansion mandrel which is mechanically pushed or pulled or hydraulically pumped through the tubulars. Also a combination of mechanical or hydraulic action is possible. The expandable tubulars are connected by means of threaded connections, which are also expanded. The threaded connection consist of a male, or pin, member, which has external threads. The female or box member of the connection has internal threads. The connection may have multiple seal features, like O-rings in addition to the threads. On assembly the prior to expansion, the box and pin member are screwed into each other. The design of threaded connections for expandable tubulars has to take into account many conflicting requirements that arise from the deployment in an oil or gas well, during the expansion and during the post-expansion well functional life.

Typically the connections for use in expandable applications preferably have a near flush internal or external profile as compared to the bodies of the tubulars that they connect. This avoids that a significant increase of the expansion force occurs while expanding through the connections. On the other side the connection preferably has a mechanical strength which is matching that of the pipe body and also is pressure tight under the acting loads. This is also more difficult to achieve for a slim connection as for a connection, which has a thicker profile than the pipe body.

The expansion mandrels used for tubular expansion typically consist of a sequence of multiple sections over which the pipe is transformed from is unexpanded to its final expanded state, for example a sequence of cylindrical, concave rounded, conical, or convex rounded sections can be used. Also a more continuously varying mandrel geometry can be used.

Figure 2 illustrates the deformation of an expandable tubular when the expansion cone is progressed through it. However, for convenience of the discussion, the cone is considered stationary and while the pipe is then assumed to flow over it. As the tubular material flows over the mandrel surface, the inner diameter of the pipe continuously increases and the wall thickness decreases.

Next to the radial expansion of the material, also bending effects occur. At the front of the expansion mandrel the material is bent form the undeformed straight shape, into a curved transition shape and then bent back straight again as it reaches up the predominant conical section of the mandrel. During this bending cycle material on the outside of the pipe is first compressed in axial direction and is thereafter elongated again. Material on the inside wall undergoes the reverse cycle. Another bending cycle is incurred when the pipe runs over the transition zone from the predominantly conical section to the final diameter of the mandrel. During this cycle, material on the outside of the pipe is first elongated in axial direction, and is subsequently compressed again when reaching is final expanded state.

When the connection is expanded by the mandrel then it has to follow nominally the same motion, but here also a relative motion between the threads of the pin and box members can occur. Threads can partly separate during and after the expansion. In addition, there can be residual clearance between the threads or at the areas of the connection where the sealing function is to be provided. For this reason many of the reported prior art connections have seal features at the extreme positions of the box and pin members, in order to have a separation of functions. The thread section in between the seals, takes account for the load mechanical transfer. In prior art the optimization of the cone shape and thread shapes have been discussed to minimize distortion of the connection geometry during and after expansion.

In addition, the connection must also provide in a sealing function. For this, it is required that the in the areas where the sealing function of a connection is to be provided, that there exists an interference or minimal gap between the pin and box members.

A further point that has to be taken into account is that the in-situ load conditions can vary, under which a connection is being expanded in a well. The combination of the in-situ loads in the well and the expansion forces affect the plastic straining during expansion and thus the post-expansion geometry, mechanical and sealing integrity of a connection.

Gravity loads act on the length of the expandable string. During the expansion of the tubulars and connections at the bottom of an expandable tubular string this induces compression in the liner just above the zone, which is actively being expanded. This compression also has to be transferred through the zone of active straining, down to the support point of the liner to the formation. The compression therefore is transferred through the connection as it is being expanded.

During the expansion at the top of an expandable liner string then no or only a small compression is to be transferred through the connections while they are being expanded.

When a tubular is expanded, it has the natural tendency to shorten in axial length. This may generate a situation where the expansion takes place under conditions that the natural shortening of the liner during expansion is restricted. This can occur when the liner gets stuck both below above the zone where active expansion takes place. As a result of this a high tensile force develops in the liner. This means that also this high tensile force is transferred through the connections while they are being expanded. These expansion conditions are called fixed-fixed conditions.

The expandable connections of prior art expandable tubular assemblies are generally designed such that prior to expansion, there is a tight engagement of the threads on the pin and the box members. The engagement after assembly is at least in radial direction, and at least on one of the flanks in axial direction. The axial clearance between the threads is incorporated in the design to compensate for machining tolerances and elastic deformations of the thread geometry during assembly. This will allow taking both expansion loads and compressions load, without causing motion due to any axial play in the threads.

The in-situ tension conditions or compression conditions remain to act during the expansion of a connection. Generally it is not certain whether the fixed-fixed condition will actually occur, and therefore the design should be capable of being expanded under both compression conditions as under the high tensile conditions.

Prior art connections can use elastomeric seal rings incorporated in concentric grooves at in the base section of the pin or box member of the connection. Such known arrangements would prevent pressure or fluids to penetrate from the bore of the expandable tubular into the annular cavity between the pin and box. The seal ring and the groove can be or other cross sectional shapes, like square, x-ring or Chevron seal. A dovetail groove shape may also be applied.

A connection that is expanded under high tension conditions, as occurs during fixed-fixed conditions, generally may induce an axial separation of the threads. This may be simulated using finite element calculations and is also observed in actual connections that are expanded under these conditions. The reason is that the cross section under a thread root stretches axially relatively to the cross section on the opposing member having the thread. In addition, the box member may become strongly deformed radially outwards at the last thread before the tip section. Further analysis showed that this outward movement / deformation of the box is caused by the high load transfer by the last thread during the final bending cycle as the connection is being expanded by the expansion mandrel. The high contact load on the last thread induces a bending moment, which cannot be resisted by the local relatively thin tip section of the box. As a result the tip section of the box bends outwards locally and thereby also stretching the material of the box member in circumferential direction over a length along the tip section.

This outward deformation of the box tip section at the last thread can cause a reduction or even the loss of seal contact and thus the loss of connection sealing integrity of prior art connections.

For a high pressure capability it is however required that any gap to be bridged by a seal is minimized, such that the seal means is not extruded into such a gap and damaged under the acting external pressure. It is the objective of the current invention to reduce minimize the gap at an external seal between the pin and box member, when expanding the connection under fixed-fixed conditions.

This is achieved in accordance with the invention by the extended lip shown in Figures 1A-C in which the box axial distance 1 is extended between the last thread 2 on the pin member 6 and the seal groove 3, significantly beyond the length strictly needed for a thread run-out (about on pitch length of the thread) and for the seal groove 3 and "down-stream" seal support crest 4. The extended length causes that any outward movement of the box member 5 can be transferred with less rotation of the box towards the seal. In addition the hoop strength of the tip section 13 of the box member 5 increases.

Adding the extended length enables in accordance with the invention to generate one or more additional "idle" thread windings 10 on the interior in of the box member 5. These threads 10 are "idle" in the sense that these threads 10 are not engaged or not transferring loads with any threads on the pin member. The advantage of the idle threads 10 is that they effectively increase the longitudinal cross section area and thus the strength of the tip section of the box in hoop direction, and thus provide a higher resistance against the bending induced by the load transfer at the last engaged thread.

Furthermore the outer diameter of the "up-stream" seal support crest 11 may be reduced such that the contact point with the box member 5 is lowered radially inwards.

The extended length in a preferred embodiment fulfills the following criterion. The gap at the "Down-stream" seal support crest 4, into which a seal can be extruded is denoted by S_{max} and is generally prescribed by seal manufacturers in dependence of a the characteristic cross section dimension of the seal, the material hardness and the pressure to be sealed. A typical value for O-ring seals with a chord diameter of 1-3 mm is a maximum radial gap with S_{max} = 0.05 mm.

Referring to Figure 1B with the outward radial movement of the box is denoted by U_b, and the axial length L_c between "Down-stream" seal support crest 4 and the contact point between the box and the pin member then the extended length of the box has the preferential length:

$L_b \geq (U_b - U_0)/S_{max} \times Lc$

wherein U_0 denotes the degree by which the radial height of the "up-stream" seal support crest has been lowered, as shown in Figure 1C.

Groove 3 for a seal means between the pin and the box members 5 and 6 may be filled with a swellable elastomer, rather than a conventional resilient seal. The swellable elastomer may be applied by brushing or spraying at a well site or at a tubing manufacturing or storage site. Also other cavities 12 between the pin and box members, may thus be filled with a swellable elastomer. The swellable elastomer is applied when assembling the connection. The swellable elastomer swells when it comes in contact with the well bore fluids and/or is heated by the friction between the expansion cone and expanded tubular string and therefore is able to compensate any created clearance. The amount by which such an elastomer can swell may be limited, and may be a fraction of the initial thickness in the as assembled state prior to expansion. Therefore, it is advantageous that the optimized pin-box design contains, preferably concentric, grooves or an alternative cavity space, which will allow for a large volume of swellable elastomer to be contained and a large clearance to be bridged by means of swell. The depth of the groove is preferably such that the remaining cross sectional area A_g underneath the elastomer filled groove is equal to or exceeds the area A_r under the root of the last engaged thread. To this end a groove may be cut in the box member 5, opposite to the tip of the pin member 6.

Experiments were performed whereby a pin box connector assembly according to the invention provided with a swellable dope was expanded and was thereafter subjected to differential pressure with water. This allowed the elastomer in the grooves to swell and bridge the gap. It is further seen that the expansion has created a clearance around the threads, but locally there was insufficient swellable elastomer present that this gap could be closed.

When expanding a connection under in-situ compression conditions in a well, then this compression has to be transferred through the connection during the expansion. The compression load affects the deformations that occur in the connection during expansion. In prior art expandable connections this results in a radial separation between threads of the pin and the box member. This also induces a separation near the external seal area at the box tip section, which could further result in a leakage.

The stab-flank / compression flank angle of prior art connections can be reduced in order to make the flanks more perpendicular to the center line of the connection. However, such a modification has limited effect on the separation occurring during expansion under compression conditions. Also it has to be taken into account that the combination of a conical thread arrangement (as most prior art connections have) and a negative stab flank of the thread shape cannot always be screwed in.

Further analysis showed that the separation of the threads occurs during the later stages of the expansion. Initially, the final threads of the box are still in good engagement when the largest section of the expansion mandrel passes along and the tip section of the box member has already been expanded to the final diameter. The thread separation occurs later when the parts further along the threaded section and towards the tip of the pin member become fully expanded. The fundamental reason for the radial thread separation is that both the pin and the box member shorten during expansion. However under compression conditions the shortening of the pin member is a fraction larger than that of the box member. In relative terms therefore the pin member shortens, while the box member tends to restrict this. The threads at the fully expanded section remain axially interhooked and as a result a compressive force in the box develops. The thickness of the box near the tip area, and therefore the compressive strength is less than those in the opposing base section of the pin. As a result of the renewed plastic deformation in the form of axial shortening occurs in the box. Because the volume of steel is retained, the box member also displaces radially outwards, i.e. belling out of the box member. This latter response causes a radial separation of the pin and box threads and a separation of the seal.

The optimized pin-box assembly according to the invention may reduce or avoid the radial separations of the threads when expanding the pin-box assembly under compression conditions.

This may be achieved by introducing in the design an axial play of at least 0.2mm, optionally between 0.3 and 0.5 mm, between the threads of the pin and the box member as shown in Figures 1 and 2. The degree of axial play can be adjusted such that after expansion there is limited axial contact along the threads, while high compression forces in the box are avoided and yield limits are not exceeded.

The axial thread play is to compensate for the effect that during the expansion of a threaded connection under compression, the axial shortening of the pin member of the connection is larger than that of the box member.

This differential shortening generates an incompatibility (with high internal forces generated in the connection, if not mitigated by the invention) which is proportional to both:

1: the axial length L_eng along which the threads on both members are engaged,

2: the expansion ratio Exp_rat, which is defined as (ID_after_exp / ID_before_exp - 1) x 100%.

In the connection design according to the invention, the pipe and connection were expanded from an initial 8.755 inch (222.377 mm) inner diameter to an expanded 10.2 inch (259.08 mm) inner diameter.

Therefore, the expansion ratio Exp_rat = (10.2 / 8.755 -1) x 100% = 16.5. The design has an axial thread engagement length of about 115mm.

In a first design I an axial play of about 0.41mm was applied on the threads before expansion. The resulting connection shape after expansion was simulated using a finite element simulation technique to model the expansion process which indicated that at all threads there still exists an amount of play after expansion. Therefore, the initial amount of axial play given was still a bit too large.

In a second further optimized thread design II the axial play on the threads before expansion was reduced to about 0.37mm. The above described finite element simulation technique was also used to generate the calculated post expansion geometry and axial gaps at both sides of the threads.

The finite element simulation technique indicated that this second thread design II is already “axially locked” in the sense that the pin member threads on the extreme right side of the connection are in contact at the left (stab) flank of thread, while the threads at the extreme left side of the thread are in contact on right (load) flank of the thread.

The finite element simulation technique indicated that an optimised thread should have an initial play which about fulfills the condition:

Axial_thread_play = Exp_Rat x L_eng x 0.37 / (115 x 16.5) = 5100 x Exp_Rat x L_eng

Wherein the feature Exp_Rat is specified in % and L_eng in mm.

The finite element simulation technique furthermore indicated that a thread design with less axial play will develop compressive loading in the box after expansion.

It is observed that this axial play is significantly more than the axial play required for free running during assembly or for compensating machining inaccuracies within generally used specifications of threads for interconnecting oilfield tubulars.

Therefore, the method, system and/or any products according to present invention are well adapted to attain the ends and advantages mentioned as well as those that are inherent therein.

The particular embodiments disclosed above are illustrative only, as the present invention may be modified, combined and/or practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein.

Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below.

It is therefore evident that the particular illustrative embodiments disclosed above may be altered, combined and/or modified and all such variations are considered within the scope of the present invention as defined in the accompanying claims.

While any methods, systems and/or products embodying the invention are described in terms of "comprising," "containing," or "including" various described features and/or steps, they can also "consist essentially of" or "consist of" the various described features and steps.

All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values.

Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

Moreover, the indefinite articles "a" or "an", as used in the claims, are defined herein to mean one or more than one of the element that it introduces.

If there is any conflict in the usages of a word or term in this specification and one or more patent or other documents that may be cited herein by reference, the definitions that are consistent with this specification should be adopted.

CLAIMS:

1. A method for expanding a pair of well tubulars that are interconnected by a pin-box connector assembly comprising pin and box connector members with intermeshing external and internal screw thread profiles, the method comprising:
   - configuring the pin and box connector members such that they are optimized for expansion by inserting a swellable dope in the gap between the pin and box connector members;
   - interconnecting the pair of well tubulars by means of the optimized pin-box connector assembly; and
   - radially expanding the interconnected well tubulars by moving an expansion cone therethrough.
2. The method of claim 1, wherein the method furthermore comprises configuring the pin and box connector members such that the box member has at least one thread that does not engage a thread on the pin connector member.
3. The method of claim 1 or 2, wherein the method furthermore comprises configuring the pin and box connector members such that in axial direction a gap of at least 0.2 mm is present between the external and internal screw thread profiles.
4. The method of claim 1,2, or 3 wherein:
   - the pin and box connector members each have base and tip sections that are configured such that a base section of the pin connector member engages a tip section of the box connector member and a tip section of the pin connector member engages a base section of the box connector member, and
   - the box connector member has an extended tip section that comprises a ring-shaped sealing lip

that engages a ring-shaped sealing shoulder at the base section of the pin connector member.

5. The method of claim 4, wherein the at least one thread of the box connector member that does not engage a thread on the pin connector member is an idle thread that forms part of the extended tip section of the box connector member.

6. The method of any one of claims 1-5, wherein the swellable pipe dope swells upon contact with a wellbore fluid and/or heating during the expansion process.

7. The method of claim 6, wherein the swellable pipe dope fills upon swelling at least a substantial part of an annular space at the extended tip section of the box connector member within the ring-shaped sealing lip that engages the ring-shaped sealing shoulder at the base section of the pin connector member.

8. The method of any one of claims 1-7, wherein a base section of the pin connector member is configured in an substantially similar mirrored manner as the tip section of the box connector member and the well tubulars are expanded within a wellbore through which, after well completion, crude oil, natural gas and/or other hydrocarbon fluids are produced.

9. The method of claim 8, wherein the well tubulars are expanded to generate a MOnoDiameter(MOD) casing or liner assembly with a substantially constant internal diameter of a hydrocarbon fluid production well, through which, after completion of the well, a larger flux of crude oil, natural gas and/or another hydrocarbon fluid can be produced than through conventional telescoping wells, and/or

which can reach formation layers from which no hydrocarbon fluid can be economically produced with conventional telescoping wells.

10. The method of claim 9, wherein at least ten adjacent pairs of well tubulars are each interconnected at a wellhead by the screw threaded pin-box assemblies to an elongate upper expandable tubular string having a length between 200 and 2000 meters and the elongate expandable tubular string is expanded downhole by moving an expansion cone therethrough.

11. The method of claim 10, wherein:

- a subsequent lower wellbore section having a length between 200 and 2000 meters is drilled below a lower end of the expanded tubular string;
- at least ten adjacent pairs of lower well tubulars are each interconnected at the wellhead by the screw threaded pin-box assemblies to an additional lower expandable tubular string having a length between 200 and 2000 meters;
- the additional lower expandable tubular string is lowered through the expanded upper tubular string until an area of overlap between the upper and lower tubular strings has a length between 10 and 100 meters, optionally between 30 and 70 meters; and
- the lower expandable tubular string is expanded downhole by moving an expansion cone therethrough, thereby expanding the lower tubular string in the area of overlap against the upper tubular string.

12. The method of claim 11, wherein the lower expandable tubular string has after expansion thereof, except in the area of overlap, an internal

width substantially similar to an internal width of the expanded upper tubular string.

13. A well tubular assembly for use in the method according to any one of claims 1-12, the well tubular assembly comprising a screw threaded pin-box connector assembly wherein a swellable pipe dope is inserted between the pin and box connector members, which pipe dope swells upon contact with a wellbore fluid and/or heating during the expansion process.

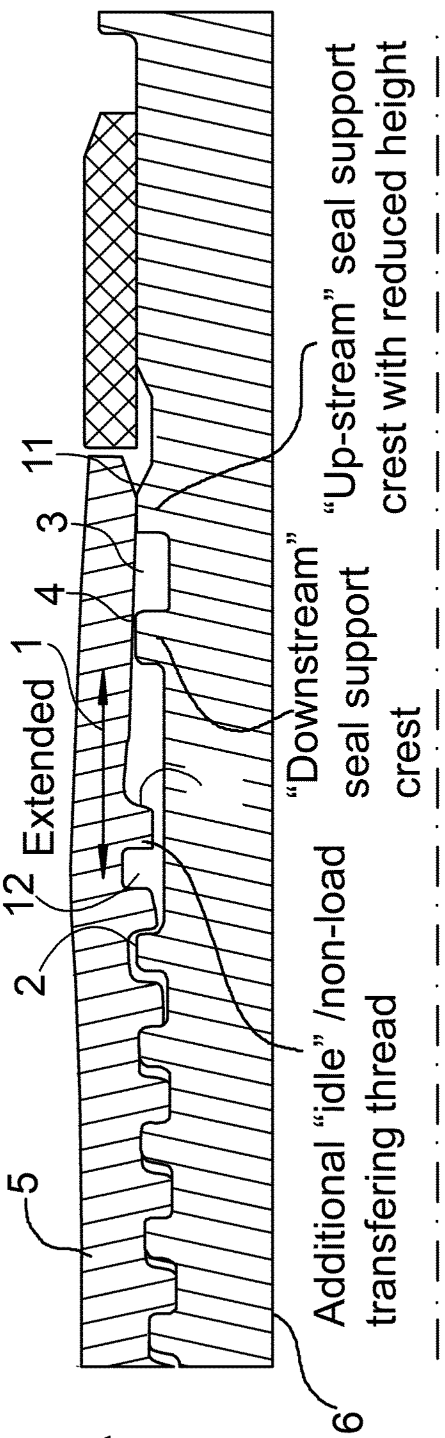
11
3
4
“Up-stream” seal support crest with reduced height
“Downstream” seal support crest
Extended
1
12
2
Additional “idle” /non-load transfering thread
5
6

Fig.1A

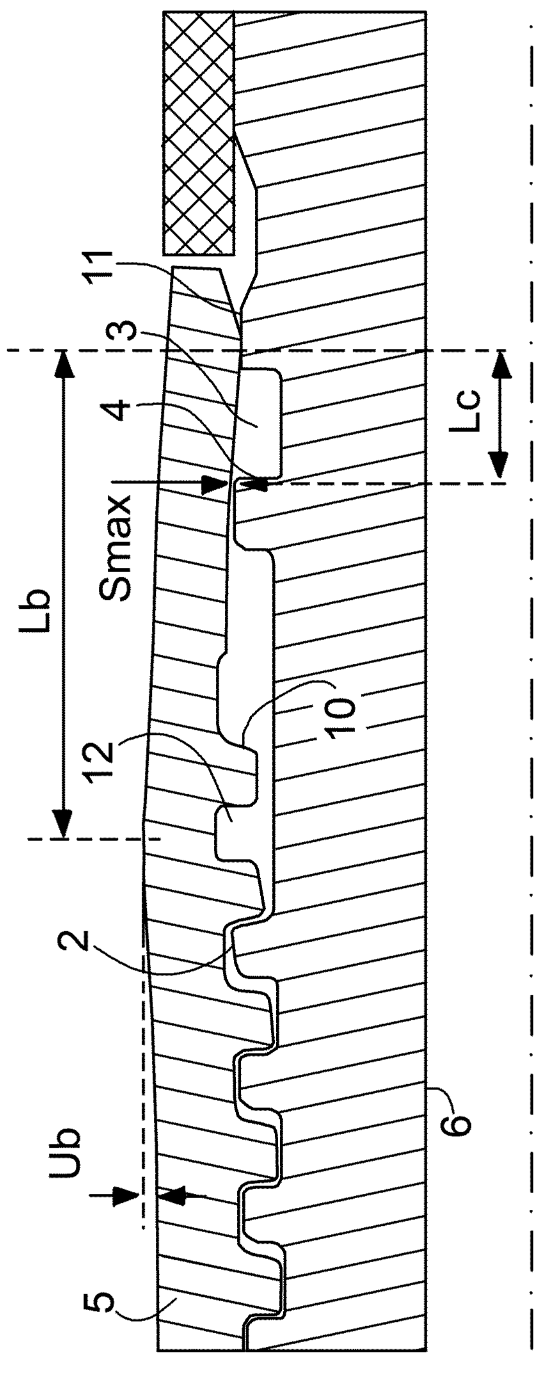
11
3
4
Lc
Smax
Lb
10
12
2
Ub
5
6

Fig.1B

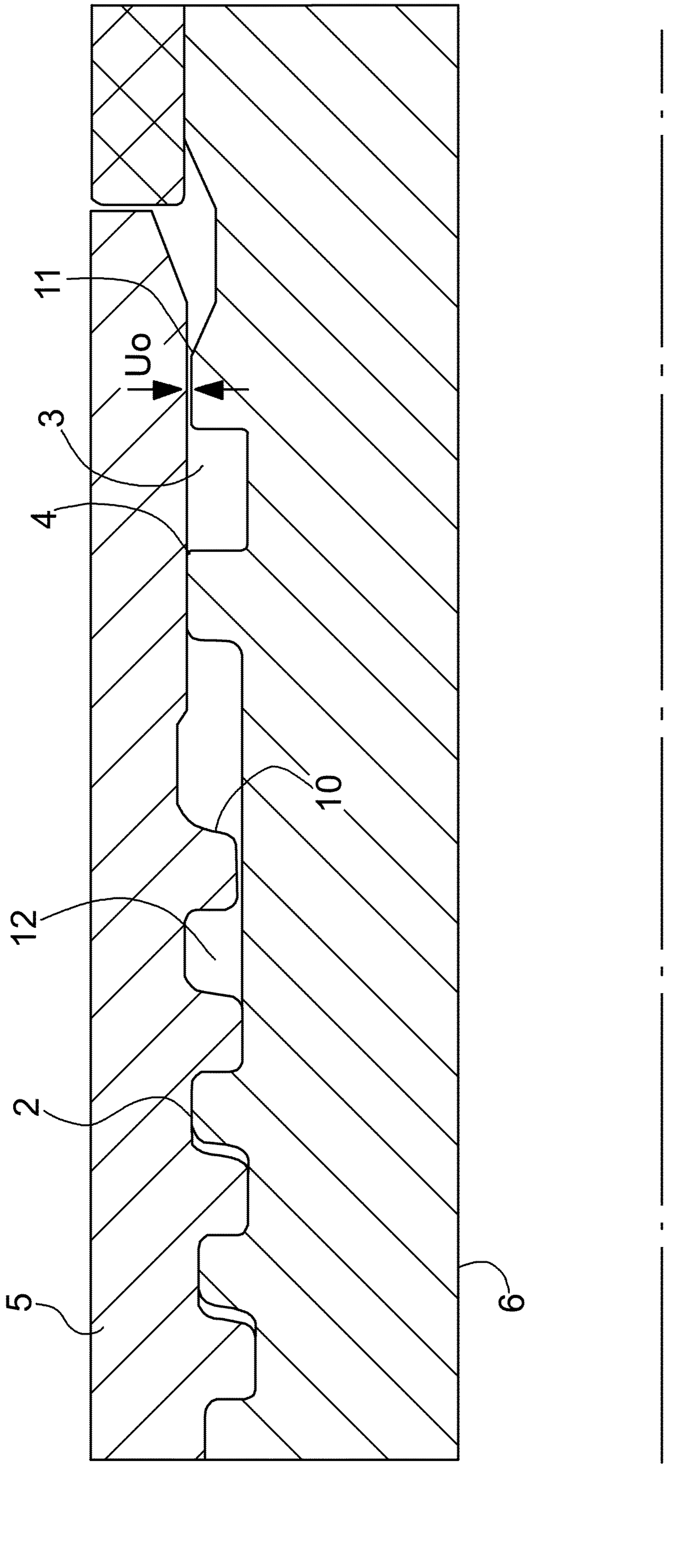

Fig.1C

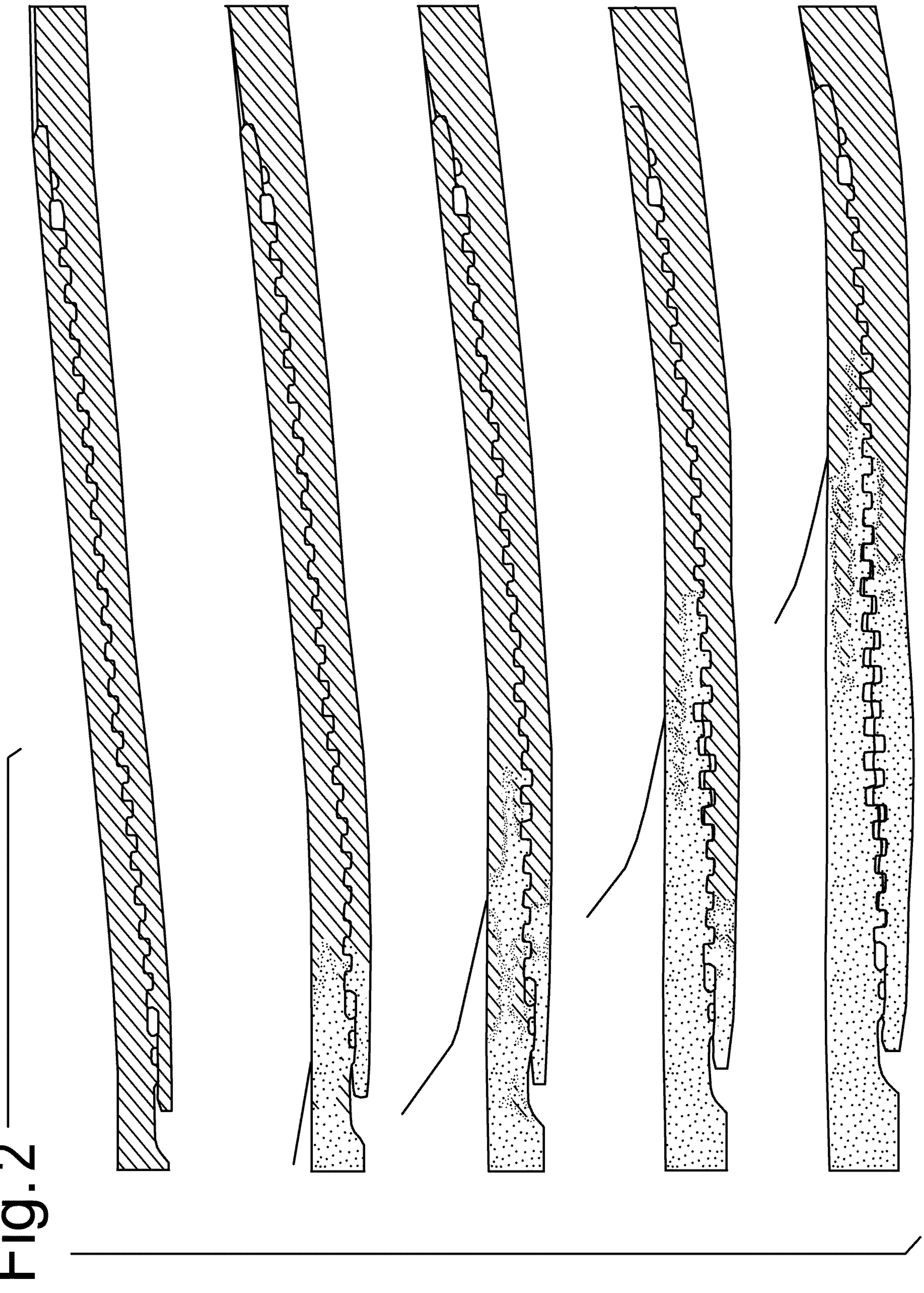

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/065172

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B43/10 E21B17/02 E21B17/042 F16L13/16
ADD.

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 F16L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/060706 A1 (STEPHENSON DAVID J [AE]) 1 April 2004 (2004-04-01)	1,6-13
Y	paragraphs [0002], [0009], [0026],	3,4
A	[0027], [0031] - [0033]	2,5
Y	US 2007/102927 A1 (DUBEDOUT LAURENT [FR] ET AL) 10 May 2007 (2007-05-10)	3,4
A	paragraphs [0001], [0011], [0039], [0062], [0080]; claim 12; figure 1	1,2,5-13
A	WO 2014/154577 A1 (SHELL INT RESEARCH [NL]; SHELL OIL CO [US]) 2 October 2014 (2014-10-02) the whole document	1-13

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"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	Date of mailing of the international search report
25 August 2016	19/09/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Simunec, Duro

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2016/065172

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 2014154577 A1	02-10-2014