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(54) **Title:** MECHANISM FOR COUPLING TUBULARS

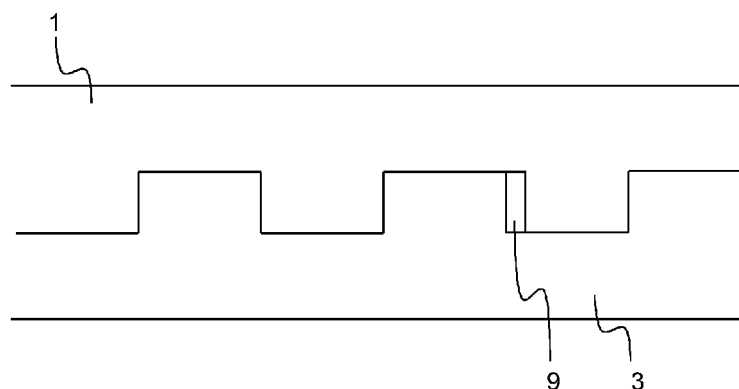


Figure 5

(57) **Abstract:** A mechanism for coupling together a first tubular and a second tubular is described. The first tubular has a first substantially frustoconical mating surface provided at an end. The first mating surface has formed thereon a plurality of circumferentially extending and axially spaced grooves. The second tubular has a second substantially frustoconical mating surface provided at an end, the second mating surface having formed thereon a plurality of circumferentially extending and axially spaced ridges. Respective ridges and grooves are configured to interlock with one another to sealingly couple the first and second tubulars together such that the interlocking is effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together. The plurality of grooves and ridges have an aperiodic spacing along a main axis of the tubulars so that wherein a spacing of at least one corresponding interlocking groove and ridge is such that a width of the groove is different to a width of the corresponding ridge.



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Mechanism for Coupling Tubulars

TECHNICAL FIELD

5 The present invention relates to the field of mechanisms for coupling tubulars, such as well casing tubulars or drill pipe.

BACKGROUND

10 Tubular sections are typically coupled together using a helical thread located at a corresponding end of each tubular. For example, when casing a well such as an oil well using metal tubulars, a first tubular is lowered into the entrance to the well. The first tubular has a helical thread at each end portion. A second tubular is lowered onto the first tubular. The second tubular also has a helical thread at each end portion. Where the first and second tubulars meet, the corresponding threaded end portions come into contact. The first and second tubulars are rotated about their main axis with
15 respect to one another (typically the second tubular is rotated while the first tubular remains stationary) such that the corresponding helically threaded end portions interlock.

20 When using casing joints to case a well, each casing joint may have a male thread at one end and a female thread at the other end. Alternatively, each casing joint has a male thread at each end, and a shorter coupling is used to connect the casing joints. The coupling has a female thread at each end.

25 A problem with either coupling mechanism is that if the first tubular and second tubular are not accurately aligned then the helically threaded end portions can become cross-threaded. Cross threading leads to a weaker connection between the two tubulars, and can also reduce the ability of the connection to be fluid tight, causing fluid leaks at the cross threaded connection.

30 A further problem with this coupling mechanism is that a tubular the threaded portions are the weakest point of a casing joint. A casing joint may be up to twelve metres in length, and the weight of such as casing joint can damage the threads. Again, this can lead to a weakened connection that may not be fluid tight. Helical threads under pretension can leave a gap on the opposite side of the pretension. This gap guides
35 any fluid leak all the way though the helical thread.

A helically threaded connection is normally designed to take stress in axial direction, which is the same direction from which pretension forces arise. This means that some of the capacity of the connection is required to allow for the pretension, and the operative load is in addition to the pretension. The connection must therefore be stronger than that required to handle the operative forces alone.

A further problem with helically threaded connections is that they must be uniformly shaped along the entire connection (in order for the connection to be made). This means that no compensation can be made for local areas of high stress. This leads to increased wear, and also requires lubrication.

SUMMARY

It is an object to provide an improved coupling mechanism for coupling tubulars that does not rely on helical threads.

According to a first aspect, there is provided a mechanism for coupling together a first tubular and a second tubular. The first tubular has a first substantially frustoconical mating surface provided at an end. The first mating surface has formed thereon a plurality of circumferentially extending and axially spaced grooves. The second tubular has a second substantially frustoconical mating surface provided at an end, the second mating surface having formed thereon a plurality of circumferentially extending and axially spaced ridges. Respective ridges and grooves are configured to interlock with one another to sealingly couple the first and second tubulars together such that the interlocking is effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together. The plurality of grooves and ridges have an aperiodic spacing along a main axis of the tubulars so that wherein a spacing of at least one corresponding interlocking groove and ridge is such that a width of the groove is different to a width of the corresponding ridge. An advantage of this is that stresses around a ridge and corresponding groove that have different widths is reduced, and so stresses can be controlled along the length of the mating surface.

As an option, the first tubular comprises a first casing joint and the second tubular comprises any of a second casing joint and a casing coupling joint.

A ridge at an end portion of the plurality of ridges optionally has a lower width than a corresponding groove at an end portion of the plurality of grooves.

5 As an option, the first tubular has a first end portion of grooves, a middle portion of grooves and a second end portion of grooves disposed along the axial length of the first tubular. The first tubular has a reduced wall thickness at at least a portion of the outer wall of the first tubular in proximity to the middle portion of grooves. This allows easier elastic deformation of the tubular in this region, thereby reducing the forces required to make the connection.

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As an option, at least one groove comprises a first ratchet profile extending around a circumference of the groove, and the corresponding ridge comprises a second ratchet profile extending around a circumference of the ridge. The first and second ratchet profiles are arranged to, during connection of the first and second tubulars, slide over one another when the tubulars are rotated relative to one another, thereby effecting a radial increase in the at least one groove and the at last one ridge. This has the effect of allowing the ridges to lift out of the grooves on twisting to reduce the force required to separate the tubulars.

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20 The first ratchet profile and the second ratchet profile optionally have a saw-tooth profile, although it will be appreciated that other profile shapes are possible.

As an option, friction welding material is disposed between at least one groove and corresponding ridge. An advantage of this is that rotation of the first and second tubulars relative to one another is restricted. Furthermore, the welding material contributes to the mechanical strength of the connection and provides an improved seal.

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According to a second aspect, there is provided a tubular comprising a first substantially frustoconical mating surface provided at an end of the tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves. The grooves are arranged to interlock with corresponding ridges of a second mating surface of a second tubular such that the interlocking is effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together to connect the first tubular to the second tubular. The plurality of

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grooves have an aperiodic spacing along a main axis of the tubular such that a spacing of at least one corresponding interlocking groove and ridge is such that a width of the groove is different to a width of the corresponding ridge. An advantage of this is that stresses around a ridge and corresponding groove that have different widths is reduced, and so stresses can be controlled along the length of the mating surface.

According to a third aspect, there is provided a mechanism for coupling together a first tubular and a second tubular. A first substantially frustoconical mating surface is provided at an end of the first tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves. A second substantially frustoconical mating surface is provided at an end of the second tubular, the second mating surface having formed thereon a plurality of circumferentially extending and axially spaced ridges. Respective ridges and grooves are configured to interlock with one another to sealingly couple the first and second tubulars together such that the interlocking is effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together. At least one groove comprises a first ratchet profile extending around a circumference of the groove, and the corresponding ridge comprises a second ratchet profile extending around a circumference of the ridge. The first and second ratchet profiles are arranged to, during connection of the first and second tubulars, slide over one another when the tubulars are rotated relative to one another, thereby effecting a radial increase in the at least one groove and the at last one ridge. An advantage of this is the ridges lift out of the grooves on twisting to reduce the force required to separate the tubulars.

As an option, the first ratchet profile and the second ratchet profile have a saw-tooth profile.

The first tubular optionally comprises a first casing joint and the second tubular comprises any of a second casing joint and a casing coupling joint.

As an option, the first tubular has a first end portion of grooves, a middle portion of grooves and a second end portion of grooves disposed along the axial length of the first tubular. The first tubular has a reduced wall thickness at at least a portion of the outer wall of the first tubular in proximity to the middle portion of grooves.

The plurality of grooves and ridges optionally have an aperiodic spacing along a main axis of the tubulars, and wherein a spacing of at least one corresponding interlocking groove and ridge is such that a width of the groove is different to a width of the corresponding ridge. This allows stresses to be controlled along the length of the mating connection. As a further option, ridge at an end portion of the plurality of ridges has a lower width than a corresponding groove at an end portion of the plurality of grooves, as stresses can be higher at the end portions.

The mechanism optionally further comprises friction welding material disposed between at least one groove and corresponding ridge.

According to a fourth aspect, there is provided a tubular comprising a first substantially frustoconical mating surface provided at an end of the tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves, the grooves arranged to interlock with corresponding ridges of a second mating surface of a second tubular such that the interlocking is effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together to connect the first tubular to the second tubular. At least one groove comprises a first ratchet profile extending around a circumference of the groove, the first ratchet profile arranged to during connection of the tubular to a second tubulars, slide over one a corresponding second ratchet profile when the tubulars are rotated relative to one another, thereby effecting a radial increase in the at least one groove.

According to a fifth aspect, there is provided a method of for coupling together a first tubular and a second tubular. The method comprises providing a first substantially frustoconical mating surface at an end of the first tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves. A second substantially frustoconical mating surface is provided at an end of the second tubular, the second mating surface having formed thereon a plurality of circumferentially extending and axially spaced ridges. The plurality of grooves and ridges have an aperiodic spacing along a main axis of the tubulars, and a spacing of at least one corresponding interlocking groove and ridge is such that a width of the groove is different to a width of the corresponding ridge. The method further comprises pushing the mating surfaces axially together such that respective ridges and grooves interlock with one another to sealingly couple the first and second tubulars together

such that the interlocking is effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together.

According to a sixth aspect, there is provided a method of coupling together a first tubular and a second tubular. A first substantially frustoconical mating surface is provided at an end of the first tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves, at least one groove comprising a first ratchet profile extending around a circumference of the groove. A second substantially frustoconical mating surface is provided at an end of the second tubular, the second mating surface having formed thereon a plurality of circumferentially extending and axially spaced ridges, at least one ridge comprising a second ratchet profile extending around a circumference of the ridge. The first and second mating surfaces are pushed together such that the first and second ratchet profiles slide over one another when the tubulars are rotated relative to one another, thereby effecting a radial increase in the at least one groove and the at least one ridge. This effects interlocking of the corresponding grooves and ridges to sealingly couple the first and second tubulars together.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following text, the invention will be described in detail with reference to the attached drawings. These schematic drawings are used for illustration only and do not in any way limit the scope of the invention.

Figure 1 is a cross-section schematic view of a coupling between two tubulars;

Figures 2a and 2b are cross-section schematic views of exemplary coupling profiles between two tubulars;

Figure 3 illustrates a first exemplary coupling mechanism having a ratchet profile between two tubulars;

Figures 4a and 4b illustrate exemplary ratchet profiles around a circumference of the tubulars;

Figure 5 illustrates schematically a second exemplary coupling mechanism;

DETAILED DESCRIPTION

5 Referring to Figure 1 herein, there is shown a mechanism for coupling together first and second tubulars. The first tubular 1 has a substantially frustoconical first mating surface provided at an end. A plurality of circumferentially extending and axially spaced grooves 2 is provided on the first mating surface. Each groove effectively forms a ring around the circumference of the first mating surface.

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The second tubular 3 also has a substantially frustoconical second mating surface provided at an end of the second tubular 3. A plurality of circumferentially extending and axially spaced metal ridges 4 is formed on the second mating surface. Each ridge effectively forms a ring around the circumference of the first mating surface.

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When the corresponding end portions of the first tubular 1 and the second tubular 3 are axially pushed together, respective ridges 4 and grooves 2 are configured to interlock with one another to sealingly couple the first tubular 1 to the second tubular 3. The interlocking is effected by elastic deformation of the surfaces or parts of the surfaces as the surfaces are pushed axially together. The depth and spacing of the grooves 2 and ridges 4 is calculated based on the forces required to engage the connection, and depend on factors such as the yield strength, tensile strength and Young's modulus of the material from which the first tubular 1 and the second tubular 3 are formed, and the tensile strength required from the connection. Furthermore, the first and second mating surfaces are designed to withstand the compressive loads that they must bear.

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It will be appreciated that the first mating surface has both ridges and grooves, and the second mating surface has corresponding grooves and ridges. To simplify the explanation below, the first mating surface is described as having grooves 2 and the second mating surface is described as having ridges 4. However, it is also possible to define the first mating surface as having ridges and the second mating surface as having grooves.

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In the example of Figure 1, the first mating surface is on an inner wall of the first tubular 1 and the second mating surface is on an outer wall of the second tubular 3. Again, it

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will be appreciated that the first mating surface may be on the outer wall of the first tubular 1, in which case the second mating surface will be on the inner wall of the second tubular 3.

5 The ridges 4 and grooves 2 shown in all of the figures are not shown to scale. Typically, they will have a spacing of less than 10mm and a depth of less than 1mm. The slope of the frustoconical portion is selected such that the connection can withstand tensile forces without the ridges and grooves disengaging from one another.

10 An advantage of using grooves 2 and ridges 4 instead of a helical thread is that each corresponding groove 2 and ridge 4 forms a seal. There are many grooves 2 and ridges in each frustoconical end portion, and so the coupling between the first tubular 1 and the second tubular 3 is fluid tight.

15 US 4,298,221 and US 5,954,374 describe similar concepts to that described above.

A problem with the coupling mechanism described above is that the two tubulars 1, 3 are able to rotate with respect to each other because the grooves 2 and ridges 4 are ring shaped. One way to prevent this is to use a friction weld. As shown in Figure 1, in
20 an optional embodiment, a small amount of welding material (which may well be the same steel as the rest of the tubular) 5 is located in a groove 2, a ridge 4, or both the grooves and the ridges 4. Any rotational movement between the first tubular 1 and the second tubular 3 causes welding, which locks the first tubular 1 and the second tubular in place with respect to one another. If the friction weld is continuous, it may assist in
25 forming a seal. Welding material may be located in all or only some of the corresponding grooves 2 and ridges 4.

Note that the drawings do not show other technical features that would, in practice, be present on a tubular but do not interfere with the way the connection operates. For
30 example, the tubulars 1, 3 would have a lifting collar.

The profile of the interlocking grooves 2 and ridges 2(4) may be designed to allow a tighter or a weaker seal. For example, the profile shown in Figure 2a allows the connection to be disengaged with the application of a tensile force to pull the first
35 tubular 1 away from the second tubular 3. The tensile force must be sufficient to allow

elastic deformation of the grooves 2 and ridges 4 without exceeding the elastic limit. This ensures that the first tubular 1 and the second tubular 3 can be re-used, as the grooves 2 and ridges 4 are not damaged when disengaging the first tubular 1 from the second tubular 3.

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If a stronger connection is required, the profile of the corresponding grooves 2 and ridges 4 may be designed such that the tensile force to disengage the first tubular 1 from the second tubular 4 would cause sufficient force around the grooves 2 and ridges 4 to exceed the elastic limit of the grooves 2 and ridges 4, as shown in Figure 2b. In this case, disengagement of the first tubular 1 from the second tubular 3 would damage the grooves 2 and ridges 4.

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Referring to Figure 3 herein, there is shown a first specific embodiment in which the corresponding grooves 2 and ridges 4 are provided with interlocking ratchet profile. Again, this is not shown to scale, but is shown with an exaggerated size to illustrate the concept.

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In the example of Figure 3, a ridge 4 on the first tubular 1 is provided with a first ratchet profile 6 and the corresponding groove 2 on the second tubular 3 is provided with a corresponding second ratchet profile 7. The first ratchet profile 6 is configured to interlock with the second ratchet profile.

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In use, the first tubular 1 and the second tubular 3 are axially brought together such that the corresponding grooves 2 and ridges 4 interlock. The first tubular 1 and the second tubular 3 are then rotated about their main axis with respect to one another to ensure that the first ratchet profile 6 interlocks with the second ratchet profile 7. When the two ratchet profile slide against one another, they force apart corresponding grooves 2 and ridges, therefore lowering the compressive force required to connect the first tubular to the second tubular 3 and reducing the risk of damage to the grooves 2 and ridges 4. Furthermore, when disconnection the tubulars 1, 3, the ridges 4 lift out of the grooves 2 when the first tubular 1 is rotated axially with respect to the second tubular 4, which reduces the force required to separate the tubulars 1, 3.

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The use of the interlocking ratchet profiles 6, 7 ensures that the first tubular 1 does not rotate with respect to the second tubular 3 below a predetermined rotational force.

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In order to disengage the first tubular 1 from the second tubular 3, the first tubular 1 is rotated with respect to the second tubular 3 such that the interlocking ratchet profiles slide against one another and force the corresponding grooves 2 and ridges 4 apart.
5 This reduces the tensile force required to disengage the first tubular 1 from the second tubular 3, and reduces the risk of damage to the grooves 2 and ridges 4 when disengaging the first tubular 1 from the second tubular 3.

Different ratchet profiles can be designed depending on the level of strength required.
10 Figure 4a shows a first exemplary ratchet profile having a simple saw-tooth shape. When the first tubular 1 is rotated relative to the second tubular 3, the first exemplary ratchet profile requires no more force than that required to overcome the friction between the first ratchet profile 6 and the second ratchet profile 7, and that required to overcome the elastic strain of the corresponding grooves 2 and ridges 4.

15 In some case, a stronger fit is required. For example, a well casing comprising tubular casing joints is typically only ever disconnected if a mistake is made. It is therefore acceptable in these circumstances to have ratchet profiles that need to be destroyed in order to disconnect the first tubular 1 from the second tubular 3. The ratchet profiles
20 shown in Figure 4b has a raised portion 8 that, once engaged, cannot become disengaged without exceeding the elastic limit of the ratchet profiles 6, 7. This increases the force required to disconnect the first tubular 1 from the second tubular 3, but disconnection damages the ratchet profiles 6, 7.

25 When making up a connection between two tubulars, regardless of whether or not a ratchet profile is used, the strain necessary to connect the first tubular 1 to the second tubular 3 is proportional to the height of a ridge 4 (and, of course, the depth of a corresponding groove 2). By doubling the number corresponding grooves 2 and ridges
30 4, the height of each ridge 4 can be halved. By reducing the height of a ridge 4 by 50% without changing the width of the ridge 4, the pretension is lower, so the stab-in force required is reduced by 50%. However, the load capacity of the connection is also reduced, since the total "locking area" (the area projected to a plane perpendicular to the centre line) is reduced both for tension and compression. However, when smaller
35 ridges are used the margin to meet the requirement of one ridge only being in contact with a neighbouring ridge of its corresponding groove in order for the connection to be

either 100% on or not on at all is greatly increased. By reducing the ridge width by, for example, 50%, the margin is back down to what it was before the ridge height reduction while the number of ridges is doubled. Surprisingly, this means that the total locking area remains as for a connection with fewer ridges having a higher width, and so the strength of the connection is the same regardless of the width/number of ridges. However, the ridges reduced in width by 50% will have a force required to make the connection reduced by 50%. The main limitation on reducing the width of the ridges (and consequently increasing the number of the ridges) is machining tolerances.

For a connection described above using grooves 2 and ridges 4, it is known that the first and the last corresponding grooves 2 and ridges in a connection are typically under more stress than a corresponding set of grooves 2 and ridges 4 in the middle of the connection (if we assume that the geometry of all grooves 2 and ridges 4 are the same). In a further specific embodiment, as illustrated in Figure 5, a spacing of a ridge 4 at one end of the connection is slightly offset relative to the spacing of the corresponding groove 2. This essentially forms a gap 9 in the corresponding grooves 2 and ridges 4 at either end of the connection. This reduces the stresses on the grooves 2 and ridges 4 at either end of the connection and more evenly distributes the load on the connection. The same principle can obviously be used at any place of the connection if, for whatever reason, there is a concentration of stresses. For example, if it is known that a particular area of the connection is likely to undergo high flexural forces, the stresses on the grooves 2 and ridges in this area 4 can be reduced in this way.

Such aperiodic spacing of grooves 2 and ridges 4 can be used to reduce or increase the stress at any point along the length of the plurality of grooves 2 and ridges 4, and if regions of high stress are identified the spacing of the corresponding grooves 2 and ridges 4 can be adjusted accordingly.

In a further specific embodiment, as shown in Figure 6, the connection is divided into zones along its length. The zones shown in Figure are a first end zone 10, a middle zone 11 and a second end zone 12. At each end zone, the thickness of the outer tubular (the second tubular 3 in the first end zone 10 and the first tubular 1 in the second end zone 12) is lower than the thickness in the middle of each tubular 1, 3 owing to the frustoconical shape of the connectors. The tubulars are therefore easier to deflect in

each end zone 10, 12 and a lower connection force is required to overcome the elasticity of the corresponding grooves 2 and ridges in the end zones 10, 12. However, in the middle zone 11 each tubular is relatively thick and therefore more resistant to the flexure required. In order to reduce the force required to connect the first tubular 1 to the second tubular 3, the thickness of each tubular can be reduced in the middle zone 11. For example, this may be achieved by the provision of outer grooves 13, 14 on the outside surface of each tubular 1, 3 in the middle zone 11 or simply by thinning the wall thickness of each tubular 1, 3 in the middle zone 11.

In some cases it may be required to connect the first tubular 1 to the second tubular 2 in the presence of a liquid. This can lead to a problem of hydraulic locking preventing the corresponding grooves 2 and ridges 4 from properly connecting together. In a further specific embodiment, in order to reduce this problem, passages may be introduced within the walls of one or both tubulars 1, 3 at each groove 2 (or ridge 4). These passages allow the evacuation of fluid that may otherwise be trapped between a corresponding groove 2 and ridge 4. A valve (such as a float valve) may be provided in fluid connection with each passage in order to ensure that fluid can only flow away from the grooves 2 and ridges 4 and not towards the grooves 2 and ridges 4.

There is also described a mechanism for coupling together a first tubular and a second tubular, the mechanism comprising a first substantially frustoconical mating surface provided at an end of the first tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves. The mechanism also comprises a second substantially frustoconical mating surface provided at an end of the second tubular, the second mating surface having formed thereon a plurality of circumferentially extending and axially spaced ridges. Respective ridges and grooves are configured to interlock with one another to sealingly couple the first and second tubulars together such that the interlocking is effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together.

The invention is not limited to the specific examples described above. While the invention finds particular use where the tubulars are casing joints (or a casing joint and a corresponding casing coupling), it may be used for other types of tubular. Furthermore, the tubular material is typically a metal but the tubulars may be formed from any type of suitable material that allows sufficient elastic deformation of the

grooves and ridges to allow the tubulars to fit together. In some applications, tubulars made from plastics may be adequate.

CLAIMS:

1. A mechanism for coupling together a first tubular and a second tubular, the mechanism comprising:

5 a first substantially frustoconical mating surface provided at an end of the first tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves;

10 a second substantially frustoconical mating surface provided at an end of the second tubular, the second mating surface having formed thereon a plurality of circumferentially extending and axially spaced ridges;

respective ridges and grooves being configured to interlock with one another to sealingly couple the first and second tubulars together such that the interlocking is effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together;

15 wherein the plurality of grooves and ridges have an aperiodic spacing along a main axis of the tubulars, and wherein a spacing of at least one corresponding interlocking groove and ridge is such that a width of the groove is different to a width of the corresponding ridge.

20 2. The mechanism according to claim 1, wherein the first tubular comprises a first casing joint and the second tubular comprises any of a second casing joint and a casing coupling joint.

25 3. The mechanism according to claim 1 or 2, wherein a ridge at an end portion of the plurality of ridges has a lower width than a corresponding groove at an end portion of the plurality of grooves.

30 4. The mechanism according to any one of claims 1 to 3, wherein the first tubular has a first end portion of grooves, a middle portion of grooves and a second end portion of grooves disposed along the axial length of the first tubular, the first tubular having a reduced wall thickness at at least a portion of the outer wall of the first tubular in proximity to the middle portion of grooves.

35 5. The mechanism according to any one of claims 1 to 4, wherein at least one groove comprises a first ratchet profile extending around a circumference of the

groove, and the corresponding ridge comprises a second ratchet profile extending around a circumference of the ridge, the first and second ratchet profiles arranged to, during connection of the first and second tubulars, slide over one another when the tubulars are rotated relative to one another, thereby effecting a radial increase in the at least one groove and the at last one ridge.

6. The mechanism according to claim 5, wherein the first ratchet profile and the second ratchet profile have a saw-tooth profile.

7. The mechanism according to any one of claims 1 to 6, further comprising friction welding material disposed between at least one groove and corresponding ridge.

8. A tubular comprising a first substantially frustoconical mating surface provided at an end of the tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves, the grooves arranged to interlock with corresponding ridges of a second mating surface of a second tubular such that the interlocking is effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together to connect the first tubular to the second tubular;

wherein the plurality of grooves have an aperiodic spacing along a main axis of the tubular such that a spacing of at least one corresponding interlocking groove and ridge is such that a width of the groove is different to a width of the corresponding ridge.

9. A mechanism for coupling together a first tubular and a second tubular, the mechanism comprising:

a first substantially frustoconical mating surface provided at an end of the first tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves;

a second substantially frustoconical mating surface provided at an end of the second tubular, the second mating surface having formed thereon a plurality of circumferentially extending and axially spaced ridges;

respective ridges and grooves being configured to interlock with one another to sealingly couple the first and second tubulars together such that the interlocking is

effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together;

5 wherein at least one groove comprises a first ratchet profile extending around a circumference of the groove, and the corresponding ridge comprises a second ratchet profile extending around a circumference of the ridge, the first and second ratchet profiles arranged to, during connection of the first and second tubulars, slide over one another when the tubulars are rotated relative to one another, thereby effecting a radial increase in the at least one groove and the at last one ridge.

10 10. The mechanism according to claim 9, wherein the first ratchet profile and the second ratchet profile have a saw-tooth profile.

11. The mechanism according to claim 9 or 10, wherein the first tubular comprises a first casing joint and the second tubular comprises any of a second casing joint and a casing coupling joint.
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12. The mechanism according to any one of claims 9 to 11, wherein the first tubular has a first end portion of grooves, a middle portion of grooves and a second end portion of grooves disposed along the axial length of the first tubular, the first tubular having a reduced wall thickness at at least a portion of the outer wall of the first tubular in proximity to the middle portion of grooves.
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13. The mechanism according to any one of claims 9 to 12, wherein the plurality of grooves and ridges have an aperiodic spacing along a main axis of the tubulars, and wherein a spacing of at least one corresponding interlocking groove and ridge is such that a width of the groove is different to a width of the corresponding ridge.
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14. The mechanism according to claim 13, wherein a ridge at an end portion of the plurality of ridges has a lower width than a corresponding groove at an end portion of the plurality of grooves.
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15. The mechanism according to any one of claims 9 to 14, further comprising friction welding material disposed between at least one groove and corresponding ridge.
35

16. A tubular comprising a first substantially frustoconical mating surface provided at an end of the tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves, the grooves arranged to interlock with corresponding ridges of a second mating surface of a second tubular such that the interlocking is effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together to connect the first tubular to the second tubular;

wherein at least one groove comprises a first ratchet profile extending around a circumference of the groove, the first ratchet profile arranged to during connection of the tubular to a second tubular, slide over one a corresponding second ratchet profile when the tubulars are rotated relative to one another, thereby effecting a radial increase in the at least one groove.

17. A method of for coupling together a first tubular and a second tubular, the method comprising:

providing a first substantially frustoconical mating surface at an end of the first tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves;

providing a second substantially frustoconical mating surface at an end of the second tubular, the second mating surface having formed thereon a plurality of circumferentially extending and axially spaced ridges, wherein the plurality of grooves and ridges have an aperiodic spacing along a main axis of the tubulars, and wherein a spacing of at least one corresponding interlocking groove and ridge is such that a width of the groove is different to a width of the corresponding ridge;

pushing the mating surfaces axially together such that respective ridges and grooves interlock with one another to sealingly couple the first and second tubulars together such that the interlocking is effected by elastic deformation of the mating surfaces as the surfaces are pushed axially together.

18. A method of coupling together a first tubular and a second tubular, the method comprising:

providing a first substantially frustoconical mating surface at an end of the first tubular, the first mating surface having formed thereon a plurality of circumferentially extending and axially spaced grooves, at least one groove comprising a first ratchet profile extending around a circumference of the groove;

providing a second substantially frustoconical mating surface at an end of the second tubular, the second mating surface having formed thereon a plurality of circumferentially extending and axially spaced ridges, at least one ridge comprising a second ratchet profile extending around a circumference of the ridge;

5 pushing the first and second mating surfaces together such that the first and second ratchet profiles slide over one another when the tubulars are rotated relative to one another, thereby effecting a radial increase in the at least one groove and the at last one ridge; and

10 effecting interlocking of the corresponding grooves and ridges to sealingly couple the first and second tubulars together.

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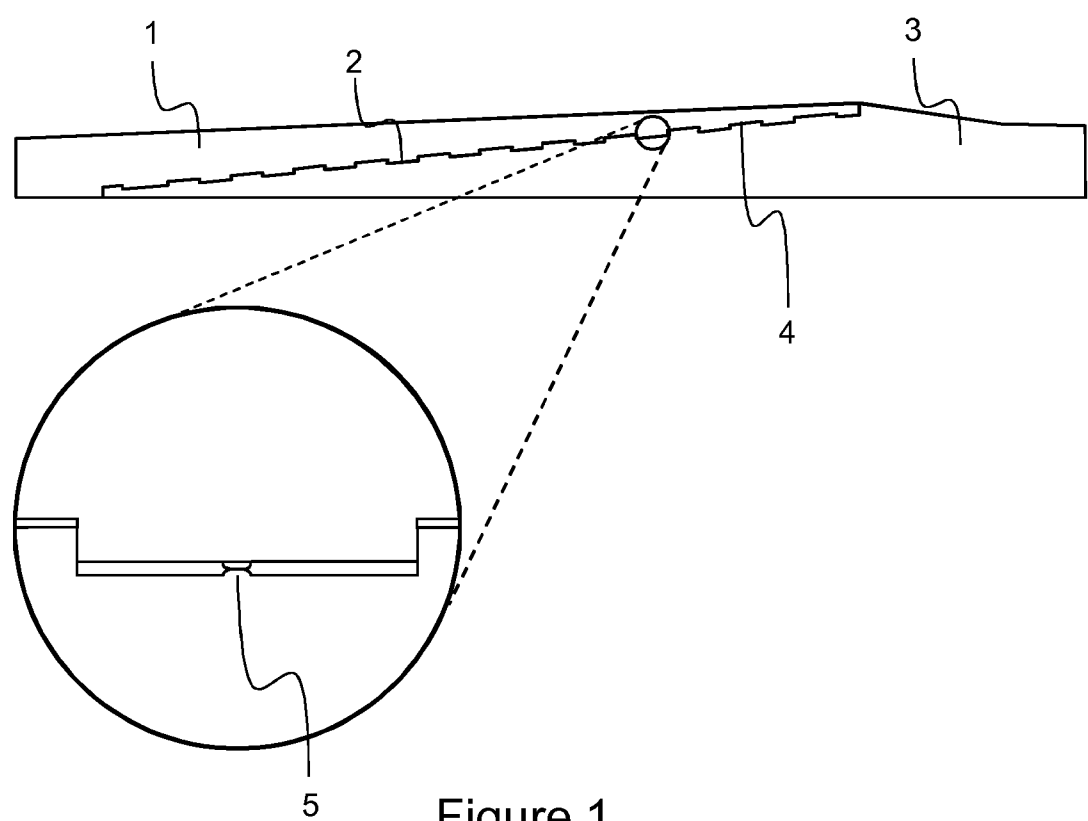


Figure 1

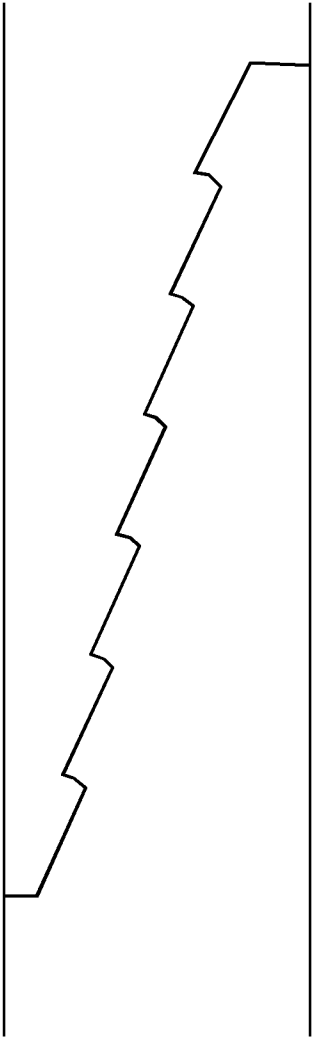


Figure 2a

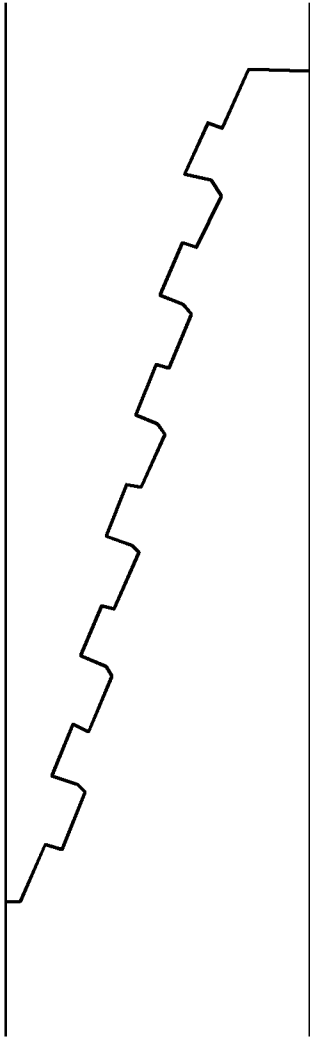


Figure 2b

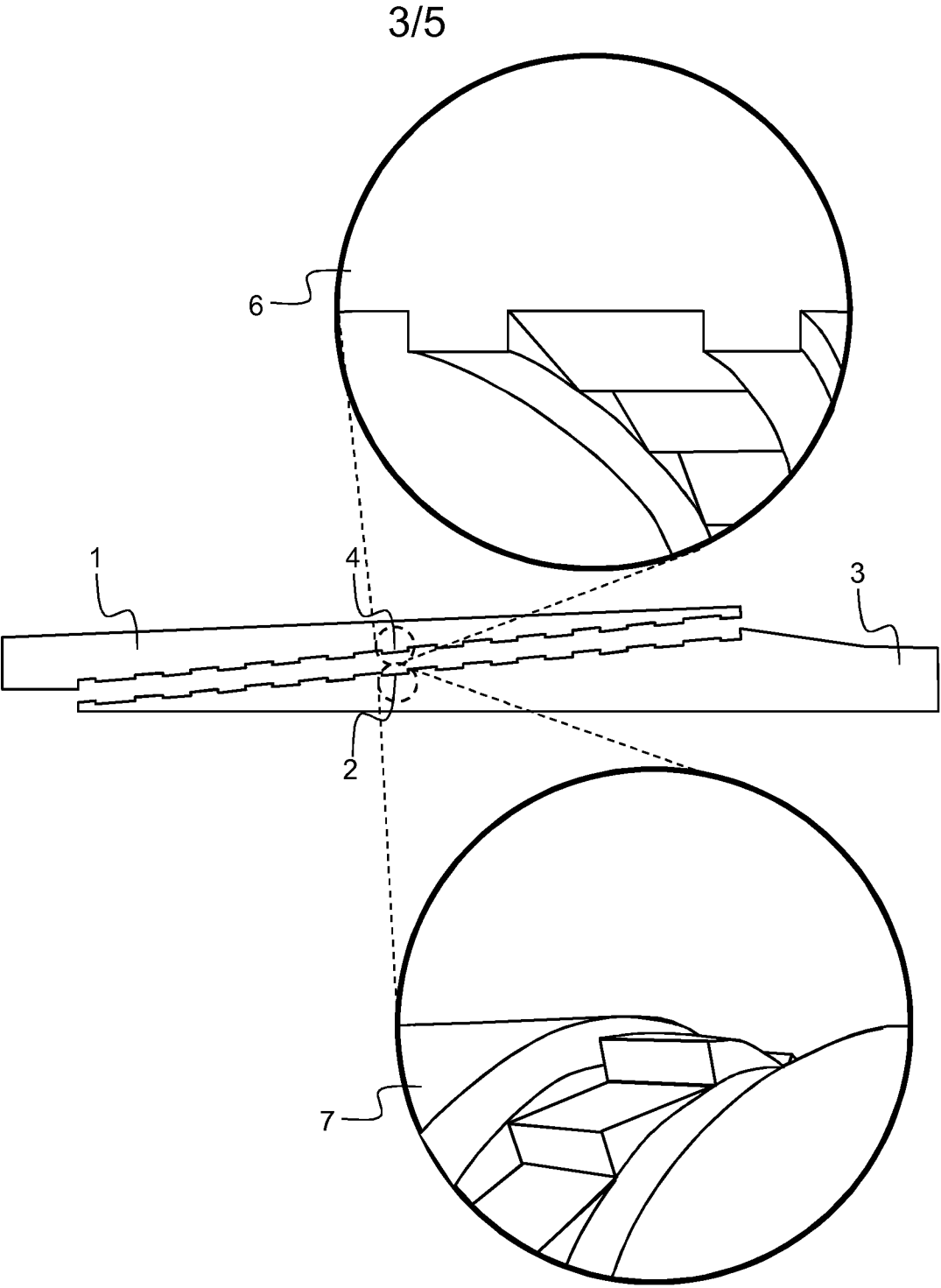


Figure 3

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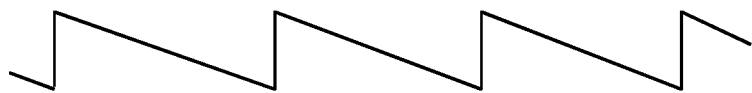


Figure 4a

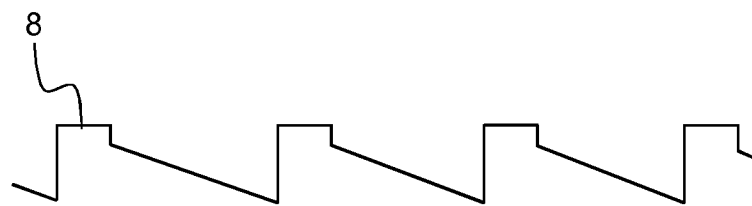


Figure 4b

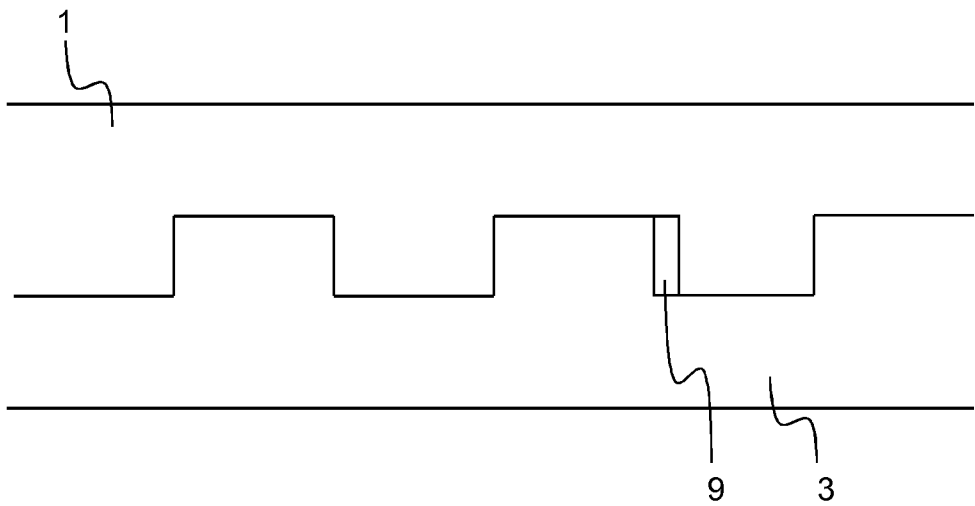


Figure 5

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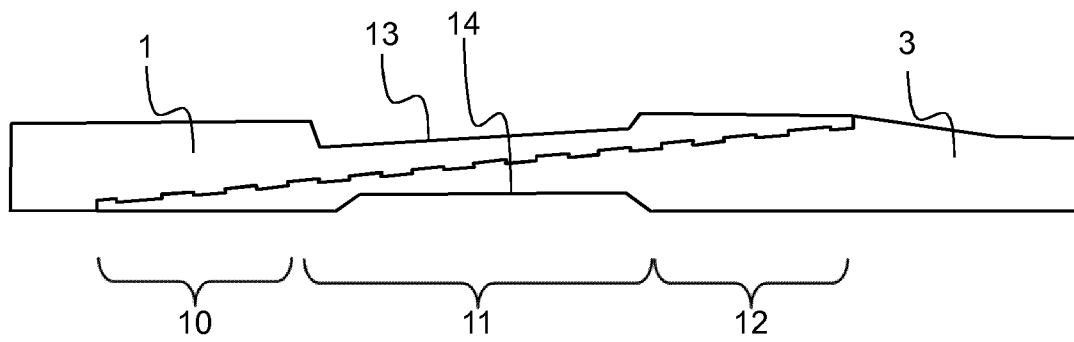


Figure 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/063648

A. CLASSIFICATION OF SUBJECT MATTER

INV. E21B17/046 F16L37/02 F16L37/04
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	GB 2 113 335 A (HUNTING OILFIELD SERVICES) 3 August 1983 (1983-08-03)	1-3,8,17
Y	figures 1-9	4,7
A	page 1, lines 6-9	5,6,
	page 1, lines 58-93	9-16,18
	page 2, lines 28-116	
	page 3, lines 42-58	
Y	----- US 2006/162145 A1 (VERGER ERIC [FR] ET AL) 27 July 2006 (2006-07-27) paragraphs [0001], [0004] paragraphs [0062], [0069] figure 5 ----- -/-	4



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

"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 October 2015

Date of mailing of the international search report

27/10/2015

Name and mailing address of the ISA/

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Authorized officer

Altamura, Alessandra

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/063648

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/093250 A1 (SANTI NESTOR J [AR] ET AL) 5 May 2005 (2005-05-05) paragraph [0002] paragraphs [0007] - [0008] paragraph [0024] -----	7
A	US 2008/219800 A1 (VAN COR DALE E [US]) 11 September 2008 (2008-09-11) figures 20A,20B paragraph [0131] -----	5,6, 9-16,18
A	WO 2014/093025 A2 (VETCO GRAY INC [US]) 19 June 2014 (2014-06-19) figure 1 pages 1-2 pages 4-5 -----	5,6, 9-16,18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2015/063648

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-18

Coupling with frustoconical mating surfaces having circumferentially extending and axially spaced grooves and ridges.

1.1. claims: 1-8, 17

Coupling with frustoconical mating surfaces having circumferentially extending, axially and aperiodic spaced grooves and ridges.

1.2. claims: 9-16, 18

Coupling with a ratchet profile extending around a circumference of a groove and of the corresponding ridge.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/063648

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 2005045188 A1	19-05-2005
US 2008219800	A1	11-09-2008	NONE
WO 2014093025	A2	19-06-2014	GB 2523051 A 12-08-2015
		US 2014167408 A1	19-06-2014
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