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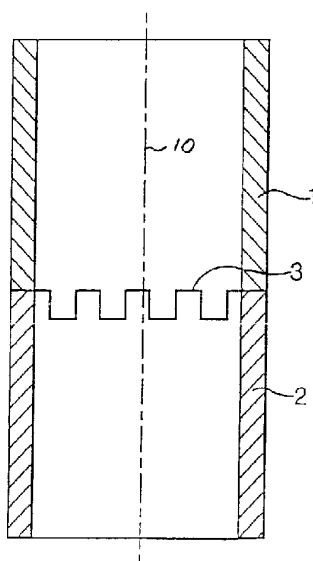
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(54) Title: FORGE WELDING OF HEAVY DUTY TUBULARS



(57) Abstract: A method of joining heavy duty oilfield, well, or other tubulars comprises joining the tubulars by forge welding and flushing a reducing flushing gas around the heated tubular ends during at least part of the forge welding operation such that oxides are removed from the forge welded tubular ends and the amount of oxide inclusions and irregularities between the forge welded tubular ends is limited. The tubular ends may have a teetted or non-planar shape to inhibit any abrupt variations of the wall strength in the welding area and/or to reduce shear forces to the forge weld when the tubulars are twisted and/or radially expanded.

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FORGE WELDING OF HEAVY DUTY TUBULARSBackground of the Invention

The invention relates to an improved method for forge welding of heavy duty tubulars such that a welded connection of high strength and quality is obtained.

5 Heavy duty tubulars may be formed by oilfield, well and/or other tubulars which are in use subject to high mechanical and/or thermal stresses as a result of their use in an irregular borehole or hostile on- or offshore environment. Thus the heavy duty tubulars may frequently
10 be subject to large radial, tangential and/or shear stresses which cause a high elastic, plastic and/or pseudo plastic deformation of the tubular wall and any tubular joints. The heavy duty tubulars may be tubulars which are expanded downhole to a larger diameter and
15 plastically deformed during the expansion process, drill pipes which may be 10 kilometers long and twisted over 30 times of the pipe circumference as a result of the torque transmitted to the drill bit and friction between the drill pipe and the irregular borehole wall or heater well casings, steam injection and/or other heater pipes which
20 are subject to high thermal expansion and may be squeezed by the thermal expansion of the surrounding formation and/or subsidence during the production operations.

Forge welding involves circumferential heating of the
25 pipe ends that are to be joined and subsequently pressing the pipe ends together to form a metallurgical bond.

A large variety of heating technologies may be used to make the pipe ends hot enough such that the metallurgical bond can be made. The heating techniques

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may involve electric, electromagnetic, induction, infrared, sparking and/or friction heating or combinations of these and other heating methods.

When used in this specification the term forge
5 welding is intended to encompass all techniques which involve circumferential heating of pipe ends and subsequent metallurgical bonding the heated pipe ends, including welding techniques that are generally known as diffusion welding, friction welding, flash welding and/or
10 butt welding.

US patent No. 2,604,569 discloses a butt welding technique wherein the ends of metallic members that one to be joined have complementary sinusoidal shapes and are heated by passing low frequency or direct current
15 longitudinally of the members.

It is known from US patents 4,566,625; 4,736,084; 4,669,650 and 5,721,413 issued to Per H. Moe that it may be beneficial to flush the pipe ends just before and during the forge welding operation with a reducing
20 flushing gas, such as hydrogen or carbon monoxide, such that any oxygen skin is removed from the heated pipe ends and a metallurgical bond with a minimal amount of irregularities is obtained. It is also known from US patents 2,719,207 and 4,728,760 to use non explosive
25 mixtures comprising about 95% by volume of a substantially inert gas, such as argon, nitrogen and/or helium, and about 5% by volume of a reducing gas, such as hydrogen and/or carbon monoxide for flash welding and induction butt welding.

30 Experiments have shown that forge welding techniques are capable to generate high quality metallurgical bonds between the tubular ends, in particular if the pipe end

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are flushed with a reducing flush gas mixture during the welding operation.

It is an object of the invention to provide a method for forge welding of heavy duty well, oilfield and or
5 other tubulars which is able to generate a forge welded tubular connection in within a few minutes only and which generates a weld at which the pipe wall in the region of the weld is weakened and/or stiffened only to a minimal extent and optionally such that only a gradual variation
10 of any strength variation occurs in longitudinal direction of the tubulars.

Summary of the Invention

In accordance with the invention there is provided an improved method of joining heavy duty tubulars, the
15 method comprising:

joining the tubulars by forge welding and flushing a reducing flushing gas around the heated tubular ends during at least part of the forge welding operation such that oxides are removed from the forge welded tubular
20 ends and the amount of oxide inclusions and irregularities between the forge welded tubular ends is limited wherein the tubular ends are heated by passing high frequency electrical current through the tubular ends by means of a series of electrodes, characterized in
25 that the tubular ends have an intermeshing regular sinusoidal or teethed shape around the circumference of the tubulars and that the electrodes are pressed against the inner and/of outer surface of the tubular ends adjacent to the tips of the teeth and/or sinusoidal end
30 faces;

the use of tubular ends which have in circumferential direction a complementary teethed sinusoidal shape alleviates forces to the forge welded tubular ends during

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use of the heavy duty tubular string. The intermeshing
teethed or sinusoidal ends may be pressed against each
other during the forge welding operation by moving the
tubular ends in a longitudinal direction towards each
other during the welding process, whilst the
circumferential orientation of the tubular ends is
controlled such that along the entire circumference a gap
of a substantially constant width is present during the
heat up phase.

The non-planar shaped tubular ends preferably have a
regular intermeshing sinusoidal or teethed shape in order
to inhibit in particular shear stresses on the forge
welded joint when the tubular string is twisted and/or
radially expanded, while the tubular string is rotated
and/or radially stretched in a cavity, such as an
underground borehole.

In such case the tubular ends may be heated by
passing a high frequency current in circumferential
direction through the tubular walls near the tubular ends
that are to be joined and wherein the presence of cold
spots along the circumference of the heated tubular ends
is reduced by arranging a series of longitudinal ferrite
bars around the outer surface of the tubular ends and/or
within the interior thereof.

The flushing gas may be a non-explosive mixture of a
substantially inert gas and a reducing gas, more in
particular, the flushing gas comprises more than 90% by
volume of a substantially inert gas, such as nitrogen,
helium or argon and more than 2% by volume of hydrogen.

The heavy duty tubular string may be a casing while
drilling string, which carries a drill bit while drilling
the hole and which remains in the borehole in an expanded

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or unexpanded configuration after completion of the drilling process.

5 The tubulars may also be joined downhole by forge welding after a tube expansion operation wherein a spear is inserted into the region of the tubular ends which then heats the tubular end to a forge welding temperature and presses them together the spear flushes a reducing flushing gas around the heated tubular ends during at least part of the forge welding operation.

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In such case the ends of the tubulars may at least partly overlap each other and the spear and or other forge welding device is inserted into the inner tubular which heats up the tubular end, flushes a reducing
5 flushing gas into any gap remaining between the overlapping tubular ends and which subsequently presses the outer surface of the heated end of the inner tubular against the inner surface of the outer tubular to join said tubular ends by forge welding.

10 In such case the partially overlapping tubular ends are teathed or have a complementary sinusoidal shape in order to alleviate the presence of abrupt stress variations to the forge welded expanded tubular ends when the tubular string is bent, compressed and/or otherwise
15 deformed.

Description of Preferred Embodiments

The invention will be described in more detail and by way of example with reference to the accompanying drawings in which:

20 Fig. 1 shows two pipe ends with complementary teathed end faces. The teathed end faces can be used to align the tubulars in angular direction;

Fig. 2 show two pipe ends with complementary non-planar end-faces, which are in this case of a sinusoidal
25 shape; and

Fig. 3 shows two partially overlapping pipe ends of which the end surfaces have a sinusoidal shape.

As illustrated in Fig. 1 welding of the teathed ends 3 of adjacent pipes 1,2 together along the length of the
30 contour of the intermeshing non-planar teathed ends 3 which are rotation symmetrical relative to a longitudinal axis 10 of the pipes 1,2 provides a total length of the weld which is larger than the total

circumferential length of the pipes and thereby reduces the loading of the weld compared to that of the pipe body.

5 In Fig. 2 the non planar ends 6 of two adjacent pipe sections 4 and 5 have an in circumferential direction sinusoidal shape which is rotation symmetrical relative to a longitudinal axis 11 of the pipe sections 4 and 5.

Fig. 3 shows two pipe ends 7 and 8 which are partly overlapping. The inner pipe end 8 is provided with a non-
10 planar rotation symmetrical sinusoidal end face 9 which is in contact with the outer pipe 7, whereas the outer pipe 7 has a non-planar rotation symmetrical sinusoidal end face 12 which is in contact with the inner pipe 8. Welding of the pipes 7 and 8 together along the length of
15 the overlapping pipe sections 13 between the non-planar end faces 9 and 12 yields a weld length which is larger than the length of the circumference of the pipes and thereby reduces the loading of the weld compared to that of the pipe bodies. In addition, this configuration
20 yields a gradual transfer of the loading from one pipe body to the other pipe body and supports the mitigation of stress concentrations in the overlap zone of the pipes when the pipes are twisted by torsional forces and/or bent and/or radially expanded.

The claims defining the invention are as follows:

1. A method of joining heavy duty tubulars, the method comprising joining the tubulars by forge welding and flushing a reducing flushing gas around the heated tubular ends during at least part of the forge welding operation such that oxides are removed from the forge welded tubular ends and the amount of oxide inclusions and irregularities between the forge welded tubular ends is limited wherein the tubular ends have a non-planar shape and an intermeshing regular sinusoidal or toothed shape around the circumference of the tubulars and wherein the tubular ends have complementary end faces.
2. The method of claim 1, wherein the flushing gas is a non-explosive mixture of a substantially inert gas and a reducing gas, such as a mixture comprising more than 90% by volume of a substantially inert gas, such as nitrogen, helium or argon and more than 2% by volume of hydrogen.
3. The method of any one of claims 1-2, wherein the heavy duty tubular string is a casing while drilling string which carries a drill bit while drilling the hole and which remains in the borehole in an expanded or unexpanded configuration after completion of the drilling process.
4. The method of claim 1, wherein the tubular ends are heated by passing a high frequency current in circumferential direction through the tubular walls near the tubular ends that are to be joined and wherein the presence of cold spots along the circumference of the heated tubular ends is reduced by arranging a series of longitudinal ferrite bars around the outer surface of the tubular ends and/or within the interior thereof.
5. The method of claim 1, wherein the tubulars are joined downhole by forge welding after a tube expansion operation and the tubular ends are heated to a forge welding temperature and pressed together whilst a reducing flushing gas is flushed around the heated tubular ends during at least part of the forge welding operation.
6. The method of claim 5, wherein the ends of the tubulars at least partly overlap each other and a forge welding device is inserted into the inner tubular which heats up the tubular ends, flushes a reducing flushing gas into any gap remaining between the overlapping tubular ends and which subsequently presses the outer surface of the

heated end of the inner tubular against the inner surface of the outer tubular to join said tubular ends by forge welding, and wherein the end surfaces of the partially overlapping tubular ends are teathed or have a complementary sinusoidal shape in order to alleviate forces to the forge welded expanded tubular ends.

7. The method of claim 1, wherein the tubular ends are heated by passing high frequency electrical current through the tubular ends by means of a series of electrodes which are pressed against the inner and/or outer surface of the tubular ends adjacent to the tips of the teeth and/or sinusoidal end faces.

8. A method of joining heavy duty tubulars, said method being substantially as hereinbefore described with reference to any one embodiment, as that embodiment is depicted in Fig. 1, Fig. 2 or Fig. 3 of the accompanying drawings.

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Fig.1.

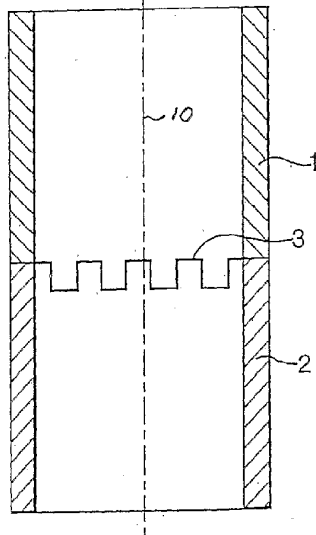


Fig.2.

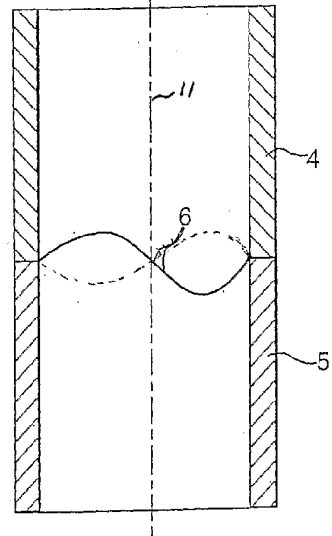


Fig.3.

