

SPECIFICATION

Method and apparatus for improving the mechanical properties of butt welded tubular products

This invention relates to a method and apparatus for improving the mechanical properties of butt welded tubular products and has particular but not exclusive reference to the attachment of a tool joint to a drill pipe.

One commonly accepted technique for manufacturing drill string used in drilling wells involves joining a threaded coupling, commonly referred to as a tool joint, to a straight section of tubular stock, commonly referred to as drill pipe, by butt welding. Normally, the welding process is accomplished by friction welding, inertia welding, flash welding, or other modern welding techniques. Because of the high temperature required for the welding operation, the microstructure of the steel in the welded area is drastically altered from the microstructure present in the drill pipe and tool joint outside of the weld area. This altered microstructure usually results in a weakening of the steel in the weld area that could cause failure in service of drill string so manufactured. Usual attempts to strengthen the weld area generally may weaken other portions of the drill pipe and the tool joint.

The methods utilized in the prior art either introduce cooling too rapidly and cause cracking or else introduce cooling too slowly and do not achieve optimum martensite formation.

Because of the thickness of the tool joint welded area, a rapid cooling obtained with a quenchant such as straight water on both sides of the weld will cause external martensite formation first, resulting in a skin or shell of hard material around a hot metal core. As the hot core cools and forms martensite, the natural increase in volume from the martensite formation causes expansion and cracking of the already formed outer shell of martensite.

Other prior art methods have attempted to prevent cracking of the thicker welded section by quenching both sides of the weld zone with a lighter quenchant such as air or other gas. One example of this can be seen in U.S. Patent No. 3,997,374. This method suffers from the disadvantage that the quenching effect is not rapid enough to obtain optimum amounts of martensite in the weld area, and thus the strength of the welded parts is not maximized.

An object of the present invention is to obviate or mitigate the aforesaid disadvantages.

According to the present invention there is provided a method of treating a first member after welding a second member thereto, said method being particularly advantageous for eliminating stresses and hardening the weld area, and said method comprising:

placing said welded first and second members inside a heating means;

thoroughly heating the weld area of the first and second members to a temperature above their austenitic transformation temperature;

holding the weld area temperature above the austenitic transformation temperature for a sufficient time to allow substantial transformation of the metal in the weld area to austenite;

rapidly quenching the first member only side of the weld area to a temperature sufficiently below the austenite transformation temperature to transform substantial quantities of the total weld metal to martensite;

allowing further air cooling of the weld area to approximately 400°F (205°C) or less; and tempering the weld area by reheating to a temperature below the austenite transformation temperature.

According to a further aspect of the present invention there is provided a method of attaching a first member to a second member to obtain substantially the inherent strength of the first member in the area of attachment

between the first and second members; said method comprising:

attaching a second member to a first member by butt welding;

removing any excess weld material from the exterior and interior surfaces of the welded parts;

raising the temperature of the weld area to above the austenite transformation temperature;

holding the weld area above the austenite transformation temperature a sufficient time to allow substantial transformation of the weld area metal to austenite;

quenching the first member portion only of the weld area, after said transformation, to a quenched temperature sufficiently below the austenite transformation temperature to transform a substantial portion of the austenite into martensite; and

reheating the weld area to a tempering temperature between the quenched temperature and the transformation temperature to reduce stresses.

The present invention also provides means for thermally treating the welded area to enhance its strength and toughness while minimizing microstructural change in adjacent areas of the drill pipe and tool joint. This desirable improvement is accomplished by

heating the entire weld area to a temperature above the austenite transformation temperature, holding at that temperature for a sufficient period of time for the transformation to austenite to be completed, then immediately

cooling the heated drill pipe side of the weld area, by means of a quenchant to be described later, at such a rate to essentially avoid the transformation of austenite to microstructures other than martensite. Simultaneously, heat is extracted from the heated tool

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joint side of the weld area by conduction across the weld line to the quenched drill pipe side of the weld area at a rate fast enough to essentially avoid the transformation of austenite to microstructures other than martensite, yet slow enough to avoid transformation cracking of the more susceptible tool joint material. After transformation is completed, the entire weld area is reheated to a temperature below the austenite transformation temperature to temper the martensite transformation products, thereby developing improved strength and toughness in the weld area without affecting the strength and toughness in the other portions of the drill pipe and tool joint. The apparatus generally comprises means for raising the welded area to a predetermined temperature above the transformation temperatures of the steel, then immediately quenching a controlled portion of the heated area, after which the entire weld area is tempered to develop the desired strength and toughness.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a side schematic view showing a drill pipe immediately prior to attachment to a tool joint.

Figure 2 is a cross-sectional side view of the drill pipe having the tool joint welded thereto.

Figures 3A and 3B illustrate the quenching apparatus of the present invention illustrated in side and end views respectively.

Figure 4 is an axial end view shown in partial cross section of the quenching apparatus.

Figure 5 is a side view of the apparatus of Fig. 3 taken in full cross section.

Figures 6A and 6B are side cross-sectional views of the induction heating and the quenching apparatus in position around the welded drill pipe.

Figure 7 is a cross-sectional side view of the invention in place around a welded drill pipe.

Figure 8 is a cross-sectional side view of an alternative embodiment of the invention.

Referring to the drawings, Fig. 1 illustrates in schematic cross-sectional side view a cylindrical internally threaded tool joint 10 having an abutment section 11 and coupling section 12. Abutment section 11 comprises relatively thick cylindrical wall section 13 having a squared off abutment end 14. The bore passage 15 extends longitudinally through tool joint 10 along a central longitudinal axis A. A section of drill pipe 16 having an internal bore passage 17 generally coextensive with bore 15 of tool joint 10 also has an abutment end 18 comprising a cylindrical section with a squared off relatively flat end portion 19 of generally the same configuration as section 13. The section of drill pipe 16 is readily available in the art as is the tool joint 10. The formation of a section of drill string is accom-

plished by the joining of pipe section 16 with the threaded tool joint 10 at surfaces 14 and 19. This most often involves welding of the two faces together by means such as flash welding, friction welding, or inertia welding.

Fig. 2 is a side cross-sectional schematic view of the drill string after the tool joint section 10 has been welded to the drill pipe section 16. In Fig. 2 the welded drill string has been partitioned according to the steps of the present invention. The weld area contains a weld interface line 20 and heat affected zones 21 and 22 on either side of the weld interface line 20. The heat affected zones 21 and 22 are relatively wide sections of the welded parts containing metal that has been affected by the temperature of welding. A raised annular ridge 23 is a normal result of welding procedures used wherein the two pieces to be welded are forged together during the welding operation. The raised annular ridge 23 exists around the circumference of the welded pieces both internally and externally. Normally, these ridges are machined off the part to provide smooth, essentially flush surfaces before thermal treatment.

Referring now to Fig. 3A, quenching apparatus 24 is disclosed which comprises a generally circular quench ring 25, and located substantially in the centre thereof is a tubular internal quench pipe 26 having a closed end 27 extending slightly through ring 25. A quenchant inlet line 28 is also attached to ring 25. Fig. 3B represents an axial end view in schematic of the quenching apparatus 24 showing the same inlet line 28 feeding into the ring 25 with the quench pipe 26 located in the centre thereof. A plurality of spray nozzles 29 are situated on the inner wall of ring 25 and are in communication with the fluid chamber therein. A central opening 30 of ring 25 has pipe 26 located centrally therein. A support bracket 31 is located beneath ring 25 with upwardly extending side arms 32 for support of ring 25. A central brace 33 provides support for pipe 26.

Fig. 4 is an enlarged view of the quenching apparatus of Fig. 3A and 3B shown in partial cross-sectional view. In Fig. 4 the quench ring 25 contains an annular manifold chamber 34. Concentrically inward from the annular chamber 34 are the fluid manifold spray nozzles 29, in fluidic communication with inlet line 28 via manifold chamber 34 to receive incoming liquid and inject it radially inward from ring 25. The inner quench pipe 26 has an interior bore 35, which communicates with the horizontal portion of the tube located inside ring 25. A large number of radial spray ports 36 are located through the wall of tube 26 to allow incoming liquid from bore 35 to emit outwards in a radial spray pattern.

Fig. 5 is a side view in cross section of the apparatus in Fig. 4 at section line 5-5. The quenchant manifold chamber for the entire

cross section of the weld is more clearly identified therein. Likewise, the relationship between tube 26 and nozzles 29 is shown.

Fig. 6A and 6B illustrate a side view of an induction coil 38, its power source 39 and the quenching apparatus 24. After proper location of a welded tubular part 40 inside the circular induction coil 38, which is of the type known in the art, generally comprising one or more turns of electrically conductive material, the power source is energized and the induction coil heats the entire weld area on both sides of the weld line 20 above the transformation temperature into the austenitic range. Heating is continued for a sufficient period of time for the entire cross section of the weld area to attain the desired temperature and for essentially completely austenitic transformation to occur. The usual desired temperature is in the range of 1600–1800°F (870–985°C). The necessary heating time is determined by the varying compositions, sizes, and thicknesses of the welded parts. After this heating time has been completed, the heated area is rapidly moved horizontally within 3 to 5 seconds over the quench pipe 26 and inside of quench ring 25, as shown in Fig. 6B.

Fig. 7 shows a closeup view of how the welded part is located horizontally such that heat-affected zone 22 lies concentrically between quench ring 25 and perforated section 36 of tube 26. After proper location of the tool joint end of the drill pipe over quench tube 26, which proper location is facilitated by abutting the end of the tool joint with a radially extending alignment flange 37 secured to the external portion of tube 26, the quenching process may be performed. After proper location of the welded tubular part over the quench tube inside of the quench rings and against alignment flange 37, the quenching ring 25 is connected to a quenching source through inlet line 28 and quenching of the heat affected zone 22 is carried out by the injection of a quenching liquid having a cooling rate sufficient to achieve desirable microstructural transformations in the weld area without causing cracking from thermal shock.

Quenchants which have been found to provide the necessary cooling rate are the complex polar organic compounds, such as polyvinyl alcohol and polyalkylene glycol, mixed with water. One particularly advantageous quenching liquid consists of ten to twenty-five percent volume of one of these organic compounds mixed in water. The velocity and volume of the quenchant are selected to rapidly lower the temperature of the quenched area to a temperature in the range of 600–650°F (315 to 345°C). In one instance, a quench time of 40 to 56 seconds with a liquid quenching agent was required to lower the temperature to approximately 600°F

(315°C). The quenchant enters simultaneously through quenchant pipe 26 and inlet ring 25 to be injected onto the weld area through injection spray ports 36 and nozzles 29. The velocity and volume of the quenchant may be adjusted through varying pressure and flow supplied to the manifold chamber and quench tube as well as by varying the orifice sizes of nozzles 29 and injection ports 36. As illustrated in Fig. 7, the quenchant is applied only to the drill pipe side 22 of the weld area. It has been found that a sufficient cooling rate can be obtained by directing the quenchant to within one-tenth to one-half inch of the weld line 20 thereby avoiding a flow of quenchant on the more susceptible tool joint side 21 of the weld area. The quenchant should cover the entire heated area on the drill pipe side 22 of the weld area and generally covers an area extending up to one and one-half inches from the weld line 20.

After the quenchant has cooled the drill pipe side 22 of the weld area to approximately 600–650°F (315–345°C) the entire weld area is allowed to cool in air to at least 400°F (205°C) to complete the martensite transformation. The entire welded area is then reheated to a temperature somewhat below the austenite transformation temperature by any of the processes well known in the art. This tempering operation produces a strength and toughness in the weld area closely equivalent to the strength and toughness of the drill pipe and tool joint. The tempering temperature is usually in the range of 900–1200°F (480–650°C).

Fig. 8 illustrates another embodiment of the quenching apparatus providing a quench ring 125 located adjacent to and concentrically with a heating coil 138. Likewise, a quench pipe 126 having a set of spray parts 136 is located inside the welded drill pipe. The welded part is brought to the predetermined austenizing temperature in the weld zone through heating by induction coil 138, the power to the coil is cut off and quenching fluid is injected through pipe 126 and ring 125 to spray radially against the drill pipe heat-affected zone. The apparatus is particularly advantageous in that it applies the austenizing heat to the weld area in an even and efficient step and immediately after bringing the weld area to the desired temperature allows the quenching operation to be performed without need for the removal or substitution of mechanical equipment around the welded tubular part.

Thus, it can be seen that the present invention provides means and methods for improving the toughness and strength of the weld area after joining two sections of cylindrical tubular products such as drill pipe and tool joints. The present invention embodies the process of butt welding the two tubular sections by known means such as flashwelding,

then machining the excess weld material from the exterior and interior surfaces of the welded tubular part. After the excess weld material is removed from the welded tubular

- 5 product, the product is located in an induction coil and the welded area is heated to a predetermined temperature above the transformation temperature of steel, then immediately moved into a quenching apparatus comprising
10 an internal quench tube located concentrically inside a quench ring where the quenching operation is performed. The apparatus is particularly advantageous in that the quench zone is restricted during the quench, thus reducing
15 thermal shock along the weld line. Furthermore, the present invention discloses a process for introducing martensite structures and tempering these structures in many steels, which strengthens the normally weakened
20 weld areas and provides additional toughness of the welded part. By the use of the present invention, which utilizes the quench system in conjunction with an advantageous quenchant such as polyvinyl alcohol and polyalkylene
25 glycol, mixed with water, a tough strong weld having minimum residual weaknesses resulting from the welding process is obtained. Although certain preferred embodiments of the invention have been herein described in
30 order to provide an understanding of the general principles of the invention, it will be appreciated that various changes and innovations can be affected in the described methods and apparatus without departing these principles. For example, whereas the first embodiment is illustrated as a single row of
35 nozzles and ports directed radially toward the drill pipe quenchant zone, it is clear that the apparatus of the first embodiment could be modified by directing the nozzles in a slanted
40 direction by alternating each nozzle toward a different area in the drill pipe zone. Likewise, the parts in the quench pipe could be drilled at an angle so that alternate ports could be
45 directed at alternate areas of the zone. In this modification, the quench pipe and injection nozzles could be located directly over the weld line yet quenchant could be directed at an angle from the weld line into the quench
50 zone.

CLAIMS

1. A method of treating a first member after welding a second member thereto, said
55 method being particularly advantageous for eliminating stresses and hardening the weld area, and said method comprising:
placing said welded first and second members inside a heating means;
60 thoroughly heating the weld area of the first and second members to a temperature above their austenitic transformation temperature;
holding the weld area temperature above the austenitic transformation temperature for a
65 sufficient time to allow substantial transforma-

tion of the metal in the weld area to austenite; rapidly quenching the first member side of the weld area to a temperature sufficiently below the austenite transformation temperature to transform substantial quantities of the total weld metal to martensite;

- 70 allowing further air cooling of the weld area to approximately 400°F (205°C) or less; and tempering the weld area by reheating to a
75 temperature below the austenite transformation temperature.

2. A method as claimed in claim 1 wherein said quenching step comprises spraying onto the weld metal in a zone separated from the weld line a quenchant selected from polyvinyl alcohol and water or polyalkylene glycol and water.

3. A method as claimed in claim 1 or 2, wherein said quenching step comprises rapidly quenching the weld area to a temperature between about 500°F (260°C) and about 700°F (375°C).

4. A method as claimed in any preceding claim, wherein said tempering step comprises reheating said weld area to a temperature between about 900°F (480°C) and about 1200°F (650°C).

5. A method as claimed in any preceding claim in which the first member is a drill pipe
95 and the second member is a tool joint.

6. A method of attaching a first member to a second member to obtain substantially the inherent strength of the first member in the area of attachment between the first and
100 second members; said method comprising:
attaching a second member to a first member by butt welding;
removing any excess weld material from the exterior and interior surfaces of the welded
105 parts;

raising the temperature of the weld area to above the austenite transformation temperature;

holding the weld area above the austenite transformation temperature a sufficient time to allow substantial transformation of the weld area metal to austenite;

quenching the first member portion only of the weld area, after said transformation, to a
115 quenched temperature sufficiently below the austenite transformation temperature to transform a substantial portion of the austenite into martensite; and

reheating the weld area to a tempering temperature between the quenched temperature and the transformation temperature to reduce stresses.

7. A method as claimed in claim 6, wherein the quenchant used during said quenching step is a mixture of water and a complex polar organic compound.

8. A method as claimed in claim 6 or 7 further comprising immediately prior to said quenching step rapidly moving the welded
130 parts from a heating means to a quenching



then machining the excess weld material from the exterior and interior surfaces of the welded tubular part. After the excess weld material is removed from the welded tubular product, the product is located in an induction coil and the welded area is heated to a predetermined temperature above the transformation temperature of steel, then immediately moved into a quenching apparatus comprising an internal quench tube located concentrically inside a quench ring where the quenching operation is performed. The apparatus is particularly advantageous in that the quench zone is restricted during the quench, thus reducing thermal shock along the weld line. Furthermore, the present invention discloses a process for introducing martensite structures and tempering these structures in many steels, which strengthens the normally weakened weld areas and provides additional toughness of the welded part. By the use of the present invention, which utilizes the quench system in conjunction with an advantageous quenchant such as polyvinyl alcohol and polyalkylene glycol, mixed with water, a tough strong weld having minimum residual weaknesses resulting from the welding process is obtained. Although certain preferred embodiments of the invention have been herein described in order to provide an understanding of the general principles of the invention, it will be appreciated that various changes and innovations can be affected in the described methods and apparatus without departing these principles. For example, whereas the first embodiment is illustrated as a single row of nozzles and ports directed radially toward the drill pipe quenchant zone, it is clear that the apparatus of the first embodiment could be modified by directing the nozzles in a slanted direction by alternating each nozzle toward a different area in the drill pipe zone. Likewise, the parts in the quench pipe could be drilled at an angle so that alternate ports could be directed at alternate areas of the zone. In this modification, the quench pipe and injection nozzles could be located directly over the weld line yet quenchant could be directed at an angle from the weld line into the quench zone.

CLAIMS

1. A method of treating a first member after welding a second member thereto, said method being particularly advantageous for eliminating stresses and hardening the weld area, and said method comprising:
placing said welded first and second members inside a heating means;
thoroughly heating the weld area of the first and second members to a temperature above their austenitic transformation temperature;
holding the weld area temperature above the austenitic transformation temperature for a sufficient time to allow substantial transforma-

tion of the metal in the weld area to austenite; rapidly quenching the first member side of the weld area to a temperature sufficiently below the austenite transformation temperature to transform substantial quantities of the total weld metal to martensite;

allowing further air cooling of the weld area to approximately 400°F (205°C) or less; and tempering the weld area by reheating to a temperature below the austenite transformation temperature.

2. A method as claimed in claim 1 wherein said quenching step comprises spraying onto the weld metal in a zone separated from the weld line a quenchant selected from polyvinyl alcohol and water or polyalkylene glycol and water.

3. A method as claimed in claim 1 or 2, wherein said quenching step comprises rapidly quenching the weld area to a temperature between about 500°F (260°C) and about 700°F (375°C).

4. A method as claimed in any preceding claim, wherein said tempering step comprises reheating said weld area to a temperature between about 900°F (480°C) and about 1200°F (650°C).

5. A method as claimed in any preceding claim in which the first member is a drill pipe and the second member is a tool joint.

6. A method of attaching a first member to a second member to obtain substantially the inherent strength of the first member in the area of attachment between the first and second members; said method comprising:
attaching a second member to a first member by butt welding;
removing any excess weld material from the exterior and interior surfaces of the welded parts;
raising the temperature of the weld area to above the austenite transformation temperature;

holding the weld area above the austenite transformation temperature a sufficient time to allow substantial transformation of the weld area metal to austenite;

quenching the first member portion only of the weld area, after said transformation, to a quenched temperature sufficiently below the austenite transformation temperature to transform a substantial portion of the austenite into martensite; and

reheating the weld area to a tempering temperature between the quenched temperature and the transformation temperature to reduce stresses.

7. A method as claimed in claim 6, wherein the quenchant used during said quenching step is a mixture of water and a complex polar organic compound.

8. A method as claimed in claim 6 or 7 further comprising immediately prior to said quenching step rapidly moving the welded parts from a heating means to a quenching



means.

9. A method as claimed in any of claims 6 to 8, in which the first member is a drill pipe and the second member is a tool joint.

5 10. A method of treating a first member after welding a second member thereto substantially as hereinbefore described with reference to Figs. 1 to 7 or Fig. 8 of the accompanying drawings.

10 11. A method of attaching a first member to a second member substantially as hereinbefore described with reference to Figs. 1 to 7 or Fig. 8 of the accompanying drawings.

Printed for Her Majesty's Stationery Office,
by Burgess & Son (Abingdon) Ltd.—1982.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.