

APPARATUS AND METHOD TO ELECTROPLATE A TUBULAR STRUCTURE SURFACE

TECHNICAL FIELD

The present invention relates to electroplating, and more particularly relates to an apparatus and method to electroplate a surface of a tubular structure, and an electroplating system comprising more than one of the apparatus.

BACKGROUND

Electroplating is a process that uses an electric current to reduce dissolved metal ions to form a thin coherent metal coating on a surface of an object. Electroplating is primarily used to change an object's surface properties such as abrasion and wear resistance, corrosion protection, lubricity or aesthetic properties. For example, electroplating is used to coat threaded surfaces of steel pipes with copper to increase its lubricity and prevent galling at such threaded surfaces when multiple steel pipes are engaged together. Typically, a threaded surface found on an outer periphery of one end of a steel pipe is called a male thread, while a threaded surface found in an inner periphery of a steel pipe is called a female thread. The male thread on one steel pipe is screwed into the female thread on another steel pipe to connect the steel pipes.

During electroplating, air bubbles of hydrogen are usually generated at the same time as the electroplating layer is deposited on the surface. If the air bubbles remain on the surface for an extended period of time, this would disrupt the electroplating process, resulting in unequal coating. This is a particular problem when electroplating threaded surfaces of steel pipes because air bubbles are more likely to be trapped in between the grooves of the threaded surface. As a result, this would increase the incidence of galling at the connecting portions between the steel pipes.

Previous attempts to address this problem include electrobrushing, in which localized areas or entire items are plated using a brush saturated with a plating solution. The brush, typically a stainless steel body wrapped with an absorbent cloth material that both holds the plating solution and prevents direct contact with the item being plated, is connected to an anode of a low voltage direct current power source, and the item to be plated is connected to a cathode. An operator dips the brush in plating solution and applies it to the item, moving the brush continually to get an even distribution of the plating material. Disadvantages of electrobrushing include increased cost because of the reliance on a skilled person to carry out the electrobrushing process and the long hands-on hours, and inconsistency in the thickness of the coated layer because electrobrushing is a manual process.

Another attempt to address this problem, more particularly for female threads, is to use an electroplating apparatus comprising a plurality of nozzles to inject electroplating solution onto the threaded surface of the steel pipe. The nozzles in the electroplating apparatus extend in a radial manner with the center at the pipe axis of the steel pipe. Each nozzle is typically inclined at an angle larger than 20 degrees and smaller than 90 degrees towards the threaded surface relative to a plane perpendicular to the pipe axis. Through the nozzles, the electroplating apparatus generates a spiral jet stream of electroplating solution directed at the threaded surface for electroplating the threaded surface. Such jet stream also helps to remove small air bubbles generated during the electroplating process by pushing the air bubbles to leave the thread roots of the threaded surface. However, a disadvantage of this technique involving nozzles is that it involves large consumption of electroplating solution.

SUMMARY

According to an example of the present disclosure, there are provided an apparatus and a method of electroplating as claimed in the independent claims. Some optional features are defined in the dependent claims.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 shows a schematic diagram of a first example of the electroplating apparatus according to the present disclosure for plating an interior surface of a tubular structure.

Figure 2 shows a more detailed cross-sectional representation of the electroplating apparatus of Figure 1.

Figure 3A to 3C illustrates how a barrier is adjusted to plug an inner channel portion of the tubular structure.

Figure 4A to 4C illustrates how the electroplating apparatus can be tilted to inclined, horizontal and reclined configurations.

Figure 5 shows a schematic diagram of a second example of the electroplating apparatus according to the present disclosure for plating an exterior surface of a tubular structure.

Figure 6 shows connection between two conduits and illustrates how fluid flow in the narrower conduit is expedited by flow in the wider conduit.

Figure 7 shows a more detailed cross-sectional representation of the electroplating apparatus of Figure 5.

Figure 8 shows a schematic diagram of a circulatory system of a fluid supply system of an example of an electroplating system covered in the present disclosure.

Figure 9 shows a flow chart of an example of an electroplating process according to the present disclosure.

DETAILED DESCRIPTION

In view of existing technology, a need is identified for a simpler, and less reagent-consuming electroplating apparatus and method of electroplating. Additionally, it would be beneficial if such electroplating apparatus can be applied to both male and female threads of a tubular structure (e.g. steel pipe) to be electroplated. Other desirable features and characteristics will become apparent in the following disclosure and the appended claims, taken in conjunction with the accompanying drawings.

Examples of the present disclosure relate to an electroplating apparatus and a method of electroplating a surface of a tubular structure. The tubular structure can be a fluid conduit comprising electrically conductive surfaces to be electroplated. It can be a steel pipe and the like. Such electroplating apparatus and method can be automated, are less reagent-consuming, and capable of being applied to electroplate multiple tubular structures in an electroplating system comprising a plurality of the electroplating apparatus. The present electroplating apparatus and method are also suitable to be applied for electroplating threaded surfaces on internal and external surfaces of a tubular structure. Specifically, the electroplating apparatus and method also solve a problem of uneven plating of threaded surfaces caused by a build-up of air bubbles during the electroplating process. This problem is significant in the case of threaded surfaces as air bubbles can build up and get trapped in between grooves of the threaded surfaces during the electroplating process. This leads to a higher incidence of galling at connecting portions between the tubular structures if such tubular structures are configured to connect to one another at such connecting portions via the threaded surfaces.

The present electroplating apparatus and method distinguishes from the prior art in that the electroplating process is carried out via an immersion method and the electroplating apparatus is configured for such immersion. Specifically, an electroplating chamber is formed with portions or surfaces of the tubular structure to be electroplated via a chamber forming mechanism. Once the electroplating chamber is formed, an electrolyte (or electroplating solution) then enters and fills up the chamber during the electroplating process, immersing the portions or surfaces of the tubular structure with the electrolyte. The electroplating process commences when a potential difference is applied. Such immersion technique has advantages over the prior art, including at least a more uniform plating thickness, especially in comparison to the existing electrobrushing technique, and it is believed that lesser electrolyte would be used compared to the existing technique involving nozzles.

For the avoidance of doubt, "to immerse" in respect of the immersion method described in the present disclosure involves filling up the electroplating chamber (formed from the chamber forming mechanism and portions of the tubular structure to be electroplated) with the electroplating fluid completely such that the portion or surface of the tubular structure to be electroplated is completely covered with the electroplating fluid during the electroplating process. The electroplating fluid in the electroplating chamber may be replaced continuously when coupled to a fluid supply system. In addition, the immersion method may be carried out with the electroplating chamber at an inclined, neutral or reclined angle relative to a horizontal axis.

The “tubular structure” referred to in the present disclosure is a structure with a tubular portion that comprises a surface for electroplating. The tubular portion comprises a cross-section that may be circular, elliptical, quadrilateral, pentagonal, hexagonal, octagonal, and the like. The tubular portion may be a substantial portion or less substantial portion of the tubular structure. Examples of the tubular structure include tubings, wireline, slickline, and tubular couplers used in oil and gas industries etc. The surface of the tubular structure to be electroplated may be threaded or not threaded.

A. Electroplating apparatus for electroplating an internal threaded surface

Figure 1 shows a first example of an electroplating apparatus 100 of the present disclosure for electroplating an internal threaded surface 132 of a tubular structure 102. In this example, the tubular structure 102 is a cylindrical steel pipe with two opposing open end portions and an internal threaded surface 132 that is circumferentially disposed in the inside of the tubular structure 102. In this example, the internal threaded surface tapers for a substantial length beginning from one wider end portion of the openings in a direction towards a narrower end portion of the openings. It should be appreciated that the tubular structure 102 is not limited to just the configuration of the tubular structure 102 of Figure 1. It could be that the threaded surface 132 is not tapered and not extending for a substantial length. The electroplating apparatus 100 comprises a programmable logic controller (not shown) for controlling the method to electroplate the internal threaded surface 132 of the tubular structure 102, a chamber forming mechanism 104 for forming an electroplating chamber 120 with portions of the tubular structure 102, and a central fluid supply system 106 for delivery of fluids to the electroplating chamber 120. A cross-section of the tubular structure 102 and the electroplating apparatus 100 is represented in Figure 1.

The electroplating apparatus 100 of Figure 1 carries out the electroplating process via the immersion technique, as mentioned above. It involves enclosing the portions of the tubular structure 102 to be electroplated via the chamber forming mechanism 104 to form an electroplating chamber 120, which is to be filled up by the electrolyte during the electroplating process. The chamber forming mechanism 104 comprises an inlet 124 to allow fluid to enter and fill up the electroplating chamber 120 and immerse the surface of the tubular structure 102 to be electroplated and an outlet 122 to allow fluid to exit the electroplating chamber 120. The term “fluid” covers liquid and gas. In the present example, the chamber forming mechanism 104 has a cover 114 for sealing one of the opposing end portions of the tubular structure 102. The inlet 124 and outlet 122 are located at this cover 114. The chamber forming mechanism 104 further comprises an electrode 116 extending from the cover 114 of the chamber forming mechanism 104 and projecting into the electroplating chamber 120. The electrode 116 is centrally located inside the electroplating chamber 120. The electrode 116 is tubular in shape and may be in a meshed form. The electrode 116 is an anode in the present example and is disposed opposite of the portions of the tubular structure 102 to be electroplated. The electrode 116 can be made of any suitable metal for an anode, which may include platinum. When a potential difference (voltage difference) is applied between the electrode 116 and the tubular structure 102, metal ions in the electrolyte will begin to deposit on the surface or surfaces of the tubular structure 102 (in this case, the threaded surface 132) to be electroplated. It should be appreciated that the present electroplating apparatus 100 is also capable of electroplating an internal surface of the tubular structure that is not threaded as well.

Notably, the electroplating apparatus 100 of the present example does not comprise the nozzles mentioned in the background of the present disclosure.

Depending on the configuration of the tubular structure 102, there can be many ways to secure the chamber forming mechanism 104 and the tubular structure 102 in position. The chamber forming mechanism 104 is shaped and configured to prevent leakage of fluid from the electroplating chamber 120 that is formed. In the present example, the electroplating apparatus 100 comprises a clamping mechanism 140 to secure the chamber forming mechanism 104 to the tubular structure 102, such that one or more seals 112 disposed between the chamber forming mechanism and the tubular structure 102 are compressed when the electroplating chamber 120 is formed. In the present example, there is only one seal 112. Compression of the one or more seals 112 prevent fluid leakage from the electroplating chamber 120. Specifically, in the present example, the clamping mechanism 140 comprises a first jaw 108 configured to contact a first portion of the tubular structure 102. The first jaw 108 can be referred to as a stopper. In the present example, this first portion of the tubular structure

102 is one of the opposing open end portions of the tubular structure 102. The clamping mechanism 140 further comprises the chamber forming mechanism 104 as a second jaw opposite to the first jaw 108 to contact a second portion of the tubular structure 102. Specifically, in the present example, the second jaw is the cover 114 of the chamber forming mechanism 104. This second portion of the tubular structure 102 is the other one of the opposing open end portions of the tubular structure 102. The distance between the first jaw 108 and the second jaw 114 is adjustable according to the dimensions of the tubular structure 102. A locking mechanism can be provided to lock the position of the first jaw 108 relative to the second jaw 114 and tighten the grip of the first jaw 108 and the second jaw 114 on the tubular structure 102. It is appreciated that the clamping mechanism 140 is not limited to that disclosed in the present example and other suitable clamping mechanisms to secure the chamber forming mechanism 104 to the tubular structure 102 can be used as well. The working principles and design of the clamping mechanism 140 can be based on that of a bench vice that is used to clamp or retain a workpiece (in the present example, the workpiece is the tubular structure 102), allowing work to be securely performed on the workpiece.

In addition to the outlet 122 for a fluid to exit the electroplating chamber 120, the chamber forming mechanism 104 may include a second outlet 126 as shown in Figure 1. The second outlet 126 is located at a top portion of the electroplating chamber 120. In the present example, the second outlet 126 is located on the cover 114. This second outlet 126 is for the removal of waste gases from the electroplating chamber 120 during the electroplating process. Waste gases, which include hydrogen, interfere with the plating uniformity of the electroplating process. These waste gases in the form of air bubbles will float upwards and will become problematic especially at a top portion of an internal surface of the tubular structure 102 like in the case of the example of Figure 1. The second outlet 126 advantageously allows the waste gases or air bubbles to escape so that the top portion of the internal surface of the tubular structure 102 to be electroplated will be fully immersed with the electrolyte during the electroplating process. In this way, uniform plating at the top portion of the tubular structure 102 is ensured.

In the present example, the second outlet 126 is disposed above the inlet 124. However, in another example, the second outlet 126 may be disposed above the outlet 122 for fluid to exit. In this case, the inlet 124 can be placed below the outlet 122. This is to facilitate the removal of the waste gases by the movement of the fluid exiting the electroplating chamber 120 via the outlet 122 below. Specifically, the movement of the fluid out of the outlet 122 would assist to direct the waste gases, in the form of air bubbles, to float upward and toward the second outlet 126 (which is disposed above the outlet 122) for their removal. This is particularly advantageous during the electroplating process of an internal threaded surface, whereby air bubbles, which are typically trapped between the grooves on such threaded surface, are removed via the second outlet 126 when the fluid exits the electroplating chamber 120 via the outlet 122. As mentioned above, this promotes a more even plating process of the threaded surface and prevents the incidence of galling at the threaded surface, which may occur in the connection of the tubular structure 102 with another tubular structure.

With reference to Figure 1 and Figure 6, a first conduit 502 may be connected to the second outlet 126 and a second conduit 504 for channeling exiting fluid may be connected to the outlet 122 for fluid to exit. A third conduit 503 (not shown in Figure 6) may be connected to the inlet 124. The third conduit 503 is connected to a source (not shown in Figure 6) for supplying fluid into the electroplating chamber 120 through the inlet 124. The second conduit 504 is for directing fluid to be removed from the electroplating chamber 120 to a destination (not shown in Figure 6). The first conduit 502 is for removing waste gases exiting the second outlet 126 and if no waste gases are present to remove, the first conduit 502 directs fluid to be removed from the electroplating chamber 120 as well. The first conduit 502 may have a diameter that is smaller than the second conduit 504 and the first conduit 502 may be connected to the second conduit 504. Specifically, a first end of the first conduit 502 is connected to the second outlet 126 and a second end opposite to the first end of the first conduit 502 is connected to the second conduit 504. In this configuration, as fluid is exiting in the second conduit 504, waste gases can be removed more efficiently due to larger volume of fluid flow 514 through the second conduit 504 compared to lesser volume of fluid flow 512 through the first conduit 502. The larger volume of fluid flow 514 drags and expedites the lesser volume of fluid flow 512.

Referring back to Figure 1, to further facilitate the removal of waste gases via the second outlet 126, there is an option of including a tilting mechanism 128. The tilting mechanism 128 comprises a platform 110 configured for mounting the tubular structure 102 thereon. Specifically, before any tilting,

the tubular structure 102 will sit in a horizontal orientation on the platform 110 such that a longitudinal axis 2012 of a hollow elongate core of the tubular structure 102 is substantially parallel to a horizontal axis. There may be a plurality of rollers 136 disposed on the platform on which the tubular structure 102 can sit and slide over. The plurality of rollers 136 facilitates adjustment of the positioning of the tubular structure 102, for instance, when the tubular structure 102 is subject to clamping by the clamping mechanism 140. Furthermore, the platform 110 is pivotably mounted in the tilting mechanism 128 and is adjustable to tilt. As the platform 110 is adjusted to tilt, the mounted tubular structure 102 is correspondingly tilted such that the longitudinal axis 2012 of the tubular structure 102 forms an angle relative to the horizontal axis. Preferably, the tilting mechanism 128 is capable of tilting the tubular structure 120 from a horizontal orientation or horizontal axis by 0 to 45 degrees, or preferably 0 to 15 degrees. Tilting the tubular structure 102 at an inclined angle during the electroplating process elevates the top portion of the electroplating chamber 120 where the second outlet 126 is located and this would advantageously facilitate the removal of gas bubbles trapped in grooves of the threaded surface forming at the top portion of the electroplating chamber 120. This is because the gas bubbles would migrate towards the elevated portion of the electroplating chamber 120 and escape from the electroplating chamber 120 via the second outlet 126. An example of the tilting mechanism 128 can include a fulcrum or pivot, wherein the platform 110 is pivotably mounted to the pivot. The platform 110 is pivotable about the fulcrum or pivot to tilt the mounted tubular structure 102 to the desired angle. One or more locking mechanism can be provided to lock the platform 110 in the tilted configuration.

In another example of the present disclosure, the chamber forming mechanism 104 may form the electroplating chamber 120 with inner walls comprising: (a) internal surface of the tubular structure 102 and (b) the surface of one or more portion of the chamber forming mechanism 104 covering one or more respective opening of the tubular structure 102. For example, the chamber forming mechanism 104 may be configured to comprise the clamping mechanism 140. The first jaw and the second jaw of the clamping mechanism 140 would then constitute the surface of the one or more portion of the chamber forming mechanism 104 covering one or more respective opening of the tubular structure 102. If the tubular structure 102 has 2 openings like in the case of Figure 1, the first jaw and second jaw can cover the 2 openings respectively. Accordingly, if the tubular structure 102 has more openings, more jaws can be provided to cover the openings.

In the example of Figure 1, an additional barrier 118 is provided for plugging an inner channel portion of the tubular structure 102 to prevent fluid leakage into the inner channel portion and this barrier 118 forms part of an inner wall of the electroplating chamber 120. In the present example, the barrier 118 plugs the open end of the tubular structure 102 opposite to the cover 114. Specifically, the electroplating chamber 120 of the example of Figure 1 has the following as inner walls: the threaded surface 132 of the tubular structure 102 in Figure 1; the cover 114 of the chamber forming mechanism 104 acting as the second jaw of the clamping mechanism 140, which is sealing one opening of the tubular structure 102; and the barrier 118 disposed at a distance from the cover 114 substantially equivalent to the length of the threaded surface 132. The seal 112 is disposed between the second jaw 114 and the opening of the tubular structure 102 to prevent fluid leakage from the electroplating chamber 120.

The barrier 118 may comprise of a resilient flexible material, like rubber at least at the edges for contacting inner walls of the tubular structure 102. The barrier 118 may have a slightly larger diameter than an inner diameter of the tubular structure 102 at which the barrier 118 is to be placed to ensure tight sealing of the inner channel of the tubular structure 102. It is understood that only the portion or portions of the tubular structure 102 that bound the electroplating chamber 120 would be electroplated since it is these portion or portions that will be immersed with the electrolyte during the electroplating process. Hence, the distance of the barrier 118 away from the cover 114 of the chamber forming mechanism 104 acting as the second jaw of the clamping mechanism 140 would determine how much of the internal threaded surface 132 of the tubular structure 102 is to be subjected to electroplating.

An adjustment mechanism 119 can be mounted to the barrier 118. The adjustment mechanism 119 is configured to move the barrier 118 to a position at the inner channel portion where the barrier 118 is to be placed. Specifically, the adjustment mechanism may comprise a handle 121 rotatable to make the adjustment. In the present example, the handle 121 is coupled to a spindle 125 that is connected to the barrier 118. The spindle 125 is adjustable to extend into the electroplating chamber 120. A seal

115 is disposed at a joint between the cover 114 and the spindle 125 to prevent fluid leakage from the electroplating chamber 120 at such joint. By rotating the handle 121, distance between the barrier 118 and the cover 114 can be adjusted. In the present example, the barrier 118 is moved to a distance such that the barrier 118 is pushed against an inner wall of the tubular structure 102 having smaller diameter than the diameter of the barrier 118. The inner wall of the tubular structure 102 having the smaller diameter obstructs further movement of the barrier 118. To prevent the tubular structure 102 from being moved by the barrier 118, the first jaw 108 of the clamping mechanism 140 has to be locked and tightened in position relative to the second jaw i.e. the cover 114 before the distance between the barrier 118 and the cover 114 is adjusted.

It is understood that the electroplating apparatus 100 can be of different dimensions adapted for electroplating tubular structures of different sizes.

Figure 2 shows an example of a more detailed cross-sectional representation of the electroplating apparatus 100 of Figure 1. Reference numerals for common components having similar function of the electroplating apparatus 100 in Figure 1 are re-used for the electroplating apparatus 100 in Figure 2. Similarly, the electroplating apparatus 100 of Figure 2 is for electroplating an internal threaded surface 132 of a tubular structure 102 with opposing open end portions. The electroplating apparatus 100 of Figure 2 comprises a chamber forming mechanism 104 for forming an electroplating chamber 120 with portions of the tubular structure 102.

With reference to Figure 2, the chamber forming mechanism 104 comprises an inlet 124 to allow fluid to enter and fill up the electroplating chamber 120 and immerse the surface of the tubular structure 102 to be electroplated and an outlet 122 to allow fluid to exit the electroplating chamber 120. The chamber forming mechanism 104 has a cover 114 for sealing one of the opposing open end portions of the tubular structure 102. A moveable barrier 118 is provided for plugging an inner channel portion of the tubular structure 102 disposed at a distance from the cover 114. Consequently, the electroplating chamber 120 of the example of Figure 2 has the following as inner walls: the threaded surface 132 of the tubular structure 102; the cover 114 of the chamber forming mechanism 104, which is sealing one of the opposing end portions of the tubular structure 102; and the moveable barrier 118 disposed at a distance from the cover 114. The moveable barrier 118 is for sealing the inner channel portion of the tubular structure 102. The chamber forming mechanism 104 comprises a meshed electrode 116 extending from the cover 114 of the chamber forming mechanism 104 and projecting into the electroplating chamber 120.

In the electroplating apparatus 100 of Figure 2, there is provided a clamping mechanism 140 to secure the chamber forming mechanism 104 to the tubular structure 102, such that one or more seals 112 disposed between the chamber forming mechanism 104 and the tubular structure 102 are compressed when the electroplating chamber 120 is formed. Compression of the one or more seals 112 prevents fluid leakage from the electroplating chamber 120. In the present example of Figure 2, the clamping mechanism 140 comprises a first jaw 108 configured to contact a first end portion of the tubular structure 102, which is at one of the opposing open end portions of the tubular structure 102. The clamping mechanism 140 further comprises the chamber forming mechanism 104 as a second jaw 114 opposite to the first jaw 108 to contact a second end portion of the tubular structure 102, which is at the other end of the opposing open end portions of the tubular structure 102. Specifically, in the present example, the second jaw is the cover 114 of the chamber forming mechanism 104 and the second jaw also has the reference number 114 in the present disclosure.

In the electroplating apparatus 100 of Figure 2, the first jaw 108 has a bracket 2008 that is fixed at a position and comprises a press screw 2002 that is configured to screw through a threaded hole portion 2010 of the bracket 2008. The threaded hole portion 2010 may be formed by welding a nut such that the threaded hole of the nut corresponds with a position of a hole drilled in the bracket 2008. The hole in the bracket 2008 is for the press screw 2002 to go through and the threaded hole of the nut provides the threaded hole portion 2010 for the press screw 2002 to make adjustments. The press screw 2002 comprises a threaded shaft with a clamp 2004 fixed at one end of the threaded shaft and a rotatable handle 2006 fixed at an opposing end of the threaded shaft. In use, the press screw 2002 is screwed through the threaded hole portion 2010 of the bracket 2008. The clamp 2004 is adjustable to move in a direction towards the second jaw 114 or move in a direction away from the second jaw 114 by rotating the handle 2006. As the handle 2006 rotates, the threaded shaft screws pass the threaded hole portion 2010. The clamp 2004 is configured to exert pressure on the first end portion of

the tubular structure 102 when the handle 2006 is rotated to move the clamp 2004 against the first end portion of the tubular structure 102. The chamber forming mechanism 104, which forms the second jaw 114 of the clamping mechanism 104, is fixed at a second position. The cover 114 of the chamber forming mechanism 104 is placed in contact with the second end portion of the tubular structure 102. When the handle 2006 is rotated to tighten the clamp 2004 against the first end portion of the tubular structure 102, the tubular structure 102 is pressed against the cover 114 of the chamber forming mechanism 104. It should be appreciated that the configuration of the first jaw 108 is not limited to the design in the present example.

With reference to Figure 2, the clamping mechanism 140 may further comprise a third clamp 160 comprising a third jaw and a fourth jaw for clamping external walls of the tubular structure 102 for additional stability. Specifically, the first and second jaws 108, 114 described above are for clamping the tubular structure 102 to fix it in position along a longitudinal axis 2012. The third and fourth jaws are for clamping the tubular structure 102 to fix it in position along a vertical axis 2014. The third jaw comprises a press screw 2022 similar to the press screw 2002 of the first jaw 108. The press screw 2022 comprises a threaded shaft fixed to a rotatable handle 2020 at one end and a clamp 2016 fixed at an opposing end of the threaded shaft. As the handle 2020 is rotated, the threaded shaft screws and rotates pass a threaded hole portion 2024 that is fixed in position. As the threaded shaft is rotated, the clamp 2016 is adjusted to move towards or away from the fourth jaw depending on the direction of rotation of the handle 2020. The fourth jaw is comprised of a plurality of rollers 2018, which the tubular structure 102 is placed on. The rollers 2018 are fixed in position. The rollers 2018 facilitate horizontal movement of the tubular structure 102 along the horizontal axis during the clamping of the first and second jaws 108 and 114 of the clamping mechanism 140. Although it is described that the clamping mechanism 140 in the present example of Figure 2 comprises four jaws, only the first and second jaws are essential in securing the tubular structure to the chamber forming mechanism i.e. the third and fourth jaws are optional.

In addition to the outlet 122 for the fluid to exit the electroplating chamber 120, the chamber forming mechanism 104 may include a second outlet 126 as shown in Figure 2. The second outlet 126 is located at a top portion of the electroplating chamber 120 for removal of waste gases from the electroplating chamber 120 during the electroplating process. Waste gases include hydrogen, which interfere with the plating uniformity of the electroplating process. Hence, the second outlet 126 advantageously allows the waste gases or air bubbles to escape and the top portion of the tubular structure 102 to be electroplated will be fully immersed with the electrolyte during the electroplating process. In this way, uniform plating at the top portion of the tubular structure 102 is ensured. Figure 6 is applicable to the second outlet 126 and the outlet 122 of Figure 2.

In the electroplating apparatus 100 of Figure 2, the chamber forming mechanism 104 is mounted to a vertical alignment mechanism 150 and a horizontal alignment mechanism 152. The vertical alignment mechanism 150 is for adjusting the position of the chamber forming mechanism 104 relative to the vertical axis 2014. The vertical alignment mechanism 150 comprises a threaded shaft that can be screwed through a threaded hole portion 2026 that is fixed in position. The threaded shaft is fixed to a rotatable handle 156 at one end and an opposing end of the threaded shaft is mounted to a bracket 2028 that is mounted to the cover 114 of the chamber forming mechanism 104. The threaded shaft is mounted to the bracket 2028 in a manner that will allow the threaded shaft to rotate at the spot that is mounted to the bracket 2028. The chamber forming mechanism 104 can be adjusted to move up or down by rotating the handle 156. Rotating the handle 156 in turn moves the threaded shaft pass the threaded hole portion 2026 to raise or lower the chamber forming mechanism 104. In this manner, the chamber forming mechanism 104 can be adjusted to a desired position vertically. In the present example, the chamber forming mechanism 104 is adjusted so that the barrier 118 is centered with the tubular structure 102 and the barrier 118 can fit into an inner channel portion of the tubular structure 102. The horizontal alignment mechanism 152 is for adjusting distance of the barrier 118 away from or towards the cover 114. The vertical alignment mechanism 150 and the horizontal alignment mechanism 152 work together to enable coupling of the chamber forming mechanism 104 to tubular structures 102 of different sizes or diameters. The barrier 118 is changeable to larger or smaller size to fit and seal channels of tubular structures 102 for different sizes. The horizontal alignment mechanism 152 has a similar purpose as the adjustment mechanism 119 described with reference to Figure 1, which is to facilitate movement of the barrier 118 to a position in the inner channel portion of the tubular structure 102 where the barrier 118 is to be placed. The horizontal alignment mechanism 152 comprises an elongate shaft 2030 with one end fixed with a handle 121 and an opposing end of

the elongate shaft 2030 is fixed to the barrier 118. The handle 121 is used to activate and deactivate a sealing feature of the barrier 118. The horizontal alignment mechanism 152 comprises a handle 154 for adjusting the barrier 118 to a desired distance from the cover 114.

An example of the horizontal alignment mechanism 152 of Figure 2 will now be described in more detail with reference to Figures 3A, 3B and 3C. Figures 3A, 3B and 3C are cross-sectional drawings focusing on the horizontal alignment mechanism 152 and they illustrate sequential movements of the horizontal alignment mechanism 152 when it is in use.

In Figure 3A, it is shown that the barrier 118 is centered with the tubular structure 102 such that the barrier 118 and the tubular structure 102 share the same center along the longitudinal axis 2012. The horizontal alignment mechanism 152 comprises a tubular extension 322 extending from the cover 114 in a direction away from the electroplating chamber 120 to be formed. The horizontal alignment mechanism 152 comprises a first tubular member 312 and a second tubular member 314 that is telescopically coupled to the first tubular member 312. The first tubular member 312 comprises a first portion 320 for mounting to an open end of the tubular extension 322. The first portion 320 comprises a first part for inserting into the first tubular member 312, and a second part external to the tubular extension 322. The handle 154 of the horizontal alignment mechanism 152 is connected to the second part of the first portion 320 of the first tubular member 312. The first tubular member 312 further comprises a second portion 318 comprising an external threaded portion. The second portion 318 extends from the first portion 320 in a direction towards the barrier 118. The second portion 318 has a diameter smaller than the first portion 320.

The first tubular member 312 is detachably connected to the tubular extension 322 and is rotatable about the longitudinal axis 2012. Specifically, the first part of the first portion 320 is mounted in the tubular extension 322 and two or more ball bearings 324 are disposed between the first part of the first portion 320 and the first tubular member 312 to enable rotation of the first tubular member about the longitudinal axis 2012. The handle 154 is rotatable to rotate the external threaded portion of the second portion 318 of the first tubular member 312.

The first tubular member 312 comprises a hollow core in which the elongate shaft 2030 is in slidable contact. The barrier 118 is fixed to one end of the second tubular member 314 with an interior threaded portion corresponding to the external threaded portion of the second portion 318 and the interior threaded portion can be fastened to or unfastened from the external threaded portion. The second tubular member 314 has a diameter that is substantially the inner diameter of the tubular extension 322. The second tubular member 314 extends pass the cover 114 and is adjustable to extend the barrier 118 in a direction away from the cover 114. A seal 326 (ring shape) for preventing fluid flow into the tubular extension 322 is located close to a chamber formed by the cover 114 and the seal 326 is disposed between the cover 114 and the second tubular member 314. The elongate shaft 2030 is fixed to the barrier 118 at one end and the opposing end of the elongate shaft 2030 is fixed to the handle 121. The center of the elongate shaft 2030 extends through a hollow core of both the first tubular member 312 and the second tubular member 314.

By rotating the handle 154 clockwise or anti-clockwise, the external threaded portion of the first tubular member 312 is rotated by the handle 154. As the external threaded portion rotates, the external threaded portion in turn fastens or unfastens the second tubular member 314 such that the barrier 118 that is fixed to the second tubular member 314 respectively retracts towards the cover 114 or extends away from the cover 114 in the direction of the arrows shown in Figure 3A. The seal 326 has a secondary function to hold the second tubular member 314 steady to facilitate the fastening and unfastening of the second tubular member 314 as the first tubular member 312 is rotated through the handle 154. In this manner, the distance between the barrier 118 and the cover 114 can be adjusted.

The position of the barrier 118 in the inner channel of the tubular structure 132 would determine how much of the internal threaded surface 132 of the tubular structure 102 is to be electroplated. In the present example, the entire internal threaded surface 132 is to be electroplated. In the example of Figure 3A, the inner channel profile of the tubular structure 102 is such that the threaded surface 132 extends for a length in the inner channel of the tubular structure 102 and ends before a tapered non-threaded portion 304 of the inner walls of the tubular structure 102. The tapered non-threaded portion 304 tapers or narrows the inner channel portion down to a smaller diameter compared to the diameter of the inner channel of the tubular structure 102 that comprises the threaded surface 132. In the

present example, the diameter of the barrier 118 is designed to snugly fit in the tapered non-threaded portion 304 and to seal the inner channel of the tubular structure 102 at the position of the tapered non-threaded portion 304. Figure 3B shows the barrier 118 snugly fitted to the tapered non-threaded portion 304 of the tubular structure 102.

With reference to Figure 3A, the barrier 118 comprises two plates 306 and 308 disposed adjacent to each other that are configured to be brought together to assume a sealing configuration. Otherwise, the two plates 306 and 308 are kept apart in a non-sealing configuration. The plates 306 and 308 are shaped according to the channel of the tubular structure 102 that the barrier 118 is configured to seal. In the present example, the plates 306 and 308 are circular in shape. The plate 308 is located further away from the cover 114 than the plate 306. Located between the circumferential edges of the two plates 306 and 308 is a groove on which a seal 310 (ring shape) made of an elastic material is placed. In the present example, rotational forces on the handle 121 is translated into linear movement of the plate 306 to bring it into contact with the plate 308 to assume the sealing configuration or to move the plate 306 away from the plate 308 to assume the non-sealing configuration. This force translation can be achieved by connecting the plates 306 and 308 via a screw 328 that can be fastened to bring the plate 306 towards the plate 308 and unfastened to move the plate 306 away from the plate 308. Such screw 328 is in turn connected to the end of the elongate shaft 2030 that is opposite to the end of the elongate shaft 2003, which the handle 121 is connected. In the present example, the seal 310 is always seated on the plate 308. By rotating the handle 121 in a predetermined direction i.e. clockwise or anti-clockwise, the seal 310 is stretched and pushed by a circumferential extension of the plate 306 towards a seat in the circumferential plate 308. Otherwise, by rotating the handle 121 in a counter direction, force of the plate 306 acting on the seal 310 is released and the seal 310 automatically retracts due to its elasticity to assume a position that is out of the seat.

Figure 3B illustrates the sealing configuration. With reference to Figure 3B, specifically, the seat described above is sloped such that, when the two plates 306 and 308 are brought together to assume the sealing configuration, the seal 310 is stretched and pushed up-slope towards the tapered non-threaded portion 304 until the seal 310 comes into contact with the tapered non-threaded portion 304 of the tubular structure 102. Setting the seal 310 in this manner prevents leakage of fluid from the electroplating chamber 120. When the handle 121 is rotated to release force of the plate 306 acting on the seal 310, the seal 310 automatically retracts due to its elasticity and returns down-slope away from the tapered non-threaded portion 304 to assume the non-sealing configuration. To achieve the sealing configuration, the handle 121 is tightened such that the plate 306 may be moved to press the seal 310 against the plate 308. As the plate 306 moves to press the seal 310 against the plate 308, the seal comes into contact with the inner walls of the tubular structure 102 and provide a strong sealing effect. A biasing mechanism 316 such a spring is provided between the plates 306 and 308 to exert a force to keep the plates 306 and 308 apart unless the handle 121 is adjusted to move the plate 306 to push the seal 310 on the plate 308. The biasing mechanism 316 facilitates the return of the seal 310 from the sealing configuration to the non-sealing configuration.

Figure 3C illustrates the non-sealing configuration, wherein the seal 310 of Figure 3B has returned from the sealing configuration to the non-sealing configuration after the handle 121 is rotated to release the force of the plate 306 acting on the seal 310 and after the handle 154 is rotated to move the barrier 118 away from the tapered non-threaded portion 304.

Figures 4A to 4C shows more detailed representations of the tilting mechanism 128 of Figure 1 at different configurations i.e. a neutral or horizontal configuration (Figure 4A); an inclined configuration (Figure 4B); and a reclined configuration (Figure 4C). Reference numerals for common components having similar function of the electroplating apparatus 100 in Figures 1, 2, and 3A to 3C are re-used for the electroplating apparatus 100 shown in Figures 4A to 4C.

With reference to Figure 4A, the tilting mechanism 128 comprises a pivotable platform 110 upon which the electroplating apparatus 100 is placed, a pivot or fulcrum 402 about which the pivotable platform 110 pivots, an actuator 404 for pivoting the pivotable platform 110, together with the electroplating apparatus 100, about the pivot 402 and a frame 406 for supporting the pivotable platform 110. The tilting mechanism 128 may be mobile with wheels 410 installed at the base of the frame 406. The wheels 410 may be lockable to prevent unintentional movement.

Figure 4A shows a clamping mechanism 140 comprising a first jaw 108 and a second jaw 104 for securing a tubular structure 102. The features of the first jaw 108 are the same as that described with reference to Figure 2. The second jaw 104 is in the form of the chamber forming mechanism 104 for forming an electroplating chamber 120 with the tubular structure 102 and a barrier 118 placed in an inner channel of the tubular structure 102. The features of the second jaw 104 and the way the electroplating chamber 120 is formed are the same as that described with reference to Figure 2. The clamping mechanism 140 is fixed on the pivotable platform 110 of the tilting mechanism 128. Depending on the dimensions of the tubular structure 102, the first jaw 108 may be mounted at predetermined positions (e.g. 408a, 408b) along the pivotable platform 110. To electroplate a larger tubular structure 102, the first jaw 108 may be positioned at a predetermined position further away from the second jaw 104, which is the chamber forming mechanism 104. The first and second jaws 108, 104 of the clamping mechanism 140 may be secured at the predetermined positions by various securing means e.g. bolt and nut.

With reference to Figure 4A, which shows the tilting mechanism 128 in the neutral configuration, the longitudinal axis 2012 of the tubular structure 102 is substantially parallel and coincides with a horizontal axis that is always in horizontal orientation. The tilting mechanism 128 is in the neutral configuration during the setup of the electroplating apparatus 100, which includes the steps of (a) centering the barrier 118 to align with the tubular structure 102 via the vertical alignment mechanism 150, (b) securing the chamber forming mechanism 104 to the tubular structure 102 via the clamping mechanism 140 and (c) sealing the inner channel portion of the tubular structure 102 with the barrier 118. These steps were described earlier with reference to Figures 2, 3A, 3B and 3C.

At certain steps during the electroplating process (more details provided below), the tilting mechanism 128 may be inclined at an angle i.e. in an inclined configuration as shown in Figure 4B. As described earlier, such inclined configuration would advantageously facilitate the removal of gas bubbles trapped in the grooves of a threaded surface 132 to be electroplated that resides at a top portion of an electroplating chamber 120 during the electroplating process. This is because the gas bubbles would migrate towards the elevated portion of the electroplating chamber 120 and escape from the electroplating chamber 120 via a second outlet 126 of the chamber forming mechanism 104. The second outlet 126 has the same features as the second outlet 126 described earlier with reference to Figures 1 and 2. In order to tilt the electroplating apparatus 100 to an elevated configuration or inclined configuration, there is provided an actuator 404 that is coupled to a base of the pivotable platform 110 at a position on which the electroplating apparatus 100 is mounted on. The actuator 404 is configured to extend to elevate the pivotable platform 110 or retract to lower the pivotable platform 110, and the electroplating apparatus 100 disposed on the pivotable platform 110 is elevated or lowered accordingly. The actuator 404 may comprise a motor for driving movement of a mechanical arm 412 that may comprise hydraulic and/or pneumatic components.

As shown in Figure 4B, the tilting mechanism 128 tilts the electroplating apparatus 100 by an inclined angle of about 7 degrees relative to the horizontal axis (always horizontal).

Figure 4C shows the tilting mechanism 128 in a reclined configuration. The reclined configuration is to facilitate a drying step during the electroplating process where air is being pumped into the electroplating chamber 120 (more details provided below). This would advantageously remove fluid from the electroplating chamber 120 for example after a washing step where water is pumped into the electroplating chamber 120 and before a coating step where a plating solution is pumped into the electroplating chamber 120. In the reclined configuration, migration of the fluid (e.g. water) toward an outlet 122 occurs with the assistance of gravity. The outlet 122 has the same features as the outlet 122 described earlier with reference to Figures 1 and 2. In order to tilt the electroplating apparatus 100 to the reclined configuration, the actuator 404 shortens the mechanical arm 412 to recline the pivotable platform 110 along with the electroplating apparatus 100. As shown in Figure 4C, the tilting mechanism 128 tilts the electroplating apparatus by a reclined angle of 7 degrees relative to the horizontal axis (always horizontal).

B. Electroplating apparatus for electroplating an external threaded surface

Figure 5 shows a second example of an electroplating apparatus 200 of the present disclosure for electroplating an external threaded surface 232 of a tubular structure 202. In this example, the tubular structure 202 is a steel pipe with two opposing open end portions. The tubular structure 202

comprises a cylindrical portion 202a and a plate 202b attached to a base of the cylindrical portion 202a such that the cylindrical portion 202a extends perpendicularly from the plate 202b. There is a channel between the two opposing open end portions. The channel extends through the length of the cylindrical portion 202a and through the plate 202b. Hence, one of the open end portions is at a channel end of the cylindrical portion 202a and the other one of the open end portions is at a channel end of the plate 202b. It should be appreciated that the tubular structure 202 is not limited to just the configuration of the tubular structure 202 of Figure 5. The electroplating apparatus 200 comprises a programmable logic controller (not shown) for controlling the method to electroplate the external threaded surface 232 of the tubular surface 202, a chamber forming mechanism 204 for forming an electroplating chamber 220 with portions of the tubular structure 202, and a central fluid supply system 206 for delivery of fluids to the electroplating chamber 220. A cross-section of the tubular structure 202 and the electroplating apparatus 200 is represented in Figure 5.

Similar to the first electroplating apparatus 100, the second electroplating apparatus 200 carries out the electroplating process of the external threaded surface 232 in the tubular structure 202 via the immersion technique, as mentioned above. The second electroplating apparatus 200 encloses the portion i.e. the external threaded surface 232 of the tubular structure 202 to be electroplated via a chamber forming mechanism 204 to form an electroplating chamber 220, which is to be filled up by the electrolyte during the electroplating process. The chamber forming mechanism 204 comprises an inlet 224 and an outlet 222 to allow fluid to enter and exit the electroplating chamber 220 respectively. The term "fluid" covers liquid and gas. In the present example, the chamber forming mechanism 204 has a cover 214 for sealing the open channel end of the cylindrical portion 202a of the tubular structure 202. A seal 213 is disposed between the cover 214 and the open channel end of the cylindrical portion 202a. The inlet 224 and outlet 222 are located at this cover 214. The chamber forming mechanism 204 further comprises an electrode 216 extending from the chamber forming mechanism 204 and projecting into the electroplating chamber 220. The electrode 216 is centrally located inside the electroplating chamber 220, and tubular in shape to allow the cylindrical portion 202a to slot in such that the electrode 216 surrounds the external threaded surface 232 to be electroplated. The electrode 216 is in a meshed form allowing fluid to flow through to immerse the external threaded surface 232. The electrode 216 is an anode in the present example. The electrode 216 can be made of any suitable metal for an anode, which may include platinum. When a potential difference is applied between the electrode 216 and the tubular structure 202, metal ions in the electrolyte will begin to deposit on the surface or surfaces of the tubular structure 202 (in this case, the threaded surface 232) to be electroplated. The present electroplating apparatus 200 is also capable of electroplating an external surface of the tubular structure that is not threaded as well.

Notably, the electroplating apparatus 200 of the present example also does not comprise the nozzles mentioned in the background of the present disclosure.

Depending on the configuration of the tubular structure 202, there can be many ways to secure the chamber forming mechanism 204 and the tubular structure 202 in position. The chamber forming mechanism 204 is shaped and configured to prevent leakage of fluid from the electroplating chamber 220 that is formed. In the present example, the electroplating apparatus 200 comprises a clamping mechanism 240 to secure the chamber forming mechanism 204 to the tubular structure 202, such that one or more seals 212 and 213 disposed between the chamber forming mechanism 204 and the tubular structure 202 are compressed when the electroplating chamber 220 is formed. Compression of the one or more seals 212 and 213 prevents fluid leakage from the electroplating chamber 220. Specifically, in the present example, the clamping mechanism 240 comprises a first jaw 208 configured to contact a first portion i.e. a first side of the plate 202b of the tubular structure 202. The first jaw 208 can be referred to as a stopper. The clamping mechanism 240 further comprises the chamber forming mechanism 204 as a second jaw opposite to the first jaw 208 to contact a second portion i.e. a second side of the plate 202b. In this example, the second side of the plate 202b is opposite to the first side of the plate 202b. The distance between the first jaw 208 and the second jaw 204 is adjustable according to the dimensions of the tubular structure 202. A locking mechanism can be provided to lock the position of the first jaw 208 relative to the second jaw and tighten the grip of the first jaw 208 and the second jaw on the tubular structure 202. It should be understood that the clamping mechanism 240 is not limited to that disclosed in the present example and other suitable clamping mechanisms to secure the chamber forming mechanism 204 to the tubular structure 202 can be used as well. The working principles and design of the clamping mechanism 240 can be

based on that of a bench vice that is used to clamp or retain a workpiece (in the present example, the workpiece is the tubular structure 202), allowing work to be securely performed on the workpiece.

In addition to the outlet 222 for a fluid to exit the electroplating chamber 220, the chamber forming mechanism 204 may include a second outlet 226 as shown in Figure 5. The second outlet 226 is located at the cover 214 and located at a top portion of the electroplating chamber 220. This second outlet 226 is for removal of waste gases from the electroplating chamber 220 during the electroplating process. Such waste gases include hydrogen. The second outlet 226 advantageously allows the waste gases to escape.

In the present example, the second outlet 226 is disposed above the inlet 224. However, in another example, the second outlet 226 may be disposed above the outlet 222 for fluid to exit. In this case, the inlet 224 can be placed below the outlet 222. This is to facilitate the removal of the waste gases by the movement of the fluid exiting the electroplating chamber 220 via the outlet 222 below. Specifically, the movement of the fluid out of the outlet 222 would assist to direct the waste gases, in the form of air bubbles, to float upward and toward the second outlet 226 (which is disposed above the outlet 222) for their removal.

Figure 6 is also applicable to the example of Figure 5. With reference to Figures 5 and 6, the first conduit 502 may be connected to the second outlet 226, and a second conduit 504 for channeling exiting fluid may be connected to the outlet 222 for fluid to exit. A third conduit 503 (not shown in Figure 6) may be connected to the inlet 224. The third conduit is connected to a source (not shown in Figure 6) for supplying fluid into the electroplating chamber 220 through the inlet 224. The second conduit 504 is for directing fluid to exit from the electroplating chamber 220 to a destination (not shown in Figure 5). The first conduit 502 is for removing waste gases exiting the second outlet 226 and if no waste gases are present to remove, the first conduit 502 directs fluid to be removed from the electroplating chamber 220 as well. The first conduit 502 may have a diameter that is smaller than the second conduit 504 and the first conduit 502 may be connected to the second conduit 504. Specifically, a first end of the first conduit 502 is connected to the second outlet 226 and a second end opposite to the first end of the first conduit 502 is connected to the second conduit 504. In this configuration, as fluid is exiting in the second conduit 504, waste gases can be removed more efficiently due to larger volume of fluid flow 514 through the second conduit 504 compared to lesser volume of fluid flow 512 through the first conduit 502. The larger volume of fluid flow 514 drags and expedites the lesser volume of fluid flow 512.

Referring back to Figure 5, to further facilitate the removal of waste gases via the second outlet 226, there is the option of including a tilting mechanism 228. The tilting mechanism 228 comprises a platform 210 configured for mounting the tubular structure 202 thereon. Specifically, the tubular structure 202 will sit in a horizontal orientation on the platform 210 such that a longitudinal axis 2012 of a hollow elongate core of the tubular structure 202 is substantially parallel to a horizontal axis (always horizontal). There may be a plurality of rollers 236 disposed on the platform 210 on which the tubular structure 202 can sit and slide over. The plurality of rollers 236 facilitates adjustment of the positioning of the tubular structure 202, for instance, when the tubular structure 202 is subject to clamping by the clamping mechanism 240. Furthermore, the platform 210 is pivotably mounted in the tilting mechanism 228 and is adjustable to tilt. As the platform 210 is adjusted to tilt, the mounted tubular structure 202 is correspondingly tilted such that the longitudinal axis 2012 of the tubular structure 202 forms an angle relative to the horizontal axis (always horizontal). Preferably, the tilting mechanism 228 is capable of tilting the tubular structure 220 from a horizontal orientation or horizontal axis by 0 to 45, preferably 0 to 15 degrees. Tilting the tubular structure 202 at an inclined angle during the electroplating process elevates the top portion of the electroplating chamber 220 where the second outlet 226 is located and this would advantageously facilitate the removal of gas accumulating at the top portion of the electroplating chamber 220. This is because the gas bubbles would migrate towards the elevated portion of the electroplating chamber 220 and escape from the electroplating chamber 220 via the second outlet 226. An example of the tilting mechanism 228 can include a fulcrum or pivot, wherein the platform 210 is pivotably mounted to the pivot. The platform 210 is pivotable about the fulcrum or pivot to tilt the mounted tubular structure 202 to the desired angle. One or more locking mechanism can be provided to lock the platform 210 in the tilted configuration.

In the example of Figure 5, an additional barrier 218 is provided for plugging an inner channel portion of the tubular structure 202 to prevent fluid leakage into the inner channel portion and this barrier 218 forms part of an inner wall of the electroplating chamber 220. This barrier 218 is located at the open end portion of the tubular structure 202. Specifically, the electroplating chamber 220 of the example of Figure 5 has the following as inner walls: the threaded surface 232 of the tubular structure 202 in Figure 5; the side of the chamber forming mechanism 204 acting as the second jaw of the clamping mechanism 240, which is C-shaped in the cross-sectional view of Figure 5; a portion of the plate 202b enclosed by the chamber forming mechanism 204; and the barrier 218. Specifically, the chamber forming mechanism 204 resembles a cup from a three-dimensional perspective and has a rim 258 projecting towards the longitudinal axis 2012 that is configured to press against the second side of the plate 202b. The seal 212 is disposed between the portion of the plate 202b enclosed by the chamber forming mechanism 204 and the chamber forming mechanism 204 to prevent fluid leakage. Another seal 213 is placed between the chamber forming mechanism 204 and the open channel end of the cylindrical portion 202a of the tubular structure 202.

The barrier 218 may comprise of a resilient flexible material, like rubber at least at edges for contacting inner walls of the tubular structure 202. In the present example, a seal 235 made of such resilient flexible material is disposed at the edges of the barrier 218. The barrier 218 may have a slightly larger diameter than the inner diameter of the tubular structure 202 at which the barrier 218 is to be placed to ensure tight sealing of the inner channel of the tubular structure 202.

An adjustment mechanism 219 can be mounted to the barrier 218. The adjustment mechanism 219 is configured to move the barrier 218 to a position at the inner channel portion where the barrier 218 is to be placed. Specifically, the adjustment mechanism 219 may comprise a handle 221 rotatable to make the adjustment. In the present example, the handle 221 is coupled to a spindle 225 that is connected to the barrier 218. The spindle 225 is adjustable to extend into the electroplating chamber 220. A seal 215 is disposed at a joint between the cover 214 and the spindle 225 to prevent fluid leakage from the electroplating chamber 220 at such joint. By rotating the handle 221, distance between the barrier 218 and the cover 214 can be adjusted. In the present example, the barrier 218 is moved to a distance close to the open channel end of the cylindrical portion 202a so as to prevent fluid leakage into the internal channel portion of the tubular structure 202. To prevent the tubular structure 202 from being moved by the barrier 218, the first jaw 208 of the clamping mechanism 240 has to be locked and tightened in position relative to the cover 214 before the distance between the barrier 218 and the cover 214 is adjusted.

It is understood that the electroplating apparatus 200 can be of different dimensions adapted for electroplating tubular structures of different sizes.

Figure 7 shows an example of a more detailed cross-sectional representation of the electroplating apparatus 200 of Figure 5 for electroplating an external threaded surface 232 of a tubular structure 202. Reference numerals for common components having similar function of the electroplating apparatus 200 in Figure 5 are re-used for the electroplating apparatus 200 in Figure 7. Similarly, the electroplating apparatus 200 of Figure 7 is also comprises a chamber forming mechanism 204 for forming an electroplating chamber 220 with portions of the tubular structure 202. The tubular structure 202 of Figure 7 is slightly different from that described in Figure 5. The tubular structure 202 of Figure 7 is substantially cylindrical in shape and comprises the external threaded surface 232 and a non-threaded surface. The diameter of the portion of the tubular structure 202 comprising the external threaded surface 232 is smaller than the diameter of the portion of the tubular structure 202 that is not threaded. There is a tapered portion 701 between the external threaded surface 232 and the non-threaded surface.

The chamber forming mechanism 204 comprises an inlet 224 to allow fluid to enter and fill up the electroplating chamber 220 and immerse the surface of the tubular structure 202 to be electroplated and an outlet 222 to allow fluid to exit the electroplating chamber 220. The chamber forming mechanism 204 has a C-shaped cover 214 (in the cross sectional view of Figure 7) for encapsulating one of the opposing end portions of the tubular structure 202 including the external threaded surface 232. Specifically, the chamber forming mechanism 204 is resembles a cup from a three-dimensional perspective and has an interchangeable rim 258 projecting towards the tubular structure 202 that is configured to grip the tubular structure 202. A moveable barrier 218 is provided for plugging an inner channel portion of the tubular structure 202 disposed at a distance from the C-shaped cover 214.

Consequently, the electroplating chamber 220 of the example of Figure 7 has the following as inner walls: the external threaded surface 232 of the tubular structure 202; the C-shaped cover 214 of the chamber forming mechanism 204, which is encapsulating one of the opposing end portions of the tubular structure 202 including the external threaded surface 232; and the barrier 218 disposed at a distance from the C-shaped cover 214 and which is sealing the inner channel portion of the tubular structure 202. The chamber forming mechanism 204 comprises a meshed electrode 216 extending from the cover 214 of the chamber forming mechanism 204 and projecting into the electroplating chamber 220. The barrier 218 of Figure 7 is in a form of a circular disc.

In the present electroplating apparatus 200 of Figure 7, there is provided a clamping mechanism 240 to secure the chamber forming mechanism 204 to the tubular structure 202, such that one or more seals 212 disposed between the chamber forming mechanism and the tubular structure 202 are compressed when the electroplating chamber 220 is formed. Compression of the one or more seals 212 prevents fluid leakage from the electroplating chamber 220. In the present example of Figure 7, the clamping mechanism 240 comprises a first jaw 208 configured to contact a first portion of the tubular structure 202 which is one of the opposing open end portions of the tubular structure 202. The clamping mechanism 240 comprises the chamber forming mechanism 204 as a second jaw opposite to the first jaw 208 to contact a second portion of the tubular structure 202 which is the other end of the opposing open end portions of the tubular structure 202. Specifically, in the present example, the second jaw is the C-shaped cover 214 (in the cross sectional view of Figure 7) of the chamber forming mechanism 204 and is also given the reference numeral of 214 in the present disclosure.

The second jaw 214 comprises the interchangeable rim 258 that is detachably attachable to the second jaw 214. The rim 258 is ring-shaped (i.e. circular shape with a lumen in the center) and made of a rigid material. After the rim 258 is attached to the second jaw 214, an inner surface of the rim 258 forms part of a wall of the electroplating chamber 220. The rim 258 comprises a sloped portion 705 configured to match the tapered portion 701 of the tubular structure 202. The rim 258 is configured to engage the tapered portion 701 of the tubular structure 202 and a seal 212 is disposed between the sloped portion 705 and the tapered portion 701 to prevent leakage of fluid from the electroplating chamber 220.

In the present electroplating apparatus 200 of Figure 7, the first jaw 208 is identical to the first jaw 108 of Figure 2. The first jaw 208 has a bracket 708 that is fixed at a position and comprises a press screw 702 that is configured to screw through a threaded hole portion 710 of the bracket 708. The threaded hole portion 710 may be formed by welding a nut such that the threaded hole of the nut corresponds with a position of a hole drilled in the bracket 708. The hole in the bracket 708 is for the press screw 702 to go through and the threaded hole of the nut provides the threaded hole portion 710 for the press screw 702 to make adjustments. The press screw 702 comprises a threaded shaft with a clamp 704 fixed at one end of the threaded shaft and a rotatable handle 706 fixed at an opposing end of the threaded shaft. In use, the press screw 702 is screwed through the threaded hole portion 710 of the bracket 708. The clamp 704 is adjustable to move in a direction towards the second jaw 214 or move in a direction away from the second jaw 214 by rotating the handle 706. As the handle 706 rotates, the threaded shaft screws pass the threaded hole portion 710. The clamp 704 is configured to exert pressure on the first end portion of the tubular structure 202 when the handle 706 is rotated to move the clamp 704 against the first end portion of the tubular structure 202. The chamber forming mechanism 204, which forms the second jaw 214 of the clamping mechanism 204, is fixed at a second position via a bracket 709. The cover 214 of the chamber forming mechanism 204 is disposed to enclose the external threaded surface 232 of the tubular structure 202 to be electroplated. When the handle 706 is rotated to tighten the clamp 704 against the first end portion of the tubular structure 202, the tubular structure 202 is pressed against the chamber forming mechanism 204. More specifically, the tapered portion 701 of the tubular structure 202 is pressed against the sloped portion 705 of the rim 258. As the tapered portion 701 and the sloped portion 705 are brought together by rotating the handle 706, the seal 212 placed between the sloped portion 705 and the tapered portion 701 is compressed to provide strong sealing effect.

In addition to the outlet 222 for the fluid to exit the electroplating chamber 220, the chamber forming mechanism 204 may include a second outlet 226 as shown in Figure 7. The second outlet 226 is located at a top portion of the electroplating chamber 220 for removal of waste gases from the electroplating chamber 220 during the electroplating process. Waste gases include hydrogen, which

interfere with the plating uniformity of the electroplating process. Hence, the second outlet 226 advantageously allows the waste gases or air bubbles to escape and the top portion of the tubular structure 202 to be electroplated will be fully immersed with the electrolyte during the electroplating process. In this way, uniform plating at the top portion of the tubular structure 202 is ensured. Figure 6 is applicable to the second outlet 226 and the outlet 222 of Figure 7.

In the electroplating apparatus 200 of Figure 7, the chamber forming mechanism 204 is mounted to a vertical alignment mechanism 250 and a horizontal alignment mechanism 252. The vertical alignment mechanism 250 is almost identical to the vertical alignment mechanism 150 of Figure 2. The vertical alignment mechanism 250 is for adjusting the position of the chamber forming mechanism 204 relative to a vertical axis 2014. The vertical alignment mechanism 250 comprises a threaded shaft that can be screwed through a threaded hole portion 266 that is fixed in position. The threaded shaft is fixed to a rotatable handle 256 at one end and an opposing end of the threaded shaft is mounted to a bracket 228 that is mounted to the cover 214. The threaded shaft is mounted to the bracket 268 in a manner that will allow the threaded shaft to rotate at the spot that is mounted to the bracket 268. The chamber forming mechanism 204 can be adjusted to move up or down by rotating the handle 256. Rotating the handle 256 in turn moves the threaded shaft pass the threaded hole portion 266 to raise or lower the chamber forming mechanism 204. In this manner, the chamber forming mechanism 204 can be adjusted to a desired position vertically. In the present example, the chamber forming mechanism 204 is adjusted so that the barrier 218 is centered with the tubular structure 202. Unlike the barrier 218 of Figure 5, the barrier 218 of Figure 7 is not configured to fit into an inner channel portion of the tubular structure 202. The barrier 218 of Figure 7 is instead configured to engage and seal a second end portion of the tubular structure 202 that is opposite to the first end portion of the tubular structure 202, which is in contact with the clamp 704 of the first jaw 208. A seal 712 (ring shape) is disposed between the second end portion of the tubular structure 202 and the barrier 218 to prevent leakage of fluid from the electroplating chamber 220 into the inner channel of the tubular structure 202. A seal 714 (ring shape) is disposed between the cover 214 and a circumferential side of the barrier 218 to prevent fluid leakage from the electroplating chamber 220 to parts of the cover 214 that is not forming a wall of the electroplating chamber 220.

The horizontal alignment mechanism 252 is for adjusting distance of the barrier 218 away from or towards the cover 214. The vertical alignment mechanism 250 and the horizontal alignment mechanism 252 work together to enable coupling of the chamber forming mechanism 204 to tubular structures 202 of different sizes or diameters. The barrier 218 is changeable to larger or smaller size to suit the size of the cover 214 and tubular structures 202 of different sizes. The horizontal alignment mechanism 252 has a similar purpose as the adjustment mechanism 219 described with reference to Figure 5, which is to facilitate movement of the barrier 218. The horizontal alignment mechanism 252 comprises a threaded shaft 716 with one end fixed with a handle 254 and an opposing end of the threaded shaft 716 is fixed to the barrier 218. The cover 214 has a threaded opening 718 located centrally configured for the threaded shaft 716 to screw through. The handle 254 can be rotated to fasten or unfasten the threaded shaft 716 to move the barrier 218 away from the tubular structure 202 to disengage from tubular structure 202 or towards the tubular structure 202 to engage the tubular structure 202.

C. Electroplating System Comprising Electroplating Apparatus and Central Fluid Supply System

With reference to the examples of Figures 1 and 5, the central fluid supply systems 106 and 206 present in these examples are similar. Specifically, the central fluid supply systems 106 and 206 each comprises several reservoirs, fluid receptacles or storage tanks containing fluids to be delivered to the electroplating chamber 120 and 220 respectively. Each reservoir, receptacle or tank contains a specific fluid. Such fluids may include degreasing agent, a washing agent or an electrolyte such as copper (II) salt or nickel salt. The degreasing agent is used to degrease the surface of the tubular structure 102 and 202 to be electroplated. The washing agent is used to clean the electroplated surface of the tubular structure 102 and 202. The electrolyte solution is used for coating the plating material on the surface of the tubular structure 102 and 202 to be electroplated. The fluid also includes air for drying and/or flushing other fluid out of the electroplating chamber 120 and 220. One of the fluids may be water.

The inlets 124 and 224 for fluid to enter are connected to respective conduits 503 and the outlets 122 and 222 for fluid to exit are connected via respective conduits 504 to the central fluid supply system 106 and 206. A central supply pipe 134 and 234 may be connected to the plurality of storage tanks of the central fluid supply system 106 and 206 for channeling the different fluids respectively into the electroplating chambers 120 and 220 from the plurality of storage tanks. A valve 138 and 238 is provided at a first supply junction connecting the central supply pipe 134 and 234, the conduit 503 and a supply pipe 142 and 242 for drawing upwards a specific fluid from a specific storage tank of the plurality of storage tanks. Upstream of the first supply junction includes more supply junctions and each of these other supply junctions also has a valve similar to the valve 138 and 238. Upstream in regard to fluid supply is defined as the direction away from the electroplating chamber 120 and 220 and downstream in regard to fluid supply is defined as the direction towards the electroplating chamber 120 and 220. In general, upstream refers to a direction opposite of fluid flow and downstream refers to a direction along fluid flow. Furthermore, each of these other supply junctions connects the central supply pipe 134 and 234 to a pipe similar to the supply pipe 142 and 242 for drawing another fluid from another storage tank of the plurality of storage tanks. The supply pipe 142 and 242 is connected to a pump 130 and 230 configured to draw the fluid upwards to the valve 138 and 238. The plurality of supply valves (including valve 138 and 238) connected to the central supply pipe 134 and 234 is each configured to close fluid flow from upstream of the valve (i.e. from another supply junction) and to allow fluid driven by the pump 130 and 230 to flow downstream towards the electroplating chamber 120 and 220. Furthermore, each of the plurality of supply valves 138 and 238 is configured to allow fluid from either the supply pipe 142 and 242 or the central supply pipe 134 and 234 to go towards the electroplating chamber 120 and 220 at any one time. This is to prevent mixing or contamination of different fluids in the central supply pipe 134 and 234. In one of the supply pipes connected to one of the junctions connecting the supply pipe to the central supply pipe 134 and 234, the supply pipe is connected to a blower (not shown) and not a pump 130 and 230 to blow air downstream towards the electroplating chamber 120 and 220. No storage tank is required in the case which the fluid is air. Furthermore, in one of the supply pipes connected to one of the junctions connecting the pipe to the central supply pipe 134 and 234, the supply pipe is optionally connected to a public utility water supply via, for instance, a water tap. Each supply valve may be controlled electronically.

The central fluid supply systems 106, and 206 are configured to maintain a continuous flow of the fluid in the electroplating chamber 120 and 220 by the use of the respective pumps 130 and 230, the respective blowers, and public utility water supply. The respective pumps 130 and 230 are configured to constantly pump the respective fluid from a tank of the plurality of storage tanks to the electroplating chamber 120, 220 so that the fluid in the electroplating chamber is constantly replaced. The replaced fluid exiting the electroplating chamber 120 and 220 through the outlets 122 and 222 is directed back to the same tank thereby achieving circulation of the fluid between the electroplating chamber 120 and 220 and the same tank. The fluid can be channeled back to the tank from the electroplating chamber 120 and 220 via the outlet 122 and 124, through the conduit 504 of the outlet 122, 124, and towards a return valve 139 and 239 located at a first return junction connecting the conduit 504, a central return pipe 135 and 235, and a return pipe 144 and 244 for dispensing the fluid to its specific storage tank among the plurality of storage tanks. This specific storage tank is the same tank from which the fluid is drawn by the pump 130 and 230. Downstream of the first return junction includes more return junctions and each of these other return junctions also has a return valve similar to the return valve 139 and 239. Downstream in regard to fluid return is defined as the direction away from the electroplating chamber 120, 220 and upstream in regard to fluid return is defined as the direction towards the electroplating chamber 120, 220. In general, upstream refers to a direction opposite of fluid flow and downstream refers to a direction along fluid flow. Furthermore, each of these other return junctions connects the central return pipe 135 and 235 to a pipe similar to the return pipe 144 and 244 for returning another fluid to another storage tank of the plurality of storage tanks. The plurality of return valves (including valve 139 and 239) connected to the central return pipe 135 and 235 is each configured to close fluid flow moving downstream of the central return pipe 135 and 235 and to allow returning fluid to flow into the respective storage tank. Furthermore, each of the plurality of return valves 139 and 239 is configured to allow fluid to flow into either the return pipe 144 and 244 to go towards their respective storage tank or into the central return pipe 135 and 235 to another return junction downstream. This is to prevent mixing or contamination of different fluids in the central return pipe 135 and 235. Each return valve may be controlled electronically. The continuous circulation or recycling of fluids between the electroplating chamber 120, 220 and the reservoir, fluid receptacle, or storage tank allows the reduction of consumption of reagents and fluids such as

electrolytes, which is an advantage of the present electroplating system. Once the concentration of an electrolyte falls below a predetermined level, the reservoir is replaced with fresh electrolyte. Other than the electrolyte, the other fluids that can be recycled in this manner are the degreasing agent and the washing agent.

Not shown in Figures 1 and 2 is the programmable logic controller (PLC) that is part of the electroplating apparatus 100 or 200 for automating the method to electroplate targeted portion or surface 132 and 232 of the tubular structure 102 and 202. Alternatively, a processor of a computer may be used instead. Of course, there will be accompanying electrical/electronic circuitries, components and configurations required to connect to the PLC and/or the processor to control the process performed by the electroplating apparatus 100 and 200. Such components may include e.g. memory for storing instructions, electrical cables, databus, database, Input/Output (I/O) interfaces, I/O devices, display or displays for displaying a Graphical User Interface for control, connection to electrical power mains, voltage regulator, Alternating Current (AC) to Direct Current (DC) convertor, etc. The PLC or processor executes instructions stored in a memory to operate the PLC or processor to send signals or instructions at the right time to activate or deactivate connected devices such as fluid supply or return valve electrically controllable to close and/or open fluid passages, fluid pump electrically controllable to commence or stop pump and/or increase or decrease pumping intensity, etc.

Figure 8 shows an example of a more detailed schematic diagram of the central fluid supply systems 106 and 206. There is comprised a plurality of storage tanks 506 (i.e. tanks 1 to 8) containing fluids to be delivered to the electroplating chamber 120 and 220. Each tank contains a specific fluid. Such fluids may include degreasing agent, a washing agent or an electrolyte such as copper (II) salt or nickel salt. The fluid also includes air for drying and/or flushing other fluid out of the electroplating chamber 120 and 220. One of the fluids may be water.

With reference to Figure 8, there is provided a first set of conduits 503 for delivering fluids into the electroplating chambers 120 and 220 via their respective inlets 124 and 224 and second set of conduits 504 to let fluid exit the electroplating chambers 120 and 220 via their respective outlets 122, 222. A central supply pipe 134 and 234 may be connected to the plurality of storage tanks 506 of the central fluid supply system 106 and 206 for channeling the different fluids respectively into the electroplating chambers 120 and 220 from the plurality of storage tanks 506. A supply valve 138 and 238 is provided at a first supply junction connecting the central supply pipe 134 and 234 and a supply pipe 142 and 242 for drawing upwards a specific fluid from a specific storage tank of the plurality of storage tanks 506. Upstream of the first supply junction includes more supply junctions and each of these other supply junctions also has a valve similar to the valve 138 and 238. Upstream in regard to fluid supply is defined as the direction away from the electroplating chamber 120, 220 and downstream in regard to fluid supply is defined as the direction towards the electroplating chamber 120, 220. In general, upstream refers to a direction opposite of fluid flow and downstream refers to a direction along fluid flow. Furthermore, each of these other supply junctions connects the central supply pipe 134 and 234 to a pipe similar to the supply pipe 142 and 242 for drawing another fluid from another storage tank of the plurality of storage tanks 506. The supply pipe 142 and 242 is connected to a pump 130 and 230 configured to draw the fluid upwards to the valve 138 and 238. The plurality of supply valves (including valve 138 and 238) connected to the central supply pipe 134 and 234 is each configured to close fluid flow from upstream of the valve (i.e. from another supply junction) and to allow fluid driven by the pump 130 and 230 to flow downstream towards the electroplating chamber 120 and 220. In one of the supply pipes connected to one of the junctions connecting the supply pipe to the central supply pipe 134 and 234, the supply pipe is connected to a blower 510 and not a pump 130, 230 to blow air downstream towards the electroplating chamber 120 and 220. No storage tank is required in the case which the fluid is air. In addition, the temperature of the air that is blown into the electroplating chamber 120 and 220 may be controlled electronically by an inline heater 520. Furthermore, in one of the supply pipes 142 and 242 connected to one of the junctions connecting the pipe to the central supply pipe 134 and 234, the supply pipe is optionally connected to a public utility water supply 508 via, for instance, a water tap. Each supply valve 138 and 238 may be controlled electronically.

The central fluid supply systems 106 and 206 are configured to maintain a continuous flow of the fluid in the electroplating chamber 120 and 220 by the use of the respective pumps 130 and 230, the respective blowers 510, and public utility water supply 508. The respective pumps 130 and 230 are configured to constantly pump the respective fluid from a tank of the plurality of storage tanks 506 to

the electroplating chamber 120 and 220 so that the fluid in the electroplating chamber is constantly replaced. The replaced fluid exiting the electroplating chamber 120 and 220 through the outlets 122 and 222 is directed back to the same tank thereby achieving circulation of the fluid between the electroplating chamber 120 and 220 and the same tank. The fluid can be channeled back to the tank 506 from the electroplating chamber 120 and 220 via the outlet 122 and 222, through the conduit 504 and towards a return valve 139 and 239 located at a first return junction connecting a central return pipe 135 and 235, and a return pipe 144 and 244 for dispensing the fluid to its specific storage tank among the plurality of storage tanks 506. This specific storage tank 506 is the same tank from which the fluid is drawn by the pump 130, 230. Downstream of the first return junction includes more return junctions and each of these other return junctions also has a return valve similar to the return valve 139, 239. Downstream in regard to fluid return is defined as the direction away from the electroplating chamber 120, 220 and upstream in regard to fluid return is defined as the direction towards the electroplating chamber 120, 220. In general, upstream refers to a direction opposite of fluid flow and downstream refers to a direction along fluid flow.

Furthermore, each of these other return junctions connects the central return pipe 135 and 235 to a pipe similar to the return pipe 144, 244 for returning another fluid to another storage tank of the plurality of storage tanks 506. The plurality of return valves (including return valve 139 and 239) connected to the central return pipe 135 and 235 is each configured to close fluid flow moving downstream of the central return pipe 135 and 235 and to allow returning fluid to flow into the respective storage tank 506. Each return valve may be controlled electronically. The continuous circulation or recycling of fluids between the electroplating chamber 120 and 220 and the storage tank 506 allows the reduction of consumption of reagents and fluids such as electrolytes, which is an advantage of the present electroplating system. Once the concentration of an electrolyte falls below a predetermined level, the reservoir is replaced with fresh electrolyte. Other than the electrolyte, the other fluids that can be recycled in this manner are the degreasing agent and the washing agent.

As shown in Figure 8, there may be provided an electroplating system comprising more than one of the electroplating apparatus 100 and 200 for electroplating more than one tubular structure 102 and 202 simultaneously. In such an electroplating system, there is provided a divergence point 522 wherein the flow of fluid in the central supply pipe 134 and 234 diverges and is carried to the multiple electroplating apparatuses 100 and 200 via their respective conduits 503. There is also provided a convergence point 524 wherein the fluid returning from the multiple electroplating apparatuses via their respective conduits 504 converges to form the central return pipe 135 and 235. The plurality of electroplating apparatuses may be controlled from a central programmable logic controller or processor of a computer for electroplating a plurality of tubular structures 102 and 202. This would increase the throughput and also save time and manpower. One central fluid supply system comprising several large fluid storage tanks can be provided instead of providing several smaller storage tanks of the central fluid supply systems 106, 206. There can be several central supply pipes 134, 234 and several corresponding central return pipes 135, 235 but the fluid storage tanks from which fluid is drawn and returned are the same large fluid storage tanks. Fluid in each storage tank should be changed periodically to reduce the level of contamination in the fluid such as grease, dirt, etc. Otherwise, the electroplating efficiency and quality may deteriorate after repeated use of recycled fluid. The central fluid supply systems 106 and 206 described above are also applicable to the examples of Figures 2 and 7.

D. Method of Electroplating a Surface of a Tubular Structure

Another aspect of the present disclosure is a method of electroplating a surface (e.g. 132 and 232) of a tubular structure (e.g. 102 and 202) using the electroplating apparatus (e.g. 100 and 200) as described above. It comprises filling up an electroplating chamber (e.g. 120 and 220) formed by the apparatus with fluid to immerse the surface of the tubular structure to be electroplated in the fluid during the electroplating process. As mentioned above, this immersion technique has advantages over the prior art, including a more uniform plating thickness, especially in comparison to electrobrushing.

Figure 9 shows a flow chart 900 of an example of a method of electroplating a targeted portion or surface of a tubular structure. The targeted portion or surface of the tubular structure to be electroplated has to be electrically conductive. The tubular structure comprises at least one channel running therethrough and the channel has corresponding open channel ends. The method comprises

a series of steps. First, the tubular structure (e.g. 102 and 202) is secured to a chamber forming mechanism (e.g. 104 and 204) to form an electroplating chamber (e.g. 120 and 220) in a step 902, which comprises further sub-steps. In sub-step (i) of the step 902, the tubular structure is placed on a platform (e.g. 110 and 210) in a horizontal orientation. In sub-step (ii) of the step 902, a clamping mechanism (e.g. 140 and 240) with two jaws is used. A first jaw (e.g. 108 and 208) of the clamping mechanism clamps a first end portion of the tubular structure, and a second jaw (e.g. 114 and 214) of the clamping mechanism clamps a second end portion of the tubular structure. In one example, the platform may be part of the clamping mechanism. The first and second end portions of the tubular structure can be different for different types of tubular structures and different for different surfaces of the tubular structures to be electroplated. However, generally, the first and second end portions of the tubular structure are the respective open channel ends of the tubular structure. The second jaw is part of the chamber forming mechanism. The two jaws come together such that seals (e.g. 112, 212, and 213) disposed between the chamber forming mechanism and the tubular structure are compressed. The inner wall of the electroplating chamber comprises at least the second jaw and the targeted portion or surface of the tubular structure. In an example of the present disclosure, the first jaw may be an inner wall of the electroplating chamber as well. The clamping mechanism and the clamping process can be handled by a human operator or fully automated by machines.

There is a last sub-step (iii) of the step 902 of Figure 9 comprising plugging a portion of the tubular structure via a horizontal alignment mechanism (e.g. 152) to prevent fluid leaks. The portion of the tubular structure can be plugged with a barrier (e.g. 118, 218). The barrier (e.g. 118, 218) may form another inner wall of the electroplating chamber. An adjustment to the horizontal alignment mechanism moves the barrier to a desired position for plugging the tubular structure.

After the tubular structure is secured to the chamber forming mechanism to form the electroplating chamber and the electroplating chamber is sealed to prevent fluid leakage, an electroplating sequence is initiated via the programmable logic controller or a processor of a computer in a step 904. If multiple tubular structures are to be electroplated concurrently, the programmable logic controller or processor can be used to initiate the electroplating sequence in multiple electroplating apparatuses used to perform the concurrent electroplating of the multiple tubular structures. This would increase the throughput and also save time and manpower.

The electroplating sequence is performed at a step 906 and is fully automated. The electroplating sequence comprises several steps. Firstly, a degreasing step is initiated by channeling a degreasing agent from a central fluid supply system (e.g. 106, 206) through an inlet located at the chamber forming mechanism into the electroplating chamber to immerse the enclosed portion of the tubular structure completely in the degreasing agent to degrease the enclosed portion of the tubular structure. Next, a washing step is initiated by channeling a washing agent, which can be water, from the central fluid supply system through the inlet into the electroplating chamber to immerse the enclosed portion of the tubular structure in the washing agent completely to wash the enclosed portion of the tubular structure. Thereafter, there is provided a coating step to channel an electrolyte solution from the central fluid supply system through the inlet into the electroplating chamber to coat a plating material (e.g. copper or nickel) on the surface of the tubular structure to be electroplated. Specifically, when a potential difference is applied between an electrode extending into the electroplating chamber from the chamber forming mechanism and the electrically conductive portion of the tubular structure, the relevant ions in the electrolyte (e.g. Cu^{2+} or Ni^{2+} ions) would migrate to the tubular structure, which is negatively charged to coat the surface of the tubular structure to be electroplated.

A key step of the method is filling up the electroplating chamber with fluid to immerse the surface of the tubular structure to be electroplated in the fluid during the electroplating process i.e. the coating step.

The fluid used to immerse the surface of the tubular structure to be electroplated can be continuously replaced during the electroplating sequence. Even when the electroplating chamber is filled up with a fluid, the same fluid is continuously pumped into the electroplating chamber and the fluid continuously exits the electroplating chamber through an outlet located at the chamber forming mechanism. Continuously replacing the fluid helps to flush out greasy fluid in the case of use of the degreasing agent, flush out contaminants (e.g. debris, dirt etc.) in the case of use of the washing agent, and to replenish the fluid with the required metal ions in the case of use of the electroplating solution.

The fluid exiting the electroplating chamber can be recycled by channeling the fluid back to the same fluid storage tank that supplies the fluid to the electroplating chamber. Such fluid in the storage tank should be changed periodically to maintain the level of concentration of the desired fluid and reduce the level of contamination in the fluid such as grease, dirt, presence of other fluids used in the process, etc. Otherwise, the electroplating efficiency and quality may deteriorate after repeated use of recycled fluid. Specifically, during the degreasing step, washing step or coating step, the respective degreasing agent, washing agent or electrolyte solution are constantly circulated between a respective tank in the central fluid supply system and the electroplating chamber formed by the apparatus. This can be achieved via respective pumps pumping the degreasing agent, washing agent or electrolyte solution from the respective tank in the central fluid supply system into the electroplating chamber and pumping them out through the outlet for returning the respective fluid back to the respective tank in the central fluid supply system. The constant circulation of the fluids also helps to reduce the consumption of reagents and fluids such as electrolytes, which is an advantage of the present method.

The electroplating apparatus can comprise a second outlet disposed at a top portion of the chamber forming mechanism for removal of waste gas. The top portion of the chamber forming mechanism corresponds to a top portion of the electroplating chamber. To better facilitate waste gas to escape from the second outlet, the electroplating chamber can be subjected to a tilting step to tilt the electroplating chamber at an inclined angle relative to horizontal axis during the coating step such that the location of the second outlet is elevated. This tilting step can be accomplished by a tilting mechanism (e.g. 128, 228). Once the location of the second outlet is elevated, waste gas generated in the electroplating chamber will be directed to escape through the second outlet. This tilting is particularly advantageous in the electroplating process of an internal threaded surface of a tubular structure with threaded surface forming the top portion of the electroplating chamber. Gas bubbles are generated during the coating step. The tilting helps to remove gas bubbles trapped in grooves of the threaded surface because such air bubbles would migrate towards the elevated location of the second outlet and escape through the second outlet. These trapped gas bubbles are known to cause uneven plating at the grooves of the threaded surface. In this manner, coating uniformity is ensured, especially at the top portion of the threaded surface of the tubular structure and this can prevent galling at connection portions of the tubular structures that had been subjected to electroplating.

A drying step can be implemented after one or more or after each of the degreasing step, washing step and coating step. The drying step is to dry the enclosed portions of the tubular structures and prevent carry over and contamination of fluid from one step to the next. The drying step can be accomplished by channeling air via a blower (or air pump) into the electroplating chamber and flushing the respective degreasing fluid, washing agent and electrolyte solution out. The drying step can be carried out with the electroplating chamber tilted at a reclined angle relative to horizontal axis to direct the fluid downwards with the help of gravity out of the electroplating chamber. It should be noted that the angle discussed earlier is for tilting the electroplating chamber so that the second outlet located at the top portion of the electroplating chamber is elevated. However, the reclined angle for directing the fluid downwards is to facilitate lowering of the outlet for fluid to exit from the electroplating chamber so that fluid can exit the outlet more efficiently with the assistance of gravity. This lowering of the outlet for fluid to exit can be accomplished by the same tilting mechanism (e.g. 128, 228) used to elevate the second outlet.

With reference to Figure 9, upon the completion of the electroplating sequence, the chamber forming mechanism is released from the tubular structure in a step 908. This involves loosening of the clamping mechanism such that the tubular structure is freed from the first and second jaws, and any locking or tightening mechanism working together with the clamping mechanism is released. The horizontal alignment mechanism is also adjusted to retract the barrier from the inner channel of the tubular structure.

The electroplated surface of the tubular structure is inspected at a step 910 for quality control and to ensure that the desired thickness is coated onto the tubular structure and to check for any defects in the coated surface. Once the electroplated surface meets the desired thickness requirement and is free of defects, the method is completed at a step 912.

Figure 4A to 4C and the corresponding description illustrating the features and operation of the tilting mechanism 128 of Figure 2 can be adapted for the tilting mechanism 128 of Figure 1, and the tilting mechanisms 228 of Figures 5 and 7.

In summary, examples of the present disclosure may include the following features.

An apparatus to electroplate a surface of a tubular structure, wherein the apparatus comprises:

- a chamber forming mechanism configured to enclose portions of a tubular structure to form an electroplating chamber with an inner wall comprising a surface of the tubular structure to be electroplated,

wherein the chamber forming mechanism comprises:

- an inlet to let fluid for use in an electroplating process to enter and fill up the electroplating chamber to immerse the surface of the tubular structure to be electroplated in the fluid during the electroplating process;

- an outlet to let the fluid exit the electroplating chamber as required during the electroplating process; and

- an electrode extending from the chamber forming mechanism into the electroplating chamber, wherein the surface of the tubular structure to be electroplated is electrically conductive.

The apparatus may further comprise a clamping mechanism configured to clamp the chamber forming mechanism to the tubular structure to compress one or more seals disposed between the chamber forming mechanism and portions of the tubular structure enclosed by the chamber forming mechanism.

The clamping mechanism may comprise a first jaw configured to contact a first portion of the tubular structure; and a portion of the chamber forming mechanism as a second jaw opposite to the first jaw for covering a second portion of the tubular structure, wherein distance between the first jaw and the second jaw is adjustable to clamp the chamber forming mechanism to the tubular structure.

The chamber forming mechanism may comprise a second outlet located at a top portion of the electroplating chamber for removing waste gas from the electroplating chamber.

The second outlet may be disposed above the outlet for fluid to exit.

A first conduit may be connected to the second outlet and a second conduit for channeling exiting fluid may be connected to the outlet for fluid to exit and the first conduit may be connected to the second conduit.

The apparatus may comprise a tilting mechanism comprising a platform configured to mount the tubular structure in a horizontal orientation, and the platform is adjustable to tilt by an angle relative to the horizontal orientation to correspondingly tilt the tubular structure mounted to the platform to direct waste gas in the fluid to move upwards to the second outlet.

The angle may be 0 to 45 degrees, preferably 0 to 15 degrees, or more preferably 0 to 7 degrees.

The platform may be adjustable to tilt by an angle relative to the horizontal orientation to correspondingly tilt the tubular structure mounted to the platform to direct, with assistance of gravity, fluid downwards to the outlet for fluid to exit.

The chamber forming mechanism may be configured to form the electroplating chamber with inner walls comprising: internal surface of the tubular structure to be electroplated; and surface of one or more portion of the chamber forming mechanism covering one or more respective opening of the tubular structure.

The apparatus may comprise a barrier for plugging an inner channel portion of the tubular structure to prevent fluid leakage pass the inner channel portion.

The barrier may comprise a seal and the barrier may be adjustable to press the seal against the inner wall of the tubular structure at the inner channel portion.

The barrier may comprise two plates and the seal is disposed such that when the two plates are adjusted to come together, the seal is compressed to press against the inner wall of the tubular structure at the inner channel portion.

The seal may be seated on one of the two plates and the plate on which the seal is seated may comprise a slope for the seal to stretch and move up the slope when the two plates are adjusted to come together and to retract and move down the slope when the two plates are adjusted to move apart.

The chamber forming mechanism may comprise an adjustment mechanism mounted to the barrier via a support member, wherein the adjustment mechanism is configured to adjust movement of the barrier to a position of the inner channel portion where the barrier is to be placed.

The adjustment mechanism may comprise: a handle rotatable to make the adjustment; and a spindle with one end connected to the handle and another end connected to the barrier, wherein rotation of the handle moves the barrier to the position of the inner channel portion where the barrier is to be placed.

The chamber forming mechanism may be configured to form the electroplating chamber with inner walls comprising: internal surface of the tubular structure to be electroplated; surface of one or more portion of the chamber forming mechanism covering one or more respective opening of the tubular structure; and surface of the barrier.

The chamber forming mechanism may comprise a housing configured to enclose external surface of the tubular structure to form the electroplating chamber with inner walls comprising: the external surface of the tubular structure to be electroplated; and walls of the housing of the chamber forming mechanism.

The fluid may comprise a degreasing agent to degrease the surface of the tubular structure to be electroplated, a washing agent to clean the electroplated surface of the tubular structure, an electrolyte solution for coating plating material on the surface of the tubular structure to be electroplated while a potential difference between the electrode and the tubular structure is applied, or air for drying and/or flushing other fluid out of the electroplating chamber.

The inlet to let fluid enter and the outlet to let fluid exit may be connected via respective conduits to a central fluid supply system comprising a plurality of storage tanks for holding different fluids.

The central fluid supply system may comprise a central pipe connected to the plurality of storage tanks for channeling the different fluids into the electroplating chamber from the plurality of storage tanks.

The central pipe may be connected to a blower for channeling air into the electroplating chamber.

The central pipe may be connected to a water supply for channeling water into the electroplating chamber.

The apparatus may comprise a pump configured to constantly pump fluid from a tank to the electroplating chamber so that the fluid in the electroplating chamber is constantly replaced.

The replaced fluid exiting the electroplating chamber through the outlet may be directed back to the tank thereby achieving circulation of the fluid between the electroplating chamber and the tank.

The surface of the tubular structure to be electroplated may be an internal or external threaded surface of the tubular structure.

An electroplating system comprising more than one of the aforementioned apparatus for electroplating more than one tubular structure simultaneously.

A method to electroplate a surface of a tubular structure using the aforementioned apparatus, wherein the method comprises: filling up with fluid the electroplating chamber formed by the apparatus to

immerse the surface of the tubular structure to be electroplated in the fluid during electroplating process.

The method may further comprise the following steps:

- a degreasing step to channel degreasing agent through the inlet into the electroplating chamber to immerse the enclosed portions of the tubular structure in the degreasing agent to degrease the enclosed portions of the tubular structure;

- a first drying step to channel air through the inlet into the electroplating chamber to flush the degreasing fluid through the outlet and to dry the enclosed portions of the tubular structure;

- a washing step to channel washing agent through the inlet into the electroplating agent to immerse the enclosed portions of the tubular structure in the washing agent to wash the enclosed portions of the tubular structure;

- a second drying step to channel air through the inlet into the electroplating chamber to flush the washing agent through the outlet and to dry the enclosed portions of the tubular structure;

- a coating step to channel electrolyte solution through the inlet into the electroplating chamber to coat the plating material on the surface of the tubular structure to be electroplated while applying a potential difference between the electrode of the apparatus and the tubular structure; and

- a third drying step to channel air through the inlet into the electroplating chamber to flush the electrolyte solution through the outlet and to dry the enclosed portions of the tubular structure, wherein the surface of the tubular structure to be electroplated is immersed in the electrolyte solution in the electroplating chamber during the coating step.

The method may comprise:

- a tilting step to tilt the tubular structure during the coating step to direct waste gas to move upwards to an outlet at a top portion of the electroplating chamber formed by the apparatus.

The method may comprise:

- during the degreasing step, washing step or coating step, a pumping step to constantly pump the respective degreasing agent, washing agent or electrolyte solution from a respective tank into the electroplating chamber formed by the apparatus so that the degreasing agent, washing agent or electrolyte solution in the electroplating chamber is constantly replaced.

The method may comprise:

- directing the respective degreasing agent, washing agent or electrolyte solution from the electroplating chamber back to the respective tank thereby achieving circulation of the respective degreasing agent, washing agent or electrolyte solution between the electroplating chamber and the respective tank.

The method may comprise:

- a clamping step to clamp the chamber forming mechanism of the apparatus to the tubular structure by compressing one or more seal disposed between the chamber forming mechanism and portions of the tubular structure enclosed by the chamber forming mechanism.

The method may comprise:

- a plugging step to plug an inner channel portion of the tubular structure to prevent fluid leakage pass the inner channel portion.

In the specification and claims, unless the context clearly indicates otherwise, the term "comprising" has the non-exclusive meaning of the word, in the sense of "including at least" rather than the exclusive meaning in the sense of "consisting only of". The same applies with corresponding grammatical changes to other forms of the word such as "comprise", "comprises" and so on.

While the invention has been described in the present disclosure in connection with a number of embodiments and implementations, the invention is not so limited but covers various obvious modifications and equivalent arrangements, which fall within the purview of the appended claims. Although features of the invention are expressed in certain combinations among the claims, it is contemplated that these features can be arranged in any combination and order.