Performing softening process

Loading the tube component

Bringing the upper and lower dies together and mounting the hydraulic cylinder

Supplying forming hydraulic pressure (hydro-forming process)

Taking the tube component out of the upper and lower dies and then performing hardening process
Fig. 1

1. loading the tube component
2. bringing the lower and upper dies together and mounting the hydraulic cylinder
3. supplying hydraulic pressure and heating the tube component
4. supplying forming hydraulic pressure (warm hydro-forming process)
5. taking the tube component out of the upper and lower dies

Fig. 2
**Fig. 7**

![Graph showing tensile strength and elongation vs. temperature.](image)

- **tensile strength**
- **elongation**

**Fig. 8**

- performing softening process
- loading the tube component
- bringing the upper and lower dies together and mounting the hydraulic cylinder
- supplying forming hydraulic pressure (hydro-forming process)
- taking the tube component out of the upper and lower dies and then performing hardening process
WARM HYDRO-FORMING METHOD AND APPARATUS FOR ALUMINUM ALLOYS

FIELD OF THE INVENTION

[0001] The present invention relates to a hydro-forming method for an aluminum alloys and an apparatus thereof, and more particularly, to a warm hydro-forming method and an apparatus thereof which are capable of securing forming characteristics in the range of warm forming temperatures using elongation characteristics of a high strength aluminum tube component that are dependent on its temperature, and which thereby successively preform a tube hydro-forming process.

BACKGROUND OF THE INVENTION

[0002] A hydro-forming method is a tube-forming method using hydraulic pressure, and is generally performed at a normal temperature range of between 10 and 30 degrees Celsius. Tube hydro-forming technology is widely used in the automotive industry. For example, this technology is used for manufacturing various components of a vehicle such as body structure components, and is cost-effective.

[0003] Recently, instead of iron group materials, high strength aluminum alloys have become widely used in hydro-forming processes. Such high strength aluminum alloys have poorer forming characteristics at room temperature than does steel. Therefore, a softening process is used to secure forming characteristics, and then hydro-forming processes are successively performed. The softening process increases elongation (%) while decreasing the strength of aluminum materials, and an annealing process is most widely used as such a softening process.

[0004] In order to secure the forming characteristics of the high strength aluminum materials, sufficient elongation for the most severely deformed portion of a fully formed component must be secured. For example, in order to secure elongation of greater than 20%, the softening process must be performed.

[0005] A conventional aluminum tube hydro-forming method, as shown in FIGS. 8 to 12, includes a softening process for a high strength aluminum tube 100 in order to secure elongation for forming a component (S110).

[0006] The tube 100 is then, as shown in FIG. 9, loaded on a lower die 101 of a pressing machine (S120). Subsequently, in a state in which an upper die 103 descends, as shown in FIG. 10, hydraulic cylinders 105 and 107 axially compress the tube 100, and thereby creating a seal in the bore of the tube 100 (S130).

[0007] Hydraulic pressure is then supplied into the tube 100, so that the tube 100 is expanded to forming surfaces 109 and 111 by the hydraulic pressure and axial force transmitted from the hydraulic cylinders 105 and 107 (S140).

[0008] After the hydro-forming process, the tube 100 is taken out from the upper and lower dies 101 and 103. The fully formed tube component 100 then undergoes a hardening process to increase its strength (S150).

[0009] In such conventional tube hydro-forming method, a softening process prior to hydro-forming is inevitable. However, such a softening process may drastically decrease the strength of the material, and this damages the quality of the formed products. Also, a separate hardening process after the hydro-forming process is needed. Such a hardening process may also negatively affect the product quality, as well as the manufacturing costs.

[0010] The information disclosed in this Background of the Invention section is only for enhancement of understanding of the background of the invention and should not be taken as an acknowledgement or any form of suggestion that this information forms the prior art that is already known to a person skilled in the art.

SUMMARY OF THE INVENTION

[0011] Therefore, a motivation of the present invention is to provide a warm hydro-forming method for aluminum alloys and an apparatus thereof which successively perform tube hydro-forming processes after securing forming characteristics within a predetermined temperature range, using an elongation characteristic of high strength aluminum tube component.

[0012] In a preferred embodiment of the present invention, a warm hydro-forming method for forming a tube component of aluminum alloys that is disposed in a hydro-forming apparatus along a forming surface of a first die and a second die, by a compressing force of hydraulic cylinders disposed at both ends of the tube component and hydraulic pressure supplied to the tube component, wherein hydro-forming of the tube component is performed while it is in a heated state by supplying forming hydraulic pressure into the tube component, after increasing a temperature of the tube component to a predetermined temperature within a predetermined temperature range in a state such that the tube component is charged by hydraulic pressure just before hydro-forming.

[0013] It is preferable that the predetermined temperature range is a range of between 50 and 300 degrees Celsius.

[0014] Preferably, the hydraulic pressure is supplied into the tube component by one of water, a water-soluble liquid, and an oily liquid that can be used as pressure-transmitting medium in the predetermined temperature range.

[0015] It is further preferable that the tube component is made of an aluminum-based material.

[0016] In another preferred embodiment of the present invention, the hydro-forming method for aluminum alloys comprises: loading a tube component made of an aluminum alloy on a die of a hydro-forming apparatus; bringing a first die and a second die together in a state in which the tube component is loaded, and sealing and axially compressing the tube component by an operation of a hydraulic cylinder disposed on each side of the tube component; heating the tube component to a temperature within a predetermined temperature range; forming the tube component along forming surfaces formed on the first die and the second die by providing an axial compressing force of the hydraulic cylinder and supplying hydraulic pressure into the tube component, when the tube component is heated to the predetermined temperature; and taking the formed tube component out of the first and second dies, and cooling the tube component.

[0017] In yet another preferred embodiment of the present invention, the hydro-forming apparatus for an aluminum
alloy comprises a first die, a second die, a pair of hydraulic cylinders, and a heating unit. The first die and the second die define forming surfaces for a tube component, and the tube component is compressed between the first and second dies. The hydraulic cylinders are configured to axially compress both sides of the tube component and to supply hydraulic pressure for tube forming. The heating unit is disposed in at least one of the first and second dies at positions corresponding to the forming surfaces of the first and second dies, and the heating unit heats the tube component.

[0018] It is preferable that the heating unit is a heating coil that is operated in response to an electrical signal of a control unit, and the heating coil heats the tube component to a predetermined temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate an embodiment of the invention, and, together with the description, serve to explain the principles of the invention, where:

[0020] FIG. 1 is a flowchart for a warm tube hydro-forming method according to the preferred embodiment of the present invention;

[0021] FIGS. 2 to 6 show successive states of a hydro-forming apparatus according to the preferred embodiment of the present invention;

[0022] FIG. 7 shows relations between tensile strength and elongation according to temperatures of a high strength aluminum alloy (AL 7075);

[0023] FIG. 8 is a flowchart for the tube hydro-forming method according to the prior art; and

[0024] FIGS. 9 to 12 show successive states of the hydro-forming apparatus according to the prior art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] Hereinafter, a preferred embodiment of the present invention will be described in detail with reference to the accompanying drawings.

[0026] The warm hydro-forming method according to the preferred embodiment of the present invention uses the variation of elongation characteristics of aluminum alloys according to temperature, such that if the temperature of aluminum alloys increases to a high range (approximately between 50 and 300 degrees Celsius), its strength decreases and elongation rapidly increases, and if its temperature decreases back to a normal range (approximately between 10 and 30 degrees Celsius), its strength increases and elongation decreases to the initial values. Therefore, the warm hydro-forming method according to the preferred embodiment of the present invention is performed at a high temperature range (approximately between 50 and 300 degrees Celsius) without performing a softening process through thermal treatment, so that forming characteristics and desired strength can simultaneously be obtained.

[0027] A warm hydro-forming apparatus according to the preferred embodiment of the present invention, as shown in FIG. 2, includes a lower die 1 disposed in a lower portion of a pressing device (not shown) and an upper die 5 disposed above the lower die 1. The upper die 5 moves down toward the lower die 1, and a tube component 3 is compressed between the lower and upper dies 1 and 5.

[0028] A left hydraulic cylinder 7 and a right hydraulic cylinder 9 are respectively disposed on both sides of the lower die 1, and they are configured to be inserted into both ends of the tube component 3, so that they may axially compress the tube component 3 and create a seal in a bore thereof.

[0029] The left and right hydraulic cylinders 7 and 9 supply a pressure transmitting medium into the tube component 3, thereby supplying hydraulic pressure into the tube component 3.

[0030] An upper forming surface 11 is provided at a bottom surface of the upper die 5, and a lower forming surface 13 is provided at an upper surface of the lower die 1.

[0031] A heating unit is disposed in the lower and upper dies 1 and 5 behind the forming surfaces 11 and 13, that is, at positions corresponding to the forming surfaces 11 and 13. The heating unit may be a heating coil 21 that operates in response to an electrical signal of a control unit 20. The heating coil 21 is designed to emit heat to a predetermined temperature. In this manner, heat emitted from the heating coil 21 heats the tube component 3 and the pressure transmitting medium to the predetermined temperature.

[0032] In this embodiment of the present invention, the heating coil 21 is provided in order to heat the tube component 3 to a desired temperature. However, a person skilled in the art can easily know that the tube component 3 can be heated by supplying a hot pressure transmitting medium that is heated by a separate heating apparatus, into the tube component 3, without the heating coil 21 disposed inside the upper and lower dies 1 and 5.

[0033] The warm hydro-forming method according to the preferred embodiment of the present invention can, as shown FIGS. 2 to 6, be applied to the above stated hydro-forming apparatus, as follows.

[0034] At first, the tube component 3 that is disposed between the lower and upper dies 1 and 5 is expanded along the forming surfaces 11 and 13 by an axial compressing force provided by the hydraulic cylinders 7 and 9 and hydraulic pressure that is provided into the tube component 3.

[0035] During this process, a temperature of the tube component 3 is raised to a predetermined temperature within a predetermined temperature range by the heating coil 21 just before the expansion of the tube component 3, in a state such that the hydraulic pressure is provided into the tube component 3, and the hydraulic pressure is then finally provided into the tube component 3 so that the tube component 3 is formed in a heated state.

[0036] That is, the warm hydro-forming method according to the preferred embodiment of the present invention uses a temperature-dependant elongation characteristic of the high strength aluminum alloy.

[0037] In the predetermined temperature range, the strength of the tube component 3 drops slightly, but elongation thereof drastically increases, so that a sufficient shape
change can be secured in that temperature range. The predetermined temperature range in which elongation of the tube component 3 drastically increases may preferably be in a range of between 50 and 300 degrees Celsius.

[0038] FIG. 7 shows relations between tensile strength and elongation of the tube component 3 (made of aluminum alloy material (Al 7075)) according to temperature. Referring to FIG. 7, in a normal temperature range of 25 and 100 degrees Celsius, the tensile strength is between 570 MPa and 525 MPa (Mega Pascal), and elongation is between 11% and 14%. However, in a high temperature range (between 150 and 300 degrees Celsius), the tensile strength drastically decreases to a range of between 285 MPa and 40 MPa, but elongation drastically increases to a range of between 23% and 70%.

[0039] Because the warm hydro-forming method according to the preferred embodiment of the present invention is performed at a high temperature, a hydraulic fluid (pressure-transmitting medium) that has stability at the high temperature range (for example, 50 to 300 degrees Celsius) must be used as the hydraulic pressure-transmitting medium.

[0040] Water, a water-soluble liquid, or an oily liquid that can be used as a pressure-transmitting medium in the predetermined temperature range (between 50 and 300 degrees Celsius) can be used as a pressure-transmitting medium of the hydraulic cylinders 7 and 9. More specifically, in the present embodiment of the present invention, silicon oil can be used as the hydraulic fluid.

[0041] In the hydro-forming method according to the preferred embodiment of the present invention, the aluminum alloy tube component 3 is first loaded between the lower and upper dies 1 and 5 (S10).

[0042] The lower and upper dies 1 and 5 are then brought together, and the hydraulic cylinders 7 and 9 are coupled on both sides of the tube component 3, thereby sealing the tube component 3 and axially compressing the tube component 3 (S20).

[0043] Under this condition, hydraulic fluid at a high temperature within a predetermined temperature range is supplied into the tube component 3, and the tube component 3 is simultaneously heated to the predetermined temperature by heat emitted from the heating coil 21 (S30).

[0044] When the tube component 3 is heated to the predetermined temperature, the strength of the tube component 3 slightly decreases and elongation thereof drastically increases, so that the tube component 3 is formed along the forming surfaces 11 and 13 by the compressing force of the hydraulic cylinders 7 and 9 and hydraulic pressure supplied into the tube component 3 (S40).

[0045] Finally, after the warm hydro-forming, the formed tube component 3 is taken from the lower and upper dies 1 and 5, and it is then cooled. The tube component 3 recovers its strength at the initial normal temperature, and elongation of the tube component 3 substantially decreases. Therefore, the tube component 3 recovers its mechanical characteristics of the normal temperature (S50).

[0046] As stated in the above, the warm hydro-forming method and apparatus according to the preferred embodiment of the present invention use elongation characteristics of the high strength aluminum alloy according to its temperature, and tube hydro-forming is performed in a state in which forming characteristics are secured in a predetermined temperature range. Therefore, in the warm hydro-forming method according to the present invention, softening and hardening processes of the conventional hydro-forming method can be eliminated, so forming quality and productivity can be improved.

[0047] Although preferred embodiments of the present invention have been described in detail hereinabove, it should be clearly understood that many variations and/or modifications of the basic inventive concepts herein taught which may appear to those skilled in the present art will still fall within the spirit and scope of the present invention, as defined in the appended claims.

[0048] Throughout this specification and the claims which follow, unless explicitly described to the contrary, the word "comprise" or variations such as "comprises" or "comprising" will be understood to imply the inclusion of stated elements but not the exclusion of any other elements.

What is claimed is:

1. A warm hydro-forming method for forming a tube component of an aluminum alloy that is disposed in a hydro-forming apparatus along a forming surface of a first die and a second die, by a compressing force of hydraulic cylinders disposed at both ends of the tube component and hydraulic pressure supplied to the tube component, wherein hydro-forming of the tube component is performed while it is in a heated state by supplying forming hydraulic pressure into the tube component, after increasing a temperature of the tube component to a predetermined temperature within a predetermined temperature range in a state such that the tube component is charged by hydraulic pressure just before hydro-forming.

2. The warm hydro-forming method of claim 1, wherein the predetermined temperature range is a range of between 50 and 300 degrees Celsius.

3. The warm hydro-forming method of claim 1, wherein the hydraulic pressure is supplied into the tube component by one of water, a water-soluble liquid, and an oily liquid that can be used as a pressure-transmitting medium in the predetermined temperature range.

4. The warm hydro-forming method of claim 1, wherein the tube component is made of an aluminum-based material.

5. A hydro-forming method for an aluminum alloy, comprising:

- loading a tube component made of an aluminum alloy on a die of a hydro-forming apparatus;
- bringing a first die and a second die together in a state in which the tube component is loaded, and sealing and axially compressing the tube component by operation of a hydraulic cylinder disposed on each side of the tube component;
- heating the tube component to a temperature within a predetermined temperature range;
- forming the tube component along forming surfaces formed on the first die and the second die by providing an axial compressing force of the hydraulic cylinders and supplying hydraulic pressure into the tube component, when the tube component is heated to the predetermined temperature; and
taking the formed tube component out of the first and second dies, and cooling the tube component.

6. The warm, hydro-forming method of claim 5, wherein in the step of heating the tube component, the tube component is heated by hydraulic fluid, which is supplied into the tube component through the hydraulic cylinder, at a high temperature within a predetermined temperature range, and by a heating unit.

7. The warm hydro-forming method of claim 5, wherein the predetermined temperature is a temperature within a range of between 50 and 300 degrees Celsius.

8. The warm hydro-forming method of claim 5, wherein the hydraulic pressure is supplied by one of water, a water-soluble liquid, and an oily liquid.

9. A hydro-forming apparatus for an aluminum alloy, comprising:

a first die and a second die defining forming surfaces for a tube component, the tube component being compressed between the first and second dies; and

a pair of hydraulic cylinders configured to axially compress both sides of the tube component and to supply hydraulic pressure for tube forming, wherein a heating unit is disposed in at least one of the first and second dies at positions corresponding to the forming surfaces of the first and second dies, and the heating unit heats the tube component.

10. The hydro-forming apparatus of claim 9, wherein the heating unit is a heating coil that is operated in response to an electrical signal of a control unit, and the heating coil heats the tube component to a predetermined temperature.

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