METALLIC MEMBER FORMING METHOD

Inventors: Haruo Watanabe, Aichi (JP); Hiroyuki Iseki, Aichi (JP)

Correspondence Address:
Jeffrey W. Salmon
Welsh & Katz, Ltd.
22nd Floor
120 S. Riverside Drive
Chicago, IL 60606 (US)

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Abstract

A metallic member forming method capable of achieving both formability of a metallic member and highly strengthening same. Cylindrical metallic member 1 having a hollow space 10 and forming die 3 having a forming face 31 are used. Metallic member 1 is heated up to a temperature range capable of quench-reinforcing (e.g., not less than A1 transformation point). By increasing internal pressure of gas contained in the hollow space 10 of the metallic member 1 a wall 1a of the metallic member 1 is bulged and/or deformed, and the bulged, deformed wall 1a of the metallic member 1 is deformed by bringing it into intimate contact with the forming face 31 of the forming die concurrently with quench-reinforcing it. High strengthening of the metallic member 1 is achieved.
METALLIC MEMBER FORMING METHOD

FIELD OF THE INVENTION

[0001] This invention relates to a metallic member forming method capable of enhancing formability of a metallic member and highly strengthening the same.

BACKGROUND OF THE INVENTION

[0002] As a metallic member forming method, a hydro-forming forming method is known. The hydro-forming method is a technique of: using tubular or cylindrical metallic member having a hollow space and forming die having a forming face designed to have a target shape; feeding water into the hollow space of the metallic member to bulge and deform the metallic member's wall, and then forming the bulged, deformed wall by bringing into intimate contact (i.e., contact closely or without clearance) with the forming face of the forming die.

[0003] According to the aforementioned hydro-forming method, the wall of the metallic member becomes bulged and deformed by feeding water into the hollow space of the metallic member, and consequently, forming the wall can be realized. However, there are limitations for satisfying both formability of a metallic member and highly strengthening the same.

[0004] Particularly in recent automotive parts and the like, it is required to thin the thickness of the material for lightening weight. However, in case of thinning the thickness of the material, forming force required for forming a metallic member can be lessened, but there lie limitations with respect to highly strengthening the metallic member.

[0005] Moreover in the case where the material is iron-based, it is required to improve its tensile strength (i.e., produce high tensile steel) by increasing the content of an alloy element while thinning its thickness is realized. However, in the case where the material is improved in tensile strength in such a way, improvement in strength of the metallic member can be realized, but because of decreasing elongation of the material, formability of the material becomes deteriorated, and accordingly, there is a fear of causing cracks and other defects in the course of bulging and deforming the metallic member as a result of applying the hydro-forming method.

[0006] WO 01/23116 A1 (Apr. 5, 2001) discloses a method of forming an elongated tubular blank into a tubular structural component by applying high pressure gas so as to conform to the inner surface of the shell in which the tubular component is heated by inductively heating the shell. The resultant product is further brought to a separate quench station. However, the quenching cannot be carried out simultaneously with the forming step, and there is much to be desired for further improvement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The benefits and advantages of the present invention will become more readily apparent to those of ordinary skill in the relevant art after reviewing the following detailed description and accompanying drawings, wherein:

[0008] FIG. 1 is a perspective view associated with a 1st example of the invention showing schematically a process of forming an expanded part at both ends of a metallic member and placing the same in a furnace chamber of a furnace respectively.

[0009] FIG. 2 is a cross-sectional view associated with the 1st example of the invention showing schematically a state of placing the heated metallic member in a forming die.

[0010] FIG. 3 is a cross-sectional view associated with the 1st example of the invention showing schematically a state of feeding gas into a hollow space of the metallic member and swelling a wall of the metallic member under the condition that the heated metallic member is placed in the forming die.

[0011] FIG. 4 is a cross-sectional view associated with a 2nd example of the invention showing schematically a state of heating a metallic member facing a forming die.

[0012] FIG. 5 is a cross-sectional view associated with the 2nd example of the invention showing schematically a state immediately before feeding gas into a hollow space of the heated metallic member placed so as to face the forming die.

[0013] FIG. 6 is a cross-sectional view associated with a 3rd example of the invention showing schematically a state of heating a metallic member placed so as to face the forming die.

[0014] FIG. 7 is a cross-sectional view associated with the 3rd example of the invention showing schematically a state immediately before feeding gas into a hollow space of the heated metallic member placed so as to face the forming die.

[0015] FIG. 8 is a cross-sectional view associated with a 4th example of the invention showing schematically a state of heating a metallic member placed so as to face the forming die.

[0016] FIG. 9 is a cross-sectional view associated with the 4th example of the invention showing schematically a state immediately before feeding gas into a hollow space of the heated metallic member placed so as to face the forming die.

[0017] FIG. 10 is a perspective view showing a 1st applied example of the invention.

[0018] FIG. 11 is a perspective view showing a 2nd applied example of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0019] While the present invention is susceptible of embodiment in various forms, there is shown in the drawings and will hereinafter be described a presently preferred embodiment with the understanding that the present disclosure is to be considered an exemplification of the invention and is not intended to limit the invention to the specific embodiment illustrated.

[0020] It should be further understood that the title of this section, namely, “Detailed Description of the Invention”, relates to a requirement of the United States Patent Office, and does not imply, nor should be inferred to limit the subject matter disclosed herein.

[0021] In the present disclosure, the words “a” or “an” are to be taken to include both the singular and the plural. Conversely, any reference to plural items shall, where appropriate, include the singular.
The present invention has been made under such circumstances as described above. It is an object of the present invention to provide a metallic member-forming method comprising the steps of: providing and using (a) a typically cylindrical or tubular (herein termed "cylindrical comprehensively") metallic member having a hollow space and forming die having a forming face; and performing a forming and quench-reinforcing step by increasing an internal pressure of gas contained in the hollow space of the metallic member heated up to a temperature range capable of reinforcing by quenching (i.e., quench-reinforcement) to bulge and/or deform a wall of the metallic member, wherein forming of the bulged, deformed wall of the metallic member is performed by bringing the same wall into intimate contact with the forming face of the forming die accompanied by simultaneous quench-reinforcing of the wall.

According to the metallic member-forming method of the invention, at first, a metallic member is heated up to a temperature range capable of quench-reinforcing. Then, in a forming and quench-reinforcing step, a wall of the metallic member is changed into a bulged and/or deformed state by increasing internal pressure of the gas contained in a hollow space of the metallic member. During this span of time, the metallic member can be maintained at a significantly high temperature as compared with the case where water is contained in the hollow space of the metallic member as the case with the hydro-forming method.

Besides, according to the metallic member forming method of the invention, the wall of the metallic die, bulged and/or deformed as above described, is formed by bringing it into intimate contact with a forming face of a forming die, and thereupon simultaneous quench-reinforcing takes place. In bulging and/or deforming the metallic member in this way, elongation of the metallic member can be ensured, since the metallic member has been heated up to a temperature range capable of quench-reinforcing. As a result, plastic deformability of the metallic member can be improved, and also bulged deformability and/or formability of the metallic member can be enhanced.

The term "bulge" used herein does not mean that the workpiece is "bulged" in its entirety, but encompasses the case of partial bulging, i.e., a case where only part of a workpiece is bulged or deformed under the applied high pressure within the internal hollow space of the workpiece.

In addition, in the above described forming and quench-reinforcing step, the metallic member can be quenched and reinforced by bringing the bulged and/or deformed metallic member into intimate contact with a forming face of a forming die to realize high strengthening of the metallic member.

According to a second aspect of the present invention, there is provided a method for forming metallic member comprising the steps of:

(a) placing a cylindrical metallic member having a hollow space in a forming die assembly,

(b) heating said metallic member placed in the forming die assembly,

(c) bringing a prescribed surface of said metallic member into intimate contact with a prescribed face of the forming die assembly by introducing a pressurized gas into said hollow space of the metallic member heated in the forming die assembly, to thereby plastically deform said metallic member, and,

(d) quenching said metallic member immediately following the deformation of the metallic member through cooling said metallic member in a state of being placed in the forming die assembly.

By this method, the heating, deformation and cooling are carried out consecutively or continuously within the die assembly. That is the formation and heat treatment of the metallic member are performed continuously in situ, resulting in an improved operation.

According to a third aspect of the present invention, there is provided a method for forming metallic member comprising the steps of:

(a) heating a cylindrical metallic member having a hollow space,

(b) placing said heated metallic member into a forming die assembly,

(c) bringing said heated metallic member into intimate contact with a prescribed face of the forming die assembly by introducing a pressurizing gas into the hollow space of said metallic member, to thereby plastically deform said metallic member,

(d) quenching said metallic member immediately following the deformation of said metallic member through cooling said forming die assembly, in a state that said metallic member is placed in the forming die assembly.

By this method, the deformation and cooling of the metallic member are carried out continuously within the die assembly. That is the forming and heat treatment of the metallic member are performed continuously in situ.

According to a fourth aspect, there is provided a metallic member product produced according to the method as defined in any one of preceding aspects.

According to a fifth aspect, there is provided an apparatus for forming metallic member comprising: a forming die assembly for placing a cylindrical metallic member having a hollow space into a cavity of the forming die assembly, a gas supply device for supplying a pressurizing gas into the hollow space of said metallic member heated within the forming die assembly, and a cooling device for cooling said forming die assembly configured to quench-hardening said metallic member place and plastically deformed in said forming die assembly. The apparatus further comprises a control unit for controlling said gas supply device so as to perform bulging and/or deforming of said metallic member together with quench-hardening the same. According to this apparatus, the deformation and quenching are carried out continuously within the die assembly. That is the forming and heat treatment of the metallic member are performed continuously in situ.

The apparatus may further comprise a heating device for selectively heating the metallic member placed in the cavity of said forming die assembly.
According to a metallic member forming method of the invention, at least one of the following embodiments can be employed.

A metallic member is in a cylindrical form that has a hollow space. As the cylindrical (or tubular) form, those of a circular or an angularly (i.e., polygonal or square) or any cross section may be employed. The metallic member before executing a forming and quench-reinforcing step may have a straightly cylindrical form or a cylindrical form that has at least one of curved, concave and convex portions. The metallic member may be a unitary formed (shaped) article or a joint product of plural materials.

With regard to a material of the metallic member, an embodiment can be employed of that the material is an iron-based material including an alloy steel such as high tension steel, stainless steel or the like, a titanium-based material, an aluminum-based material or a copper-based material. However, it is unnecessary to restrict the material of the metallic member to those exemplified materials. The term “high tension steel” means high tensile strength steel made of steel having a large tensile strength. As the high tension steel, iron-based metal having a tensile strength of not less than 500 MPa (50 kgf/mm²), iron-based metal having a tensile strength of not less than 600 MPa, iron-based metal having a tensile strength of not less than 800 MPa, iron-based metal having a tensile strength of not less than 1,000 MPa, or iron-based metal having a tensile strength of not less than 1,500 MPa may be employed. In general, high-tension steel has a high strength, but does not have necessarily sufficient plastic deformability. According to the invention, these metallic members are heated before being quenched and reinforced so that plastic deformability of each metallic member can be improved. As a result, bulged deformability and formability of the metallic member can be enhanced even in the case where plastic deformability of the metallic member is insufficient as is in the case where a material of the metallic member is in a high tension state. Consequently, in the case where formed shapes of metallic members are different from each other and also in that where formation degree of a metallic member is large, formability of each metallic member can be secured well.

In regard of heating a metallic member, an embodiment can be employed of that the heating is executed by at least one of operation for maintaining the metallic member in a furnace chamber of a heating furnace, induction heating operation for induction-heating the metallic member, and resistance heating operation for energizing the metallic member. At least two of these operations may be employed in a combined state. In other words, after executing the operation for maintaining the metallic member in the furnace chamber of the furnace, the induction heating operation for induction-heating the metallic member may be performed. Otherwise, after executing the operation for maintaining the metallic member in the furnace chamber of the furnace, the resistance heating operation for energizing the metallic member may be performed. If not so, without performing the operation for maintaining the metallic member in the furnace chamber of the furnace, the induction heating operation and the resistance heating operation (generally, electrical heating) may be performed. The induction heating operation and the resistance heating operation can be performed simultaneously or successively.

With regard to the operation for maintaining the metallic member in the furnace chamber of the furnace, an embodiment can be employed of that this operation is executed under the condition that the furnace chamber of the furnace has a non-oxidizing atmosphere. As the non-oxidizing atmosphere, at least one of vacuum atmosphere, reducing atmosphere and inert atmosphere may be employed. The reducing gas may be at least one of CO gas atmosphere and CO-containing gas atmosphere. The inert gas atmosphere may be a nitrogen atmosphere or a rare gas atmosphere of argon or the like.

For the induction heating operation, an embodiment can be employed wherein this operation is put into practice by applying an alternating current to an electrically conductive member for induction heating in a state of placing the conductive member close to (preferably within the hollow space of) the metallic member disposed within the forming die in order to induction-heat the metallic member (selectively, as much as possible). The conductive member for induction heating may be coil-shaped or plate-shaped. Basically, the conductive member has any shape if it can induction-heat the metallic member. Frequency of the alternating current to be applied to the conductive member may be selected properly within a frequency range capable of induction-heating the metallic member taking into account of material of the metallic member, equipment cost, induction heating ability and the like, and accordingly, low frequency region, middle frequency region or high frequency region may be applied depending on circumstances. Applicable frequencies may range, for example, 0.5 to 5,000 kHz, especially, 1 to 2,000 kHz. However, the applicable frequency range is not restricted to these exemplified frequencies.

In case of applying a high frequency alternating current to the conductive member to induction-heat the metallic member, a surface layer of the metallic member can be heated efficiently since proximity effect capable of heating efficiently the surface layer positioned near the conductive member in the metallic member and also skin effect resulting from an electric current running through the surface layer of the metallic member can be expected.

In the resistance heating operation for energizing the metallic member, an embodiment can be employed of that this operation is executed by energizing the metallic member from energizing terminals in a state of connecting the energizing terminals to the metallic member facing a forming face of a forming die to heat the metallic member by Joule heat. An electric current for energizing the metallic member from the energizing terminals may be a direct current or an alternating current (AC). In case of applying the alternating current, its frequency may be in a low, middle or high frequency region depending on circumstances taking into account of material of the metallic member, equipment cost, induction heating ability and the like. The frequency may be in a range of, e.g., from 0.5 to 5,000 kHz, especially, from 1 to 2,000 kHz. However, the frequency is not restricted to these exemplified frequencies. In case of applying a high frequency alternating current to the metallic member from one of the energizing terminals, a surface layer of the metallic member can be heated efficiently since the skin effect resulting from running an electric current through the surface layer of the metallic member can be expected.
The metallic member may be made of a iron-based material, and an embodiment can be employed of that the metallic member is heated up to a temperature range of not less than A1 transformation point (temperature capable of hardening). The term “not less than A1 point” means a temperature range higher than an austenite generation temperature. As the case may be, an embodiment also can be employed of that the metallic member is heated up to a temperature range of not less than A3 transformation point. It is preferable to set the maximum heating temperature of the metallic member at a liquid phase generation temperature of a matrix of the metallic member.

In the forming and quench-reinforcing step, at least a part of the metallic member can be hardened to provide an accelerated transformation into a martensite state by bringing a wall of the metallic member into intimate contact with a forming face of a forming die. Hardening in this way can promise to strengthen the metallic member. A constitution of generating troostite, sorbite or the like is also permissive together with or in place of martensite. Troostite or sorbite is liable to be generated when the cooling rate is lower than that required for generating martensite.

In the case where the metallic member is iron-based, it may contain an alloy element having a high multiplying factor for the purpose of enhancing the hardening property. The alloy element having a high multiplying factor includes carbon, manganese, silicon, nickel, chromium and molybdenum, and at least one of these alloy elements may be contained in the metallic member. In the case where the metallic member is of an iron-based material, there are many cases where the content of at least one alloy element described above is increased for transforming the material into a high tension one.

As for a forming die, an embodiment can be employed wherein the forming die has a cooling device for cooling the forming die. With regard to the cooling device, at least one of the following systems may be employed: a system wherein a cooling passage inside the forming die is formed and a coolant such as cooling water, refrigerant gas or the like into the cooling passage; and a system wherein a coolant such as cooling water, refrigerant gas or the like is brought into intimate contact with the forming face of the forming die. A material of the forming die includes metal having a good thermal conductivity as well as good durability such as carbon steel, alloy steel and the like.

According to the present inventive method, a wall of the metallic member is bulged and/or deformed to come into contact with the forming face of the forming die by increasing the internal pressure of a gas contained in a hollow space of the metallic member. For an operation for increasing the internal pressure, an embodiment can be employed in which an operation is performed by feeding gas into the hollow space of the metallic member. The gas to be fed into the hollow space may be at least one of air, nitrogen gas, nitrogen-rich gas, argon gas and argon-rich gas. The term “nitrogen-rich gas” means a gas having a high nitrogen concentration. The term “argon-rich gas” is referred to a gas having a high argon concentration.

With regard to the operation for feeding gas into the hollow space of the metallic member, an embodiment can be employed in which an operation is performed from a high-pressure gas supply capable of feeding a high-pressure gas. Taking into consideration of formability of the metallic member, it is preferable that pressure of the high-pressure gas is rather high. The pressure of the high-pressure gas can be set at, for example, not less than 10 MPa, not less than 15 MPa, not less than 20 MPa, or not less than 30 MPa. However, taking into consideration of applications, it is preferably in a range of from 15 to 25 MPa, from 17 to 23 MPa, or from 19 to 21 MPa, or otherwise set at 20 MPa. An exemplary high-pressure gas supply source includes bomb, factory air supply line and the like.

For the metallic member, an embodiment can be employed in which the metallic member has an opening communicating with its hollow space and formed by a tapered open (e.g., conical) wall face. In this case, an embodiment can be employed in which an opening of the metallic member is sealed by applying directly or indirectly a sealant, having a slant corresponding to that of the tapered open wall face, to the tapered open wall face. In this case, good seal is realized of the tapered opening wall face forming the opening of the metallic member since the sealant is applied to the tapered open wall face.

As an embodiment of the method for forming metallic member, the following method may be employed. Namely, the method comprises the steps of: placing a cylindrical metallic member having a hollow space in a forming die assembly; heating said metallic member placed in the forming die assembly; bringing a prescribed surface of said metallic member into intimate contact with a prescribed face of the forming die assembly by introducing a pressurized gas into said hollow space of the metallic member heated in the forming die assembly, to thereby plasticly deform said metallic member; and, quenching said metallic member immediately following the deformation of the metallic member through cooling said metallic member in a state of being placed in the forming die assembly.

Also the following method for forming metallic member may be employed. That is, the method comprises the steps of: heating a cylindrical metallic member having a hollow space; placing said heated metallic member into a forming die assembly; bringing said heated metallic member into intimate contact with a prescribed face of the forming die assembly by introducing a pressurizing gas into the hollow space of said metallic member, to thereby plasticly deform said metallic member; and quenching said metallic member immediately following the deformation of said metallic member through cooling said forming die assembly, in a state that said metallic member is placed in the forming die assembly.

A metallic member product having a desired shape may be produced according to any one of the methods as mentioned hereinafore. By employing any one of the aforementioned methods, both the forming and high-reinforcement of the metallic member can be achieved.

As an apparatus for forming metallic member, the following apparatus may be employed. The apparatus comprises a forming die assembly for placing a cylindrical metallic member having a hollow space into a cavity of the forming die assembly; a gas supply device for supplying a pressurizing gas into the hollow space of said metallic member heated within the forming die assembly configured to quench-hardening said metallic member placed and plastically deformed in said forming die assembly. The appara-
tus further comprises a control unit for controlling said gas supply device so as to perform bulging and/or deforming of said metallic member together with quench-hardening the same. As a gas supply means, a high pressure gas supply source (or line system) may be used, which comprises a bomb, valve, supply lines etc.

[0062] The apparatus may further comprise a heating device for selectively heating said metallic member placed in the cavity of said forming die assembly. In this case, induction heating or resistance heating may be utilized as the selective heating device for the metallic member.

[0063] A 1st example of the present invention will be explained below in reference to FIGS. 1 to 3. This example is an example of applying a reinforcing by quench-hardening method, which is a typical quench-reinforcing method, to a metallic member 1. The metallic member 1 used in a forming method of this example has a cylindrical (tubular) form having a hollow space 10 and made of an iron-based metal. The iron-based metal before hardening is in the condition of a high tension, i.e., has been changed into high tensile strength steel, and concretely speaking, it is made of an iron-based metal having a tensile strength of not less than 600 MPa (600 kgf/cm²), so that plastic deformability is not necessarily sufficient.

[0064] According to this example, as shown in FIG. 1, openings at either end of the metallic member having a shape of a straight pipe is expanded, so that a respective expanded part 12 spreading toward the end 12 is formed beforehand. A tapered open wall face 13, which is an inner wall face of the expanded part 12, configures an opening 13x communicating with the hollow space 10.

[0065] At first, in a heating step, the metallic member 1 is maintained in a furnace chamber 20 of a furnace 2 for a predetermined time and heated up to a temperature range capable of quench-reinforcing, i.e., temperature range of not less than A1 transformation point. In this case, the metallic member may be heated up to a temperature range of not less than A3 transformation point if necessary. Thereby all or partial metallurgical structure of the metallic member 1 is changed into an austenite state. Because of maintaining the furnace chamber 20 of the furnace 2 in a non-oxidizing atmosphere, oxidation and decarburization of the metallic member 1 can be suppressed. As the non-oxidizing atmosphere, a vacuum atmosphere, a reducing atmosphere, an inert gas atmosphere of, e.g., argon gas, or the like may be employed depending on circumstances.

[0066] Then, the metallic member 1 heated up to a target temperature range as described above is taken out of the furnace chamber 20 and, as shown in FIG. 2, placed in a forming die 3. The forming die 3 is made of a steel-based material that is one of typical metallic materials, and has a forming face 31 designed so as to have a target shape. In this case, it is preferable to initially place the metallic member 1 so as not to bring a reinforcement-requiring portion of a wall of the metallic member 1 in contact with the forming face 31 of the forming die 3. In the forming die 3, a cooling passage 33 through which a coolant such as cooling water, coolant gas or the like flows is formed as a cooling device. When a coolant such as cooling water, coolant gas or the like flows through the cooling passage 33, the forming die 3 will be cooled and become capable of quenching a formed product of the metallic member 1 on the forming face (cavity surface) 31 of the forming die 3. It is preferable to cool the forming die 3 by flowing a coolant such as cooling water, coolant gas or the like through the cooling passage 33 of the forming die 3 before or during (or in the midway) of the aforesaid heating step.

[0067] In the forming and quench-reinforcing step of this example, as shown in FIG. 2, one set of two sealants 40, 41 each having a sealing face 44 with a slant corresponding to that of the tapered open wall face 13 of the expanded part 12 of the metallic member 1 are used. The sealants 40, 41 may be made of metal or a refractory material. One sealant 40 has a passage 40x to be connected to a high-pressure gas supply source 5. The other sealant 41 has a sealing function but never connects with the high-pressure gas supply source 5. The high-pressure gas supply source 5 is used for feeding high-pressure gas and has bomb 50 having high-pressure gas enclosed therein, valve 52 having an opening/shutting valve 51 for opening and shutting the bomb 50, pressure indicator 53 functioning as pressure detection means for detecting pressure of gas enclosed in the bomb 50 and flexible feed pipe 54 functioning as a feeding passage of gas discharged from the valve 52.

[0068] Then, as shown in FIG. 2, sealants 40, 41 are respectively fixed in openings 13 disposed at both ends of the metallic member 1, and sealing is performed by applying the sealing face 44 to the tapered open wall face 13 of the expanded part 12 of the metallic member 1 directly or indirectly through a non-illustrated intermediate member. In this case, a void space W is intervenient between the wall 1a of the metallic member 1 and the forming face 31.

[0069] In the forming and quench-reinforcing step of this example, high-pressure gas (of, e.g., 20 MPa) of the high-pressure gas supply source 5 is fed into the hollow space 10 of the metallic member 1 keeping the state of sealing the sealants 40, 41 on the tapered open wall face 13 of the expanded part 12 of the metallic member 1 as above described. Explaining more concretely, the opening/shutting valve 51 of the high-pressure gas supply source 5 is opened to feed a high-pressure gas contained in the bomb 50 of the high-pressure gas supply source 5 through the feed pipe 54 and the passage 40x formed through the one sealant 40 to the hollow space 10 of the metallic member 1.

[0070] Thereby, the internal pressure of the gas contained in the hollow space 10 of the metallic member 1 is increased to bulge and/or deform the wall 1a of the metallic member 1 outwardly to the radial direction. Consequently, the wall 1a is brought into intimate contact with the forming face 31 of the forming die 3. Thereby, the wall 1a is deformed along a profile of the forming face 31 as shown in FIG. 3. In addition, the wall 1a is quenched by the forming face 31 of the forming die 3 concurrently with deformation, so that the wall 1a is hardened.

[0071] It is favorable to flow a coolant such as cooling water, coolant gas or the like through a cooling passage 33 formed through the forming die 3 and cool the forming die 3 directly before or during (or in the middle of) the forming and quench-reinforcing step of this example in order to enhance the hardening property.
employed depending on circumstances. Taking into consideration of cost reduction, air may be employed. Taking into consideration of suppressing oxidation, nitrogen gas, nitrogen-rich gas, argon gas or argon-rich gas, each of which has little or no oxidizing ability, may be employed. After finishing the deforming and the hardening of the metallic member 1 as above described, the metallic member 1 is separated from the sealants 40, 41 and from the forming die 3.

[0073] As explained above, according to this example, the metallic member 1 is heated up to a high-temperature range in the course of the deformation/bulging. Accordingly, plastic deformability of the metallic member 1 can be improved even in case of using the metallic member 1 composed of a high-tension metallic material and having low plastic deformability. As a result, plastic deformability, and accordingly, formability of the metallic member 1 can be enhanced.

[0074] Further, according to this example, the bulged and deformed wall 1a of the metallic member 1 is brought into intimate contact with the forming face 31 of the forming die 3. Accordingly, taking heat away from and thereby hardening the wall 1a of the metallic member 1 can be realized. Consequently, the wall 1a of the metallic member 1 can be reinforced. Therefore, as described above, according to the method applied in this example, improvement in the deformability of the wall 1a of the metallic member 1 and highly strengthening the same can be achieved at the same time.

[0075] According to this example in which the metallic member 1 can be reinforced in such a way as disclosed above, in spite of using the metallic member 1 made of iron-based metal having a tensile strength before hardening of not less than 600 MPa (60 kgf/mm²), the iron-based metal constituting the metallic member 1 can be reinforced to have a tensile strength of not less than 1,000 MPa (100 kgf/mm²) or of not less than 1,200 MPa, or of not less than 1,500 MPa as the case may be.

[0076] According to this example, as aforementioned, in the forming and quench-reinforcing step, the wall la of the metallic member 1 is hardened and reinforced by bringing the bulged and deformed wall la of the metallic member 1 into intimate contact with the forming face 31 of the forming die 3. Accordingly, if heating temperature of the metallic member 1 and cooling ability of the forming face 31 of the forming die 3 are controlled properly, with regard to the thickness direction of the wall 1a of the metallic member 1, a cooling rate of one surface layer 1c facing and in intimate contact with the forming face 31 of the forming die 3 (outer surface layer) can be made larger than that of the other surface layer 1d back-facing the forming face 31 of the forming die 3 (inner surface layer).

[0077] In other words, in terms of the thickness direction of the wall 1a of the metallic member 1, the cooling rate of the surface layer 1d (inner surface layer) can be made smaller than that of the surface layer 1c (outer surface layer). Accordingly, in respect of the thickness direction of the wall la of the metallic member 1, a hardening property of the surface layer 1c (outer surface layer) can be enhanced to strengthen highly this portion, and a hardening property of the surface layer 1d (inner surface layer) also can be suppressed to ensure a toughness of this portion. Namely, in the thickness direction of the wall 1a of the metallic member 1, the degree of hardening and reinforcing can be changed, and an effect of enhancing both strength and impact resistance of the metallic member 1 also can be expected.

[0078] In addition, according to this example, sealing the opening 13r of the metallic member 1 is performed by using: the sealants 40, 41 each having the sealing face 44 with a slant corresponding to that of the tapered open wall face 13 of the expanded part 12 of the metallic member 1; and pressing the sealants 40, 41 to the tapered open wall face 13 of the expanded part 12 of the metallic member 1. Accordingly, good sealing property of a boundary region between the metallic member 1 and the sealants 40, 41 can be ensured respectively. Consequently, changing the hollow space 10 of the metallic member 1 into a high-pressure state can be achieved effectively. Therefore, bulging and/or deforming ability of the wall 1a of the metallic member 1 can be enhanced.

[0079] According to this example, if the expanded part 12 positioned at either end of the metallic member 1 is unnecessary after hardening, the expanded part 12 may be removed by cutting. Or otherwise, if the expanded part 12 is necessary, it may be left as it is.

[0080] A 2nd example of the present invention will be explained concretely below in reference to FIGS. 4 and 5. The constitution, work and effect of this example are essentially the same with those of the 1st example. Explanation of this example will be made as follows focusing on difference from the 1st example. This example is an example of applying a reinforcing by hardening method, which is a typical quench-reinforcing method, to a metallic member 1 in the same way as disclosed in the 1st example. The metallic member used in a forming method of this example has a cylindrical form having a hollow space 10 and made of an iron-based metal capable of hardening. The iron-based metal is made to have a high tension, i.e., changed into high tensile strength steel, for highly strengthening so that plastic deformability is not necessarily sufficient.

[0081] At first, in a heating step, the metallic member 1 is placed in a forming die 3 so that a wall 1a of the metallic member 1 faces a forming face 31 of the forming die 3. In this case, it is preferable to place the metallic member 1 so that a reinforcement-requiring part of the wall 1a of the metallic member 1 does not come into contact with the forming face 31 of the forming die 3. Then, as shown in FIG. 4, an electrically conductive member 6 of a coil form for induction heating is placed in the hollow space 10 of the metallic member 1. Namely, the conductive member 6 for induction heating is made to close with the metallic member 1 facing the forming face 31 of the forming die 3. In this heating step, it is preferable that the forming die 3 and the metallic member 1 are maintained in no contact state with each other in order to avoid raising a temperature of the forming die 3 and also lowering the temperature of the metallic member 1.

[0082] As described above, the metallic member 1 is induction-heated by applying a high-frequency alternating current to the conductive member 6 in a state of placing the conductive member 6 for induction heating near the metallic member 1 in the hollow space 10 of the metallic member 1. The alternating current for energizing the conductive member 6 should have frequency and current values which are capable of induction-heating a reinforcement-requiring part in the wall 1a of the metallic member 1 up to a temperature.
range of not less than A1 or A3 transformation point. In case of induction-heating the wall 1a of the metallic member 1 by applying a high-frequency alternating current to the conductive member 6 in this way, a surface layer of the wall 1a of the metallic member 1 can be heated efficiently since proximity effect capable of heating efficiently the surface layer positioned near the electrically conductive member in the metallic member and also skin effect resulting from an electric current flowing through the surface layer of the metallic member can be expected. As a result of such an induction heating, all or partial metallographic structure of the metallic member 1 is changed into an austenitic state in a short time.

[0083] According to this example, raising a temperature of the forming face 31 of the forming die 3 is suppressed in the heating step for induction-heating the metallic member 1, so that a heat insulating member 9 may be placed between the forming face 31 of the forming die 3 and the metallic member 1 as shown in FIG. 4 if necessary. The heat insulating member 9 preferably has high thermal insulating property and also high magnetic flux-shielding property. It is favorable to flow a coolant such as cooling water, coolant gas or the like through a cooling passage 33 of the forming die 3 and cool the forming die 3 thereby before or in the middle of the above described heating step.

[0084] Then, after completing the heating step, in case of using the heat insulating member 9, the heat insulating member 9 is separated from the forming die 3. After completing the above-described heating step, a forming and quench-reinforcing step is performed. Namely, the forming face 31 of the forming die 3 is placed near the metallic member 1. In this case, as shown in FIG. 5, a void space W is intervenient between the wall 1a of the metallic member 1 and the forming face 31. Further, in the same way of the 1st example, as shown in FIG. 5, using sealants 40, 41 each having a slab corresponding to that of a tapered open wall face 13 of the metallic member 1, sealing is performed by applying the sealants 40, 41 to the tapered open wall face 13 of the metallic member directly or indirectly through an intermediate member.

[0085] Keeping a sealed state by applying the sealants (sealing members) 40, 41 to the tapered open wall face 13 of the expanded part 12 of the metallic member 1 in a way as described above, high-pressure gas contained in a bomb 50 of a high-pressure gas supply 5 is fed through feed pipe 54 and passage 40a of the sealant 40 to the hollow space 10 of the metallic member 1 by opening an opening/shutting valve 51. As a result, internal pressure of gas contained in the hollow space 10 of the metallic member 1 is increased, and consequently, the wall 1a of the metallic member 1 becomes bulged and deformed in its radial direction to be in intimate contact with the forming face 31 of the forming die 3. Thereby the wall 1a of the metallic member 1 is deformed along the forming face 31 of the forming die 3 to complete a forming and quench-reinforcing step.

[0086] It is preferable to cool the forming die 3 by flowing a coolant such as cooling water, coolant gas or the like through the cooling passage 33 of the forming die 3 before or in the middle of the forming and quench-reinforcing step of this example in order to enhance a hardening property.

[0087] As explained above, according to this example, the metallic member 1 is made of iron-based metal that has not necessarily sufficient plastic deformability because of being changed into a high-tension state (or high tensile strength steel). However, the metallic member 1 is heated up to a high temperature range in the course of deformation by swelling, so that plastic deformability of the metallic member 1 can be improved, and that the bulging and/or deforming ability and accordingly formability of the metallic member 1 can be enhanced.

[0088] Further, according to this example, the wall 1a of the metallic member 1 induction-heated up to no less than a hardening temperature is bulged and/or deformed to be brought into contact with the forming face 31 of the forming die 3 in the forming and quench-reinforcing step. As a result, the wall 1a of the metallic member 1 can be hardened. Accordingly, the metallic member 1 can be reinforced. Consequently, in this example, in the same way of the 1st example, both formability of the wall 1a of the metallic member 1 and highly strengthening the same can be achieved at the same time.

[0089] Further more, induction-heating the metallic member 1 is performed by applying a high-frequency alternating current to the conductive member 6 in a state of placing the conductive member for induction heating near the wall 1a of the metallic member 1 facing the forming face 31 of the forming die 3. Accordingly, the wall 1a of the metallic member 1 can be bulged and/or deformed to be formed by opening an opening/shutting valve 51 of a valve control unit 52 immediately after heating the wall 1a of the metallic member 1 up to a target temperature range and feeding high-pressure gas contained in the bomb 50 of the high-pressure gas supply 5 into the hollow space 10 of the metallic member 1. Consequently, a step of taking the metallic member 1 heated up to the target temperature range out of a furnace 2 and then carrying it into the forming die 3 can be eliminated, and lowering a temperature of the metallic member can be suppressed. Therefore, immediately before the step of forming and hardening the metallic member 1, the temperature of the wall 1a of the metallic member 1 can be maintained as high as possible, so that both forming and hardening of the metallic member 1 can be performed well. The valve control unit 52 controls the gas pressure and timing of opening/closing the valve 51. The valve control unit 52 operates in cooperation with or under control of a central control unit (not shown) for controlling the entire process of the forming method including closing/opening movement of the die assembly, energizing of heating means (i.e., supplying electric current), supplying cooling medium, placing/removing the metallic member, and inserting/retracting of an insulator, controlling the temperature of respective portions, etc.

[0090] In addition, according to this example, hardening-reinforcement by the forming face 31 of the forming die 3 can be performed at the time when the wall 1a of the metallic member 1 comes into contact with the forming face 31 of the forming die 3.

[0091] In this example, sealing is performed by applying the sealants 40, 41 to the tapered open (e.g., conical) wall face 13 of the metallic member 1 after executing the heating step of heating the metallic member 1. However, sealing is not restricted to the obtained and deformation of the sealants being applied to the tapered open wall face 13 of the metallic member 1 in the middle of or before the heating step of heating the metallic member 1.

[0092] A 3rd example of the present invention will be illustrated concretely as follows in reference to FIGS. 6 and 7. Essentially the same constitution, work and effect of the
2nd example are employed in this example. This example will be explained below focusing on difference from the 2nd example. In a heating step, a metallic member 1 is placed in the cavity of a forming die 3 so that a wall 1a of the metallic member 1 faces a forming face of the forming die 3. In this case, it is favorable to place the metallic member 1 in such a way that a reinforcement-requiring part of the metallic member 1 does not come into contact with the forming face 13 of the forming die 3.

[0093] Then, the metallic member 1 is heated up to a temperature range of not less than A1 or A3 transformation point by applying a resistance-heating operation. Namely, as shown in FIG. 6, energizing terminals 7 are connected to an expanded part 12 that is a peripheral portion of the metallic member 1 facing to the forming face 13 of the forming die 3, and keeping this state, the wall 1a of the metallic member 1 is heated up to a temperature range of not less than A1 or A3 transformation point by Joule heat by energizing the metallic member 1 from the energizing terminals 7. Respectively energizing terminal may be made of good electrically conductive metal such as copper-based, aluminum-based, titanium-based or iron-based metal or the like. An electric current for energizing the metallic member 1 from the energizing terminals 7 may be direct or alternating.

[0094] In case of energizing the metallic member 1 by applying an alternating current through the energizing terminals 7, its frequency may be in a low, middle or high frequency region depending on circumstances. In case of energizing the metallic member 1 by applying a high-frequency alternating current through the energizing terminals 7, a surface layer of the wall 1a of the metallic member 1 can be heated efficiently since a skin effect resulting from an electric current flowing through the surface layer of the metallic member can be expected.

[0095] Also in this example, sealants 40, 41 each having a slant corresponding to that of a tapered open wall face 13 of an expanded part 12 of the metallic member 1 are used in a forming and quench-reinforcing step as shown in FIG. 7. Then, sealing is performed by applying the sealants 40, 41 to the tapered open wall face 13 of the expanded part 12 of the metallic part directly or indirectly through an intermediate member. Keeping a state of sealing by applying the sealants 40, 41 to the tapered open wall face 13 of the metallic member 1 in this way, an opening/shutting valve 51 is opened to feed high-pressure gas contained in a bomb 50 of a high-pressure gas supply 5 through feed pipe 54 and passage 40a formed through the sealant 40 into a hollow space 10 of the metallic member 1. Accordingly, internal pressure of gas contained in the hollow space 10 of the metallic member 1 is increased, and the wall 1a of the metallic member 1 is bulged and deformed radially to come into intimate contact with the forming face 31 of the forming die 3. Consequently, the wall 1a of the metallic member 1 is deformed along (and corresponding to an inner profile of) the forming die 31.

[0096] As explained above, according to this example, the metallic member 1 is heated up to a high-temperature range in the course of deformation by bulging in the same way of the examples 1 and 2. Plastic deformability of the metallic member 1 can be improved and also bulging/deforming ability and formability of the metallic member 1 can be enhanced even in the case where the metallic member 1 is made of iron-based metal changed into a high tension state.

[0097] Further, according to this example, the wall 1a of the metallic member 1 can be hardened and reinforced thereby by deforming/bulging the wall 1a of the metallic member 1 induction-heated up to a hardening temperature or more to come in intimate contact with the forming face 31 of the forming die 3. Consequently, according to this example, both formability of the wall 1a of the metallic member 1 and highly strengthening the same can be achieved.

[0098] Still further, according to this example, the metallic member 1 is heated by energizing from the energizing terminals 7 in a state of connecting the terminals 7 to the metallic member 1 facing the forming face 31 of the forming die 3. Accordingly, the wall 1a of the metallic member 1 can be bulged and deformed by feeding high-pressure gas into the hollow space 10 of the metallic member 1 immediately after heating the wall 1a metallic member 1 heated up to a target temperature range out of a furnace 2 and carrying the taken-out metallic member to the forming die 3 can be omitted, and lowering a temperature of the metallic member 1 can be suppressed. Therefore, a temperature of the metallic member 1 can be maintained high in a state immediately before the steps of forming and hardening the metallic member 1. Thereby, both forming and hardening of the metallic member 1 can be performed well while a temperature drop of the heated metallic member 1 is suppressed.

[0099] Further more, according to this example, in order to suppress temperature rise of the forming face 31 of the forming die 3 in the heating step, a heat insulating member 9 may be placed between the forming face 31 of the forming die 3 and the metallic member 1 as shown in FIG. 6 depending on need. A favorable heat insulating member 9 is ones having high thermal insulating and magnetic flux-shielding properties.

[0100] A 4th example of the present invention will be explained concretely below with reference to FIGS. 8 and 9. Constitution, function and effect of this example are essentially the same with those of the 2nd example. This example will be illustrated as follows focusing on difference from the 2nd example. Also in this example, a metallic member 1 is preferably placed so as not to bring a reinforcement-requiring part of a metallic member 1 into contact with a forming face 13 of a forming die 3 in a heating step. In this case, a wall 1a of the metallic member 1 faces the forming face 31 of the forming die 3.

[0101] Also in this example, the metallic member 1 is heated up to a temperature range of not less than A1 or A3 transformation point by a resistance-heating operation. Namely, as shown in FIG. 8, energizing terminals 7 are connected to an expanded (e.g., tapered or conical) part 12 that is a peripheral portion of the metallic member 1 facing to the forming face 13 of the forming die 3, and keeping this state, the wall 1a of the metallic member 1 is heated by Joule heat by energizing the metallic member 1 from the energizing terminals 7. Further, an electrically conductive member 6 for induction heating is placed in a hollow space 10 of the metallic member 1 and then a high-frequency alternating current is applied to the conductive member 6. Thereby the wall 1a of the metallic member 1 is induction-heated.

[0102] In this way, resistance heating by energizing in use of the energizing terminals 7 and induction heating in use of the conductive member 6 for induction heating are applied in combination for heating the metallic member 1 according to this example, so that the metallic member 1 can be heated efficiently. In particular, the conductive member 6 for induction heating is placed near a part requiring the highest deformation degree or a part most requiring reinforcement.
by hardening of the wall la of the metallic member 1, so that either part can be heated up to a high-temperature range efficiently, and that plastic deformability and hardening property of the part can be enhanced. As seen from FIG. 9, the forming/quench-hardening step is carried out in the present example likewise in the 2nd Example.

[0103] FIG. 10 shows an applied example 1 of the present invention. In this applied example 1, a metallic member 1B of a straightly tubular form is used. To the metallic member B having a straightly tubular form, heating step and forming and quench-reinforcing step are applied which are the same with those of any example described above. FIG. 11 shows an applied example 2 of the invention. In this applied example 2, a tubular metallic member 1C is used which results from forming a (crank-like) curved part is beforehand e.g., by mechanical press working. Further, in this metallic member 1C, a groove 1S is formed by stamping etc. Then, to the grooved metallic member 1C, heating step and forming and quench-reinforcing step are applied substantially according to any of examples described above. In the present invention, a metallic member 1 may be applied to form a beam for use in a vehicle suspension mechanism, a suspension member, or a bumper-reinforce to be attached to a bumper. Otherwise, it may be applied also to a center pillar placed between front and back seats of a vehicle, or a center pillar-reinforce to be attached to a center pillar for reinforcing the same. It should be noted that the bulging/quench-hardening processing is best suited as an unified processing for the forming/reinforcement stage.

[0104] According to the above-described 1st example, an expanded part 12 is formed at both ends of a metallic member 1. However, sealants 40, 41 may be attached to the both ends of the metallic member 1 without forming the expanded part 12. Further, the expanded part 12 of the metallic member 1 does not need to be formed before heating and may be formed concurrently with sealing after heating. A sealing face 44 of the sealants 40, 41 has a slant of a conical face shape according to the above-described 1st example, but is not restrictive to this type, and may be straightly cylindrical.

[0105] According to the 1st example, one sealant 40 has a passage 40b to be connected to a high-pressure gas supply 5, the other sealant 41 has a sealing function, and is not connected to the high-pressure gas supply 5. This is not restrictive, and a passage to be connected to the high-pressure gas supply 5 may be formed also in the other sealant 40. In this case, high-pressure gas is fed from the both ends of the metallic member 1.

[0106] Further, according to the 1st example, the high-pressure gas supply 5 has bomb 50 having high-pressure gas enclosed therein, valve control unit 52 having an opening/shutting valve 51 for opening and shutting the bomb 50, pressure indicator 53 functioning as pressure detection means for detecting pressure of gas enclosed in the bomb 50 and flexible feed pipe 54 functioning as a feeding passage of gas discharged from the valve control unit 52. However, this is not restrictive, and that of bulging and/or deforming the metallic member 1 instantly by gas having a high-pressure state may be used. Basically, it is only required for the high-pressure gas supply source 5 to have the ability of feeding gas into a hollow space 10 of the metallic member 1 and deforming/bulging the metallic member 1 thereby.

[0107] Still further, according to the 1st example, iron-based metal constituting the metallic member 1 before hardening is changed into a high-tension state or high tensile strength steel, and has a tensile strength of not less than 600 MPa (=60 kgf/mm²), but this is not restrictive. A material constituting the metallic member 1 may be usual carbon steel or alloy steel, and basically has only to be able to be quenched and reinforced by a forming face 31 of a forming die 3.

[0108] Further more, according to the 1st example, a heating step for heating the metallic member 1 is performed separately from a forming and quench-reinforcing step for bulging/deforming a wall 1a of the metallic member 1, but this is not restrictive. The metallic member 1 may be heated in the middle of the forming and quench-reinforcing step as the case may be. For instance, the metallic member may be heated at an early stage or a middle stage of bulging/deforming the wall 1a of the metallic member 1.

[0109] According to the 3rd example shown in FIG. 6, energizing terminals 7 are connected to an end of the metallic member 1 respectively. Structure and material of the respective energizing member 7 may be selected depending on circumstances. Basically, the energizing members 7 have only to be able to energize and thereby resist-heat the metallic member 1. According to the 3rd example, the respective energizing member 7 is connected to the end of the metallic member 1, but this is not restrictive, and the energizing member 1 may be connected to a middle position of the metallic member 1.

[0110] According to the above-described 2nd and 3rd examples, the forming die 3 and the metallic member 1 are in no contact with each other, but this is not restrictive. The forming die 3 may be in partial contact with the metallic member 1 in the heating step for the purpose of holding the metallic member 1 and the like. Also in other aspects, the present invention is not limited to the above-described examples only, and modifications falling within the spirit and scope of the invention may be made depending on circumstances.

[0111] The following technical ideas can be read from the above description.

[0112] (Appendant item 1) A metallic member forming method including the steps of: using cylindrical metallic member, having a hollow space and made of iron-based metal of a high-tension state, and forming die assembly having (a cavity with) a forming face; and performing a forming and quench-reinforcing step of increasing internal pressure of gas contained in the hollow space of the metallic member heated up to a temperature range capable of quench-reinforcing to bulge and/or deform the metallic member’s wall, forming the bulged and/or deformed wall by bringing the same into intimate contact with the forming face and quench-reinforcing the wall. In this case, the metallic member made of iron-based metal of a high-tension state can be reinforced still more while its formability is ensured.

[0113] (Appendant item 2) A metallic member forming method including the steps of: using cylindrical metallic member having a hollow space and forming die assembly having (a cavity with) a forming face; and performing heating step of heating the metallic member up to a temperature range capable of quench-reinforcing and forming and quench-reinforcing step of increasing internal pressure of gas contained in the hollow space of the heated metallic member to bulge and/or deform the metallic member’s wall, forming the bulged and/or deformed wall by bringing the same wall into intimate contact with the forming face of the forming die and quench-reinforcing the wall.
The meritorious effects of the present invention are summarized as follows.

According to the metallic member forming method of the invention, a metallic member is heated up to a temperature range capable of quench-hardening. Then, in a forming and quench-hardening step, a wall of the metallic member is bulged and deformed by increasing internal pressure of gas contained in a hollow space of the metallic member, forming the bulged and/or deformed wall of the metallic member by bringing the same wall into intimate contact with a forming face of a forming die and quench-hardening the wall. The metallic member is in a heated state during the bulging/deformation, so that plastic deformability of the metallic member becomes improved and also bulging and deforming ability and accordingly formability of the metallic member becomes enhanced. Further, in the forming and quench-hardening step, the metallic member is quenched and reinforced by bringing the bulged and/or deformed wall of the metallic member into intimate contact with the forming face of the forming die. Accordingly, both formability of the metallic member and high strengthening of the same can be achieved at the same time.

According to the metallic member forming method of the invention, if heating temperature of the metallic member in a heating step, thickness of the metallic member, cooling ability of the forming face of the forming die are controlled properly, with regard to the thickness direction of the wall of the metallic member, I, a cooling rate of one surface layer facing and in intimate contact with the forming face of the forming die can be made larger than that of the other surface layer disposed opposite to the forming face of the forming die. Accordingly, in respect of the thickness direction of the wall of the metallic member, enhancing a hardening property of one surface layer facing and in intimate contact with the forming face of the forming die to strengthen highly this portion, a hardening property of the other surface layer disposed opposite to the forming face of the forming die also can be suppressed to ensure toughness of this portion.

According to the metallic member-forming method, the resultant metallic member product and the metallic member-forming apparatus, the heat treatment of the metallic member (i.e., the cooling (quenching) or heating and cooling) can be carried out under the state of holding the metallic member within the die (assembly). For instance, surface hardening of the metallic member may be achieved by quench-hardening caused by the cooled die. Accordingly, a metallic member for which the forming processing is difficult, can be efficiently formed by means of formation using the pressurized gas medium, simultaneously achieving efficient reinforcement of the same due to quench-hardening occurring within the die cavity caused by cooled die.

It should be noted that other objects, features and aspects of the present invention will become apparent in the entire disclosure and that modifications may be done without departing the gist and scope of the present invention as disclosed herein and claimed as appended herewith.

Also it should be noted that any combination of the disclosed and/or claimed elements, matters and/or items may fall under the modifications aforementioned.

From the foregoing it will be observed that numerous modifications and variations can be effected without departing from the true spirit and scope of the novel concepts of the present invention. It is to be understood that no limitation with respect to the specific embodiments illustrated is intended or should be inferred. The disclosure is intended to cover by the appended claims all such modifications as fall within the scope of the claims.

What is claimed is:

1. A method for forming metallic member comprising: providing a metallic member having a hollow space and a forming die having a forming face; and performing a forming and quench-hardening step by increasing an internal pressure of gas contained in the hollow space of said metallic member heated up to a temperature range capable of quench-hardening to bulge and/or deform said metallic member's wall, wherein forming of the bulged and/or deformed wall is performed by bringing the same into intimate contact with the forming face of said forming die accompanied by simultaneous quench-hardening of said wall.

2. The method as defined in claim 1, wherein said increasing of said internal pressure of said gas contained in said hollow space of said metallic member is performed by feeding a gas into said hollow space of said metallic member.

3. The method as defined in claim 1, wherein heating said metallic member is performed by at least one operation selected from the group consisting of operation for maintaining said metallic member in a furnace chamber of a heating furnace, induction heating operation for induction-heating said metallic member, and resistance heating operation for energizing said metallic member.

4. The method as defined in claim 3, wherein said operation for maintaining said metallic member in the furnace chamber of said furnace is performed under the condition that the furnace chamber of said furnace has a non-oxidizing atmosphere.

5. The method as defined in claim 3, wherein said induction heating operation is performed by applying an alternating current to an electrically conductive member for induction heating in a state of placing said electrically conductive member in proximity of said metallic member disposed within said forming die to induction-heat said metallic member.

6. The method as defined in claim 3, wherein said resistance heating operation is performed by energizing said
metallic member from energizing terminals in a state of connecting said energizing terminals to said metallic member disposed within said forming die to heat said metallic member by induction heating.

7. The method as defined in claim 1, wherein said metallic member is made of an iron-based material, a titanium-based material, an aluminum-based material or a copper-based material.

8. The method as claimed in claim 1, wherein said metallic member is made of an iron-based material and heated up to a temperature of not less than Al transformation point, and said forming and quench-hardening step comprises bringing the wall of said metallic member into intimate contact with the forming face of said forming die to harden at least a part of said metallic member.

9. The method as defined in claim 1, wherein said forming die has a cooling device for cooling said forming die at least a part thereof corresponding to a part of said metallic member to be quench-hardened.

10. The method as described in claim 1, wherein said gas to be fed into the hollow space of said metallic member is at least one selected from the group consisting of air, nitrogen gas, nitrogen-rich gas, argon gas and argon-rich gas.

11. The method as defined in claim 2, wherein an operation for feeding gas into the hollow space of said metallic member is performed from a high-pressure gas supply source capable of feeding high pressure gas.

12. The method as defined in claim 1, wherein said metallic member has at least one opening communicating with said hollow space and formed by a tapered open wall face, and wherein said opening is sealed by applying directly or indirectly a sealant, which has a slant corresponding to that of the tapered open wall face of said metallic member, to the tapered open wall face of said metallic member.

13. A method for forming metallic member comprising the steps of:

(a) placing a metallic member having a hollow space in a forming die assembly,

(b) heating said metallic member placed in the forming die assembly,

(c) bringing a prescribed surface of said metallic member into intimate contact with a prescribed face of the forming die assembly by introducing a pressured gas into said hollow space of the metallic member heated in the forming die assembly, to thereby plastically deform said metallic member, and,

(d) quenching said metallic member immediately following the deformation of the metallic member through cooling said metallic member in a state of said forming die assembly.

14. The method as defined in claim 13, wherein said heating of step (b) is performed within an opened space of the forming die assembly.

15. The method as defined in claim 13, wherein said heating step (b) is performed within a thermally insulated condition within an opened space of the forming die assembly.

16. The method as defined in claim 15, wherein said thermally insulated condition is provided by a thermal insulator intervening between the die and the metallic member, said insulator being removed before closing the die assembly.

17. The method as defined in claim 13, wherein said heating step (b) is carried out by induction heating by an induction conductor disposed within the hollow space of the metallic member.

18. A method for forming metallic member comprising the steps of:

(a) heating a cylindrical metallic member having a hollow space,

(b) placing said heated metallic member into a forming die assembly,

(c) bringing said heated metallic member into intimate contact with a prescribed face of the forming die assembly by introducing a pressured gas into the hollow space of said metallic member, to thereby plastically deform said metallic member,

(d) quenching said metallic member immediately following the deformation of said metallic member through cooling said forming die assembly, in a state that said metallic member is placed in the forming die assembly.

19. A metallic member product produced according to the method as defined in claim 1.

20. An apparatus for forming metallic member comprising:

a forming die assembly for placing a cylindrical metallic member having a hollow space into a cavity of the forming die assembly,

gas supply device for supplying a pressurized gas into the hollow space of said metallic member heated within the forming die assembly,

a cooling device for cooling said forming die assembly configured to quench-hardening said metallic member placed and plastically deformed in said forming die assembly, and

a control unit for controlling said gas supply device so as to perform bulging and/or deforming of said metallic member together with quench-hardening the same.

21. The apparatus as defined in claim 20, comprising a heating device for selectively heating said metallic member placed in the cavity of said forming die assembly.

22. The apparatus as defined in claim 21, further comprising a retractable thermal insulator for insulating the metallic member to be heated from the die assembly, said insulator being retracted after heating.

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