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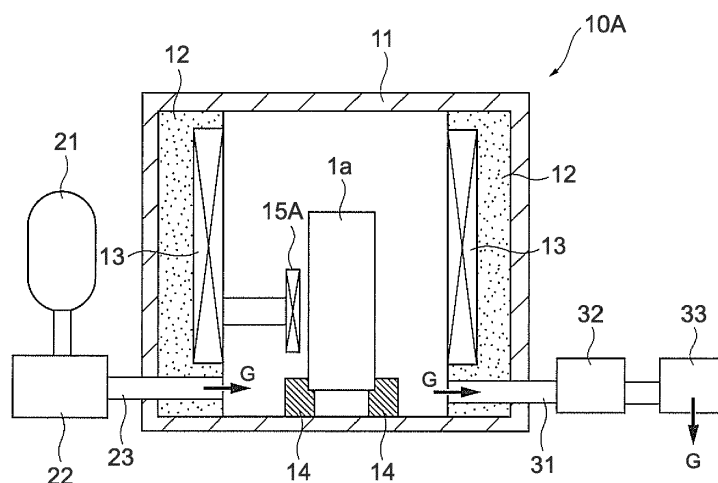
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(54) **MANUFACTURING METHOD OF STEEL IN WHICH AN ELEMENT OF TREATMENT GAS IS DISSOLVED AND DIFFUSED**

(57) A manufacturing method of steel (1a) in which an element of the treatment gas is dissolved and diffused includes heating the steel, making a treatment gas contact a surface of the steel such that an element of the

treatment gas dissolves and diffuses from the surface of the steel into a surface layer thereof, and reducing a concentration of the treatment gas near a non-treatment surface that is a portion of the surface of the steel.

FIG. 1



Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to manufacturing method of steel, in which an element of treatment gas is suitably dissolved and diffused in a portion of a surface of the steel.

2. Description of Related Art

[0002] Carburizing, nitriding, or carbonitriding or the like is applied to steel using a treatment gas in order to improve the durability and the like of the surface of the steel. In these treatments, an element of the treatment gas is dissolved and diffused from a treatment surface of the steel into a surface layer thereof, by bringing the treatment gas into contact with the surface of heated steel.

[0003] Here, performing these treatments on the entire surface layer of steel is easy, but performing these treatments on only a portion of the surface layer of steel is not. In view of this, Japanese Patent Application Publication No. 11-217626 (JP 11-217626 A), for example, proposes a gear carburizing method as one example. Here, particles of an anti-carburization agent are sprayed onto a curved surface of an addendum of a tooth profile portion of a gear, which is a non-treatment surface, such that the anti-carburization agent adheres to the curved surface of the addendum. In this state, a treatment surface that excludes the curved surface of the addendum is carburized with carburizing gas (treatment gas), and then the anti-carburization agent is removed from the curved surface of the addendum. As a result, the amount of dissolved carbon in the curved surface of the addendum of the tooth profile portion of the gear is able to be reduced.

[0004] However, with the technology described in JP 11-217626 A, because an anti-treatment agent such as the anti-carburization agent is used with carburizing, dissolution and diffusion of the element of the treatment gas in the non-treatment surface of the steel are able to be prevented or reduced. However, with this method, the anti-treatment agent must be adhered to the surface of the steel and then removed, which is troublesome and ends up taking a lot of time. Consequently, the manufacturing cost increases.

SUMMARY OF THE INVENTION

[0005] The invention thus provides a manufacturing method of steel, by which a desired amount of an element of a treatment gas is able to be dissolved and diffused into a surface layer of a treatment surface of the steel, while inhibiting the element of the treatment gas from dissolving and diffusing into a non-treatment surface of the steel, inexpensively and without requiring troublesome work.

[0006] A first aspect of the invention relates to a manufacturing method of steel in which an element of the treatment gas is dissolved and diffused that includes heating the steel; making a treatment gas contact a surface of the steel such that an element of the treatment gas dissolves and diffuses from the surface of the steel into a surface layer thereof; and reducing a concentration of the treatment gas near a non-treatment surface that is a portion of the surface of the steel.

[0007] According to this aspect of the invention, the concentration of the treatment gas near the non-treatment surface is reduced to lower than the concentration of the treatment gas near the treatment surface, by pyrolyzing the treatment gas. Therefore, the amount of the element of the treatment gas that is dissolved in the non-treatment surface is less than the amount of the element of the treatment gas that is dissolved in treatment surface. As a result, a desired amount of an element of a treatment gas is able to be dissolved and diffused into the surface layer of the treatment surface of the steel, while inhibiting dissolution and diffusion of the element of the treatment gas into the non-treatment surface of the steel, inexpensively and without requiring troublesome work.

[0008] The concentration of the treatment gas near the non-treatment surface may be reduced by pyrolyzing the treatment gas.

[0009] The method for pyrolyzing the treatment gas may be a method that pyrolyzes the treatment gas by a metal catalyst, using heat for dissolving and diffusing the element of the treatment gas, for example. Also, the steel may be arranged inside a heating furnace, the steel may be heated, and the pyrolyzing of the treatment gas may be performed by a pyrolysis heater. The manufacturing method of the steel may also include arranging the pyrolysis heater facing the non-treatment surface of the steel inside the heating furnace.

[0010] According to this aspect, the pyrolysis heater is arranged in a position facing the non-treatment surface of the steel arranged in the heating furnace, so the treatment gas near the non-treatment surface of the steel is pyrolyzed by the pyrolysis heater. Consequently, the concentration of the treatment gas near the non-treatment surface of the steel is able to be made lower than the concentration of the treatment gas near the treatment surface. As a result, a desired amount of the element is able to be dissolved and diffused into the surface layer of the treatment surface of the steel,

while inhibiting dissolution and diffusion of the element of the treatment gas in the non-treatment surface of the steel.

[0011] Also, in the aspect described above, the steel may be arranged inside a heating furnace, the steel may be heated, and the pyrolyzing of the treatment gas may be performed by a pyrolysis heater. The manufacturing method of the steel may also include dividing a space inside of the heating furnace into a treatment space and a non-treatment space by the pyrolysis heater, arranging the non-treatment surface of the steel in the non-treatment space, flowing the treatment gas into the treatment space, and pyrolyzing treatment gas that heads from the treatment space toward the non-treatment space by the pyrolysis heater.

[0012] According to this aspect, when the treatment gas flows from the treatment space to the non-treatment space, this treatment gas is pyrolyzed by the pyrolysis heater, so the concentration of the treatment gas in the non-treatment space is able to be kept lower than the concentration of the treatment gas in the treatment space. As a result, a desired amount of the element is able to be dissolved and diffused into the surface layer of the treatment surface of the steel, while inhibiting dissolution and diffusion of the element of the treatment gas in the non-treatment surface of the steel.

[0013] Supplying the treatment gas into the heating furnace, and interrupting the supply of the treatment gas into the heating furnace and discharging the treatment gas from the heating furnace, may be repeated.

[0014] According to this aspect, in supplying the treatment gas into the heating furnace, the element of the treatment gas is dissolved from the treatment surface of the steel. In interrupting the supply of the treatment gas into the heating furnace and discharging the treatment gas from the heating furnace, dissolution of the treatment gas is restricted and the steel is in a heated state, so diffusion of the once dissolved element is able to be promoted.

[0015] As a result, dissolution and diffusion of the element of the treatment gas are repeated, so the element of the treatment gas is able to be dissolved and diffused from the treatment surface into the surface layer thereof. On the other hand, the element of the treatment gas diffuses from the non-treatment surface to the inside thereof, each time it slightly dissolves, so the content of the element of the surface layer of the non-treatment surface is able to be reduced.

[0016] In interrupting the supply of the treatment gas into the heating furnace and discharging the treatment gas from the heating furnace, heating of the pyrolysis heater may be interrupted. According to this aspect, the non-treatment surface of the steel is not continuously heated by the pyrolysis heater, so a thermal effect on the portion that includes the non-treatment surface of the steel is able to be reduced.

[0017] According to this aspect of the invention, a desired amount of the element of the treatment gas is able to be dissolved and diffused into the surface layer of the treatment surface of the steel, while inhibiting the element of the treatment gas from dissolving and diffusing into the non-treatment surface of the steel, inexpensively and without requiring troublesome work.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a conceptual diagram showing a frame format of a carburizing apparatus for suitably implementing a manufacturing method of steel according to a first example embodiment of the invention;

FIG. 2 is a view of a temperature profile and treatment conditions of steel to illustrate the manufacturing method of steel according to the first example embodiment of the invention;

FIG. 3A is a perspective view of the steel before carburizing, to illustrate the manufacturing method of steel shown in FIG. 1;

FIG. 3B is a perspective view of the positional relationship between the steel at the time of carburizing and the pyrolysis heater, to illustrate the manufacturing method of steel shown in FIG. 1;

FIG. 3C is a view illustrating the carburizing of carburizing gas into a treatment surface of the steel and pyrolysis of the carburizing gas, to illustrate the manufacturing method of steel shown in FIG. 1;

FIG. 3D is a perspective view of the steel after carburizing, to illustrate the manufacturing method of steel shown in FIG. 1;

FIG. 4A is a view illustrating the positional relationship between the steel at the time of carburizing and a pyrolysis heater, to illustrate a manufacturing method of steel according to a modified example of the first example embodiment of the invention;

FIG. 4B is a perspective view of the steel after carburizing, to illustrate the manufacturing method of steel according to the modified example of the first example embodiment of the invention;

FIG. 5A is a conceptual diagram showing a frame format of a carburizing apparatus for suitably implementing a manufacturing method of steel according to a second example embodiment of the invention;

FIG. 5B is a view illustrating the positional relationship between the steel at the time of carburizing and a pyrolysis heater;

FIG. 6A is a view illustrating carburizing into a treatment surface of steel, and pyrolysis of the carburizing gas, to illustrate the manufacturing method of steel according to the second example embodiment of the invention;

FIG. 6B is a side view of the steel after carburizing, to illustrate the manufacturing method of steel according to the second example embodiment of the invention;

FIG. 6C is a sectional view illustrating a method of utilization of the steel, to illustrate the manufacturing method of steel according to the second example embodiment of the invention;

FIG. 7 is a view of a temperature profile and treatment conditions of steel, to illustrate a manufacturing method of steel according to a third example embodiment of the invention;

FIG. 8 is a view of the relationship between a concentration of carburizing gas and treatment gas temperature according to Verification test 1;

FIG. 9 is a view of the relationship between the carburizing amount in the steel and the concentration of carburizing gas according to Verification test 2;

FIG. 10A is a view of the relationship between the steel and the pyrolysis heater;

FIG. 10B is a sectional photograph of carburized steel;

FIG. 10C is an enlarged photograph of portion c in FIG. 10B; and

FIG. 10D is an enlarged photograph of portion d in FIG. 10B.

DETAILED DESCRIPTION OF EMBODIMENTS

[0019] Hereinafter, several example embodiments of a manufacturing method of steel according to the invention will be described with reference to the accompanying drawings. The term "treatment surface" in this specification may be a portion of a surface of steel, which is brought into contact with treatment gas and within which an element of the treatment gas is dissolved and diffused (i.e., the element of the treatment gas is dissolved and diffused in a surface layer of the steel), in order to obtain a desired property. On the other hand, the term "non-treatment surface" in this specification may be a portion of the surface of the steel, which is adjacent to the treatment surface and in which a dissolved amount of an element of the treatment gas is lower than it is in the treatment surface. Therefore, the non-treatment surface is not limited to a surface into which no element of the treatment gas is dissolved. Also, the term "manufacturing method of steel" in this specification may include at least dissolving and diffusing an element of the treatment gas from the surface of the steel into a surface layer thereof, and this pre-process may also include a machining process such as hot-forming or machining the steel, or a forming process such as press-forming the steel or the like.

[First example embodiment]

1. Steel

[0020] The manufacturing method of steel according to this example embodiment is a carburizing method that carburizes steel. The steel that is carburized according to this example embodiment is steel that includes a ferrite structure and a pearlite structure, for example. In this example embodiment, a block of steel is used (see FIG. 3A that will be described later).

[0021] Examples of the steel include chrome molybdenum steel (JIS standard: SCr 415 to 435) and chrome molybdenum steel (JIS standard: SCM 415 to 435) and the like. However, the material is not particularly limited to this as long as carbon is able to be dissolved and diffused from the surface of the steel into the surface layer thereof by carburizing

2. Carburizing apparatus

[0022] In this example embodiment, the steel described above is prepared, and then this steel is carburized using a carburizing apparatus 10A shown in FIG. 1. This carburizing apparatus 10A will be briefly described below. FIG. 1 is a conceptual diagram showing a frame format of the carburizing apparatus for suitably implementing the manufacturing method of steel according to the first example embodiment of the invention.

[0023] As shown in FIG. 1, the carburizing apparatus 10A according to this example embodiment is an apparatus that dissolves and diffuses carbon (an element) of carburizing gas (treatment gas) G from a treatment surface of steel 1a into a surface layer thereof, by arranging the steel 1a in a heating furnace 11 and making the carburizing gas G contact the treatment surface of the steel 1a.

[0024] More specifically, the carburizing apparatus 10A includes the heating furnace 11. A carburizing heater 13 is arranged inside of the heating furnace 11. Thermal insulating material 12 is arranged around the carburizing heater 13 so that the heat from the carburizing heater 13 does not escape to the outside. The carburizing heater 13 is a heater for heating the surface of the steel 1a and dissolving and diffusing the carbon of the carburizing gas into the surface layer of the steel 1a.

[0025] A supply line 23 is connected to the heating furnace 11 such that the carburizing gas G from a carburizing gas supply source 21 flows into the heating furnace 11 via a flow regulating device 22. Some examples of the carburizing gas are gases such as acetylene gas, butane gas, propane gas, and ethane gas, but in this example embodiment, acetylene gas is used. Acetylene gas is a gas that pyrolyzes, which will be described later, more easily than other gases, and is thus a suitable gas in this example embodiment.

[0026] Meanwhile, a discharge line 31 is connected to the heating furnace 11 such that the carburizing gas G supplied into the heating furnace 11 can be discharged from the heating furnace 11. A pressure-reducing pump 32 and a pressure regulating device 33 are connected in order to the downstream side of the discharge line 31. The pressure-reducing pump 32 draws in the carburizing gas G from inside the heating furnace 11, and the pressure regulating device 33 regulates the pressure inside the heating furnace 11 to a predetermined pressure by regulating the amount of carburizing gas that is discharged.

[0027] A jig 14 that fixes the steel 1a to be carburized, and a pyrolysis heater 15A that pyrolyzes the carburizing gas G are arranged inside the heating furnace 11. The pyrolysis heater 15A will be described in detail later.

3. Steel carburizing method (manufacturing method of the steel)

[0028] The steel 1a is carburized using the carburizing apparatus 10A shown in FIG. 1. FIG. 2 is a view of a temperature profile and treatment conditions of the steel 1a, to illustrate the manufacturing method of the steel 1a according to the first example embodiment. FIGS. 3A to 3D are views illustrating the manufacturing method of steel shown in FIG. 1. More specifically, FIG. 3A is a perspective view of the steel 1a before carburizing. FIG. 3B is a perspective view of the positional relationship between the steel 1a at the time of carburizing and the pyrolysis heater 15A. FIG. 3C is a view illustrating the carburizing of carburizing gas G into a treatment surface 2a of the steel 1a, and the pyrolyzing of the carburizing gas G. FIG. 3D is a perspective view of the steel 1A after carburizing.

[0029] First, a block of the steel 1a is prepared. In this example embodiment, the treatment surface 2a, which is a portion of the surface of the steel 1a, is provided on the surface of the steel 1a, as shown in FIG. 3A, and a predetermined amount of carbon is dissolved from the treatment surface 2a into a surface layer thereof by a treatment that will be described later. More specifically, in this example embodiment, a rectangular-shaped non-treatment surface 3a is provided adjacent to the treatment surface 2a of the steel 1a, and a predetermined amount of carbon is dissolved from the surface excluding this non-treatment surface 3a, into a surface layer thereof, by a treatment that will be described later.

[0030] Next, the prepared steel is fixed to the jig 14 inside the heating furnace 11. Here, the pyrolysis heater 15A described above is a plate-shaped heater that corresponds to the shape of the non-treatment surface 3a of the steel 1a, as shown in FIGS. 3A and 3B. This pyrolysis heater 15A is arranged facing the non-treatment surface 3a when the steel 1a is fixed to the jig 14. The pyrolysis heater 15A is designed to break down the carburizing gas G near the non-treatment surface 3a, but is not designed to promote the dissolution of carbon in the carburizing gas G by heating the non-treatment surface 3a of the steel 1a to a higher temperature than the other surface.

[0031] Next, the steel 1a that is fixed as shown in FIG. 2 is heated (in a heating process). More specifically, the steel 1A is heated by the carburizing heater 13 to a temperature equal to or greater than an A_1 transformation point, and more preferably, equal to or greater than an A_3 transformation point (a carburizing temperature) of the steel, such that the ferrite structure and the pearlite structure of the steel 1a transform into an austenite structure. In this heating process, the carburizing gas G is not introduced into the heating furnace 11, and the pyrolysis heater 15A is not activated. In this example embodiment, the steel 1a is heated by the carburizing heater 13, but the steel 1a that has been heated by another heating furnace beforehand may also be put into the heating furnace 11.

[0032] Next, the heated steel 1a is carburized (in a carburizing process), as shown in FIG. 2. More specifically, the steel 1a is maintained in a heated state by the carburizing heater 13, and the carburizing gas G is supplied from the carburizing gas supply source 21 into the heating furnace 11 via the flow regulating device 22. On the other hand, some of the carburizing gas G is discharged from the heating furnace 11 by the pressure-reducing pump 32 via the discharge line 31 to keep the concentration of the carburizing gas G inside the heating furnace 11 constant.

[0033] The pyrolysis heater 15A is activated while maintaining this kind of state inside the furnace. At this time, the temperature of the surface of the pyrolysis heater 15A is heated to a temperature at which the carburizing gas G pyrolyzes, or more preferably, to a temperature that is higher than the temperature of the surface of the heated steel 1a. As a result, the carburizing gas G around the pyrolysis heater 15A is able to be pyrolyzed before it reaches the surface of the steel 1a.

[0034] In this way, carbon in the carburizing gas G is dissolved from the treatment surface 2a of the steel 1a into the surface layer thereof, by making the carburizing gas G that is the treatment gas contact the treatment surface 2a of the steel 1a, as shown in FIG. 3C. As a result, a carburized layer 2A is formed inside the treatment surface 2a.

[0035] Meanwhile, the carburizing gas G near the non-treatment surface 3a of the steel 1A and the carburizing gas G heading toward there is pyrolyzed by the pyrolysis heater 15A. More specifically, in this example embodiment, acetylene gas is used as the carburizing gas G, so the acetylene gas breaks down into carbon and hydrogen gas. As a result, the concentration of carburizing gas G around the pyrolysis heater 15A becomes lower than that of the surrounding carburizing

gas G, and the concentration of carburizing gas G near the non-treatment surface 3a becomes lower than the concentration of carburizing gas G near the treatment surface 2a of the steel 1A.

[0036] In this way, the carbon in the carburizing gas G is able to be dissolved from the treatment surface 2a, while inhibiting carbon in the carburizing gas G from being dissolved from the non-treatment surface 3a. As a result, a predetermined amount of carbon is able to be dissolved into the surface layer of the treatment surface 2a of the steel 1a, while carbon in the carburizing gas G is able to be inhibited from being dissolved into the non-treatment surface 3a of the steel 1a.

[0037] Although some of the carbon that has been dissolved from the treatment surface 2a is diffused, much more carbon is dissolved along the treatment surface 2a from the inside. Thus, the carbon dissolved in the steel 1a is diffused therein, as shown in FIG. 2 (in a diffusing process).

[0038] More specifically, the steel 1a is kept heated by the carburizing heater 13, the supply of carburizing gas G into the heating furnace 11 is interrupted, and the carburizing gas G inside the heating furnace 11 is discharged via the discharge line 31 by the pressure-reducing pump. At this time, an inert gas such as nitrogen gas, helium gas, or argon gas may be supplied into the heating furnace 11. Heating by the pyrolysis heater 15A is interrupted at the same time that this kind of state is established in the furnace.

[0039] As a result, the carbon that has dissolved in the treatment surface 2a of the steel 1a is able to be diffused into the surface layer thereof. Also, the dissolved amount of carbon from the non-treatment surface 3a is less than the dissolved amount of carbon from the treatment surface 2a, so the carbon that has been slightly dissolved near the non-treatment surface 3a diffuses quickly therein.

[0040] Then, the steel after diffusing is cooled by water-cooling or oil-cooling (in a cooling process), such that a structure in which at least the carbon in the steel 1a that has dissolved changes from the austenite structure to a martensite structure, as shown in FIG. 2. Then, the obtained steel may be tempered.

[0041] In this way, the steel 1A that has both an anti-carburization layer 3A, in which dissolution and diffusion of the element in the carburizing gas G into the non-treatment surface 3a is inhibited, and the carburized layer 2A, which is formed by a predetermined amount of carbon dissolving and diffusing into the surface layer of the treatment surface 2a, is obtained as shown in FIG. 3D.

4. Modified example of the first example embodiment

[0042] FIG. 4 is a view illustrating a manufacturing method of steel according to a modified example of the first example embodiment. More specifically, FIG. 4A is a view showing the positional relationship between the steel at the time of carburizing and a pyrolysis heater. FIG. 4B is a perspective view of the steel after carburizing.

[0043] As shown in FIGS. 4A and 4B, in this modified example, the steel that is carburized is an input shaft 1b for a vehicle. As shown in FIG. 4A, the input shaft 1b has a stepped shaft portion 5. A gear portion 5a is formed on one side of this shaft portion 5, and a flange portion 4 is formed on an end portion on the other side.

[0044] In this modified example, a peripheral surface of the flange portion 4 and an upper edge portion thereof are the non-treatment surface 3a, and the other surface is the treatment surface 2a. The carburizing gas is made to contact the treatment surface 2a, and a predetermined amount of carbon is dissolved from the treatment surface 2a into the surface layer thereof.

[0045] More specifically, as shown in FIG. 4A, a ring-shaped pyrolysis heater 15B corresponding to the surface shape of the non-treatment surface 3a (i.e., the peripheral surface and the upper edge portion thereof) of the flange portion 4, is arranged inside the heating furnace 11 so as to cover the non-treatment surface 3a of the flange portion 4, and carburizing gas near the non-treatment surface 3a is pyrolyzed.

[0046] An input shaft 1B in which the carburized layer 2A is formed from the surface of the shaft portion 5 and the like that is the treatment surface 2a to the inside thereof, and the anti-carburization layer 3A (a portion near the base material) is formed on the peripheral surface of the flange portion 4 and the upper edge portion thereof that are the non-treatment surface 3a, is able to be obtained. The dissolved amount of carbon on the peripheral surface of the flange portion 4 and the upper edge portion thereof is less than at other portions, so cracking from thermal strain of welding is able to be prevented at this portion.

5. Another modified example

[0047] In the first example embodiment, carburizing was described, but nitridization or nitriding, for example, may also be used. More specifically, with these treatments, ammonia gas is used for the treatment gas. With nitridization, the steel is heated at 480°C to 590°C, and with nitriding, the steel is heated to 590°C to 850°C.

[0048] Then, the ammonia gas is pyrolyzed into nitrogen gas and hydrogen gas using the pyrolysis heater 15A shown in the first example embodiment (see FIGS. 3A and 3B). As a result, the nitrogen in the ammonia gas dissolves and diffuses from the treatment surface 2a of the carburizing gas G into the surface layer thereof, by making the ammonia gas contact the treatment surface 2a, just as illustrated with carburizing. Meanwhile, the concentration of ammonia gas

near the non-treatment surface 3a becomes lower than the concentration of ammonia gas near the treatment surface 2a, by the pyrolysis heater.

[0049] In this way, a desired amount of nitrogen can be dissolved and diffused into the surface layer of the treatment surface 2a of the steel, while inhibiting nitrogen in the ammonia gas from being dissolved and diffused into the non-treatment surface 3a of the steel 1a, inexpensively and without requiring troublesome work. Also, in a carbonitriding in which carburizing and nitridization are combined, both treatment gases may be pyrolyzed by the same method.

[0050] Moreover, in the first example embodiment illustrated in FIG. 1, carburizing gas is pyrolyzed using the pyrolysis heater 15A. Alternatively, for example, a pyrolysis member formed by a metal catalyst of the same shape as the pyrolysis heater 15A may be prepared, and the carburizing gas may be broken down by this metal catalyst. Furthermore, the metal catalyst may also be included in the surface of the pyrolysis heater 15A.

[0051] Similarly, when ammonia gas is used in nitridization or nitriding, Pt, Pd, Ir, or Rh or the like may be used as the metal catalyst. These are able to break down the ammonia gas at 550°C to 1100°C. As a result, the ammonia gas near the non-treatment surface is able to be broken down, while nitridization or nitriding the treatment surface.

[Second example embodiment]

[0052] FIG. 5A is a conceptual diagram showing a frame format of a carburizing apparatus for suitably implementing a manufacturing method of steel according to a second example embodiment of the invention, and FIG. 5B is a view showing the positional relationship between the steel at the time of carburizing and a pyrolysis heater.

[0053] FIG. 6 is a view illustrating the manufacturing method of steel according to the second example embodiment. More specifically, FIG. 6A is a view illustrating carburizing into a treatment surface of steel, and pyrolysis of the carburizing gas. FIG. 6B is a side view of the steel after carburizing. FIG. 6C is a sectional view illustrating a method of utilization of the steel.

[0054] The second example embodiment differs from the first example embodiment in that the steel to be treated is a weld bolt 1c, and the shape of a pyrolysis heater 15C is different. Thus, other structures having the same function are denoted by like reference characters, and detailed descriptions of these structures will be partially omitted.

[0055] As shown in FIG. 5A, with a carburizing apparatus 10B according to this example embodiment, carbon is dissolved and diffused into a plurality of weld bolts 1c inside the heating furnace 11, and the carburizing gas G is pyrolyzed by the pyrolysis heater 15C. Here, as shown in FIG. 5B, the pyrolysis heater 15C is a plate-shaped heater. A plurality of through-holes 15a that threaded portions of the weld bolts 1c are inserted through are formed in the pyrolysis heater 15C. Each through-hole 15a is large enough so that it does not contact the weld bolt 1c when the weld bolt 1c is fixed by the jig 14 (i.e., so that there is a gap between the edge of the through-hole 15a and the weld bolt 1c).

[0056] This kind of pyrolysis heater 15C is arranged in the heating furnace 11 so as to divide a space 17 inside the heating furnace 11 into a treatment space 17a and a non-treatment space 17b. With each weld bolt 1c in a state fixed by the jig 14, the treatment surface 2a of the threaded portion 6 of the weld bolt 1c is arranged in the treatment space 17a and the non-treatment surface 3a of a head portion 7 of the weld bolt 1c is arranged in the non-treatment space 17b, as shown in FIG. 6A. At this time, the weld bolt 1c is not contacting the pyrolysis heater 15C.

[0057] In this kind of arrangement state, a series of processes from heating to cooling are performed by the same method as that illustrated by FIG. 2. Here, in this example embodiment, in a carburizing process, as shown in FIG. 6A, the threaded portion 6 of the weld bolt 1c in the treatment space 17a is carburized by flowing carburizing gas G into the treatment space 17a. Meanwhile, the carburizing gas G that heads from the treatment space 17a toward the non-treatment space 17b is pyrolyzed by the pyrolysis heater 15C.

[0058] In this way, when the carburizing gas G flows from the treatment space 17a into the non-treatment space 17b, the carburizing gas G is broken down by the pyrolysis heater 15C, so the concentration of the carburizing gas G in the non-treatment space 17b is able to be kept lower than the concentration of the carburizing gas G in the treatment space 17a. As a result, a desired amount of carbon is able to be dissolved and diffused into the surface layer of the treatment surface 2a of the threaded portion 6 of the weld bolt 1c, while inhibiting the dissolution and diffusion of carbon from the non-treatment surface 3a of the head portion 7 of the weld bolt 1c.

[0059] At the time of carburizing, even if there is a through-hole 15a through which a weld bolt 1c is not inserted, from among the plurality of through-holes 15a in the pyrolysis heater 15C, when the carburizing gas G passes from the treatment space 17a to the non-treatment space 17b via this through-hole 15a, some of this gas will be pyrolyzed. As a result, the concentration of the carburizing gas G in the non-treatment space 17b is able to be kept lower than the concentration of the carburizing gas G in the treatment space 17a.

[0060] With a weld bolt 1C obtained in this way, the anti-carburization layer 3A that inhibits the element of the carburizing gas G from dissolving and diffusing into the non-treatment surface 3a is also formed on a welding protrusion 7a of the head portion 7, as shown in FIG. 6B.

[0061] As a result, even if the welding protrusion 7a of the head portion 7 of the weld bolt 1C is melted and the weld bolt 1C is welded to a steel sheet 9, as shown in FIG. 6C, the amount of carbon in this weld 7b will not be much different

than the amount of carbon in the base material, so cracking from thermal strain of the weld 7b is able to be reduced. On the other hand, a carburized layer 2A is formed on the threaded portion 6 by the desired amount of carbon dissolving and diffusing, so the strength of the weld bolt 1C at the threaded portion 6 is able to be ensured.

[0062] In this second example embodiment as well, the treatment gas may be pyrolyzed by a metal catalyst, and nitridization or nitriding may be applied instead of carburizing, as described above in section "5. Another modified example". Also, carbonitriding that is a combination of carburizing and nitridization may be applied.

[Third example embodiment]

[0063] FIG. 7 is a view of a temperature profile and treatment conditions of steel, to illustrate a manufacturing method of steel according to a third example embodiment of the invention. The third example embodiment differs from the first example embodiment with regards to the method of carburizing. Therefore, descriptions of common portions aside from this will be partially omitted.

[0064] As shown in FIG. 7, in this example embodiment, carbon is dissolved and diffused into the steel 1a inside the heating furnace 11, while the carburizing process and the diffusing process are alternately repeatedly executed. More specifically, in the carburizing process, carburizing gas G is supplied into the heating furnace 11, and in the diffusing process, the supply of carburizing gas G into the heating furnace 11 is interrupted, and the carburizing gas G is discharged from the heating furnace 11. In both the carburizing process and the diffusing process, the steel 1a is heated by the carburizing heater 13. In the carburizing process, the pyrolysis heater 15A is activated and the carburizing gas G is heated and pyrolyzed, but in the diffusing process, heating by the pyrolysis heater 15A is interrupted.

[0065] In this way, in the carburizing process, carbon in the carburizing gas G is dissolved from the treatment surface 2a of the steel 1a. On the other hand, in the diffusing process, dissolution of the carburizing gas G is restricted and the vehicle 1 is in a heated state, so the carbon that was once dissolved in the carburizing process is able to be further diffused into the surface layer of the steel 1a.

[0066] As such a result, the carbon is repeatedly dissolved and diffused, so the element of the carburizing gas G is able to be dissolved and diffused from the treatment surface 2a into the surface layer thereof. On the other hand, every time carbon in the carburizing gas G is slightly dissolved from the non-treatment surface 3a, the carbon is diffused from the non-treatment surface 3a to the inside thereof, so the content of the element in the surface layer of the non-treatment surface 3a is able to be reduced.

[0067] Also, in the diffusing process, the non-treatment surface 3a of the steel 1a is not continuously heated by the pyrolysis heater 15A, so the thermal effect on the portion that includes the non-treatment surface 3a of the steel 1a is able to be reduced. This kind of method may also be applied with nitridization or nitriding.

<Verification test 1>

[0068] In verification test 1, acetylene gas was prepared as the carburizing gas, and the phenomenon of pyrolysis of the acetylene gas was verified. More specifically, acetylene gas of a partial pressure of 100% was supplied at a flow rate of 20 m / min into a furnace, and the temperature inside the heating furnace was set to 900°C, 950°C, 1000°C, 1100°C, 1200°C, and 1300°C, and the concentration of the acetylene gas (carburizing gas) at this time, i.e., the partial pressure of the carburizing gas, was measured. The results are shown in FIG. 8. FIG. 8 is a view of the relationship between the concentration of carburizing gas and treatment gas temperature according to verification test 1. In FIG. 8, the partial pressure of the carburizing gas at the different temperatures is shown, with the partial pressure of the carburizing gas at 900°C being 100%.

[0069] From these results, it is evident that the carburizing gas heats and pyrolyzes, and the concentration of the carburizing gas inside the furnace decreases, as the temperature inside the furnace rises. From this kind of result, it may be said that the carburizing gas G (acetylene gas) is able to be pyrolyzed using the pyrolysis heater 15A, and the concentration of the carburizing gas G near the non-treatment surface of the steel 1a is able to be reduced, as shown in FIG. 1.

[0070] <Verification test 2>

[0071] In Verification test 2, acetylene gas was prepared as the carburizing gas, and the relationship between the concentration (partial pressure) of the carburizing gas (acetylene gas) and the dissolution of carbon in the steel at that time was verified. More specifically, chrome steel (JIS: SCr 20) 50 mm in length and 18 mm in diameter was prepared as the steel. Next, a mixed gas in which nitrogen is mixed with acetylene gas was supplied at a flow rate of 20 m / min, such that the partial pressure of acetylene gas would be 30%, 50%, 70%, and 100%, the steel was heated to 950°C, and the carburizing amount of carbon into the steel was measured. The results are shown in FIG. 9. FIG. 9 is a view of the relationship between the carburizing amount in the steel and the concentration of the carburizing gas according to Verification test 2.

[0072] As shown in FIG. 9, it is evident that the carburizing amount (dissolved amount) of carbon into the steel increases

as the concentration of acetylene gas that is the carburizing gas increases. From this, it can be said that the amount of carbon that dissolves from the non-treatment surface is able to be reduced if the carburizing gas G (acetylene gas) is pyrolyzed using the pyrolysis heater 15A and the concentration of carburizing gas G near the non-treatment surface of the steel 1a is reduced.

[0073] Hereinafter, the invention will be described by an example. First, a piece of circular cylindrical steel (material: chrome molybdenum steel (JIS standard: SMC 420)) 50 mm in length and 18 mm in diameter was prepared as the steel. Next, the steel was carburized by the method shown in FIG. 7, using the carburizing apparatus 10A shown in FIG. 1.

[0074] More specifically, as shown in FIG. 10A, a piece of circular cylindrical steel 1d was arranged such that a circular cylindrical pyrolysis heater (radiant tube heater) 15D was positioned 3 millimeters away from a side surface of the steel 1d. The dimensions of the pyrolysis heater are as follows: outer diameter = 400 mm, inner diameter = 300 mm, height = 200 mm.

[0075] Next, the steel was heated to 980°C within 5 minutes 15 seconds by the pyrolysis heater, and the carburizing process and the diffusing process were repeated in order under conditions such as those shown in Table 1 below. Here, in the carburizing process, acetylene gas was supplied into the furnace at 100 ml / min, and in the diffusing process, the supply of acetylene gas was interrupted, and the acetylene gas was discharged from the furnace and nitrogen gas of the same flowrate was supplied. Also, the pyrolysis heater was heated at 1200°C continuously during the carburizing process and the diffusing process. Then, the steel was tempered by oil cooling it to room temperature for 5 minutes.

[Table 1]

Process	Temperature (°C)	Time (sec)	Gas
Carburizing	980	51	Acetylene gas
Diffusing	980	269	Nitrogen gas
Carburizing	980	10	Acetylene gas
Diffusing	980	80	Nitrogen gas
Carburizing	980	10	Acetylene gas
Diffusing	980	550	Nitrogen gas

[0076] A cross-section of the obtained circular cylindrical steel was then observed microscopically. The results are shown in FIGS. 10B to 10D. FIG. 10B is a sectional photograph of the carburized steel. FIG. 10C is an enlarged photograph of portion c in FIG. 10B, and FIG. 10D is an enlarged photograph of portion d in FIG. 10B.

[0077] As shown in FIGS. 10B and 10D, a carburized layer did not form in the surface layer of the steel near the pyrolysis heater, but a carburized layer did form in the surface layer of the steel at other areas, as shown in FIGS. 10B and 10C. This is thought to be because near the pyrolysis heater, the concentration of carburizing gas was reduced due to the carburizing gas being pyrolyzed. It is also possible that even if carbon was slightly dissolved in this area, this dissolved carbon may have diffused due to repeatedly performing the diffusing process in between cycles of the carburizing process, and as a result, a carburized layer did not form.

[0078] The embodiments of the invention described above provides a manufacturing method of steel, by which a desired amount of an element of a treatment gas is able to be dissolved and diffused into a surface layer of a treatment surface of the steel, while inhibiting the element of the treatment gas from dissolving and diffusing into a non-treatment surface of the steel, inexpensively and without requiring troublesome work.

[0079] While example embodiments of the invention have been described in detail, the invention is in no way limited to these example embodiments. To the contrary, any of a variety of design changes may be implemented within the spirit of the invention as described in the claims.

A manufacturing method of steel (1a) in which an element of the treatment gas is dissolved and diffused includes heating the steel, making a treatment gas contact a surface of the steel such that an element of the treatment gas dissolves and diffuses from the surface of the steel into a surface layer thereof, and reducing a concentration of the treatment gas near a non-treatment surface that is a portion of the surface of the steel.

Claims

1. A manufacturing method of steel in which an element of a treatment gas is dissolved and diffused, **characterized by** comprising:

heating a steel (1a);
 making the treatment gas contact a surface of the steel such that the element of the treatment gas dissolves
 and diffuses from the surface of the steel into a surface layer thereof; and
 reducing a concentration of the treatment gas near a non-treatment surface that is a portion of the surface of
 the steel.

2. The manufacturing method according to claim 1, **characterized in that**
 the concentration of the treatment gas near the non-treatment surface is reduced by pyrolyzing the treatment gas.

3. The manufacturing method according to claim 2, **characterized in that**
 the steel is arranged inside a heating furnace (11), the steel is heated, and the pyrolyzing of the treatment gas is
 performed by a pyrolysis heater (15A),
 the manufacturing method further comprising:

arranging the pyrolysis heater facing the non-treatment surface of the steel inside the heating furnace.

4. The manufacturing method according to claim 2, **characterized in that**
 the steel is arranged inside a heating furnace, the steel is heated, and the pyrolyzing of the treatment gas is performed
 by a pyrolysis heater (15C),
 the manufacturing method further comprising:

dividing a space inside of the heating furnace into a treatment space (17a) and a non-treatment space (17b)
 by the pyrolysis heater;
 arranging the non-treatment surface of the steel in the non-treatment space;
 flowing the treatment gas into the treatment space; and
 pyrolyzing treatment gas that heads from the treatment space toward the non-treatment space by the pyrolysis
 heater.

5. The manufacturing method according to claim 3 or 4, **characterized by** comprising:

supplying the treatment gas into the heating furnace; and
 interrupting the supply of the treatment gas into the heating furnace and discharging the treatment gas from the
 heating furnace, **characterized in that**
 supplying the treatment gas into the heating furnace and interrupting the supply of the treatment gas into the
 heating furnace and discharging the treatment gas from the heating furnace are repeated.

6. The manufacturing method according to claim 5, **characterized in that**
 in interrupting the supply of the treatment gas into the heating furnace and discharging the treatment gas from the
 heating furnace, heating of the pyrolysis heater is interrupted.

FIG. 1

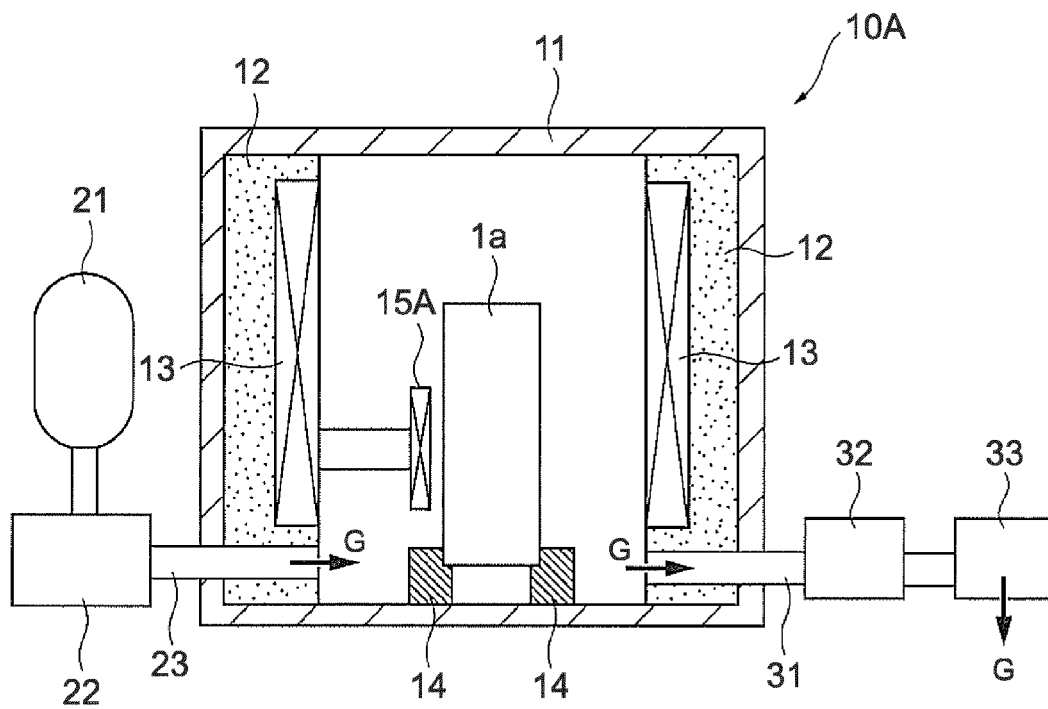


FIG. 2

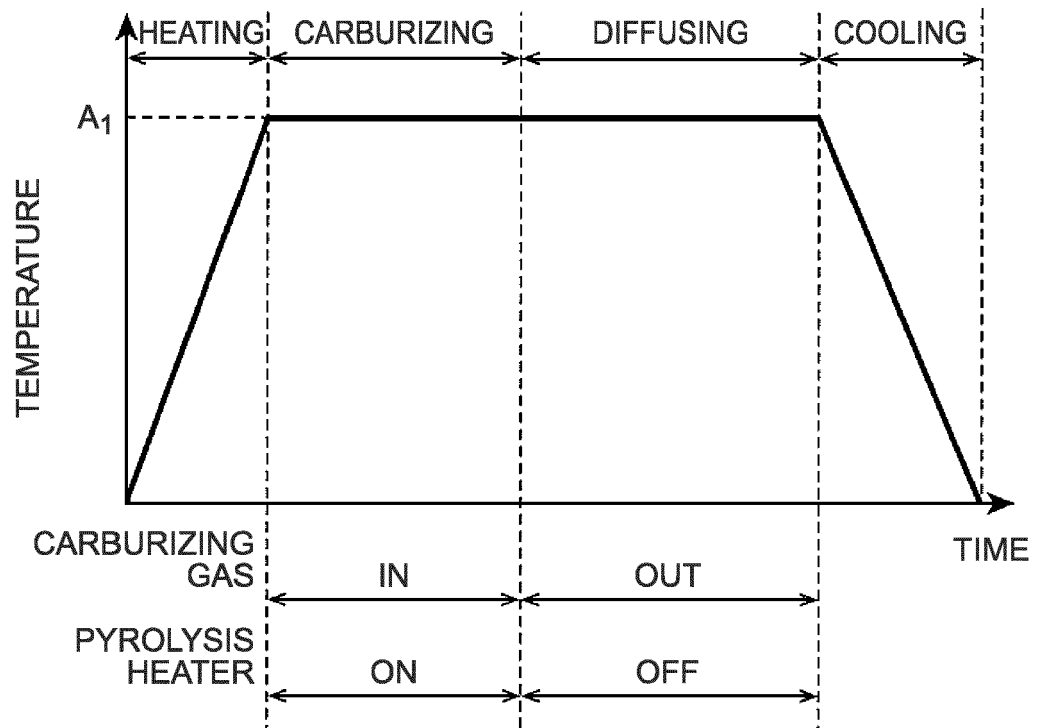


FIG. 3A

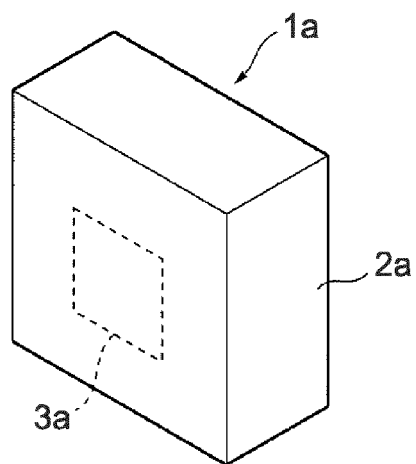


FIG. 3B

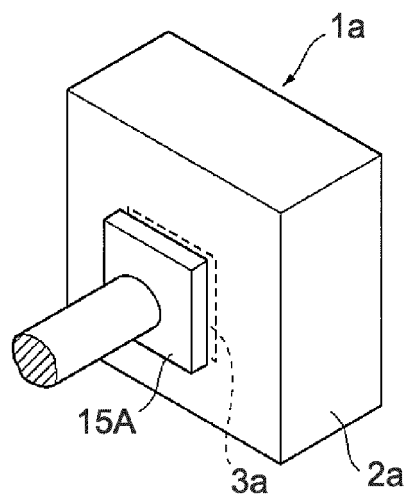


FIG. 3C

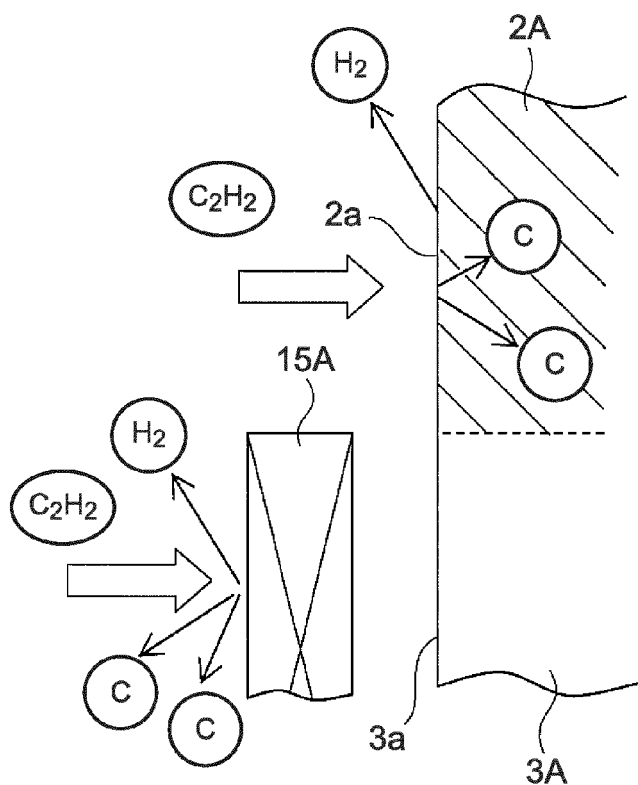


FIG. 3D

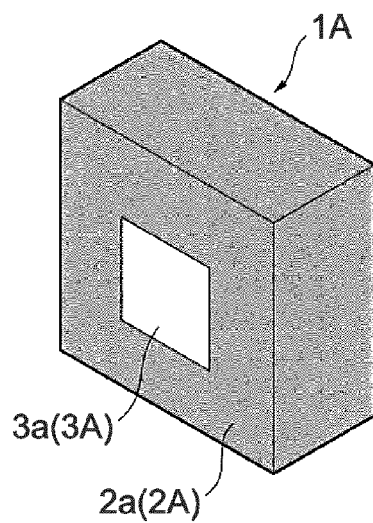


FIG. 4A

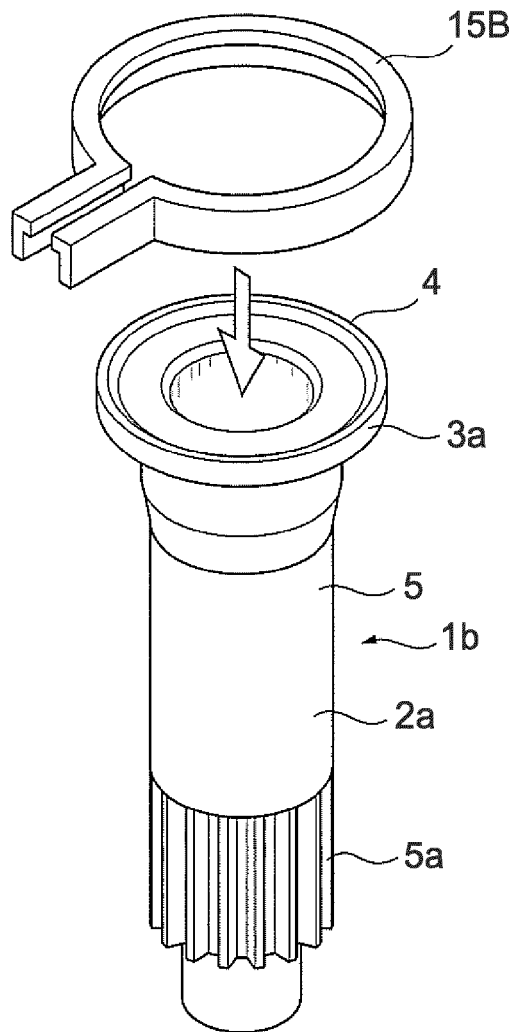


FIG. 4B

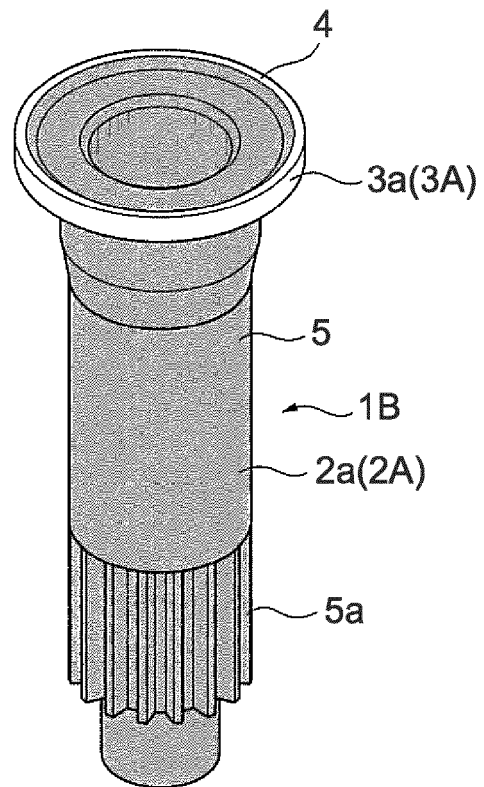


FIG. 5A

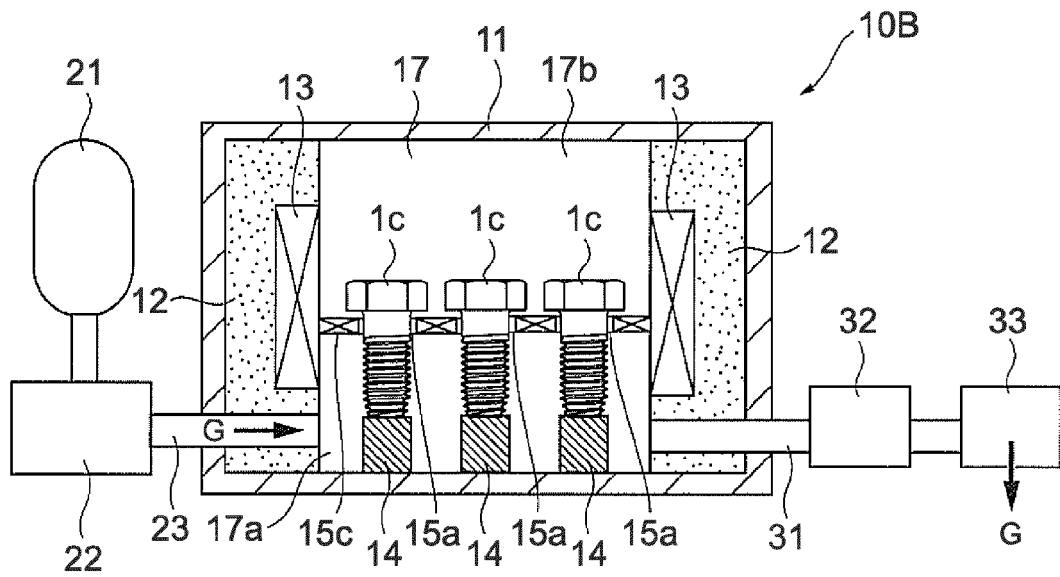


FIG. 5B

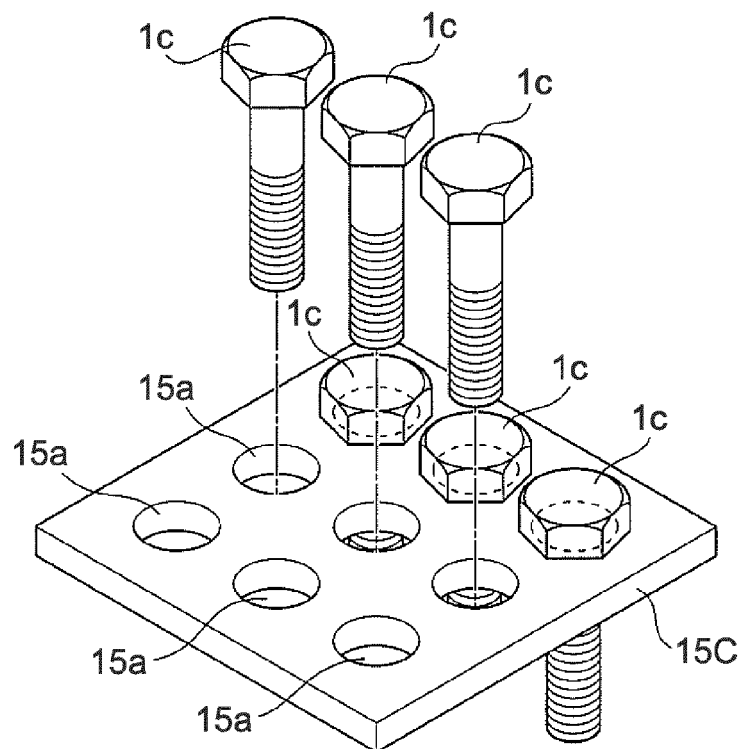


FIG. 6A

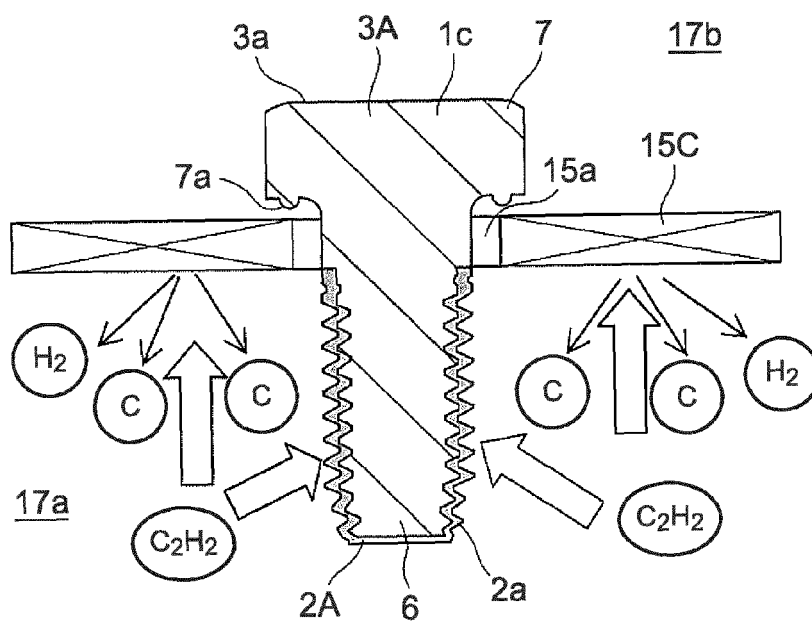


FIG. 6B

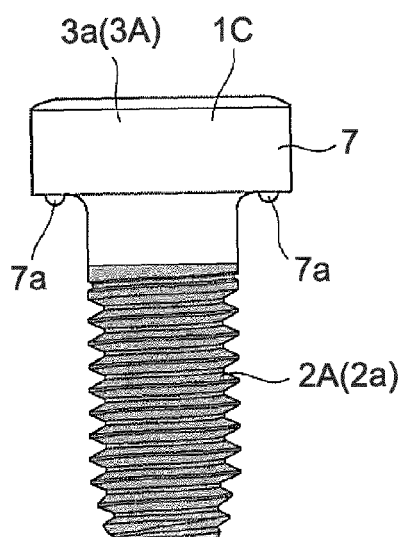


FIG. 6C

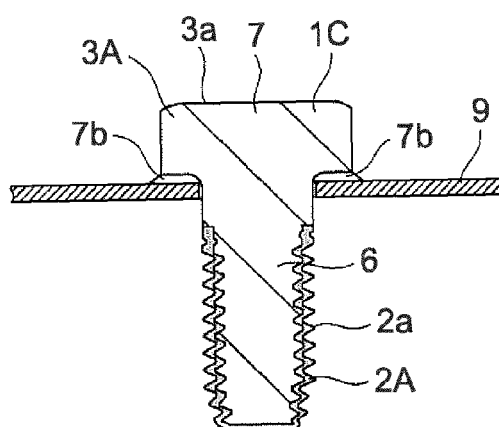


FIG. 7

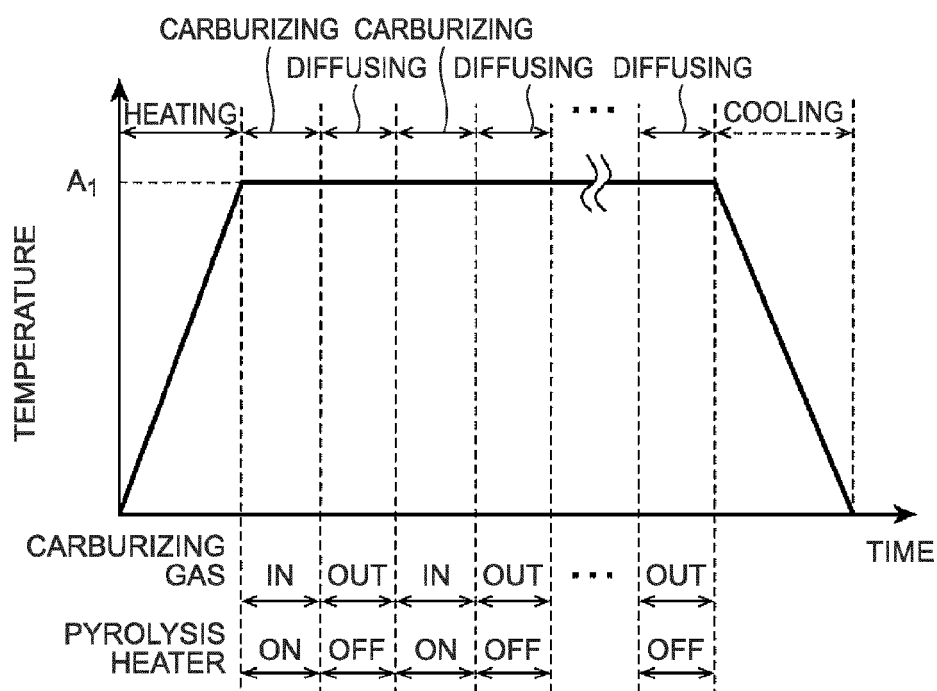


FIG. 8

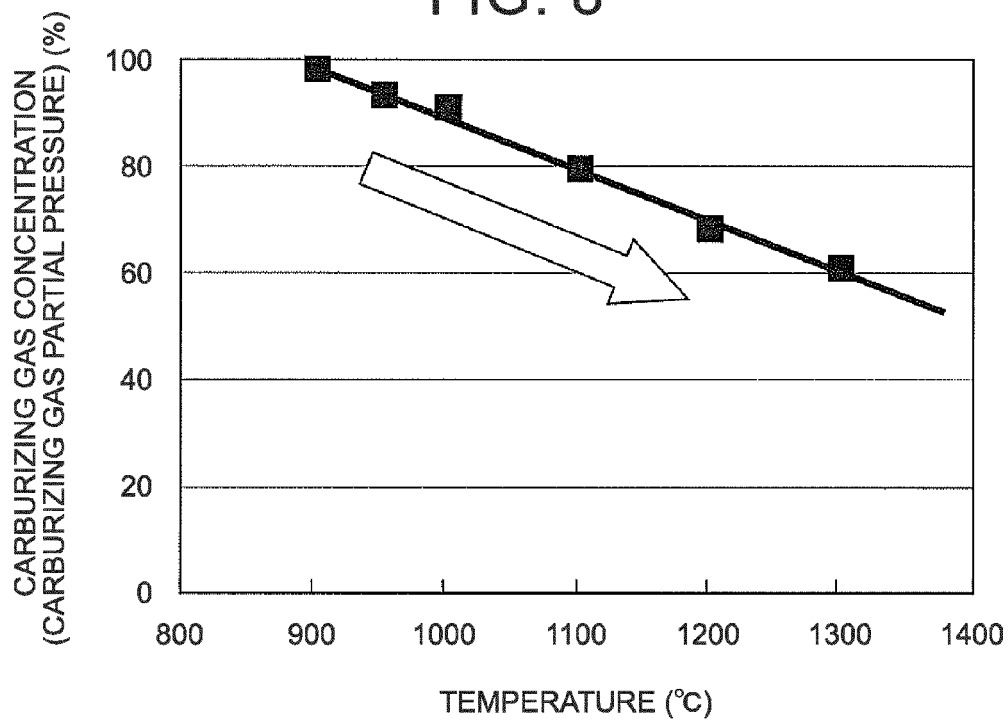


FIG. 9

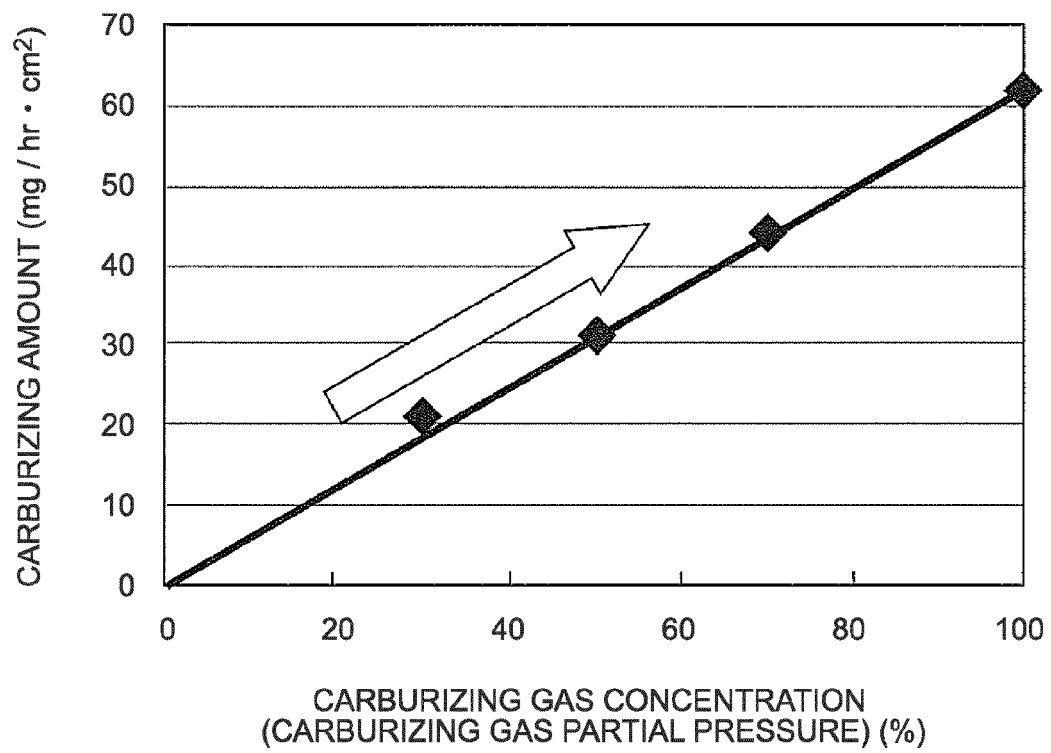


FIG. 10A

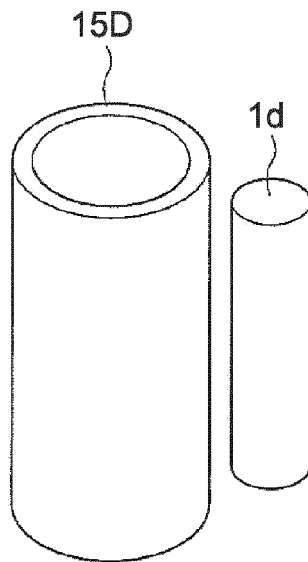


FIG. 10B

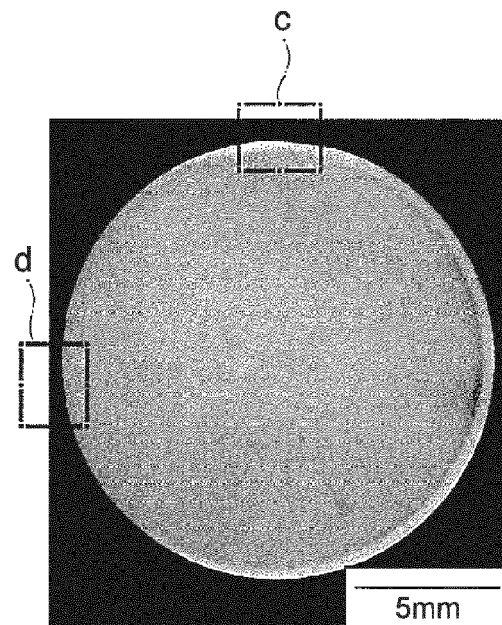


FIG. 10C

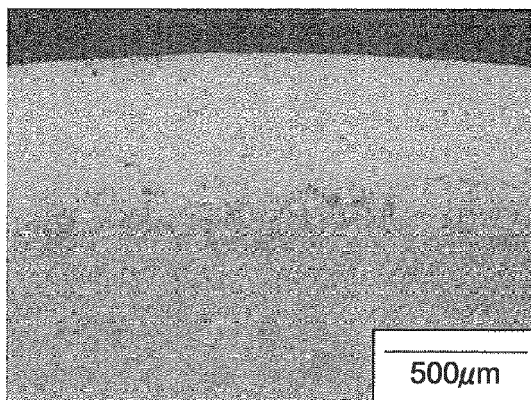
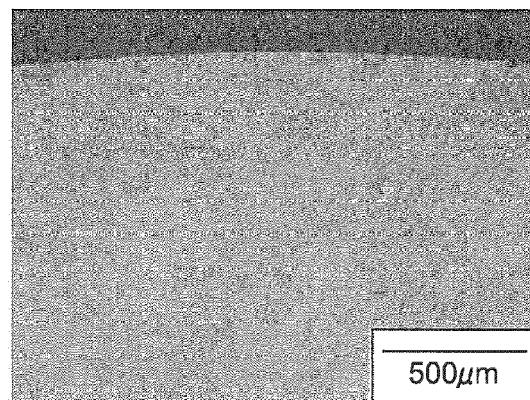


FIG. 10D





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Application Number
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A	* abstract *	2-6	C23C8/04
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A	* abstract *	2-6	C23C8/34

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	-& US 6 149 734 A (ISOGAI TAKEFUMI [JP] ET AL) 21 November 2000 (2000-11-21)		
	* the whole document *		

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Place of search		Date of completion of the search	Examiner
Munich		19 November 2015	Brisson, Olivier
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P : intermediate document		& : member of the same patent family, corresponding document	

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