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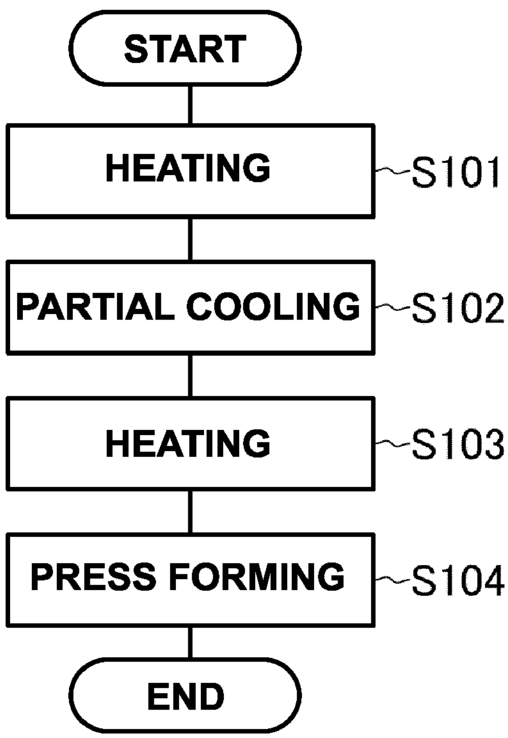
(54) MOLDING METHOD, HEAT TREATMENT SYSTEM, AND MOLDED PRODUCT

(57) In heating step S101, a steel sheet is heated and made in an austenite state. In heating step S101, the whole region of the steel sheet is evenly heated, and the whole region of the steel sheet is made in the austenite state. In cooling step S102, only a first region set on the steel sheet in the austenite state is forcibly cooled (rapidly cooled) within a temperature range of a range where martensitic transformation does not occur. In cooling step S102, a second region other than the first region is cooled by natural cooling to maintain a state in which a temperature is higher than in the first region.

FIG.1



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Description

Technical Field

[0001] The present invention relates to a steel sheet forming method, a heat treatment system, and a formed product.

Background Art

[0002] A part (vehicle body part) of a vehicle is required to have a high strength. Hence, as a material for forming a part, for example, a steel sheet with a high strength, such as a high tensile steel sheet, is used. However, since a vehicle body part is formed by press-forming a steel sheet, if a steel sheet with a high strength is used, defects of dimensional accuracy readily occur in press forming. The higher the strength of the steel sheet to be used is, the more conspicuous this is.

[0003] To cope with the above-described problem, a technique called hot press has been developed (patent literature 1). In the hot press, press forming is performed in a state in which a steel sheet is heated and softened, and at the same time, quenching is performed by bringing the steel sheet into contact with a die and cooling, thereby forming a vehicle body part having a high strength and a high dimensional accuracy.

[0004] A vehicle part is sometimes provided with a portion that is plastically deformed and absorbs impact upon receiving the impact. To form such part, there has been proposed a technique of, for example, preventing quenching by cooling by maintaining a high temperature in a portion of a die corresponding to a region that should be plastically deformed.

Related Art Literature

Patent Literature

[0005] Patent Literature 1: Japanese Patent Laid-Open No. 2018-012113

Disclosure of Invention

Problem to be Solved by the Invention

[0006] However, in the above-described technique, when releasing a formed body from a die, a region that has not undergone quenching maintains a high temperature. For this reason, torsion occurs due to a shrinkage difference caused by the temperature difference in cooling. Thus, in the conventional technique, when partially forming a region that is not quenched by hot press, normal forming is impossible.

[0007] The present invention has been made to solve the above-described problem, and has as its object to normally execute forming, by hot press, partially including a region that is not quenched.

Means of Solution to the Problem

[0008] A forming method according to the present invention comprises a heating step of heating a steel sheet and changing the steel sheet to an austenite state, a cooling step of forcibly cooling only a first region set on the steel sheet in the austenite state within a temperature range of a range where martensitic transformation does not occur, and a forming step of hot-press-forming the steel sheet including the first region that is not in the austenite state, and a second region other than the first region, which is in the austenite state.

[0009] In an example of the configuration of the forming method, in the cooling step, the first region is cooled to a temperature at which a ferrite/pearlite phase is generated.

[0010] In an example of the configuration of the forming method, in the heating step, a whole region of the steel sheet is evenly heated.

[0011] In an example of the configuration of the forming method, the forming method further comprises a reheating step of, after the cooling step, heating the steel sheet to make the second region in the austenite state or maintain the austenite state of the second region, wherein the forming step is performed after the reheating step.

[0012] In an example of the configuration of the forming method, in the cooling step, the second region is cooled by natural cooling to maintain a state in which the temperature is higher than in the first region, in the reheating step, the steel sheet is heated under a condition of such a range that the first region is not made in the austenite state, and in the forming step, only the second region is transformed to martensite.

[0013] In an example of the configuration of the forming method, a plating layer made of aluminum is formed on a surface of the steel sheet, and in the heating step, a whole of the plating layer is alloyed, a composition ratio of iron is not less than a composition ratio of γ-phase iron in an alloy of iron, aluminum, and silicon, and a thickness of a diffusion layer formed on a steel sheet side between the plating layer and the steel sheet is not more than 10 μm.

[0014] In an example of the configuration of the forming method, in the forming step, the steel sheet including the first region that is not in the austenite state, and the second region in the austenite state is hot-press-formed, a strength of the first region is set to not more than 780 MPa without a quenching process, and a strength of the second region is set to not less than 1,300 MPa after having undergone a quenching process, and the diffusion layer is evenly formed with a thickness of not more than 10 μm in a whole region including the first region and the second region.

[0015] A heat treatment system according to the present invention, is a heat treatment system for forming, on a steel sheet, a first region that is not in an austenite state and a second region other than the first region to form a region to be partially plastically deformed by hot press forming of the steel sheet, the heat treatment system comprising a heat treatment apparatus configured to heat the steel sheet and make the steel sheet in the austenite state, and a cooling processing apparatus configured to forcibly cool only the first region set on the steel sheet in the austenite state within a temperature range of a range where martensitic transformation does not occur.

[0016] In an example of the configuration of the heat treatment system, the heat treatment system is a heat treatment system configured to form the first region and the second region to form the region to be partially plastically deformed by hot-press-forming the steel sheet for which a plating layer of aluminum added with silicon is formed on a surface, and the heat treatment apparatus heats the steel sheet to make the steel sheet in the austenite state, and to alloy a whole of the plating layer to have a composition ratio of iron which is not less than a composition ratio of iron of an γ-phase alloy of iron, aluminum and silicon, and set a thickness of a diffusion layer formed on the side of the steel sheet on which the plating layer is formed not more than 10 μm.

[0017] In an example of the configuration of the heat treatment system, the heat treatment system further comprises a reheat treatment apparatus configured to heat the steel sheet processed by the cooling processing apparatus under such a condition that the diffusion layer does not grow to make the second region in the austenite state or maintain the austenite state of the second region.

[0018] In an example of the configuration of the heat treatment system, the reheat treatment apparatus comprises a heat source configured to irradiate the steel sheet with infrared rays, and a cover configured to cover the first region of the steel sheet, and in the cover, a plurality of through holes are formed in a surface irradiated with the infrared rays.

[0019] In an example of the configuration of the heat treatment system, the cover is formed as a box body opening on a steel sheet side.

[0020] A formed product according to the present invention is a formed product obtained by forming a steel sheet for which a plating layer of aluminum added with silicon is formed on a surface, comprising a first region having a strength of not more than 780 MPa without a quenching process, and the second region having a strength of not less than 1,300 MPa after having undergone a quenching process, wherein a whole of the plating layer is alloyed, the formed product comprises a diffusion layer in which a composition ratio of iron is not less than a composition ratio of γ-phase iron in an alloy of iron, aluminum, and silicon and which is formed on a steel sheet side of the plating layer, and the diffusion layer is evenly formed with a thickness of not more than 10 μm in a whole region including the first region and the second region.

Effect of the Invention

[0021] As described above, according to the present invention, a steel sheet is made in an austenite state in a heating step, and then, only the first region is forcibly cooled, thereby enabling normal execution of forming, by hot press, partially including a region that is not quenched.

Brief Description of Drawings

[0022]

Fig. 1 is a flowchart for explaining a forming method according to the embodiment of the present invention;

Fig. 2 is a graph showing a temperature change in the forming method according to the embodiment of the present invention;

Fig. 3 is a view showing the configuration of a heat treatment system according to the embodiment of the present invention; and

Fig. 4 is a view showing the configuration of a reheat treatment apparatus 103 of the heat treatment system according to the embodiment of the present invention.

Best Mode for Carrying Out the Invention

[0023] A forming method according to the embodiment of the present invention will now be described with reference to Figs. 1 and 2.

[0024] First, in heating step S101, a steel sheet is heated and made in an austenite state. In heating step S101, the whole region of the steel sheet is evenly heated, thereby changing the whole region of the steel sheet to the austenite state. The steel sheet can be made in the austenite state by heating it to a temperature Ac3 or more at which the transformation to the austenite state starts. For example, the whole region of the steel sheet is heated to about 900°C using a heating apparatus such as an oven, thereby changing the whole region of the steel sheet to the austenite state. For example, the steel sheet is made of manganese boron steel, and can be made in the austenite state by heating it to 823°C or more.

[0025] Next, in cooling step S102, only a first region set on the steel sheet in the austenite state is forcibly cooled (rapidly cooled) within a temperature range of a range where martensitic transformation does not occur [(a) of Fig. 2]. The forcible cooling is performed in the range of temperatures higher than a temperature Ms at which generation of martensite starts. In this step, it is important to rapidly cool the first region to a temperature at which a ferrite/pearlite phase is generated.

[0026] For example, only the first region can be rapidly cooled by making it contact a cooling block cooled by water cooling. Alternatively, only the first region can rapidly be cooled by blowing a gas such as air, water, mist, or the like only to the first region. In cooling step S102, a second region other than the first region is cooled by natural cooling to maintain a state in which the temperature is higher than in the first region [(b) in Fig. 2]. For example, the whole region of the process target steel sheet other than the first region is the second region.

[0027] Note that in cooling step S102, the first region may rapidly be cooled to the lowest temperature within the range where martensitic transformation does not occur. In cooling step S102, however, it is important that the first region is at a temperature higher than a temperature at which bainitic transformation occurs. Depending on the type of steel forming the steel sheet, for example, in cooling step S102, only the first region is rapidly cooled to a temperature within the range of 550°C to 650°C.

[0028] When rapid cooling is performed, the temperature instantaneously lowers to 750°C or less at which the ferrite phase is generated, forming a trigger of austenite -> ferrite transformation in the first region. Ferrite transformation does not occur only by rapid cooling. When a state in which the first region is rapidly cooled is maintained for a predetermined time (several sec), the structure grows from austenite to ferrite/pearlite. Since the rapid cooling of only the first region is performed outside a heating furnace in which the heating step is performed, the second region is naturally cooled. If the second region is cooled by natural cooling to a temperature lower than 750°C, ferrite is generated.

[0029] Next, in reheating step S103, the steel sheet is heated to make the second region other than the first region in the austenite state again, or the austenite state of the second region is maintained. In reheating step S103, the whole region of the steel sheet is evenly heated, thereby changing the second region to the austenite state. In reheating step S103, the steel sheet is heated under the condition of such a range that the first region is not made in the austenite state. For example, the above-described process can be performed by covering the first region with a thermal insulation material. The width of the transition region can be adjusted by changing the size of the thermal insulation material. In the process of cooling step S102, a difference is formed between the temperature of the first region and the temperature of the second region. For this reason, even if the whole region of the steel sheet is evenly heated, it is possible to make the second region in austenite and not to make the first region in the austenite state.

[0030] Also, after the process of cooling step S102 is performed, if the austenite state of the second region is maintained at the stage of performing reheating step S103, the heating process of reheating step S103 is a process for maintaining the austenite state of the second region to cause martensitic transformation in hot press forming of a post-process.

[0031] Also, after the process of cooling step S102 is performed, if the austenite state of the second region is sufficiently maintained at the stage of performing reheating step S103, and hot press forming of a post-process can be performed immediately after that, reheating step S103 is not performed, and subsequent forming step S104 can be performed.

[0032] Next, in forming step S104, the steel sheet including the first region that is not in the austenite state and the second region that is in the austenite state is hot-press-formed. In this hot press forming, only the second region is transformed to martensite.

[0033] A heat treatment system configured to form the first region that is not in the austenite state and the second region other than the first region on the steel sheet in the above-described forming method will be described next with reference to Fig. 3. This heat treatment system is a system configured to form the first region that is not in the austenite state and the second region other than the first region on a steel sheet to form a region to be partially plastically deformed by hot press forming of the steel sheet.

[0034] The heat treatment system includes a heat treatment apparatus 101, a cooling processing apparatus 102, and a reheat treatment apparatus 103.

[0035] The heat treatment apparatus 101 heats a steel sheet to make it in the austenite state. The heat treatment apparatus 101 can be formed by, for example, a well-known heating furnace. The heat treatment apparatus 101 evenly heats the whole region of the steel sheet.

[0036] The cooling processing apparatus 102 forcibly cools only the first region set on the steel sheet in the austenite state within a temperature range of a range where martensitic transformation does not occur. The cooling processing apparatus 102 cools the first region to a temperature at which a ferrite/pearlite phase is generated. The cooling processing apparatus 102 is arranged outside the heat treatment apparatus 101 and can forcibly cool only the first region to the temperature at which a ferrite/pearlite phase is generated within the temperature range of a range where martensitic transformation does not occur, and set the second region in a state in which it is naturally cooled and cool the second region to a temperature lower than the temperature at which transformation to austenite starts. The cooling processing apparatus 102 maintains a state in which the second region is at a temperature higher than in the first region.

[0037] The reheat treatment apparatus 103 heats the steel sheet processed by the cooling processing apparatus 102, and makes the second region in the austenite state, or maintains the austenite state of the second region. Immediately after the cooling processing apparatus 102, the reheat treatment apparatus 103 heats the steel sheet to make the second region in the austenite state, and at the same time, maintains the rapidly cooled state of the first region for a predetermined time to grow the ferrite/pearlite phase. The reheat treatment apparatus 103 can heat the steel sheet under the condition of such a range that the first region is not made in the austenite state. The reheat treatment apparatus 103 can be formed by, for example, a well-known heating furnace.

[0038] For example, as shown in Fig. 4, the reheat treatment apparatus 103 can be configured to include a heat source 131 that irradiates a steel sheet 141 with infrared rays, and a first cover 132 and a second cover 133, which cover a first region 151 of the steel sheet 141. The first cover 132 and the second cover 133 are arranged to sandwich the steel sheet 141. The first cover 132 and the second cover 133 are each formed as a box body opening on the side of the steel sheet 141. By the sizes (volumes) of the spaces of the first cover 132 and the second cover 133, which are box bodies, a heat input amount from the heat source 131 and a heat dissipation amount from the steel sheet 141 can be adjusted.

[0039] The heat source 131 can be formed by, for example, an infrared lamp or a ceramic heater. The first cover 132 covers the steel sheet 141 on the side of the heat source 131. Each of the first cover 132 and the second cover 133 can be formed by a steel sheet having a predetermined thickness. The heat source 131, the first cover 132, and the second cover 133 can be arranged in, for example, a sealable treatment furnace 135. The first cover 132 and the second cover 133 are supported by a support structure (not shown) in the treatment furnace 135.

[0040] Also, in the first cover 132, a plurality of through holes 134 are formed in a surface 132a irradiated with infrared rays. If the first cover 132 including the plurality of through holes 134 is used, it is possible to easily execute maintaining a second region 152 of the steel sheet 141 at a temperature at which it is in the austenite state and maintaining the first region 151 within such a range that it is not in the austenite state (a temperature range in which the ferrite/pearlite phase is generated). The temperature difference between the first region 151 and the second region 152 can be set by conditions such as the hole diameter of the through hole 134 and the number of through holes 134 (the ratio of the total area of all through holes 134 on the surface 132a). In addition, the first cover 132 and the second cover 133 are detachable/attachable and can therefore be used repetitively, and maintenability is high.

[0041] According to the above-described embodiment, as the result of hot press forming, the second region is in a quenched state and becomes martensite. On the other hand, the first region is in an annealed state and becomes a portion which is easy to be modified in composition. Also, according to this embodiment, since the whole region has a low temperature at the stage of releasing the formed body from the die, a problem such as so-called spring back does not arise. As described above, according to this embodiment, it is possible to normally execute, by hot press forming, forming partially including a region that is not quenched. Note that if the temperature on the low temperature side from the cooling step to the reheating step is controlled within the temperature range near a point where martensitic transformation occurs, structure transformation including a bainitic phase is also possible.

[0042] For example, according to this embodiment, by the hot press forming, the first region can have a tensile strength of 780 MPa or less and a hardness of 220 HV or less, and the second region can have a tensile strength of 1,300 MPa or more and a hardness of 400 HV or more. In addition, a boundary region with a width of about 50 mm in which hardness gradually transitions can be formed between the first region and the second region.

[0043] As described above, for example, a vehicle body part is provided with a portion that is plastically deformed and absorbs impact upon receiving the impact. The first region is a region serving as this portion. If a state in which the ferrite/pearlite phase is generated is obtained, the first region becomes softer than bainite and obtains ductility. Since the first region in this state is more easily deformed, a deformation part can be limited in advance. In addition, if a state in which the ferrite/pearlite phase is generated is obtained, a state in which the ductility is high can be obtained, and the region hardly breaks at the time of deformation and is stretcheable and tough.

[0044] To form the two regions of different temperatures as described above before press, partial heating is also possible. In this case, however, a facility for the partial heating is necessary, and the facility may be bulky. To the contrary, a facility for partial cooling needs no bulky facility, unlike heating, and is considered to be advantageous in terms of cost.

[0045] If a part constituting a vehicle needs corrosion resistance, a rust-proofing treatment or metal coating is performed for the surface of the part after the process. In this case, a surface cleaning step or a surface treatment step is needed, and productivity lowers. Hence, in general, coating is performed for the steel sheet in advance. To make the coating correspond to the heating temperature in hot press forming, an aluminum plated steel sheet that has undergone coating of aluminum is used.

[0046] In an aluminum plated steel sheet of this type, to suppress expansion of a layer of an alloy of aluminum and iron, which is formed between a plating layer and the steel sheet, a plating layer of aluminum added with silicon is used. The forming method according to the above-described embodiment can also be applied to a steel sheet including a plating layer. The formed body can be used as, for example, a part such as the center pillar of a door of an automobile.

[0047] To partially form a region that is not quenched by hot press forming on the aluminum plated steel sheet as described above, it is important to control the state of alloying in the plating layer. For example, it is important that the whole plating layer is alloyed, as is well known. When partially forming a region that is not quenched by hot press forming on the aluminum plated steel sheet, it was confirmed that the joining strength of welding varies. It was considered that this occurs because the alloyed state of the plating layer varies, and a plating layer that is not appropriately alloyed exists. As described above, conventionally, when forming partially including a region that is not quenched on a steel sheet with a plating layer, it is not easy to appropriately form the plating layer to be alloyed.

[0048] To solve the above-described problem, in a steel sheet (Al plated steel sheet) including, on the surface, a plating layer of aluminum added with silicon, first, in heating step S101 shown in Fig. 1, the steel sheet is heated to be in an austenitic state, and all of the plating layers are alloyed. The thickness of a diffusion layer formed on the steel sheet side of the plating layer is 10 μm or less. The diffusion layer is a layer in which the composition ratio of iron is equal to or more than the composition ratio of γ-phase iron in the alloy of iron, aluminum, and silicon.

[0049] As described above, the steel sheet can be in an austenitic state by heating the steel sheet to the temperature Ac3 or more at which transformation to austenite occurs. For example, if the whole region of the steel sheet is heated to about 900°C, the whole region of the steel sheet can be in the austenite state. For example, the steel material can be made of manganese boron steel, and this can be made in the austenite state by heating it to 823°C or more.

[0050] Also, if an Al plated steel sheet is heated to the melting point (660°C) of aluminum or more, the aluminum plating layer is molten, and aluminum, iron, and silicon diffuse to each other, thereby generating an alloy layer (Al-Fe-Si alloy layer) of aluminum, iron, and silicon. The Al-Fe-Si alloy layer has a high melting point which is about 1,150°C. For this reason, if a whole of the plating layer is alloyed, it is not molten at the heating temperature in the heating step.

[0051] Here, as is well known, if unalloyed aluminum remains in the plating layer of aluminum, only the residual portion of aluminum rapidly corrodes, and, for example, coating film blistering readily occurs after coating. In addition, in a hot-pressed formed product, a desired strength cannot be obtained. The unalloyed portion is readily formed on the surface side of the plating layer. The generation of the unalloyed portion is a factor for causing the variation of the alloyed state in the plating layer. Hence, in the formed product after hot press forming to be described later, it is important that a whole of the plating layer is alloyed.

[0052] As the result of extensive studies of the present inventors, it was estimated that β phase ($FeSiAl_5$) of the Al-Fe-Si alloy layer, γ phase ($FeSiAl_3$) of the Al-Fe-Si alloy layer, and $FeAl_3$ mainly exist in the above-described alloy layer. It is confirmed that the $FeAl_3$ layer is a layer on the steel sheet side, and the $FeSiAl_3$ layer is formed in contact with the $FeAl_3$ layer. The portion including both the $FeAl_3$ layer and the $FeAl_3$ layer in contact with it, in other words, the portion in which the composition ratio of iron is equal to or more than the composition ratio of γ-phase iron in the alloy of iron, aluminum, and silicon is the diffusion layer.

[0053] It was found that if the above-described diffusion layer is too thick, the joining strength of welding performed after press forming lowers, and if the diffusion layer is not formed, corrosion occurs in the press-formed product. Generation of the thick portion of the diffusion layer is a factor for causing the variation of the alloyed state in the plating layer. As the result of extensive studies of the present inventors, it was found that if the thickness of the diffusion layer is 10 μm or less, sufficient corrosion resistance can be obtained, and the above-described lowering of the joining strength can be suppressed.

[0054] Also, even if the heating temperature is 700°C, if the heating is continued, the above-described diffusion layer starts being generated and grows. Within the temperature range where the diffusion layer is generated, in a low temperature region, even if an unalloyed portion exists, the growth of the diffusion layer is confirmed. In addition, if the reached temperature in the heating process is high, the whole portion is alloyed in a short process time, generation of the diffusion layer starts early, and the growth speed is high. For example, if heating is stopped, and cooling is started when the whole plating layer is alloyed, the growth of the diffusion layer stops before reaching 700°C. If reheating (at a temperature for obtaining the austenite state) is performed immediately after cooling (within the temperature range of a range where martensitic transformation does not occur), in this reheating, the diffusion layer starts growing when the temperature exceeds 890°C.

[0055] Hence, for the Al plated steel sheet, it is important that in heating step S101, a process time is set such that a whole of the plating layer is alloyed under heating temperature conditions for changing the steel sheet to the austenite state, and the diffusion layer is formed in the range of 10 μm or less in heating step S101.

[0056] Note that even for the Al plated steel sheet, cooling step S102 is the same as described above. In cooling step S102, only the first region set on the steel sheet in the austenite state is forcibly cooled (rapidly cooled) within a temperature range of a range where martensitic transformation does not occur. The forcible cooling is performed in the range of temperatures higher than the temperature Ms at which generation of martensite starts. In this step, it is important to rapidly cool the first region to a temperature at which a ferrite/pearlite phase is generated.

[0057] Also, as described above, in cooling step S102, the first region may rapidly be cooled to the lowest temperature within the range where martensitic transformation does not occur. In cooling step S102, however, it is important that the first region is at a temperature higher than a temperature at which bainitic transformation occurs. Depending on the type of steel forming the steel sheet, for example, in cooling step S102, only the first region is rapidly cooled to a temperature within the range of 550°C to 650°C.

[0058] When rapid cooling is performed, the temperature instantaneously lowers to 750°C or less at which the ferrite phase is generated, forming a trigger of austenite -> ferrite transformation in the first region. Ferrite transformation does not occur only by rapid cooling. When a state in which the first region is rapidly cooled is maintained for a predetermined time (several sec), the structure grows from austenite to ferrite/pearlite. Since the rapid cooling of only the first region is performed outside a heating furnace in which the heating step is performed, the second region is naturally cooled. If the second region is cooled by natural cooling to a temperature lower than 750°C, ferrite is generated.

[0059] On the other hand, it is important that reheating step S103 described above is performed under the condition of the range where the diffusion layer does not grow. The start of growth of the diffusion layer changes depending on the temperature condition and the process time. For example, even if the temperature is low, if the process time is long, growth of the diffusion layer starts. On the other hand, even if the temperature is high, if the process time is short, growth of the diffusion layer does not start. Here, when performing reheating step S103, the second region is made in the austenite state, or can be maintained in the austenite state. If the second region is heated to 823°C or more, it can be made in the austenite state, or can be maintained in the austenite state. While satisfying the lower limit condition of the temperature, the temperature condition of reheating step S103 is set depending on the time for performing reheating step S103. For example, if the execution time is short, a higher temperature condition can be set. On the other hand, if the execution time is long, the temperature condition is set low.

[0060] Next, in forming step S104, the steel sheet including the first region that is not in the austenite state and the second region that is in the austenite state is hot-press-formed. In this hot press forming, only the second region is transformed to martensite.

[0061] A heat treatment system configured to process the above-described Al plated steel sheet will be described. This heat treatment system is a system configured to form the first region that is not in the austenite state and the second region other than the first region on a steel sheet to form a region to be partially plastically deformed by hot press forming of the steel sheet on which a plating layer of aluminum added with silicon is formed on the surface.

[0062] In the heat treatment system, the heat treatment apparatus 101 described with reference to Fig. 3 has a configuration to be described below. The heat treatment apparatus 101 in this case heats a steel sheet and make it in the austenite state, and the thickness of a diffusion layer which is formed on the steel sheet side of the plating layer and in which a whole of the plating layer is alloyed, and the composition ratio of iron is equal to or more than the composition ratio of γ-phase iron in the alloy of iron, aluminum, and silicon is set to 10 μm or less. As described above, the heat treatment apparatus 101 in this case can also be formed by, for example, a well-known heating furnace. The heat treatment apparatus 101 evenly heats the whole region of the steel sheet. The cooling processing apparatus 102 and the reheat treatment apparatus 103 are the same as described above.

[0063] According to the above-described heat treatment system, as the result of hot press forming, the second region is in a quenched state and becomes martensite. On the other hand, the first region is in an annealed state and becomes a portion which is easy to be modified in composition. Also, according to this embodiment, since the whole region has a low temperature at the stage of releasing the formed body from the die, a problem such as so-called spring back does not arise. As described above, according to this embodiment, it is possible to normally execute, by hot press forming, forming partially including a region that is not quenched. In addition, a whole of the plating layer is alloyed, and the thickness of the diffusion layer formed in the alloyed plating layer can be set to 10 μm or less. Note that if the temperature on the low temperature side from the cooling step to the reheating step is controlled within the temperature range near a point where martensitic transformation occurs, structure transformation including a bainitic phase is also possible.

[0064] If the Al plated steel sheet is the process target, the process of heating the whole steel sheet for alloying is an essential process. In this case, to partially provide the region that is not quenched by partial heating, the whole region is heated, and after that, partial heating is performed again. In this case, a plurality of facilities for heating are necessary, resulting in an increase of cost. On the other hand, according to the forming method of the above-described embodiment, since the heating step and the reheating step can be performed by the same heating facility, the cost does not increase.

[0065] The formed product formed using an Al plated steel sheet by the forming method according to the above-described embodiment includes a first region having a strength of 780 MPa or less without a quenching process, and a second region having a strength of 1,300 MPa or more after having undergone a quenching process, includes a plating layer a whole of which is alloyed, and includes a diffusion layer which is formed on the steel sheet side between the plating layer and the steel sheet and in which the composition ratio of iron is equal to or more than the composition ratio of γ-phase iron in the alloy of iron, aluminum, and silicon. The diffusion layer is evenly formed with a thickness of 10 μm or less in the whole region including the first region and the second region.

[0066] As described above, according to the present invention, after the steel sheet is made in the austenite state in the heating step, only the first region is forcibly cooled. This makes it possible to normally execute, by hot press forming, forming partially including a region that is not quenched.

[0067] Also, according to the present invention, in the heating step, a whole of the plating layer is alloyed, and the thickness of the diffusion layer formed on the steel sheet side of the plating layer is set to 10 μm or less. For this reason, in forming partially including a region that is not quenched in the steel sheet with the plating layer of aluminum, the plating layer to be alloyed can appropriately be formed.

[0068] In the selective quenching technique of hot press forming of a steel sheet with a plating layer of aluminum, to normally form an unquenched portion in a part of a product, temperature control by heating and cooling is necessary in the manufacturing step. It is difficult to control the optimum thickness of the diffusion layer in that state. If the diffusion layer is too thick, the joining strength of welding lowers, and if the diffusion layer is not formed, corrosion occurs in the material. For this reason, when hot-press-forming of a steel sheet with a plating layer of aluminum, the heating process performed before the hot press forming, it is important that the thickness of the diffusion layer is set to satisfy the intended quality.

[0069] When partially forming a region that is not quenched by hot press forming on an aluminum plated steel sheet, the conventional variation in the joining strength of welding is considered to occur due to the existence of a plating layer that is not appropriately alloyed. This is because the condition for appropriately forming the plating layer to be alloyed is not clear. According to the present invention, the condition for appropriately forming the plating layer to be alloyed is clear, and the above-described problem can be solved.

[0070] Note that the present invention is not limited to the above-described embodiments, and it is obvious that many modifications and combinations can be implemented by those having ordinary knowledge in this field within the technical scope of the present invention.

Explanation of the Reference Numerals and Signs

[0071] 101...heat treatment apparatus, 102...cooling processing apparatus, 103...reheat treatment apparatus

Claims

1. A forming method comprising:

   a heating step of heating a steel sheet having a plating layer of aluminum added with silicon formed on a surface of the steel sheet, to make the steel sheet in an austenite state, and to alloy a whole of the plating layer to have a composition ratio of iron which is not less than a composition ratio of iron of an γ-phase alloy of iron, aluminum and silicon, and set a thickness of a diffusion layer formed on the side of the steel sheet on which the plating layer is formed not more than 10 μm;
   a cooling step of forcibly cooling only a first region set on the steel sheet in the austenite state within a temperature range where martensitic transformation does not occur;
   a reheating step of, after the cooling step, heating the steel sheet under conditions that do not allow the diffusion layer to grow such that the second region is made in the austenite state or maintain the austenite state of the second region, and
   a forming step of hot-press-forming the steel sheet including the first region that is not in the austenite state, and a second region other than the first region, which is in the austenite state,
   wherein the forming step is performed after the reheating step.

2. The forming method according to claim 1, wherein in the cooling step, the first region is cooled to a temperature at which a ferrite/pearlite phase grows.

3. The forming method according to claim 1, wherein the heating step includes heating a whole region of the steel sheet evenly.

4. The forming method according to claim 1, wherein

   the cooling step includes forcibly cooling only the first region, outside a heating furnace in which the heating step is performed, to a temperature where a ferrite/pearlite phase is formed within a temperature range where martensitic transformation does not occur, and naturally cooling the second region to a temperature lower than a temperature at which transformation to austenite starts,
   the forming step includes hot-press-forming the steel sheet including the first region that is not in the austenite state and the second region in the austenite state, and
   reheating step includes heating the steel sheet, immediately after the cooling step, to make the second region in the austenite state, and maintaining a state in which the first region is rapidly cooled for a predetermined time to grow a ferrite/pearlite phase.

5. The forming method according to claim 4, wherein

   the cooling step including maintaining a state in which the temperature of the second region is higher than the first region,
   the reheating step includes heating the steel sheet under a condition of such a range that the first region is not made in the austenite state, and the forming step includes transforming only the second region to martensite.

6. The forming method according to any one of claims 1 to 5, wherein

the forming step includes hot-press-forming the steel sheet including the first region that is not in the austenite state and the second region in the austenite state, setting a strength of the first region to not more than 780 MPa without a quenching process, and setting a strength of the second region to not less than 1,300 MPa after having undergone a quenching process, and
the diffusion layer is evenly formed with a thickness of not more than 10 μm in a whole region including the first region and the second region.

7. A heat treatment system configured to form, on a steel sheet, a first region that is not in an austenite state and a second region other than the first region to form a region to be partially plastically deformed by hot-press-forming the steel sheet for which a plating layer of aluminum added with silicon is formed on a surface, comprising:

a heat treatment apparatus configured to heat the steel sheet and make the steel sheet in the austenite state, alloy a whole of the plating layer to have a composition ratio of iron which is not less than a composition ratio of iron of an γ-phase alloy of iron, aluminum and silicon, and set a thickness of a diffusion layer formed on the side of the steel sheet on which the plating layer is formed not more than 10 μm;
a cooling processing apparatus configured to forcibly cool only the first region set on the steel sheet in the austenite state within a temperature range where martensitic transformation does not occur; and
a reheat treatment apparatus configured to heat the steel sheet processed by the cooling processing apparatus under such a condition that the diffusion layer does not grow to make the second region in the austenite state or heat the steel sheet processed by the cooling processing apparatus under such a condition that the diffusion layer does not grow to maintain the austenite state of the second region.

8. A formed product obtained by forming a steel sheet for which a plating layer of aluminum added with silicon is formed on a surface, comprising:

a first region having a strength of not more than 780 MPa without a quenching process and a hardness of not more than 220 HV, the first region not being in a martensite state; and
a second region having a strength of not less than 1,300 MPa after having undergone a quenching process and a hardness of not less than 400 HV, the second region being in the martensite state,
wherein a whole of the plating layer is alloyed,
the formed product comprises a diffusion layer in which a composition ratio of iron is not less than a composition ratio of γ-phase iron in an alloy of iron, aluminum and silicon and which is formed on a steel sheet side of the plating layer,
the diffusion layer is evenly formed with a thickness of not more than 10 μm in a whole region including the first region and the second region, and
the formed product further comprises a boundary region formed between the first region and the second region and having a width up to 50 mm, in which a hardness gradually transitions.

FIG.1

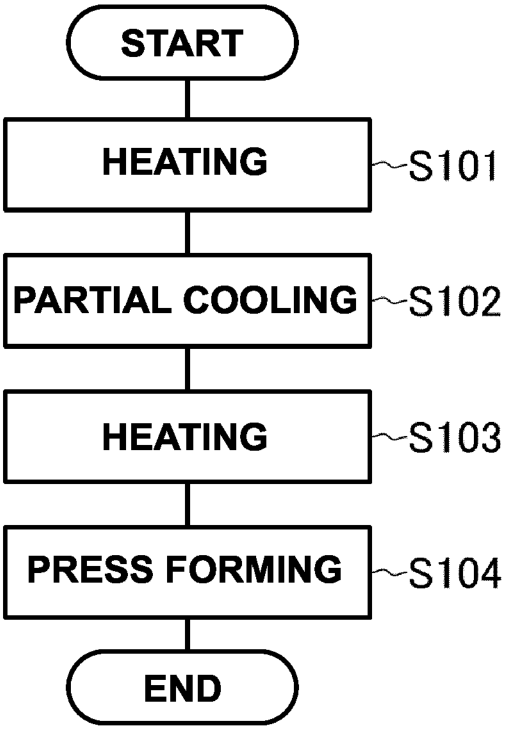

START
HEATING
S101
PARTIAL COOLING
S102
HEATING
S103
PRESS FORMING
S104
END

FIG.2

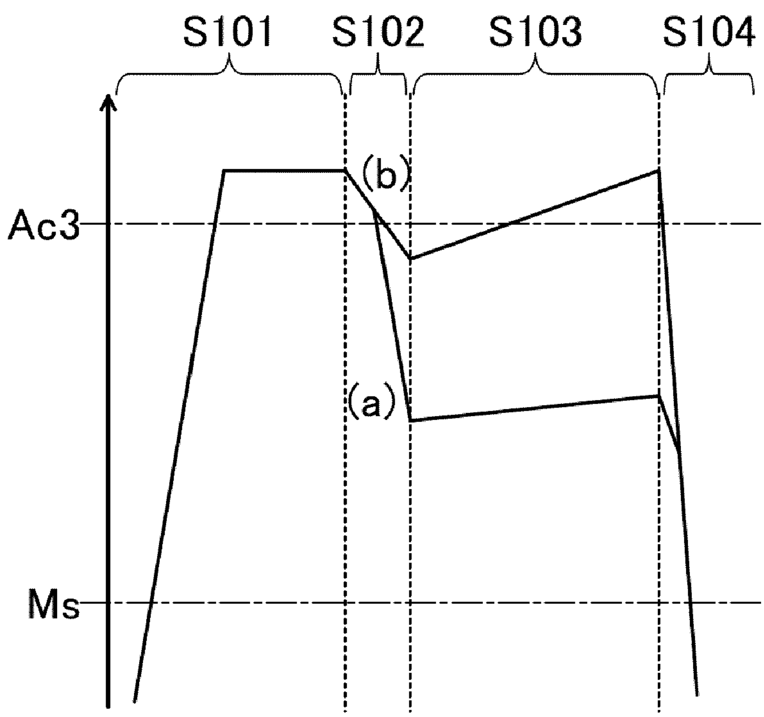

S101
S102
S103
S104
(b)
Ac3
(a)
Ms

FIG.3

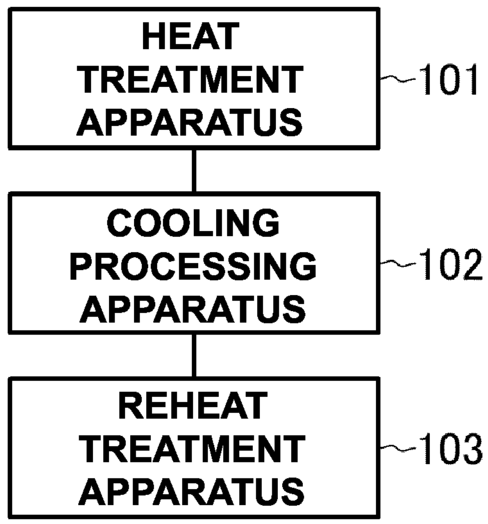
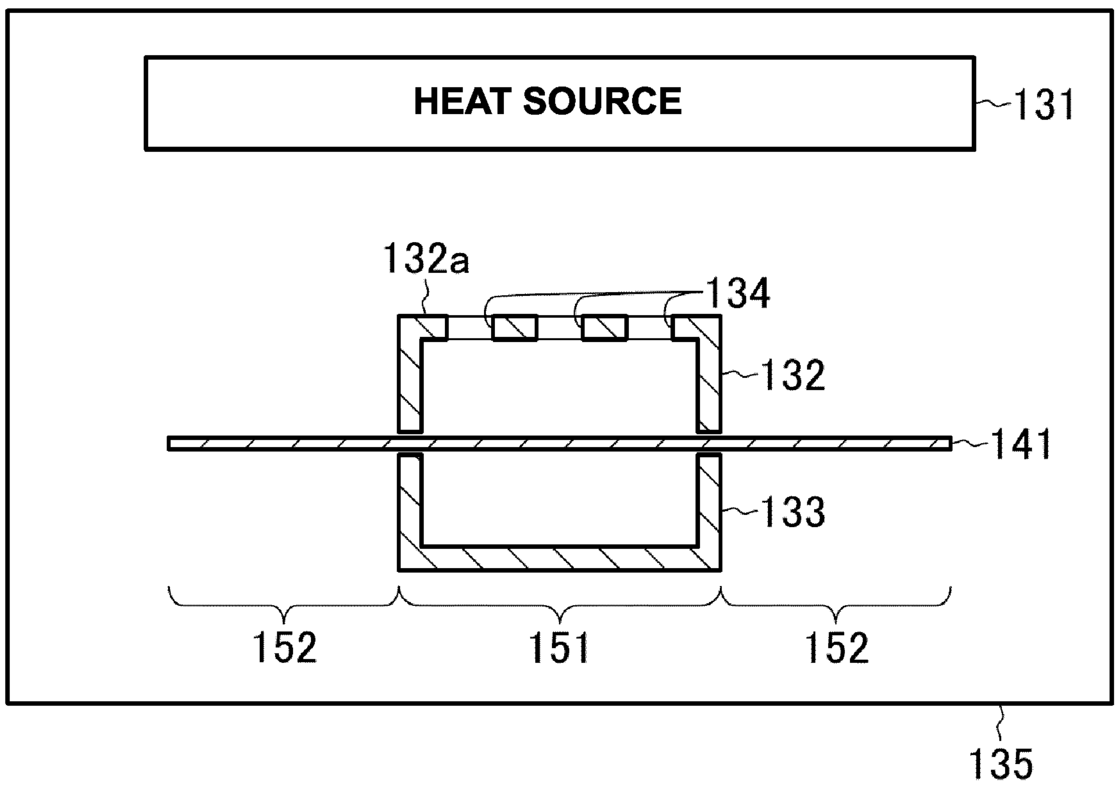

HEAT TREATMENT APPARATUS
101
COOLING PROCESSING APPARATUS
102
REHEAT TREATMENT APPARATUS
103

FIG.4


HEAT SOURCE
131
132a
134
132
141
133
152
151
152
135

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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