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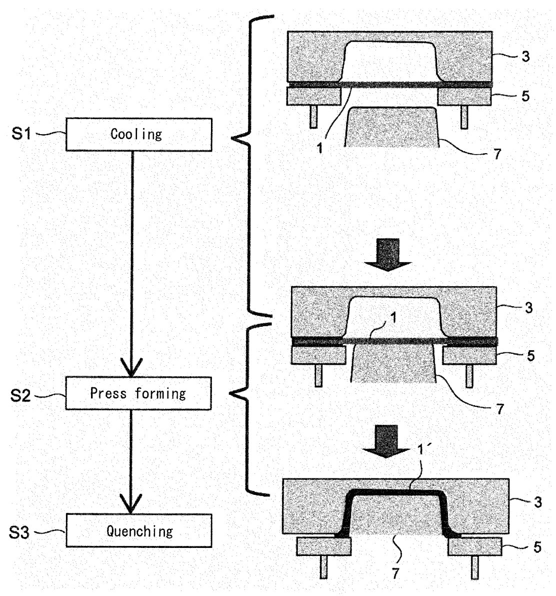
(54) METHOD FOR MANUFACTURING HOT PRESS FORMING PART AND HOT PRESS FORMING PART

(57) In manufacturing a hot press forming part by hot pressing, using a tool of press forming, a coated steel sheet that is obtained by forming a Zn-Ni coating layer on a surface of a steel sheet, the tool of press forming having a die, a blank holder, and a punch,
edges of the coated steel sheet heated to a temperature range of Ac_3 transformation temperature to 1000 °C are cooled with the edges squeezed between the die and the blank holder to a temperature of 550 °C or lower and 400 °C or higher at a cooling rate of 100 °C/s or higher,
press forming is performed so that the press forming is started when the edges reach a temperature of 550 °C or lower and 400 °C or higher, and
after the press forming, a formed body is quenched with the formed body held at the press bottom dead center while being squeezed by the tool of press forming.

FIG. 1



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Description

TECHNICAL FIELD

[0001] This disclosure relates to a hot press forming part and a method of manufacturing the same. The disclosure particularly relates to a method for manufacturing a hot press forming part from a coated steel sheet wherein, while press forming the coated steel sheet heated beforehand into a predetermined shape, the steel sheet is simultaneously quenched to attain a predetermined strength (such that the tensile strength is at least 1180 MPa grade), and a hot press forming part manufactured by the same.

BACKGROUND

[0002] In recent years, strengthening and sheet metal thinning of automotive parts have been required. As the thin steel sheets (hereinafter referred to as "steel sheets") used have higher strength, press formability is deteriorated, and forming the steel sheets into the desired part shape is more difficult.
The following technique is known to solve this problem: while hot press forming a blank sheet heated to high temperature into a desired shape using a tool of press forming, the steel sheet is quenched in the die by heat extraction, thus enhancing the hardness of the hot press formed part.
For example, GB1490535A (PTL 1) proposes a technique in which, when manufacturing a part of a predetermined shape by hot pressing a blank sheet (steel sheet) heated to an austenite single phase region of about 900 °C, the blank sheet is quenched in a tool of press forming simultaneously with the hot press forming, thus enhancing the strength of the part.
[0003] However, the technique proposed in PTL 1 has a problem in that, when heating the steel sheet to high temperature of about 900 °C before the pressing, oxide scale (iron oxide) forms on the surface of the steel sheet, and the oxide scale peels during the hot press forming and damages the die or the surface of the hot press formed part. Besides, the oxide scale remaining on the surface of the part causes poor appearance and lower coating adhesion. Accordingly, the oxide scale on the surface of the part is typically removed by a process such as pickling or shot blasting. Such a process, however, causes lower productivity. Furthermore, while suspension parts of vehicles, automotive body parts, and the like are also required to have excellent corrosion resistance, the corrosion resistance of the hot press formed part by the technique proposed in PTL 1 is insufficient because a rust preventive film such as a coating layer is not provided on the blank sheet.
[0004] For these reasons, there is demand for hot press forming techniques that can suppress the generation of oxide scale during heating before hot press forming and also improve the corrosion resistance of the hot press formed part. To meet this demand, coated steel sheets having films such as coating layers on their surfaces, hot press forming methods using coated steel sheets, etc. are proposed.
For example, JP2001353548A (PTL 2) proposes a technique in which a steel sheet coated with Zn or a zinc-based alloy is heated to 700 °C to 1200 °C and then hot press formed to obtain a hot press formed part having a Zn-Fe-based compound or a Zn-Fe-Al-based compound on its surface. PTL 2 describes that the use of the steel sheet coated with Zn or a Zn-based alloy suppresses the oxidation of the surface of the steel sheet during heating before hot press forming, and also enables a hot press formed part having excellent corrosion resistance to be obtained.
[0005] With the technique proposed in PTL 2, the generation of oxide scale on the surface of the hot press formed part is suppressed to some extent. However, Zn in the coating layer may cause liquid metal embrittlement cracking, resulting in cracks of about 100 μm in depth in the surface layer part of the hot press formed part. Such cracks pose various problems such as a decrease in fatigue characteristics of the hot press formed part.
[0006] In view of this problem, JP201391099A (PTL 3) proposes a method in which a coated steel sheet obtained by providing a Zn-Fe-based coating layer on a surface of a steel sheet is heated to a temperature not less than Ac_1 transformation temperature of the steel sheet and not more than 950 °C and then cooled to a temperature not more than the freezing point of the coating layer, before starting the forming. PTL 3 describes that liquid metal embrittlement cracking can be suppressed by starting the forming after the coated steel sheet is cooled to the temperature not more than the freezing point of the coating layer.

CITATION LIST

Patent Literature

[0007]

PTL 1: GB1490535A
PTL 2: JP2001353548A

PTL 3: JP201391099A

SUMMARY

(Technical Problem)

[0008] It is believed that the technique proposed in PTL 3 can suppress liquid metal embrittlement cracking, i.e., cracks in the surface of the hot press formed part, which are about 100 μm in depth from the interface between the coating layer and the steel toward the inside of the steel and in which Zn is detected from its interface (such cracks referred to hereinafter as "macro-cracks"). For suppressing such macro-cracks, we studied the use of Zn-Ni alloy coating obtained by blending Zn with about 9 % to 25 % of Ni as a coating layer with high fusing point. The γ-phase in the phase equilibrium diagram of Zn-Ni alloy has a fusing point of 860 °C or higher, which is very high as compared to that a normal Zn or Zn alloy coated layer, making it possible to suppress macro-cracks under normal press conditions.
However, in addition to the macro-cracks, minute cracking which is about 30 μm or less in depth from the interface between the coating layer and the steel toward the inside of the steel and in which Zn is not detected from its interface may also occur in the surface of the hot press formed part. Such minute cracking is called "micro-cracks". Micro-cracks pass through the interface between the coating layer and the steel and reach the inside of the steel (steel sheet), adversely affecting the characteristics (fatigue characteristics, etc.) of the hot press formed part.
Macro-cracks also occur in, for example, a shoulder area of die R on the punch-contacting side which is subjected to only tensile strain while press forming of a hat-shaped section part (also referred to hereinafter as a "hat-shaped part"). On the other hand, micro-cracks do not occur in such area, but on the die-contacting side of side wall portions, which are subjected to compression (due to bending) followed by tensile strain (due to bend restoration). It is thus estimated that macro-cracks and micro-cracks are produced by different mechanism.
[0009] PTL 3 may suppress the occurrence of macro-cracks in a coated steel sheet having a Zn-Fe-based coating layer formed thereon, but is not necessarily effective for suppressing the occurrence of micro-cracks, because it does not consider potential micro-cracks occurring in a coated steel sheet having a Zn-Ni coating layer formed thereon.
Additionally, PTL 3 teaches that the coated steel sheet is press formed as a whole while being cooled to a temperature at or below the freezing point of the coating layer, without specifying the lowest temperature at which the press forming is started, leading to the problem of lower forming temperature resulting in higher strength of the steel sheet during press forming, and deteriorating the shape fixability (which is a characteristic that maintains the shape at press bottom dead center even after die release, because of little springback and the like).
[0010] It could thus be helpful to provide a method for, when manufacturing a hot press formed part by hot pressing a coated steel sheet having a Zn-Ni-based coating layer formed thereon, manufacturing a hot press forming part while preventing a reduction in the shape fixability during hot press forming and suppressing the occurrence of micro-cracks, and a hot press forming part manufactured by the same.

(Solution to Problem)

[0011] We studied means for suppressing micro-cracks (minute cracking) caused when hot press forming a Zn-based coated steel sheet.
Although the micro-crack occurrence mechanism is still unclear, press forming the Zn-based coated steel sheet at high temperature may induce minute cracking in the surface of the coated steel sheet, and such minute cracking also occurs in Zn-Ni coating. The minute cracking has a depth of about 30 μm from the interface between the coating layer and the steel (steel sheet), and passes through the interface between the coating layer and the steel (steel sheet) and reaches the inside of the steel sheet. As a result of making various research on this problem, we discovered that micro-cracks are suppressed by performing hot press forming at low temperature. Further, the effect of significantly reducing the amount of coating attached to the tool of press forming, which would be quite large to cause problems with conventional coated steel sheets for hot press forming, was obtained by setting a low temperature for press forming as mentioned above.
[0012] However, when the press forming temperature is lower, the strength of the steel sheet is higher, and accordingly the shape fixability is lower. Thus, the advantages of the hot press forming cannot be exploited.
We then conceived cooling, before performing hot press forming, only those portions of the steel sheet that are processed such that micro-cracks would occur during the press process. Then we made further research on the influence of strain during forming on the occurrence of micro-cracks, and discovered that micro-cracks are not caused by compressive deformation or bending deformation alone, but are caused at those portions when being subjected to bending-bend restoration deformation resulting from the portions being bent and stretched afterwards.
[0013] A portion of the formed part, called a side wall portion, principally undergoes such bending-bend restoration deformation. FIG. 17 shows the forming conditions. Most automotive press-formed parts are of so-called hat-like shape

such as shown by "Final shape" in FIG. 17, and are manufactured by a process such as draw forming ((a) in FIG. 17) in which press forming is performed by squeezing a steel sheet between a blank holder and a die to suppress wrinkle formation, or crush forming ((b) in FIG. 17) without using a blank holder. As illustrated in FIG. 17, in either case, a steel sheet is bent against a die, and then restored to its original shape as the punch rises to have side wall portions.

[0014] In draw forming, side wall portions are formed by those portions squeezed between the die and the blank holder prior to press forming. We further investigated the way of effectively cooling only such portions. As a result, it was discovered that it is possible to suppress defects in shape accuracy and to suppress the occurrence of micro-cracks in the side wall portions by, prior to press forming, squeezing the steel sheet between the die and the blank holder and, through heat extraction at the tool of press forming, cooling the steel sheet continuously (for 0.5 seconds to 3 seconds) until the temperature of the portions at which the steel sheet is squeezed between the die and the blank holder reaches 550 °C or lower and 400 °C or higher.

[0015] The exact mechanism behind this phenomenon in which cooling in the die and blank the holder prevented lowering shape accuracy is unclear, yet the reason may be as stated below.

For hat-shaped parts, typical defects in shape accuracy include angle change such that the angle formed by two faces across the bending ridgeline becomes large relative to the die angle, and wall camber such that the planes of the side wall portions have curvature. Both of these defects occur due to the difference of any stress distribution in the sheet thickness direction, and the higher the flow stress of the steel sheet during forming, the shape accuracy decreases. In other words, in hot pressing, as the forming temperature becomes lower, the flow stress increases during forming of the steel sheet, and the shape accuracy decreases. In this respect, by performing cooling in the tool of press forming as described above, the aforementioned angle change becomes small, because the portion of the steel sheet in contact with the punch shoulder portion at the time of press forming is not cooled during the cooling process in the die and the blank holder, and this portion is processed under high-temperature conditions. It is also believed that the side wall portions are reduced in shape accuracy since the temperature of the steel sheet during processing is decreased by cooling in the die and the blank holder. However, almost no deterioration of shape accuracy was observed over a holding time (within three seconds) when the temperature of the steel sheet is 400 °C or higher. The reason may be that at a steel plate temperature of 400 °C or higher (over a holding time of 3 seconds or less), the metallographic structure during the press forming was still austenite, and the stress that had been introduced during the press forming was eased by martensitic transformation after the forming process, causing no deterioration of shape accuracy. By contrast, it is considered that if the holding time exceeds 3 seconds, the metallographic structure will have already been transformed to martensite at the time of press forming, and wall camber will be caused by the stress introduced during the press forming.

The disclosure is based on the aforementioned discoveries. We thus provide the following.

[1] A method for manufacturing a hot press forming part by hot pressing, using a tool of press forming, a coated steel sheet that is obtained by forming a Zn-Ni coating layer on a surface of a steel sheet, the tool of press forming having a die, a blank holder, and a punch, the method comprising:

cooling edges of the coated steel sheet heated to a temperature range of Ac_3 transformation temperature to 1000 °C, with the edges squeezed between the die and the blank holder, to a temperature of 550 °C or lower and 400 °C or higher at a cooling rate of 100 °C/s or higher;
performing press forming so that the press forming is started when the edges reach a temperature of 550 °C or lower and 400 °C or higher; and
after the press forming, quenching a formed body with the formed body held at the press bottom dead center while being squeezed by the tool of press forming.

[2] The method for manufacturing a hot press forming part according to [1] above, wherein the cooling and the press forming are performed while slidably moving the die with the coated steel sheet so that slidable movement is temporarily stopped before the coated steel sheet is brought into contact with the punch, or so that slidable movement before the coated steel sheet coming into contact with the punch is slower than slidable movement during press forming after the coated steel sheet coming into contact with the punch.

[3] The method for manufacturing a hot press forming part according to [1] or [2], wherein in the press forming, the blank holder is detached from the coated steel sheet to perform crush forming without using the blank holder.

[4] The method for manufacturing a hot press forming part according to [1] or [2], wherein in the press forming, draw forming is performed with the coated steel sheet squeezed between the die and the blank holder.

[5] The method for manufacturing a hot press forming part according to any one of [1] to [4], wherein the Zn-Ni coating layer contains Ni in an amount of 9 mass% or more and 25 mass% or less.

[6] A hot press forming part manufactured by the method as recited in any one of [1] to [5].

(Advantageous Effect)

[0016] According to this disclosure, micro-cracks do not occur, and it is possible to manufacture a hot press forming part with sufficient strength and hardness as well as satisfactory shape fixability, without causing a significant increase in load of press forming.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] In the accompanying drawings:

FIG. 1 illustrates a method for manufacturing a hot press forming part according to one of the disclosed embodiments;
FIG. 2 is a first schematic diagram illustrating the relationship between metallographic structures, temperature, and cooling time;
FIG. 3 is a second schematic diagram illustrating the relationship between metallographic structure, temperature, and cooling time;
FIG. 4 illustrates a general press forming method;
FIG. 5 illustrates a cooling-time control method according to one of the disclosed embodiments;
FIG. 6 illustrates a test piece used in experiments according to one of the disclosed embodiments;
FIG. 7 is a graph illustrating experimental results according to one of the disclosed embodiments, showing the change in temperature of the test piece;
FIG. 8 is a partial enlarged view of FIG. 7, with emphasis on the horizontal axis;
FIG. 9 shows SEM (scanning electron microscope) images of side wall portions demonstrating experimental results according to one of the disclosed embodiments;
FIG. 10 is a graph illustrating experimental results according to one of the disclosed embodiments, showing the relationship between press forming start temperature and press load;
FIG. 11 is a graph illustrating experimental results according to one of the disclosed embodiments, showing the relationship between press forming start temperature and amount of mouth opening deformation;
FIG. 12 illustrates different modes of operation for cooling in the tool of press forming according to one of the disclosed embodiments;
FIG. 13 illustrates a forming method according to one of the disclosed embodiments;
FIG. 14 illustrates a press forming part to be press formed in examples;
FIG. 15 illustrates a micro-crack examined in examples;
FIG. 16 illustrates the amount of mouth opening deformation examined in examples; and
FIG. 17 illustrates the stress state during the process of press forming a forming part to have a hat-shaped cross section.

DETAILED DESCRIPTION

[0018] The method for manufacturing a hot press forming part according to one of the disclosed embodiments manufactures a hot press forming part by hot pressing, using a tool of press forming, a coated steel sheet that is obtained by forming a Zn-Ni coating layer on a surface of a steel sheet, the tool of press forming having a die, a blank holder, and a punch, the method comprising, as illustrated in FIG. 1: (S1) cooling edges of coated steel sheet 1 heated to a temperature range of Ac_3 transformation temperature to 1000 °C, with the edges squeezed between die 3 and blank holder 5, to a temperature of 550 °C or lower and 400 °C or higher at a cooling rate of 100 °C/s or higher; (S2) performing press forming so that the press forming is started using the die 3, blank holder 5, and punch 7 when the edges of the coated steel sheet 1 reach a temperature of 550 °C or lower and 400 °C or higher; and (S3) after the press forming, quenching formed body 1' with the formed body held at the press bottom dead center while being squeezed by the die 3, blank holder 5, and punch 7.
The following describes the details of the blank material of the hot press formed part, the cooling (S1), the press forming (S2), and the quenching (S3).

<Blank material of hot press formed part>

[0019] A coated steel sheet obtained by providing a Zn-Ni coating layer on a surface of the steel sheet is used as the blank material of a hot press formed part. The provision of the Zn-Ni coating layer on the surface of the steel sheet ensures the corrosion resistance of the hot press formed part.
[0020] The method of forming the Zn-Ni coating layer on the surface of the steel sheet is not particularly limited, and may be any of the methods such as hot-dip galvanizing and electro-galvanizing. The coating weight per side is preferably

10 g/m^2 or more and 90 g/m^2 or less.

[0021] The Ni content in the coating layer is preferably 9 mass% or more and 25 mass% or less. In the case of forming the Zn-Ni coating layer on the surface of the steel sheet by electro-galvanizing, a γ phase having any of the crystal structures of Ni_2Zn_{11}, $NiZn_3$, and Ni_5Zn_{21} is formed when the Ni content in the coating layer is 9 mass% or more and 25 mass% or less. The γ phase has a high fusing point, and thus is advantageous in preventing the coating layer from evaporating when heating the coated steel sheet before hot press forming. The γ phase is also advantageous in suppressing liquid metal embrittlement cracking during high-temperature hot press forming.

[0022] The coated steel sheet 1 is heated to a temperature range of Ac_3 transformation temperature to 1000 °C. If the heating temperature of the coated steel sheet 1 is below Ac_3 transformation temperature, a sufficient amount of austenite cannot be obtained during heating, leading to the presence of ferrite during press forming. As a result, sufficient strength and good shape fixability are difficult to achieve through hot press forming. When the heating temperature of the coated steel sheet 1 exceeds 1000 °C, on the other hand, the coating layer evaporates or excessive oxide generation occurs in the surface layer part, as a result of which the resistance to oxidation declines or the corrosion resistance of the hot press formed part declines. Therefore, the heating temperature is from Ac_3 transformation temperature to 1000 °C. Preferably, the heating temperature is from Ac_3 transformation temperature + 30 °C to 950 °C. The method of heating the coated steel sheet 1 is not particularly limited, and may be any of the methods such as heating in an electric furnace, an induction heating furnace, and a direct current furnace. Although not particularly limited, the thickness of the steel sheet is preferably 0.8 mm to 4.0 mm from the perspective of guaranteeing the rigidity of the press formed part and ensuring the cooling rate during cooling in the tool of press forming. More preferably, the thickness is 1.0 mm 3.0 mm.

<Cooling (S1) and press forming (S2)>

[0023] In the cooling (S1), edges of the coated steel sheet thus heated are cooled, with the edges being squeezed between the die and the blank holder, to a temperature of 550 °C or lower and 400 °C or higher at a cooling rate of 100 °C/s or higher.

[0024] Additionally, in the press forming (S2), press forming is performed so that the press forming is started when the edges of the coated steel sheet reach a temperature of 550 °C or lower and 400 °C or higher.

[0025] It is noted here that in the cooling (S1), the temperature at start of cooling, with the edges of the heated coated steel sheet 1 squeezed between the die and the blank holder, is preferably 800 °C or lower from the perspective of preventing the risk of the Zn-Ni coating layer being adhered to the tool of press forming, and preferably 670 °C or higher from the perspective of guaranteeing the strength after hot press forming.

[0026] As used herein, the edges refer to those portions of the coated steel sheet that form, after subjection to the press forming, flange portions with at least the lower portions (on the flange side) of the side wall portions of a formed body. For example, when a hat-shaped section part as illustrated in FIG. 14 is formed, such edges correspond to those portions that form, on the opposite sides of the coated steel sheet, flange portions with at least lower portions (on the flange side) of the side wall portions of a formed body; or when a cup-shaped part is formed, such edges correspond to those portions that form, on the entire circumference of the coated steel sheet, flange portions with at least lower portions (on the flange side) of the side wall portions of a formed body.

[0027] In addition, cooling in the tool of press forming using the die and the blank holder is adopted because, for example, when a hat-shaped section part is formed, the edges of the steel sheet that are squeezed between the die and the blank holder will be rapidly cooled, while other portions of the steel sheet that are in contact with the shoulder areas of the punch during the press forming will hardly be cooled, and thus can be press formed while being kept at high temperature.

Moreover, the cooling rate for cooling in the tool of press forming is set to 100 °C/s or higher because, when a forming part is press formed into a hat-shaped part, for example, this cooling rate enables the side wall portions (portions squeezed by the tool of press forming) of the press formed body to have a martensite single phase structure, and thus allows for strengthening, without increasing cost, of the side wall portions.

In the following, this will be described in detail.

FIG. 2 is a schematic diagram illustrating the relationship between metallographic structure, temperature, and cooling time. Graph (a) of FIG. 2 shows a case where the press forming start temperature is high and, after the start of press forming, the coated steel sheet is rapidly cooled by heat extraction to the tool of press forming, so as to have a martensite single phase structure.

On the other hand, if the press forming start temperature is low as shown in graph (b) of FIG. 2, ferrite and bainite are formed before the start of press forming, leading to a decrease in the strength of the press formed part after subjection to the press forming.

Thus, simply lowering of the press forming start temperature results in graph (b) of FIG. 2, whereas the present disclosure adopts the cooling step that enables rapid cooling of only edges of the coated steel sheet, with the edges squeezed between the die and the blank holder before the start of press forming, so that the side wall portions of the press formed body may have a martensite single phase structure, as shown by a curve indicated by a broken line in FIG. 3. Normally, the upper limit of the cooling rate for cooling in the tool of press forming is about 500 °C/s.

[0028] In the cooling step, the edges are cooled to 550 °C or lower because, above 550 °C, cooling becomes insufficient, causing micro-cracks after subjection to the hot press forming. In addition, the lower limit of the cooling temperature is 400 °C because, if the edges are cooled below 400 °C, the coated steel sheet 1 will be excessively cooled before subjection to the press forming, leading to deterioration in shape fixability.

[0029] We conducted experiments to examine the relationship between cooling temperature, occurrence of micro-cracks, and shape fixability in the cooling step, and the results thereof will be described below.

As the blank material, a Zn-Ni coated steel sheet having a sheet thickness of 1.6 mm that was prepared by applying Zn-12% Ni coating to both surfaces thereof with a coating weight per side of 60 g/m^2 was used. The heating temperature was 900 °C, the temperature at start of cooling in the tool of press forming was about 700 °C, the blank holding force (BHF) was 98 kN, and the bottom dead center holding time was 15 s.

[0030] In the cooling step, cooling in the tool of press forming was controlled by the time for which the blank material was held by the die 3 and the blank holder 5 before the start of press forming. Specifically, in conventional press forming as illustrated in FIG. 4, after a blank material is placed on punch 7 and blank holder 5 for press forming and before the press forming is started, the die is slidably moved at a constant high speed (12 spm [Shots Per Minute]). In contrast, in an experiment according to the disclosure as illustrated in FIG. 5, as a cooling step, coated steel sheet 1 was squeezed between die 3 and blank holder 5 and, as-is, slidably moved at a low speed (lower than 0.24 spm to 12 spm) before coming into contact with the punch, while in the subsequent press forming step after the coated steel sheet 1 coming into contact with the punch, the die was slidably moved at a high speed (12 spm) as is the case with the conventional press forming. Cooling time was controlled by controlling the slidable movement speed. In the cooling step, when the slidable movement speed is from 0.24 spm to below 12 spm, the cooling time is from 0.16 s to less than 5.8 s.

For the change in temperature of a steel sheet, as indicated by steel sheet 9 in FIG. 6, metal-sheathed thermocouple 16 of 0.5 ϕ was inserted through an edge of the steel sheet to be squeezed between the die and the blank holder, and measurement was performed twice to determine the temperature of this portion.

FIG. 7 is a graph showing the results, where the vertical axis is temperature (°C) and the horizontal axis is time (s). FIG. 8 is a graph representing a partial enlarged view of FIG. 7, with emphasis on the horizontal axis, and focusing on an area enclosed by a broken line in FIG. 7.

The change in temperature of the edge of the steel sheet caused by cooling in the tool of press forming is, as illustrated in FIG. 8, about 190 °C/s, showing that cooling in the tool of press forming enables rapid cooling of the edge of the steel sheet. Also, a radiation thermometer was used to measure the surface temperature of the steel sheet at those portions to be brought into contact with the shoulder areas of the punch during press forming. These portions showed almost no drop in temperature until they were brought into contact with the punch.

[0031] For evaluation, observations were made to: (i) determine the presence of micro-cracks by observing the cross sections of the side wall portions of the press forming part; (ii) determine the hardness of the press forming part; (iii) determine the load of press forming; and (iv) determine the shape fixability by measuring the amount of mouth opening deformation of the hat-like opening of the press forming part (the difference between the width dimension of the opening after die release following the press forming and the width of the press forming part conformed to the tool of press forming).

[0032] FIG. 9 shows SEM images of cross sections of steel sheet surface layers of side wall portions on the die side. It can be seen that no micro-cracks are observed where the cooling time in the tool of press forming is 0.60 s or more (where the press forming start temperature is 550 °C or lower). Under all conditions, Hv $\geq$ 380, proving that quench hardenability does not deteriorate.

[0033] FIG. 10 is a graph illustrating the results of load of press forming, where the vertical axis is press load (kN) and the horizontal axis is press forming start temperature (°C). As used herein, the press forming start temperature refers to the temperature of the edges of the steel sheet that are squeezed between the die and the blank holder. As can be seen from the graph of FIG. 10, press load increases with decreasing press forming start temperature due to cooling in the tool of press forming prior to press forming. However, at around 550 °C at which micro-cracks do not occur, load of press forming was as low as that of mild steel (270 D, cold draw forming), which poses no problem.

[0034] FIG. 11 is a graph illustrating the results of shape fixability, where the vertical axis is the amount of mouth opening deformation (mm) of the press forming part, and the horizontal axis is press forming start temperature (°C). As shown in the graph of FIG. 11, the amount of mouth opening deformation increases due to a decrease in the forming start temperature caused by the process of cooling in the tool of press forming prior to the press forming process, which shows a tendency such that shape fixability deteriorates accordingly. However, up to the point where the press forming start temperature is 400 °C or higher, almost no deterioration of shape fixability is observed.

[0035] As described above, in the cooling step, by cooling the edges of the heated coated steel sheet, with the edges squeezed between the die and the blank holder, to a temperature of 550 °C or lower to 400 °C or higher at a cooling rate of 100 °C/s or higher before the start of press forming, it becomes possible for the press forming part to have a sufficient strength, and it becomes possible to prevent the occurrence of micro-cracks, prevent an increase in the load of press forming, and achieve satisfactory shape fixability.

[0036] While the method for cooling the coated steel sheet 1 in the tool of press forming prior to press forming is not particularly limited, as mentioned above, cooling with the blank holder 5 is preferable because it facilitates controlling surface temperature. FIG. 12 illustrates an exemplary cooling method with blank holder 5.

In FIG. 12(a), the holding position of the blank holder 5 is set above the upper surface of the punch 7, the coated steel sheet 1 is squeezed between the die 3 and the blank holder 5, and then cooling is performed during the slidable movement of the die 3 until the coated steel sheet is brought into contact with the punch 7. At this time, the cooling time of the coated steel sheet 1 can be controlled by the slidable movement speed. After starting press forming, it is preferable for the slidable movement speed to be fast in order to prevent reduction in productivity and press formability associated with the temperature drop of the coated steel sheet 1, and it is desirable to change the slidable movement speed before press forming and during press forming depending on needs. However, with some press machines, it may be difficult to freely change the slidable movement speed as described above, and even if the slidable movement speed during press forming is the same as or slower than the movement speed before press forming, the effect of the disclosure will not be impaired as long as the cooling effect by the tool of press forming is obtained during the slidable movement.

Further, the press forming start temperature at which the press forming is started is normally controlled by the cooling time. For example, the relation between the time of cooling in the tool of press forming and the decrease in blank temperature is measured beforehand, and based on this relation, the press forming start temperature is controlled. It is also possible to dispose temperature measuring elements such as a thermocouple on the surface of the tool of press forming to directly measure the temperature of the coated steel sheet 1 and control the press forming start temperature.

Further, in order to suppress the rise in temperature of the tool of press forming during continuous press forming and reduce the variation in the cooling rate, it is also possible to perform cooling of the tool of press forming by disposing water cooling piping in the die 3 or the blank holder 5, or to use material with high thermal conductivity for the surface of the die 3 or the blank holder 5.

[0037] As shown in FIG. 12(b), it is also possible to squeeze the coated steel sheet 1 between the die 3 and the blank holder 5, and then stop the slidable movement for a certain period of time to cool the coated steel sheet 1, and then perform press forming.

Further, as shown in FIG. 12(c), pressing may be performed by setting the holding position of the blank holder 5 above the upper surface of the punch 7, squeezing the coated steel sheet 1 between the die 3 and the blank holder 5 and stopping for a certain period of time, and then performing slidable movement. In such case, the stop time and the slidable movement time until the coated steel sheet 1 and the punch 7 are brought into contact added together is the cooling time of the coated steel sheet 1 before press forming. FIG. 12(d) is an example of utilizing a pad 10. For the unformed part, it is preferable that cooling is started quickly. It is also possible to utilize the pad 10 and start cooling with the pad 10 abutted against the unformed part before press forming.

While FIG. 12(d) is an example of utilizing the pad 10 for FIG. 12(a), the pad 10 can also be utilized in a similar way for the examples of FIG. 12(b) and FIG. 12(c).

Although the press forming machine to be used is not particularly limited, when the slidable movement speed is changed in FIG. 12(a), or when control is performed in which the slidable movement is temporarily stopped as in FIG. 12(B) and FIG. 12(c), a servo-press machine needs to be used.

[0038] Further, the press forming method is not particularly limited either. Possible methods include draw forming where forming is performed with the coated steel sheet 1 squeezed between the die 3 and the blank holder 5 as shown in FIG. 13(a), or crush forming where the coated steel sheet 1 is squeezed between the die 3 and the blank holder 5 to be cooled and then forming is performed with the blank holder 5 once detached from the coated steel sheet 1 as shown in FIG. 13(b). From the perspective of suppressing micro-cracks, crush forming in which the degree of processing the sidewall portion is small is preferable.

<Quenching (S3)>

[0039] In the quenching (S3), a formed body 1' after the press forming is quenched with the formed body 1' held at the press bottom dead center while being squeezed by the tool of press forming. In order to quench the formed body after press forming, the slidable movement is stopped at the press bottom dead center after press forming. Although the stop time i.e. the holding time at the press bottom dead center differs depending on the amount of heat extraction by the tool of press forming, it is preferably 3 seconds or more. Further, although the upper limit is not particularly limited, it is preferably 20 seconds or less from the perspective of productivity.

[0040] In order to hold the formed body in the tool of press forming for a certain period of time to obtain a quenched structure, for example, a hot rolled steel sheet or cold rolled steel sheet having a chemical composition that includes (consists of), in mass%, C: 0.15 % or more and 0.50 % or less, Si: 0.05 % or more and 2.00 % or less, Mn: 0.50 % or more and 3.00 % or less, P: 0.10 % or less, S: 0.050 % or less, Al: 0.10 % or less and N: 0.010 % or less, with the balance including Fe and inevitable impurities is preferably used as the steel sheet. The reasons of limitation of each component are given below. Here, "%" indicating the content of each component is "mass%", unless otherwise stated.

C: 0.15 % or more and 0.50 % or less

[0041] C is an element that improves the strength of steel. To enhance the strength of the hot pressed part, the C content is preferably 0.15 % or more. When the C content exceeds 0.50 %, on the other hand, the weldability of the hot press formed part and the blanking workability of the raw material (steel sheet) decrease significantly. Accordingly, the C content is preferably 0.15 % or more and 0.50 % or less, and more preferably 0.20 % or more and 0.40 % or less.

Si: 0.05 % or more and 2.00 % or less

[0042] Si is an element that improves the strength of steel, as with C. To enhance the strength of the hot pressed part, the Si content is preferably 0.05 % or more. When the Si content exceeds 2.00 %, on the other hand, a surface defect called red scale increases significantly during hot rolling when manufacturing the steel sheet. Accordingly, the Si content is preferably 0.05 % or more and 2.00 % or less, and more preferably 0.10 % or more and 1.50 % or less.

Mn: 0.50 % or more and 3.00 % or less

[0043] Mn is an element that enhances the quench hardenability of steel, and is effective in suppressing the ferrite transformation of the steel sheet and improving quench hardenability in the cooling process after the hot press forming. Mn also has a function of decreasing the Ac_3 transformation temperature, and so is an element effective in lowering the heating temperature of the coated steel sheet 1 before the hot pressing. To achieve these effects, the Mn content is preferably 0.50 % or more. When the Mn content exceeds 3.00 %, on the other hand, Mn segregates and the uniformity of the characteristics of the steel sheet and hot press formed part declines. Accordingly, the Mn content is preferably 0.50 % or more and 3.00 % or less, and more preferably 0.75 % or more and 2.50 % or less.

P: 0.10 % or less

[0044] When the P content exceeds 0.10 %, P segregates to grain boundaries, and the low temperature toughness of the steel sheet and hot press formed part decreases. Accordingly, the P content is preferably 0.10 % or less, and more preferably 0.01 % or less. Excessively reducing P, however, leads to longer refining time and higher cost, and accordingly, P content is preferably 0.003 % or more.

S: 0.050 % or less

[0045] S is an element that forms a coarse sulfide by combining with Mn and causes a decrease in ductility of steel. The S content is preferably reduced as much as possible, though up to 0.050 % is allowable. Accordingly, the S content is preferably 0.050 % or less, and more preferably 0.010 % or less. Excessively reducing S, however, leads to longer refining time and higher cost, and accordingly, S content is preferably 0.001 % or more.

Al: 0.10 % or less

[0046] When the Al content exceeds 0.10 %, oxide inclusions in steel increase, and the ductility of steel declines. Accordingly, the Al content is preferably 0.10 % or less, and more preferably 0.07 % or less. Meanwhile, Al functions as a deoxidizer, and so the Al content is preferably 0.01 % or more to improve the cleanliness of steel.

N: 0.010 % or less

[0047] When the N content exceeds 0.010 %, nitrides such as AlN form in the steel sheet, which causes lower formability during hot pressing. Accordingly, the N content is preferably 0.010 % or less, and more preferably 0.005 % or less. Excessively reducing N, however, leads to longer refining time and higher cost, and accordingly, N content is preferably 0.001 % or more.

[0048] These are the preferable basic components of the steel sheet. The steel sheet may further include the following elements when necessary.

At least one type selected from the group consisting of Cr: 0.01 % or more and 0.50 % or less, V: 0.01 % or more and 0.50 % or less, Mo: 0.01 % or more and 0.50 % or less, and Ni: 0.01 % or more and 0.50 % or less Cr, V, Mo, and Ni are each an element effective in enhancing the quench hardenability of steel. This effect is achieved when the content is 0.01 % or more for each of the elements. When the content exceeds 0.50 % for each of Cr, V, Mo, and Ni, however, the effect saturates and the cost increases. Accordingly, in the case where at least one type of Cr, V, Mo, and Ni is included, the content is preferably 0.01 % or more and 0.50 % or less, and more preferably 0.10 % or more and 0.40 % or less.

Ti: 0.01 % or more and 0.20 % or less

[0049] Ti is effective for strengthening steel. The strengthening effect of Ti is achieved when the content is 0.01 % or more. Ti within the specified range can be used to strengthen steel without any problem. When the Ti content exceeds 0.20 %, however, the effect saturates and the cost increases. Accordingly, in the case where Ti is included, the content is preferably 0.01 % or more and 0.20 % or less, and more preferably 0.01 % or more and 0.05 % or less.

Nb: 0.01 % or more and 0.10 % or less

[0050] Nb is also effective for strengthening steel. The strengthening effect of Nb is achieved when the content is 0.01 % or more. Nb within the specified range can be used to strengthen steel without any problem. When the Nb content exceeds 0.10 %, however, the effect saturates and the cost increases. Accordingly, in the case where Nb is included, the content is preferably 0.01 % or more and 0.10 % or less, and more preferably 0.01 % or more and 0.05 % or less.

B: 0.0002 % or more and 0.0050 % or less

[0051] B is an element that enhances the quench hardenability of steel, and is effective in suppressing the generation of ferrite from austenite grain boundaries and obtaining a quenched structure when cooling the steel sheet after the hot press forming. This effect is achieved when the B content is 0.0002 % or more. When the B content exceeds 0.0050 %, however, the effect saturates and the cost increases. Accordingly, in the case where B is included, the content is preferably 0.0002 % or more and 0.0050 % or less, and more preferably 0.0005 % or more and 0.0030 % or less.

Sb: 0.003 % or more and 0.030 % or less

[0052] Sb has an effect of suppressing a decarburized layer generated in the surface layer part of the steel sheet from when a steel sheet is heated before the hot press forming to when the steel sheet is cooled by the process of hot press forming. To achieve this effect, the Sb content is preferably 0.003 % or more. When the Sb content exceeds 0.030 %, however, the rolling load increases during steel sheet manufacture, which may cause lower productivity. Accordingly, in the case where Sb is included, the content is preferably 0.003 % or more and 0.030 % or less, and more preferably 0.005 % or more and 0.010 % or less.

[0053] The components (balance) other than the above components are Fe and inevitable impurities.

[0054] The manufacturing condition of the coated steel sheet 1 used as the raw material of the hot press formed part is not particularly limited. The manufacturing condition of the steel sheet is not particularly limited. For example, a hot rolled steel sheet (pickled steel sheet) having a predetermined chemical composition or a cold rolled steel sheet obtained by subjecting the hot rolled sheet to cold rolling may be used as the steel sheet.

The condition when forming the Zn-Ni coating layer on the surface of the steel sheet to obtain the coated steel sheet 1 is not particularly limited. In the case where a hot rolled steel sheet (pickled steel sheet) is used as the steel sheet, the coated steel sheet 1 may be obtained by subjecting the hot rolled steel sheet (pickled steel sheet) to Zn-Ni coating treatment.

[0055] In the case where a cold rolled steel sheet is used as the steel sheet, the coated steel sheet 1 may be obtained by subjecting the cold rolled steel sheet to Zn-Ni coating treatment after cold rolling.

[0056] In the case of forming a Zn-Ni coating layer on the surface of the steel sheet, for example, the Zn-Ni coating layer may be formed by cleaning and pickling the steel sheet, and then subjecting the steel sheet to electroplating treatment with a current density of 10 A/dm^2 or more and 150 A/dm^2 or less in a plating bath having a pH of 1.0 or more and 3.0 or less and a bath temperature of 30 °C or more and 70 °C or less and containing: 100 g/L or more and 400 g/L or less nickel sulfate hexahydrate; and 10 g/L or more and 400 g/L or less zinc sulfate heptahydrate. In the case where a cold rolled steel sheet is used as the steel sheet, the cold rolled steel sheet may be subjected to annealing treatment before the cleaning and pickling. The Ni content in the coating layer may be set to a desired Ni content (for example, 9 mass% or more and 25 mass% or less) by appropriately adjusting the concentration of the zinc sulfate heptahydrate or the current density within the above-mentioned range. The coating weight of the Zn-Ni coating layer may be set to a desired coating weight (for example, 10 g/m^2 or more and 90 g/m^2 or less per side) by adjusting the current passage time.

EXAMPLES

[0057] Experiments were performed to confirm the effect of the method for manufacturing a hot press forming part described herein. These experiments will be described below.

Steels having the compositions shown in Table 1 were each smelted into a casting slab, and the casting slab was heated to 1200 °C, hot rolled at a finisher delivery temperature of 870 °C, and coiled at 600 °C to obtain a hot rolled steel sheet.

[0058] [Table 1]

Table 1

Steel	Chemical composition (mass%)															Ac_3 transformation temperature (°C)
	C	Si	Mn	P	S	Al	N	Cr	V	Mo	Ni	Ti	Nb	B	Sb	
A	0.21	0.23	1.51	0.02	0.003	0.03	0.004	-	-	-	-	-	-	-	-	808
B	0.32	0.64	1.15	0.01	0.005	0.02	0.003	-	-	-	-	-	-	-	-	804
C	0.18	1.30	2.30	0.03	0.007	0.04	0.004	-	-	-	-	-	-	-	-	850
D	0.25	0.12	0.75	0.02	0.003	0.03	0.003	-	-	-	-	-	-	-	-	817
E	0.23	0.35	0.82	0.02	0.004	0.03	0.005	0.40	-	-	-	-	-	-	-	830
F	0.26	0.15	1.75	0.01	0.002	0.04	0.002	-	-	-	0.15	0.04	0.02	-	-	784
G	0.20	0.20	1.43	0.02	0.003	0.02	0.003	-	0.20	-	-	0.02	-	0.0025	-	807
H	0.25	0.50	1.30	0.01	0.002	0.03	0.004	-	-	0.30	-	-	-	-	0.007	811

[0059] The hot rolled steel sheet was then pickled and cold rolled with a rolling reduction of 50 %, to obtain a cold rolled steel sheet with a thickness of 1.6 mm. The Ac_3 transformation temperature in Table 1 was calculated according to the following Formula (1) (see William C. Leslie, The Physical Metallurgy of Steels, translation supervised by Nariyasu Kouda, translated by Hiroshi Kumai and Tatsuhiko Noda, Maruzen Co., Ltd., 1985, p. 273).

$$Ac_3\ (°C) = 910 - 203\sqrt{[C]} + 44.7 \times [Si] - 30 \times [Mn] + 700 \times [P] + 400 \times [Al] \ldots (1)$$

where [C], [Si], [Mn], [P], and [Al] are the contents (mass%) in steel of the respective elements (C, Si, Mn, P, and Al). Using the cold rolled steel sheet obtained as described above as a steel sheet, each of a pure Zn coating layer, a Zn-Fe coating layer, and a Zn-Ni coating layer was formed on the surface of the steel sheet to obtain a coated steel sheet 1. Each coating layer was formed under the following condition.

<Pure Zn coating layer>

[0060] The cold rolled steel sheet was passed through a continuous galvanizing line, heated to a temperature range of 800 °C or more and 900 °C or less at a heating rate of 10 °C/s, and held in the temperature range for 10 s or more and 120 s or less. After this, the cold rolled steel sheet was cooled to a temperature range of 460 °C or more and 500 °C or less at a cooling rate of 15 °C/s, and immersed into a galvanizing bath of 450 °C to form a Zn coating layer. The coating weight of the Zn coating layer was adjusted to a predetermined coating weight by the gas wiping method.

<Zn-Fe coating layer>

[0061] The cold rolled steel sheet was passed through a continuous galvanizing line, heated to a temperature range of 800 °C or more and 900 °C or less at a heating rate of 10 °C/s, and held in the temperature range for 10 s or more and 120 s or less. After this, the cold rolled steel sheet was cooled to a temperature range of 460 °C or more and 500 °C or less at a cooling rate of 15 °C/s, and immersed into a galvanizing bath of 450 °C to form a Zn coating layer. The coating weight of the Zn coating layer was adjusted to a predetermined coating weight by the gas wiping method. Immediately after adjusting the Zn coating layer to the predetermined coating weight by the gas wiping method, the cold rolled steel sheet was heated to 500 °C to 550 °C in an alloying furnace and held for 5 s to 60 s, to form a Zn-Fe coating layer. The Fe content in the coating layer was set to a predetermined content by changing the heating temperature in the alloying furnace or the holding time at the heating temperature within the above-mentioned range.

<Zn-Ni coating layer>

[0062] The cold rolled steel sheet was passed through a continuous annealing line, heated to a temperature range of 800 °C or more and 900 °C or less at a heating rate of 10 °C/s, and held in the temperature range for 10 s or more and 120 s or less. After this, the cold rolled steel sheet was cooled to a temperature range of 500 °C or less at a cooling rate of 15 °C/s. The cold rolled steel sheet was then cleaned and pickled, and subjected to electroplating treatment of applying current for 10 s to 100 s with a current density of 30 A/dm^2 to 100 A/dm^2 in a plating bath having a pH of 1.3 and a bath temperature of 50 °C and containing: 200 g/L nickel sulfate hexahydrate; and 10 g/L to 300 g/L zinc sulfate heptahydrate, thus forming a Zn-Ni coating layer. The Ni content in the coating layer was set to a predetermined content by appropriately adjusting the concentration of the zinc sulfate heptahydrate or the current density within the above-mentioned range. The coating weight of the Zn-Ni coating layer was set to a predetermined coating weight by appropriately adjusting the current passage time in the above-mentioned range.

[0063] A blank sheet of 200 mm x 400 mm was punched from each coated steel sheet 1 obtained as described above, and heated in an electric furnace having an air atmosphere. The blank sheet was set on a tool of press forming (material: SKD61), and then cooling and press forming was performed using the tool of press forming. After this, the blank sheet was quenched in the tool of press forming and released from the tool of press forming, thus manufacturing a press formed part with a hat-shaped cross section illustrated in FIG. 14. Regarding the shape of the tool of press forming, a tool of press forming with a shoulder area of punch R: 6 mm and a shoulder area of die R: 6 mm was used, and the press forming was performed with a punch-die clearance of 1.6 mm. Cooling in the tool of press forming prior to press forming was performed by squeezing the blank sheet between the die 3 and the blank holder 5. Press forming was performed by draw forming where forming is performed while applying a blank holder force of 98 kN, and crush forming where, after the cooling prior to press forming, the blank holder 5 is removed and forming is performed without the blank holder. As indicated in FIGs. 7 and 8, the relation between the time of cooling in the tool of press forming and the decrease in blank temperature was measured beforehand, and based on this relation, the press forming start temperature was obtained using time of cooling in the tool of press forming until press forming.

[0064] The type of coating layer, heating condition, cooling condition and press forming condition are shown in Table 2.

[Table 2]

[0065]

Table 2

Steel	Coating layer		Heating condition		Cooling Condition				Press forming condition			Evaluation					Remarks
	Type	Coating weight (g/m²)	Heating temp. (°C)	Holding time (s)	Cooling method	Cooling start temp. (°C)	Cooling time (s)	Cooling rate (°C/s)	Press forming method	Press forming start temp. (°C)	Press bottom dead center holding time (s)	Surface of steel sheet: Presence or absence of crack	Surface of steel sheet: Average crack depth (μm)	Amount of mouth opening deformation (mm)	Hardness (Hv)	Tensile strength (MPa)	
A	Zn-12Ni%	65	900	5	Cooling in tool of press forming	720	0.8	190	Crush	530	12	Absence	-	0	465	1520	Example 1
	Zn-10Ni%	40	870	90	Cooling in tool of press forming	690	1.5	147	Draw	470	15	Absence	-	0	459	1515	Example 2
	Zn-22Ni%	45	880	30	Cooling in tool of press forming	750	1.9	158	Draw	450	10	Absence	-	0	471	1550	Example 3
	Zn-15Ni%	50	910	10	Cooling in tool of press forming	670	0.7	229	Crush	510	8	Absence	-	0	460	1520	Example 4
	Zn-9%Ni	60	900	15	Cooling in tool of press forming	720	2.5	116	Draw	430	10	Absence	-	0	463	1530	Example 5
	Zn-12Ni%	30	850	20	Cooling in tool of press forming	780	1.2	233	Crush	500	15	Absence	-	0	482	1570	Example 6
	Zn-12Ni%	40	880	5	Cooling in tool of press forming	660	0.5	240	Crush	540	12	Absence	-	0	458	1505	Example 7
	Zn-12Ni%	65	900	60	Cooling in tool of press forming	700	0	-	Crush	700	10	Presence	7	0	463	1500	Comparative Example 1
	Zn-10Ni%	40	920	90	Cooling in tool of press forming	680	0.3	233	Draw	610	15	Presence	12	0	452	1480	Comparative Example 2
	Zn-22Ni%	45	880	30	Cooling in tool of press forming	720	3.5	106	Draw	350	12	Absence	-	8	481	1560	Comparative Example 3
	Zn-15Ni%	50	900	120	Cooling in tool of press forming	740	5.0	102	Crush	230	8	Absence	-	10	485	1570	Comparative Example 4
	Zn-12Ni%	65	900	5	Gas cooling	680	1.2	25	Draw	650	15	Presence	14	0	452	1490	Comparative Example 5
	Zn-12Ni%	65	880	15	Gas cooling	660	2.8	21	Crush	600	10	Presence	8	2	378	1160	Comparative Example 6
	Zn-10%Ni	50	910	5	Gas cooling	700	10.0	17	Crush	530	10	Absence	-	3	341	1080	Comparative Example 7
	Zn	45	890	10	Cooling in tool of press forming	710	1.0	170	Crush	540	15	Presence	35	0	465	1505	Comparative Example 8
	Zn-10Fe%	50	900	5	Cooling in tool of press forming	730	1.2	167	Draw	530	15	Presence	5	0	473	1550	Comparative Example 9
B	Zn-13Ni%	35	880	60	Cooling in tool of press forming	730	1.2	208	Crush	480	10	Absence	-	0	557	1720	Example 8
C	Zn-11Ni%	50	900	90	Cooling in tool of press forming	710	1.8	161	Draw	420	3	Absence	-	0	425	1330	Example 9
D	Zn-10Ni%	60	870	30	Cooling in tool of press forming	690	1.0	190	Crush	500	15	Absence	-	0	493	1580	Example 10
E	Zn-12Ni%	40	890	60	Cooling in tool of press forming	710	1.5	140	Crush	500	10	Absence	-	0	475	1540	Example 11
F	Zn-10Ni%	60	870	30	Cooling in tool of press forming	690	1.8	117	Crush	480	12	Absence	-	0	497	1590	Example 12
G	Zn-13Ni%	50	910	30	Cooling in tool of press forming	740	1.0	210	Draw	530	15	Absence	-	0	460	1500	Example 13
H	Zn-15Ni%	30	870	10	Cooling in tool of press forming	700	1.1	182	Crush	500	7	Absence	-	0	492	1580	Example 14

[0066] A sample was collected from the side wall portion of each obtained press formed part with a hat-shaped cross section, and the section of its surface was observed using a scanning electron microscope (SEM) with 1000 magnification for 10 fields per sample, to examine the presence or absence of micro-cracks (minute cracking in the surface of the sample, which passes through the interface between the coating layer and the steel sheet and reaches the inside of the steel sheet) and the average depth of micro-cracks. The average depth of micro-cracks was calculated by averaging the micro-crack depths of any 20 micro-cracks. The micro-crack depth mentioned here means the length (length h in FIG. 15) of a micro-crack 11 measured from the interface between a coating layer 13 and a steel sheet 15 toward the center in the thickness direction, as illustrated in FIG. 15. In the case where the number of micro-cracks observed was less than 20, the average depth of the depths of all observed micro-cracks was used.

Regarding the shape accuracy of the obtained press formed part, the difference between the width W of the press forming part after die release and the width W_0 of the press forming part conformed to the tool of press forming of the hat-shaped section part shown in FIG. 16 ($W - W_0$) was evaluated as the amount of mouth opening deformation.

Furthermore, a sample for hardness measurement was collected from the side wall portion of each obtained press formed part. The hardness of the cross section of the sample was measured using a micro-Vickers hardness meter. A test was conducted with a test load of 9.8 N at 5 points in the center position in the thickness direction, and the average value thereof was used as the hardness of the samples. Here, the target hardness is 380 Hv or more.

In addition, a JIS No. 13 B tensile test piece was collected from the side wall portion of each obtained press formed part. A tensile test was conducted using the collected test piece according to JIS G 0567 (1998), to measure the tensile strength at room temperature (22 ± 5 °C). The tensile test was conducted at a crosshead speed of 10 mm/min.

These results are also shown in Table 2.

[0067] In examples 1 to 12, the type of coating layer (Zn-Ni coating layer), cooling method (cooling in tool of press forming), cooling rate (appropriate range: 100 °C/s or more), and press forming start temperature (appropriate range: 400 °C to 550 °C) are all within the range of the disclosure.

In each of the samples after pressing of examples 1 to 12, micro-cracks were not generated and the amount of mouth opening deformation was 0 mm. From these results, it can be seen that, with the press forming method described herein, it is possible to suppress the occurrence of micro-cracks while ensuring good shape fixability. Further, in all of examples 1 to 12, the hardness was 380 Hv or more, and tensile strength was 1180 MPa or more.

[0068] In comparative example 1, the type of coating layer is a Zn-Ni coating layer. However, forming was performed without performing cooling in the tool of press forming. Further, in comparative examples 2 to 4, the type of coating layer is a Zn-Ni coating layer. However, the press forming start temperatures for each of comparative examples 2 to 4 were out of the appropriate range. The press forming start temperature for comparative example 2 was 610 °C which is higher than the appropriate range, and the press forming start temperatures for comparative examples 3 and 4 were 350 °C and 230 °C which are lower than the appropriate range.

[0069] As for the samples after pressing of comparative examples 1 and 2, the amount of mouth opening deformation is 0 mm. However, micro-cracks are generated. From these results, it can be seen that, when the press forming start temperature of the steel sheet is higher than 550 °C, micro-cracks are generated.

In comparative examples 3 and 4, micro-cracks are not generated. However, the amount of mouth opening deformation is 8 mm to 10 mm. From these results, it can be seen that when the cooling time is too long and the forming start temperature of the steel sheet becomes lower than 400 °C, the strength of the steel sheet increases, and thus the shape fixability decreases.

[0070] In comparative examples 5 to 7, the type of coating layer is a Zn-Ni coating layer. However, the cooling method is gas cooling and the cooling rate is not 100 °C/s or more. Therefore, in comparative examples 5 and 6, the press forming start temperatures of the steel sheet are out of the appropriate range (over 550 °C), and micro-cracks are generated. Further, in comparative example 7, the press forming start temperature of the steel sheet was 530 °C which is within the appropriate range. However, the amount of mouth opening deformation was 3 mm, and shape fixability was decreased.

This is because, since the cooling method was gas cooling, the cooling rate was slow and the metallographic structure during the press forming was ferrite or bainite instead of an austenite single phase, and therefore the martensitic transformation after forming was decreased, and the stress introduced during the forming was hardly eased. As a result, it is believed that, angle change such that the angle formed by two faces across the bending ridgeline becomes large relative to the die angle occurred.

Further, in comparative examples 6 and 7, quenching was performed after mild cooling to a certain degree by gas cooling and pressing. Therefore, the hardness of the samples after pressing was decreased.

[0071] In comparative examples 8 and 9, the cooling method (cooling in tool of press forming), cooling rate (167 °C/s, 170 °C/s), and press forming start temperature (530 °C to 540 °C) are appropriate. However, the type of coating layer is different. Specifically, comparative example 8 is a coating layer of only Zn, and comparative example 9 is a coating layer of Zn-Fe, and therefore micro-cracks are generated in the samples after pressing.

REFERENCE SIGNS LIST

[0072]

1	Coated steel sheet
1'	Formed body
3	Die
5	Blank holder
7	Punch
9	Steel sheet
10	Pad
11	Micro-crack
13	Coating layer
15	Steel sheet
16	Thermocouple

Claims

1. A method for manufacturing a hot press forming part by hot pressing, using a tool of press forming, a coated steel sheet that is obtained by forming a Zn-Ni coating layer on a surface of a steel sheet, the tool of press forming having a die, a blank holder, and a punch, the method comprising:

cooling edges of the coated steel sheet heated to a temperature range of Ac_3 transformation temperature to 1000 °C, with the edges squeezed between the die and the blank holder, to a temperature of 550 °C or lower and 400 °C or higher at a cooling rate of 100 °C/s or higher;
performing press forming so that the press forming is started when the edges reach a temperature of 550 °C or lower and 400 °C or higher; and
after the press forming, quenching a formed body with the formed body held at the press bottom dead center while being squeezed by the tool of press forming.

2. The method for manufacturing a hot press forming part according to claim 1, wherein the cooling and the press forming are performed while slidably moving the die with the coated steel sheet so that slidable movement is temporarily stopped before the coated steel sheet is brought into contact with the punch, or so that slidable movement before the coated steel sheet coming into contact with the punch is slower than slidable movement during press forming after the coated steel sheet coming into contact with the punch.

3. The method for manufacturing a hot press forming part according to claim 1 or 2, wherein in the press forming, the blank holder is detached from the coated steel sheet to perform crush forming without using the blank holder.

4. The method for manufacturing a hot press forming part according to claim 1 or 2, wherein in the press forming, draw forming is performed with the coated steel sheet squeezed between the die and the blank holder.

5. The method for manufacturing a hot press forming part according to any one of claims 1 to 4, wherein the Zn-Ni coating layer contains Ni in an amount of 9 mass% or more and 25 mass% or less.

6. A hot press forming part manufactured by the method as recited in any one of claims 1 to 5.

FIG. 1

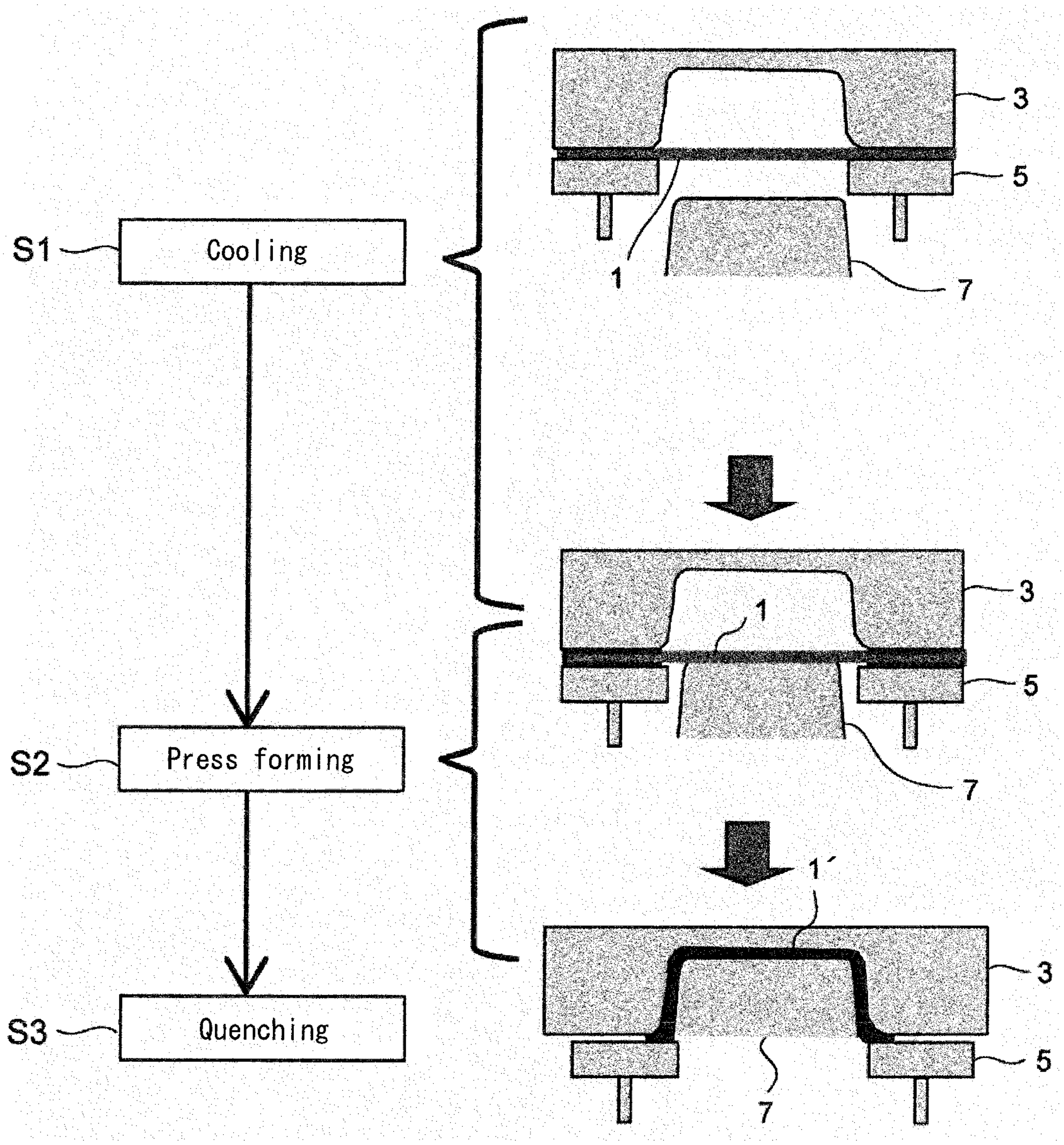


FIG. 2A

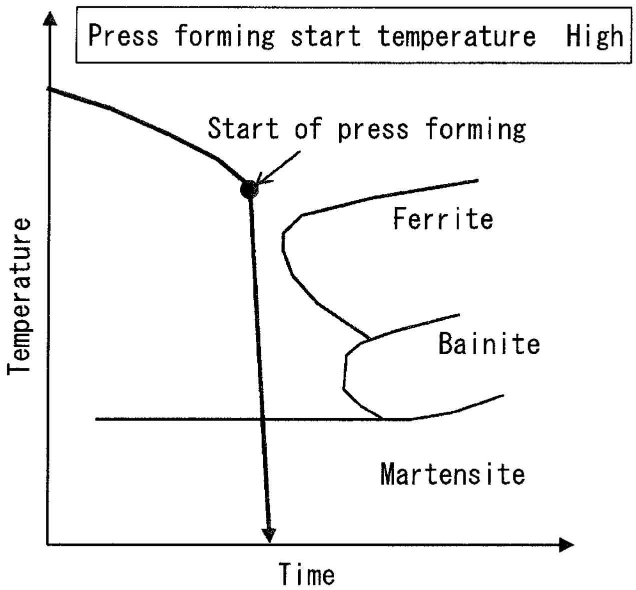

Press forming start temperature High
Start of press forming
Ferrite
Bainite
Martensite
Temperature
Time

FIG. 2B

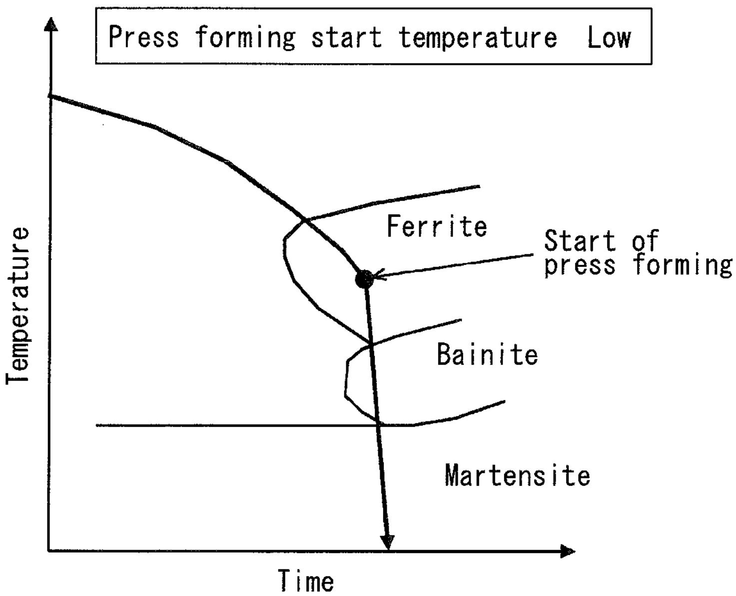

Press forming start temperature Low
Ferrite
Start of press forming
Bainite
Martensite
Temperature
Time

FIG. 3

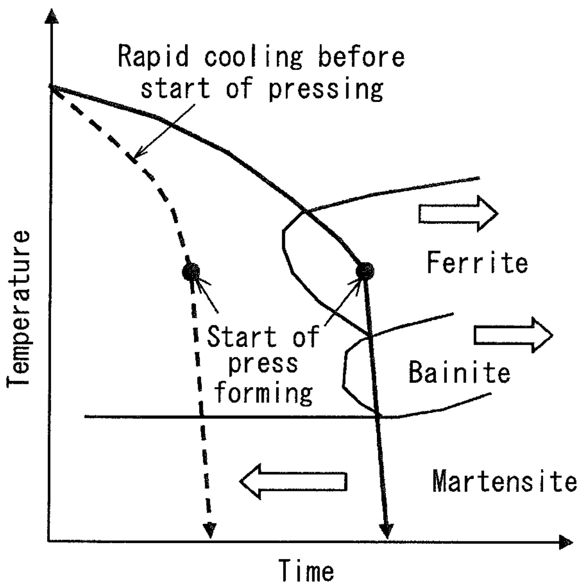

Rapid cooling before start of pressing
Temperature
Ferrite
Bainite
Start of press forming
Martensite
Time

FIG. 4

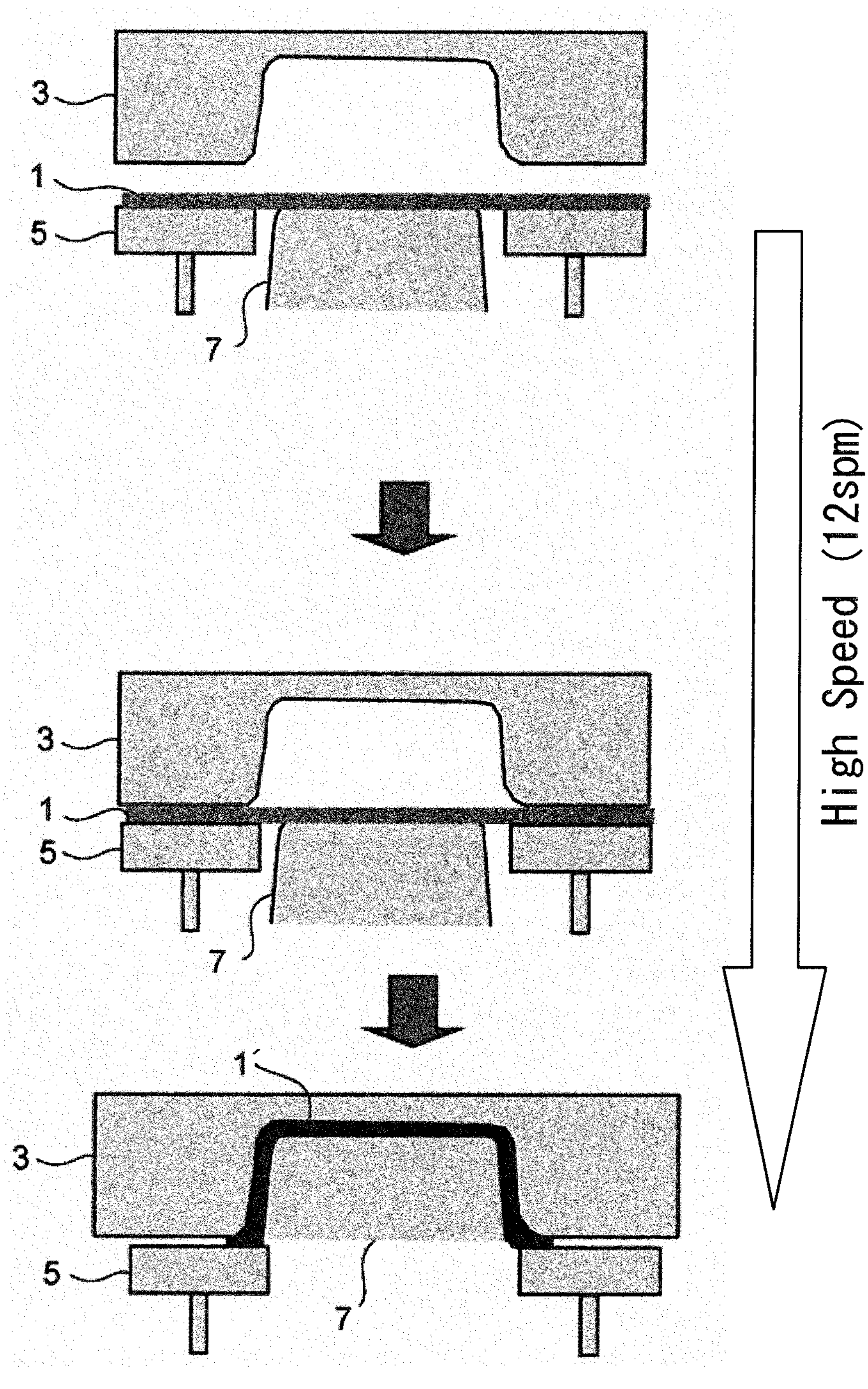


FIG. 5

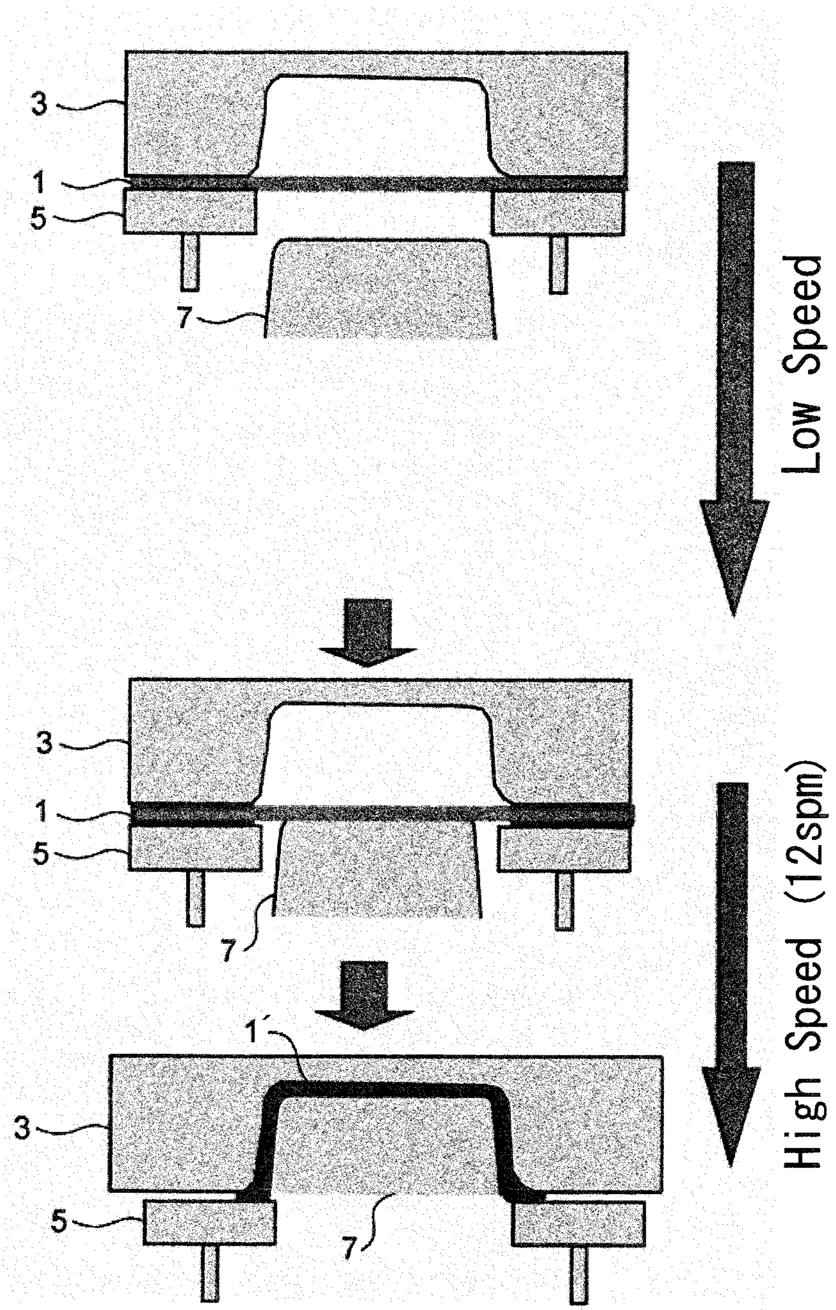


FIG. 6

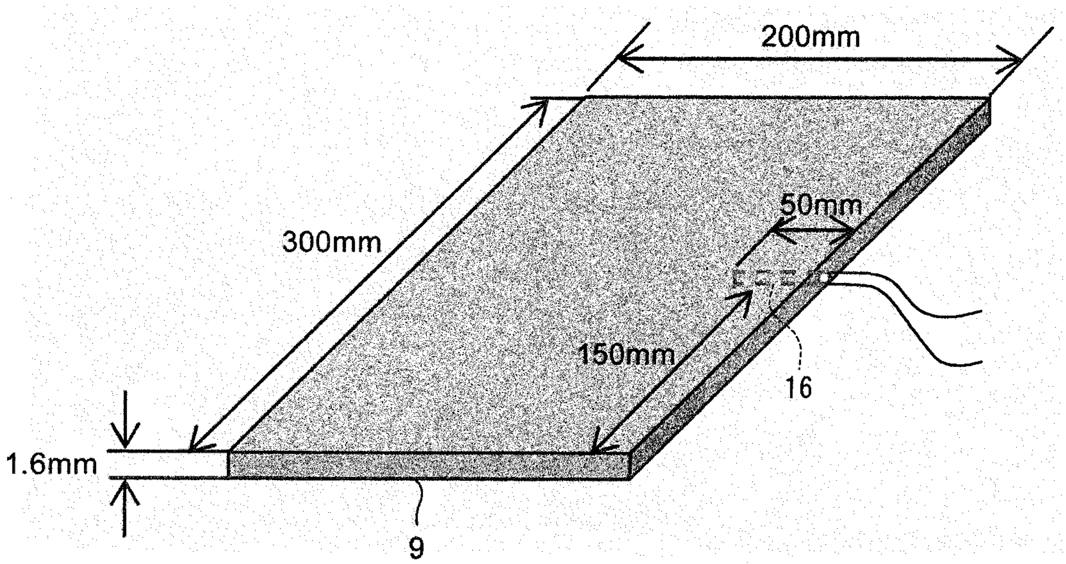


FIG. 7

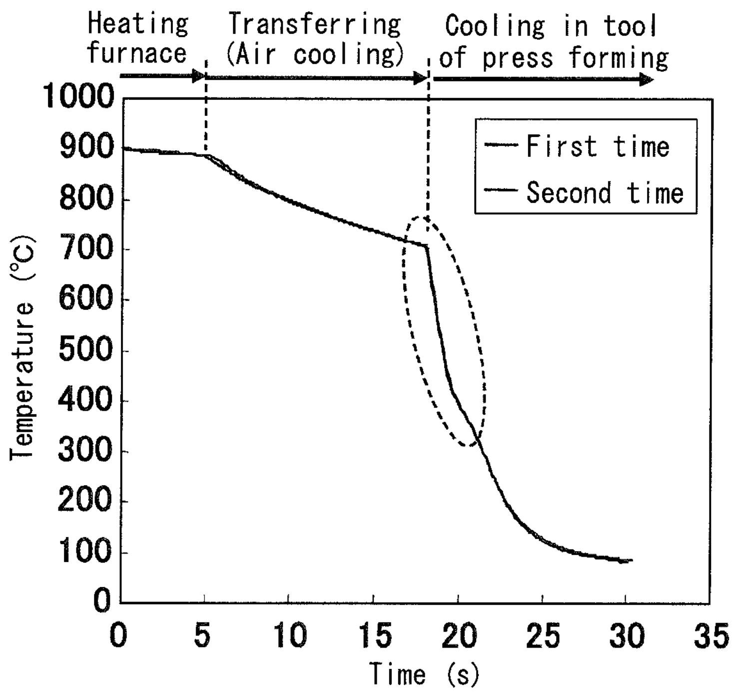

Heating furnace
Transferring (Air cooling)
Cooling in tool of press forming
First time
Second time
Temperature (°C)
1000
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
35
Time (s)

FIG. 8

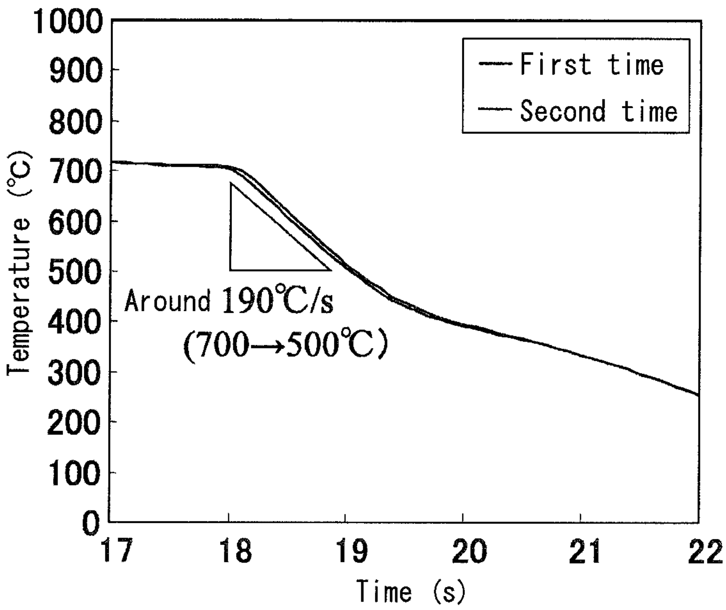

1000
900
800
700
600
500
400
300
200
100
0
Temperature (°C)
First time
Second time
Around 190℃/s
(700→500℃)
17
18
19
20
21
22
Time (s)

FIG. 9A

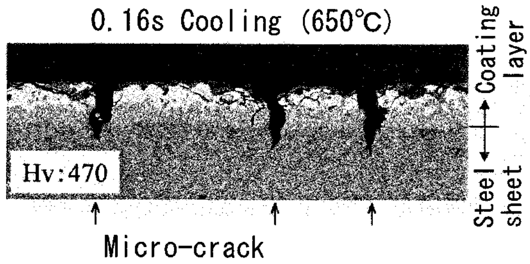


FIG. 9B

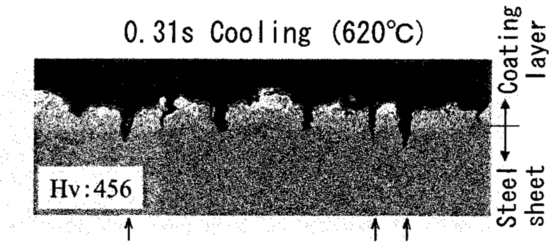


FIG. 9C

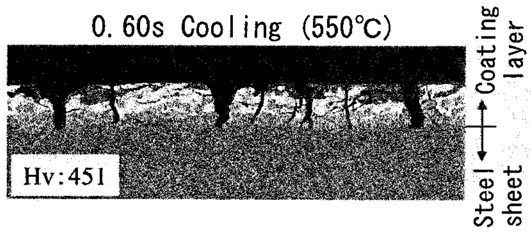


FIG. 9D

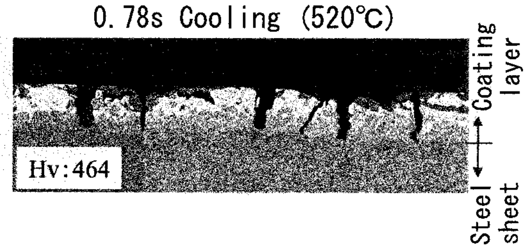


FIG. 9E

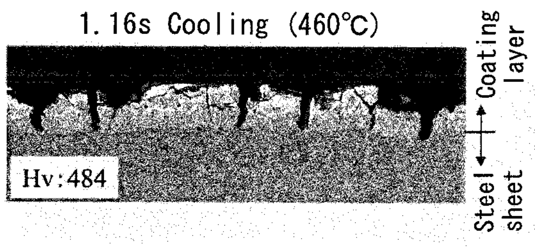


FIG. 9F

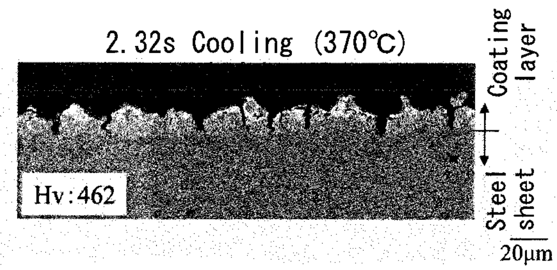


FIG. 9G

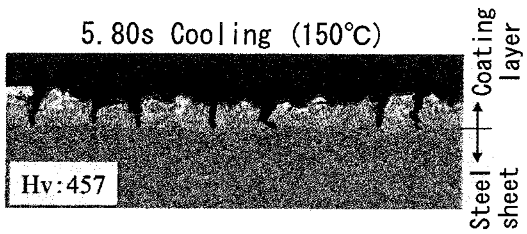


FIG. 10

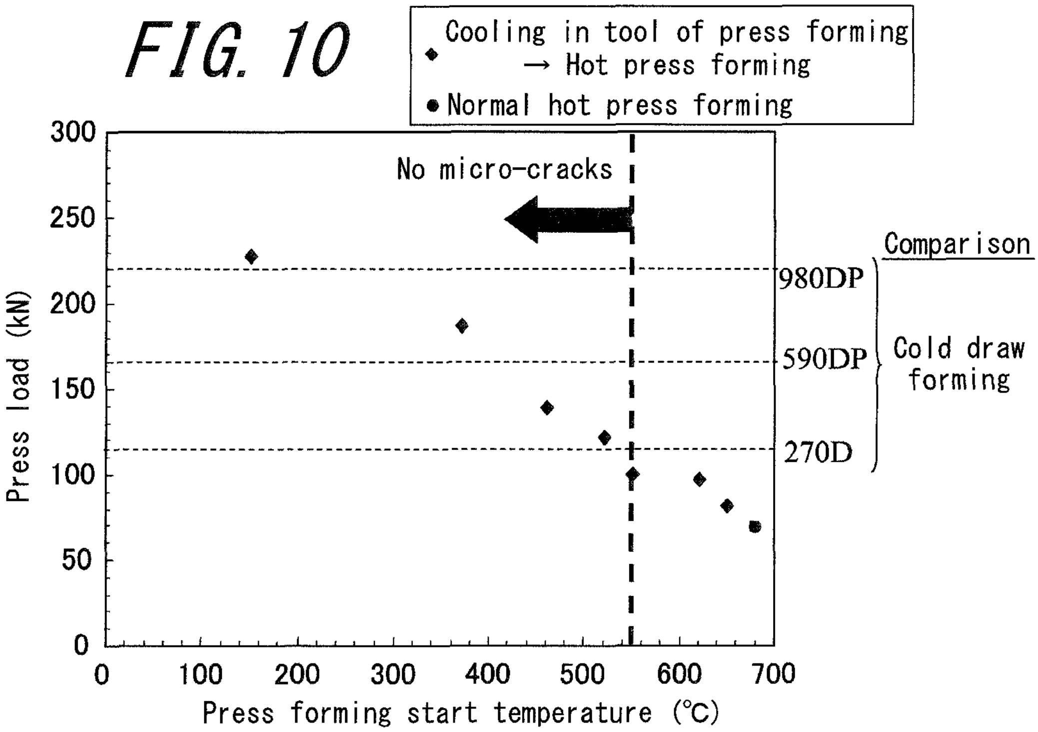

Cooling in tool of press forming
→ Hot press forming
Normal hot press forming
No micro-cracks
Comparison
980DP
590DP
270D
Cold draw forming
Press load (kN)
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
Press forming start temperature (℃)

FIG. 11

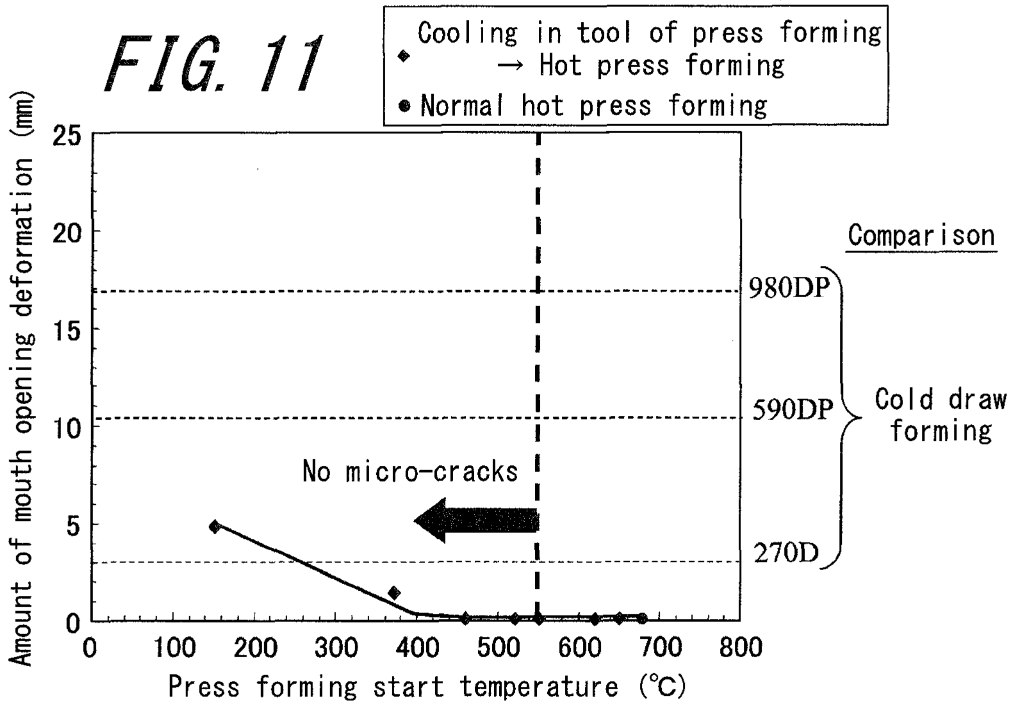

Cooling in tool of press forming
→ Hot press forming
Normal hot press forming
No micro-cracks
Comparison
980DP
590DP
270D
Cold draw forming
Amount of mouth opening deformation (mm)
25
20
15
10
5
0
0
100
200
300
400
500
600
700
800
Press forming start temperature (℃)

FIG. 12A

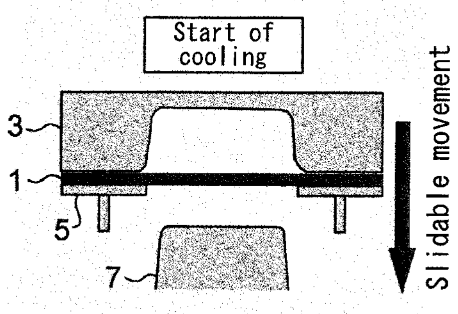


FIG. 12B

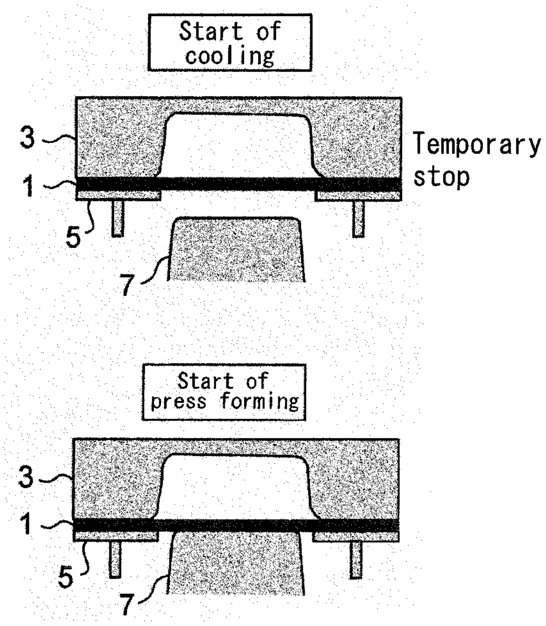


FIG. 12C

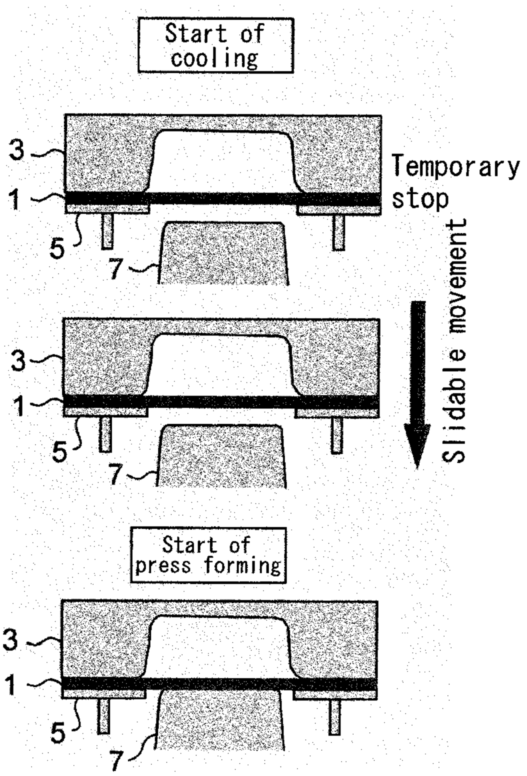


FIG. 12D

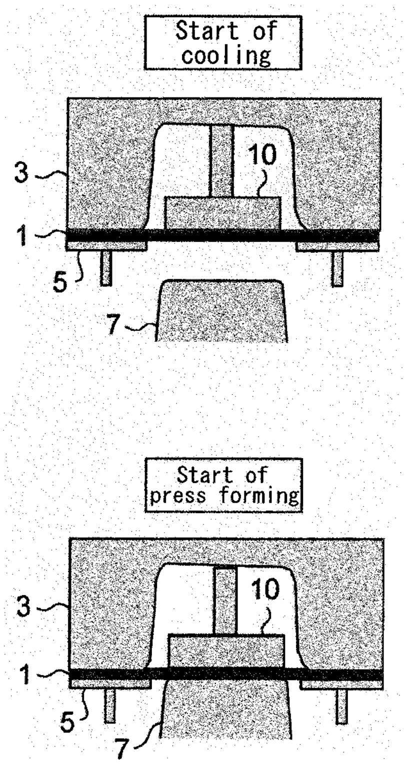


FIG. 13A

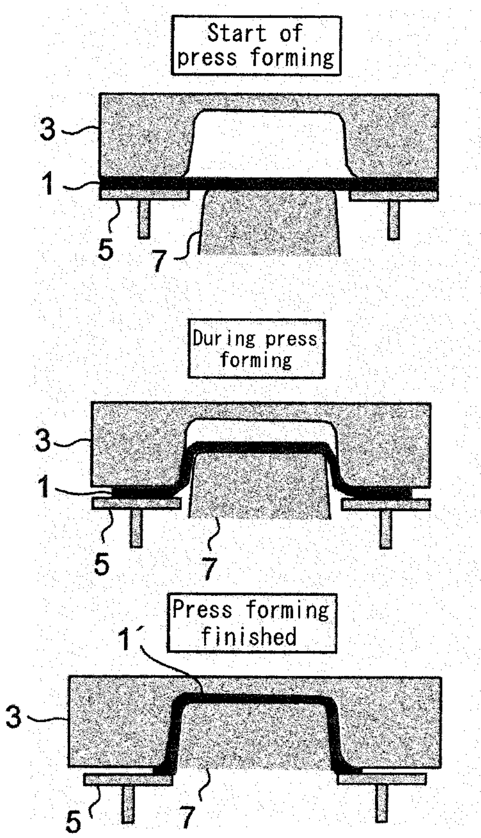


FIG. 13B

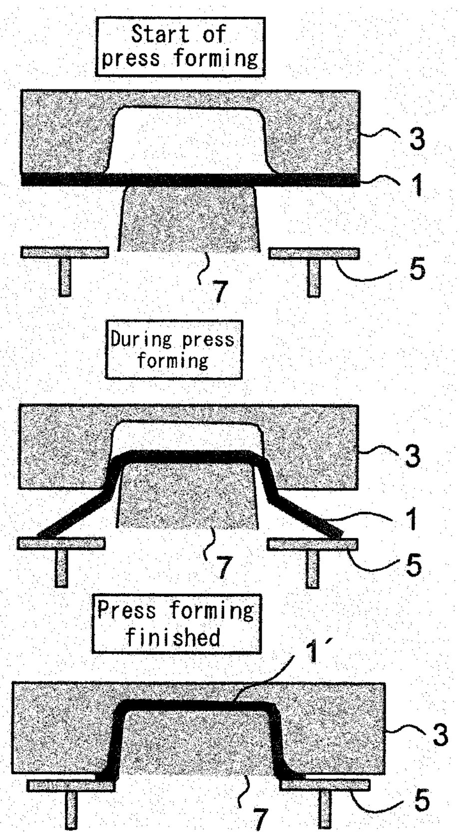


FIG. 14

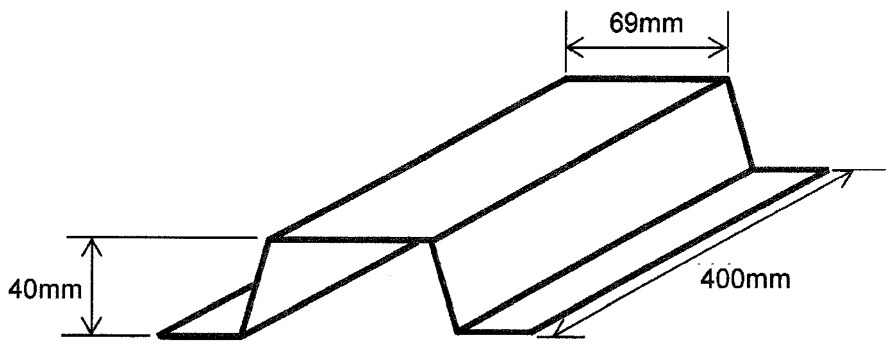


FIG. 15

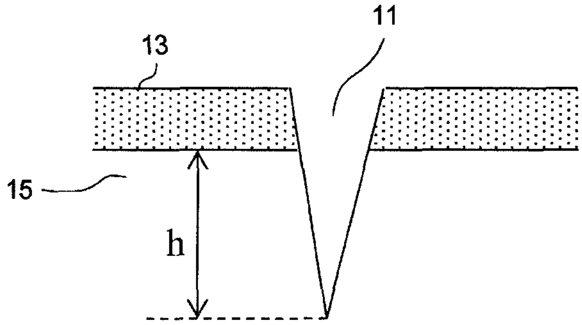

11
13
15
h

FIG. 16

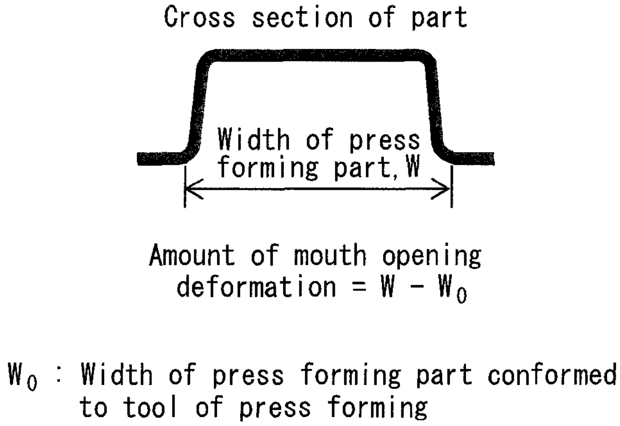
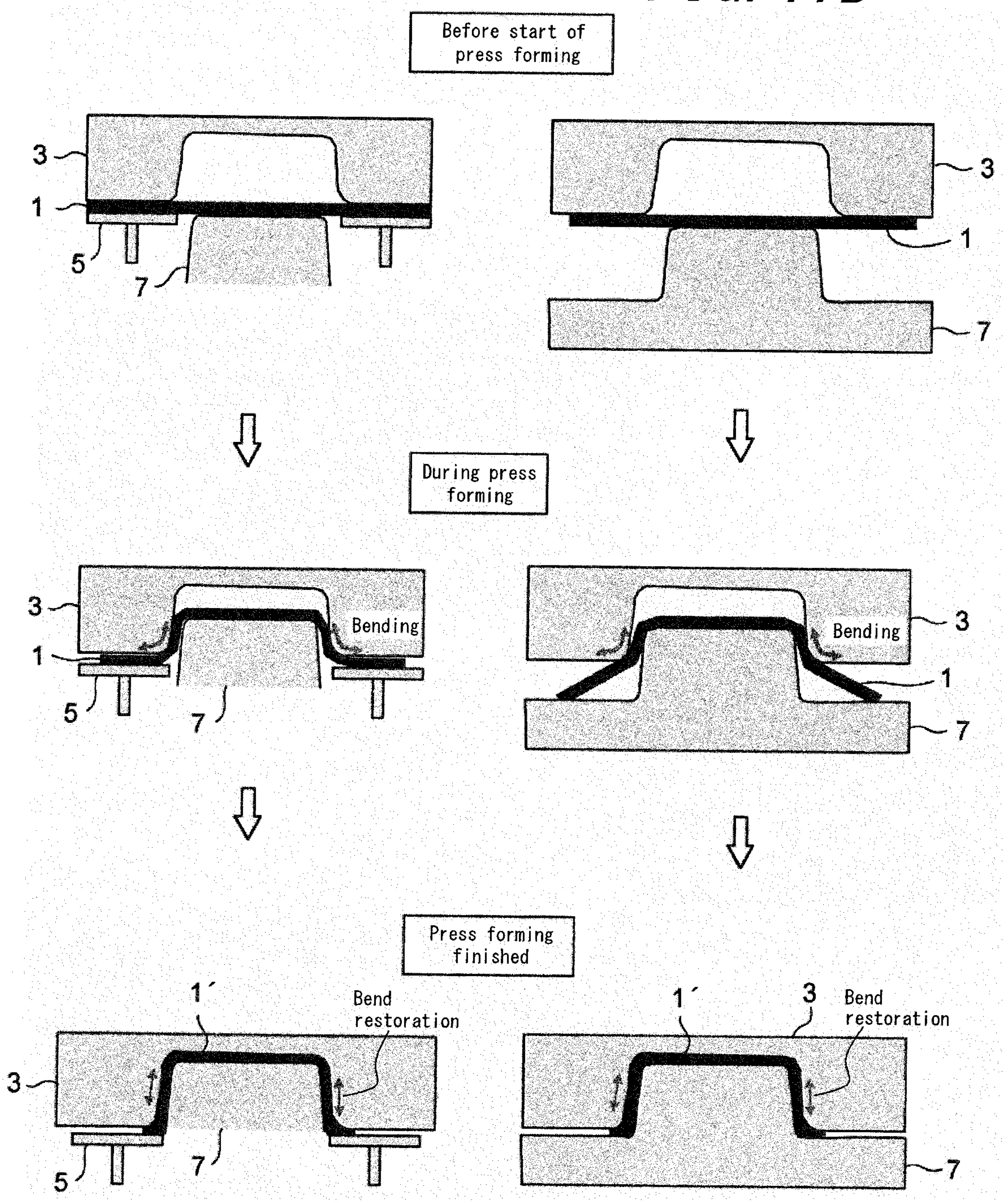

Cross section of part
Width of press forming part, W
Amount of mouth opening deformation = W - W0
W0 : Width of press forming part conformed to tool of press forming

FIG. 17A FIG. 17B



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/056439

A. CLASSIFICATION OF SUBJECT MATTER
B21D22/20(2006.01)i, *C25D5/26*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21D22/20, C25D5/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2014-507556 A (Voestalpine Stahl GmbH), 27 March 2014 (27.03.2014), claims; paragraph [0011]; fig. 6, 8 & JP 2014-505791 A & US 2014/0020795 A1 & US 2014/0027026 A1 & WO 2012/085253 A2 & WO 2012/085247 A2 & WO 2012/085248 A2 & WO 2012/085251 A2 & WO 2012/085256 A2 & DE 102010056264 A1 & DE 102011053941 A1 & DE 102011053939 A1	1-6
A	JP 2013-226599 A (Kobe Steel, Ltd.), 07 November 2013 (07.11.2013), claims; paragraph [0004]; fig. 2 & US 2015/0024234 A1 & WO 2013/147228 A1 & EP 2832466 A1 & CN 104169018 A & KR 10-2014-0130208 A	1-6

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 May 2015 (13.05.15)	26 May 2015 (26.05.15)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/056439

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2010-180428 A (Toyota Motor Corp.), 19 August 2010 (19.08.2010), claims & US 2011/0303328 A1 & WO 2010/089644 A1 & KR 10-2011-0112396 A & CN 102301014 A	1-6

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- GB 1490535 A **[0002] [0007]**
- JP 2001353548 A **[0004] [0007]**
- JP 201391099 A **[0006] [0007]**