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(54) **HOT PRESS MOLDED ARTICLE, METHOD FOR PRODUCING SAME, AND THIN STEEL SHEET FOR HOT PRESS MOLDING**

(57) There is provided a hot press-formed product, including a steel sheet formed by a hot press-forming method, and having a metallic structure that contains ferrite at 30% to 80% by area, bainitic ferrite at lower than 30% by area (not including 0% by area), martensite at 30% by area or lower (not including 0% by area), and retained austenite at 3% to 20% by area, whereby balance between strength and elongation can be controlled in a proper range and high ductility can be achieved.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a hot press-formed product required to have high strength, such as used for structural members of automobile parts, a process for producing the same, and a thin steel sheet for hot press forming. In particular, the present invention relates to a hot press-formed product that can be provided with a prescribed shape and at the same time heat treated to have prescribed strength when a preheated steel sheet (blank) is formed into the prescribed shape, a process for producing such a hot press-formed product, and a thin steel sheet for hot press forming.

BACKGROUND ART

[0002] As one of the measures for fuel economy improvement of automobiles beginning from global environmental problems, automobile body lightening has proceeded, and steel sheets to be used for automobiles need to be strengthened as highly as possible. However, highly strengthening of steel sheets for automobile lightening lowers elongation EL or r value (Lankford value), resulting in the deterioration of press formability or shape fixability.

[0003] To solve such a problem, a hot press-forming method has been adopted for production of parts, in which method a steel sheet is heated to a prescribed temperature (e.g., a temperature for change in austenite phase) to lower its strength (i.e., make it easily formable) and then formed with a press tool at a temperature (e.g., room temperature) lower than that of the thin steel sheet, whereby the steel sheet is provided with a shape and at the same time heat treated by rapid cooling (quenching), which makes use of a temperature difference between both, to secure its strength after forming.

[0004] According to such a hot pressing method, a steel sheet is formed in a state of low strength, and therefore, the steel sheet has decreased springback (favorable shape fixability). In addition, the use of a material having excellent hardenability, to which alloy elements such as Mn and B have been added, thereby obtaining a strength of 1500 MPa class in terms of tensile strength by rapid cooling. Such a hot press-forming method has been called with various names, in addition to a hot press method, such as a hot forming method, a hot stamping method, a hot stamp method, and a die quench method.

[0005] Fig. 1 is a schematic explanatory view showing the structure of a press tool for carrying out hot press forming as described above (hereinafter represented sometimes by "hot stamp"). In this figure, reference numerals 1, 2, 3, and 4 represent a punch, a die, a blank holder, and a steel sheet (blank), respectively, and abbreviations BHF, rp, rd, and CL represent a blank holding force, a punch shoulder radius, a die shoulder radius, and a clearance between the punch and the die, respectively. In these parts, punch 1 and die 2 have passage la and passage 2a, respectively, formed in the inside thereof, through which passages a cooling medium (e.g., water) can be allowed to pass, and the press tool is made to have a structure so that these members can be cooled by allowing the cooling medium to pass through these passages.

[0006] When a steel sheet is subjected to hot stamp (e.g., hot deep drawing) with such a press tool, the forming is started in a state where steel sheet (blank) 4 is softened by heating to a temperature within two-phase region, which is from Ac_1 transformation point to Ac_3 transformation point, or a temperature within single-phase region, which is not lower than Ac_3 transformation point. More specifically, steel sheet 4 is pushed into a cavity of die 2 (between the parts indicated by reference numerals 2 and 2 in Fig. 1) by punch 1 with steel sheet 4 in high-temperature state being sandwiched between die 2 and blank holder 3, thereby forming steel sheet 4 into a shape corresponding to the outer shape of punch 1 while reducing the outer diameter of steel sheet 4. In addition, heat is removed from steel sheet 4 to the press tool (punch 1 and die 2) by cooling punch 1 and die 2 in parallel with the forming, and the hardening of the material is carried out by further retaining and cooling steel sheet 4 at the lower dead point in the forming (the point of time when the punch head is positioned at the deepest level: the state shown in Fig. 1). Formed products with high dimension accuracy and strength of 1500 MPa class can be obtained by carrying out such a forming method. Furthermore, such a forming method results in that the volume of a pressing machine can be made smaller because a forming load can be reduced as compared with the case where parts of the same strength class are formed by cold pressing.

[0007] As steel sheets for hot stamp, which have widely been used at present, there are known steel sheets based on 22MnB5 steel. These steel sheets have tensile strengths of 1500 MPa and elongations of about 6% to 8%, and have been applied to impact-resistant members (members neither deformed nor fractured as much as possible at the time of impact). In addition, some developments have also proceeded for C content increase and further highly strengthening (in 1500 to 1800 MPa class) based on 22MnB5 steel.

[0008] However, there is almost no application of steel grades other than 22MnB5 steel. One can find a present situation where little consideration is made on steel grades or methods for controlling the strength and elongation of parts (e.g., strength lowering to 980MPa class and elongation enhancement to 20%) to extend their application range to other than impact-resistant members.

[0009] In middle or higher class automobiles, taking into consideration compatibility (function of, when a small class automobile comes to collide, making safe of the other side) at the time of side or back impact, both functions as an impact-resistant portion and an energy-absorbing portion may sometimes be provided in parts such as B pillars or rear side members. To produce such members, there has mainly been used so far, for example, a method in which ultra-high tensile strength steel sheets having high strength of 980 MPa class and high tensile strength steel sheets having elongation of 440 MPa class are laser welded (to prepare a tailor welded blank, abbreviated as TWB) and then cold press formed. However, in recent years, the development of a technique has proceeded, in which parts are each provided with different strengths by hot stamp.

[0010] For example, Non-patent Document 1 has proposed a method of laser welding 22MnB5 steel for hot stamp and a material that does not have high strength even if quenched with a press tool (to prepare a tailor welded blank, abbreviated as TWB), followed by hot stamp, in which method different strengths are provided so that tensile strength at a high strength side (i.e., impact-resistant portion side) becomes 1500 MPa (and elongation becomes 6% to 8%) and tensile strength at a low strength side (i.e., energy-absorbing portion side) becomes 440 MPa (and elongation becomes 12%). In addition, as the technique of providing parts each with different strengths, some techniques have also been proposed, such as disclosed in Non-patent Documents 2 to 4.

[0011] The techniques disclosed in Non-patent Documents 1 and 2 provide a tensile strength of not higher than 600 MPa and an elongation of about 12% to 18% at an energy-absorbing portion side, in which techniques, however, laser welding (to prepare a tailor welded blank, abbreviated as TWB) is needed previously, thereby increasing the number of steps and resulting in high cost. In addition, it results in the heating of energy-absorbing portions, which need not to be hardened originally. Therefore, these techniques are not preferred from the viewpoint of energy consumption.

[0012] The technique disclosed in Non-patent Document 3 is based on 22MnB5 steel, in which boron addition, however, adversely affects the robustness of strength after quenching against heating to a temperature within two-phase region, making difficult the control of strength at an energy-absorbing portion side, and further making it possible to obtain only an elongation as low as 15%.

[0013] The technique disclosed in Non-patent Document 4 is based on 22MnB5 steel, and therefore, this technique is not economic in that control is made in such a manner that 22MnB5, which originally has excellent hardenability, is not hardened (control of press tool cooling).

PRIOR ART DOCUMENTS

NON-PATENT DOCUMENTS

[0014]

Non-patent Document 1: Klaus Lamprecht, Gunter Deinzer, Anton Stich, Jurgen Lechler, Thomas Stohr, Marion Merklein, "Thermo-Mechanical Properties of Tailor Welded Blanks in Hot Sheet Metal Forming Processes", Proc. IDDRG2010, 2010.

Non-patent Document 2: Usibor1500P(22MnB5) /1500MPa-8%-Ductibor500/550-700MPa-17% [searched on April 27, 2013] Internet <http://www.arcelormittal.com/tailoredblanks/pre/selfware.p1>

Non-patent Document 3: 22MnB5/above AC3/1500MPa-8%-below AC3/Hv190-Ferrite/Cementite Rudiger Erhardt and Johannes Boke, "Industrial application of hot forming process simulation", Proc, of 1st Int. Conf. on Hot Sheet Metal Forming of High-Performance steel, ed. By Steinhoff, K., Oldenburg, M, Steinhoff, and Prakash, B., pp83-88, 2008.

Non-patent Document 4: Begona Casas, David Latre, Noemi Rodriguez, and Isaac Valls, "Tailor made tool materials for the present and upcoming tooling solutions in hot sheet metal forming", Proc, of 1st Int. Conf. on Hot Sheet Metal Forming of High-Performance steel, ed. By Steinhoff, K., Oldenburg, M, Steinhoff, and Prakash, B., pp23-35, 2008.

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0015] The present invention has been made in view of the above-described circumstances, and its object is to provide a hot press-formed product in which balance between strength and elongation can be controlled in a proper range and high ductility can be achieved, a process useful for producing such a hot press-formed product, and a thin steel sheet for hot press forming.

MEANS FOR SOLVING THE PROBLEMS

[0016] The hot press-formed product of the present invention, which can achieve the above object, is a hot press-formed product, characterized by comprising a thin steel sheet formed by a hot press-forming method, and having a metallic structure that contains ferrite at 30% to 80% by area, bainitic ferrite at lower than 30% by area (not including 0% by area), martensite at 30% by area or lower (not including 0% by area), and retained austenite at 3% to 20% by area.

[0017] In the hot press-formed product of the present invention, the chemical element composition thereof is not particularly limited, typical examples of which may include the following chemical element composition: C at 0.1% to 0.3% (where "%" means "% by mass", and the same applies to the below with respect to the chemical element composition); Si at 0.5% to 3%; Mn at 0.5% to 2%; P at 0.05% or lower (not including 0%); S at 0.05% or lower (not including 0%); Al at 0.01% to 0.1%; and N at 0.001% to 0.01%, and the remainder consisting of iron and unavoidable impurities.

[0018] In the hot press-formed product of the present invention, it is also useful to allow additional elements to be contained, when needed; for example, (a) B at 0.01% or lower (not including 0%) and Ti at 0.1% or lower (not including 0%); (b) one or more selected from the group consisting of Cu, Ni, Cr, and Mo at 1% or lower (not including 0%) in total; and (c) V and/or Nb at 0.1% or lower (not including 0%) in total. Depending on the kind of element to be contained, the hot press-formed product may have further improved characteristics.

[0019] When the hot press-formed product of the present invention is produced, the following steps may be used, i.e., heating a hot-rolled steel sheet having a metallic structure that contains ferrite at 50% by area or higher, or a cold-rolled steel sheet at a reduction of 30% or higher, to a temperature not lower than Ac_1 transformation point and not higher than (Ac_1 transformation point x 0.3 + Ac_3 transformation point x 0.7); and then starting the forming of the hot-rolled steel sheet or the cold-rolled steel sheet with a press tool to produce the hot press-formed product, during which forming an average cooling rate of 20°C/sec or higher is kept in the press tool, and which forming is finished at a temperature not higher than (bainite transformation starting temperature Bs - 100°C). The forming finishing temperature may preferably be controlled in a temperature range of not higher than (bainite transformation starting temperature Bs - 100°C) and not lower than martensite transformation starting temperature Ms point, in which temperature range the steel sheet may preferably be retained for 10 seconds or longer, followed by the forming.

[0020] Alternatively, the following method may be adopted as the other method. When a thin steel sheet is press formed with a press tool, the thin steel sheet may be heated to a temperature not lower than Ac_3 transformation point and not higher than 1000°C, and then cooled to a temperature not higher than 700°C and not lower than 500°C at an average cooling rate of 10°C/sec or lower, and then the forming of the thin steel sheet may be started, during which forming an average cooling rate of 20°C/sec or higher may be kept in the press tool, and which forming may be finished at a temperature not higher than (bainite transformation starting temperature Bs - 100°C). Also in this method, the forming finishing temperature may preferably be controlled in a temperature range of not higher than (bainite transformation starting temperature Bs - 100°C) and not lower than martensite transformation starting temperature Ms point, in which temperature range the steel sheet may preferably be retained for 10 seconds or longer, followed by the forming.

[0021] The present invention further includes a thin steel sheet for hot press forming, which is intended for producing a hot press-formed product as described above, and this thin steel sheet is characterized by being a hot-rolled steel sheet having a metallic structure that contains ferrite at 50% by area or higher, or a cold-rolled steel sheet at reduction of 30% or higher.

EFFECTS OF THE INVENTION

[0022] The present invention makes it possible that: retained austenite can be allowed to exist at a proper fraction to adjust the metallic structure of a hot press-formed product by properly controlling the conditions of a hot press-forming method; a hot press-formed product having more enhanced ductility (retained ductility) inherent to the formed product as compared with the case where conventional 22MnB5 steel is used; and strength and elongation can be controlled by a combination of heat treatment conditions and pre-forming steel sheet structure (initial structure). In addition, the control of heating temperature within two-phase region makes it possible to provide different strengths and elongations freely.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] Fig. 1 is a schematic explanatory view showing the structure of a press tool for carrying out hot press forming.

MODE FOR CARRYING OUT THE INVENTION

[0024] The present inventors have studied from various angles to realize a hot press-formed product having prescribed strength and further exhibiting excellent ductility (elongation) after forming when a steel sheet is heated to a prescribed temperature and then hot press formed to produce the formed product.

[0025] As a result, the present inventors have found that a hot press-formed product having excellent balance between strength and ductility can be achieved when the type of a steel sheet, heating temperature, and forming conditions are properly controlled so that its structure is controlled to contain retained austenite at 3% to 20% by area in the hot press forming of a steel sheet with a press tool, thereby completing the present invention.

[0026] The reasons for setting the ranges of the respective structures (basic structures) in the hot press-formed product of the present invention are as follows:

[Ferrite at 30% to 80% by area]

[0027] High ductility of a hot press-formed product can be achieved by making its structure composed mainly of fine and high-ductility ferrite. From this viewpoint, the area fraction of ferrite should be controlled to 30% by area or higher. However, when this area fraction is higher than 80% by area, prescribed strength becomes not secured. The fraction of ferrite may preferably be not lower than 40% by area as the preferred lower limit (more preferably not lower than 45% by area) and not higher than 70% by area as the preferred upper limit (more preferably not higher than 65% by area).

[Bainitic ferrite at lower than 30% by area (not including 0%)]

[0028] Bainitic ferrite is effective for strength improvement, but it causes a slight lowering of ductility. Therefore, the fraction of bainitic ferrite should be controlled to lower than 30% by area as the upper limit. The fraction of bainitic ferrite may preferably be not lower than 5% by area as the preferred lower limit (more preferably not lower than 10% by area) and not higher than 25% by area as the preferred upper limit (more preferably not higher than 20% by area).

[Martensite at 30% by area or lower (not including 0%)]

[0029] Martensite is effective for strength improvement, but it causes a considerable lowering of ductility. Therefore, the fraction of martensite should be controlled to not higher than 30% by area as the upper limit. The fraction of martensite may preferably be not lower than 5% by area as the preferred lower limit (more preferably not lower than 10% by area) and not higher than 25% by area as the preferred upper limit (more preferably not higher than 20% by area).

[Retained austenite at 3% to 20% by area]

[0030] Retained austenite is transformed into martensite during plastic deformation, thereby having the effect of increasing work hardening rate (transformation-inducing plasticity) to improve the ductility of a formed product. To make such an effect exhibited, the fraction of retained austenite should be controlled to 3% by area or higher. When the fraction of retained austenite is higher, ductility becomes more excellent. In a composition to be used for automobile steel sheets, retained austenite that can be secured is limited, of which upper limit becomes about 20% by area. The fraction of retained austenite may preferably be not lower than 5% by area as the preferred lower limit (more preferably not lower than 7% by area) and not higher than 15% by area as the preferred upper limit (more preferably not higher than 10% by area).

[0031] When the hot press-formed product of the present invention is produced, a hot-rolled steel sheet having a metallic structure that contains ferrite at 50% by area or higher, or a cold-rolled steel sheet at a reduction of 30% or higher, may be used, and when the hot-rolled steel sheet or the cold-rolled steel sheet is press formed with a pres tool, the hot-rolled steel sheet or the cold-rolled steel sheet may be heated to a temperature not lower than Ac_1 transformation point and not higher than (Ac_1 transformation point x 0.3 + Ac_3 transformation point x 0.7), and then the forming of the hot-rolled steel sheet or the cold-rolled steel sheet may be started, during which forming an average cooling rate of 20°C/sec or higher may be kept in the press tool, and which forming may be finished at a temperature not higher than (bainite transformation starting temperature Bs - 100°C). The reasons for defining the respective requirements in this process are as follows:

[Using a hot-rolled steel sheet having a metallic structure that contains ferrite at 50% by area or higher, or a cold-rolled steel sheet at a reduction of 30% or higher]

[0032] To obtain ferrite structure, which has high contributions to ductility, during heating to a temperature within two-phase region, the type of a steel sheet (steel sheet for forming) should properly be selected. When a hot-rolled steel sheet is used as the steel sheet for forming, it is important to achieve that the fraction of ferrite is high and ferrite is retained during heating to a temperature within two-phase region. From this viewpoint, the hot-rolled steel sheet to be used may preferably have a metallic structure that contains ferrite at 50% by area or higher. The fraction of ferrite may preferably be not lower than 60% by area as the preferred lower limit (more preferably not lower than 70% by area). When the fraction of ferrite in the hot-rolled steel sheet becomes too high, the fraction of ferrite in the formed product becomes too high. Therefore, the fraction of ferrite in the hot-rolled steel sheet may preferably be not higher than 95%

by area, more preferably not higher than 90% by area.

[0033] On the other hand, a cold-rolled steel sheet is used, it becomes an important requirement that recrystallization occurs during heating to form dislocation-free ferrite, and therefore, rolling (cold rolling) should be carried out at a prescribed reduction or higher so that recrystallization occurs. In the case of a cold-rolled steel sheet, it may have any structure. From this viewpoint, when a cold-rolled steel sheet is used, it is preferable to use a cold-rolled steel sheet at a reduction of 30% or higher. The reduction may preferably be 40% or higher, more preferably 50% or higher. The "reduction" as used herein is a value determined by formula (1) below.

$$\text{Reduction (\%)} = [(\text{thickness of steel sheet before cold rolling} - \text{thickness of steel sheet after cold rolling}) / \text{thickness of steel sheet before cold rolling}] \times 100 \cdots (1)$$

[Heating a steel sheet to a temperature not lower than Ac_1 transformation point and not higher than (Ac_1 transformation point x 0.3 + Ac_3 transformation point x 0.7), and then starting the forming]

[0034] To cause the partial transformation, while retaining, of ferrite, which is contained in the steel sheet, into austenite, the heating temperature should be controlled in a prescribed range. The proper control of the heating temperature makes it possible to cause transformation into retained austenite or martensite in the subsequent cooling step to provide the final hot press-formed product with a desired structure. When the heating temperature of the steel sheet is lower than Ac_1 transformation point, a sufficient fraction of austenite cannot be obtained during heating, and therefore, a prescribed fraction of retained austenite cannot be secured in the final structure (the structure of a formed product). When the heating temperature of the thin steel sheet is higher than (Ac_1 transformation point x 0.3 + Ac_3 transformation point x 0.7), the fraction of transformed austenite is increased too highly during heating, and therefore, a prescribed fraction of ferrite cannot be secured in the final structure (the structure of a formed product).

[During forming, an average cooling rate of 20°C/sec or higher is kept in the press tool, and the forming is finished at a temperature not lower than (bainite transformation starting temperature Bs - 100°C)]

[0035] To change the austenite, which was formed in the above heating step, into a prescribed fraction of retained austenite, while preventing the formation of cementite, the average cooling rate during forming and the forming finishing temperature should properly be controlled. From this viewpoint, the average cooling rate during forming should be controlled to 20°C/sec or higher, and the forming finishing temperature should be controlled to a temperature not higher than (bainite transformation starting temperature Bs point - 100°C, sometimes abbreviated as "Bs - 100°C"). The average cooling rate during forming may preferably be 30°C/sec or higher (more preferably 40°C/sec or higher). With respect to the forming finishing temperature, the forming may be finished, while cooling to room temperature at an average cooling temperature as described above. Alternatively, the cooling is stopped after the cooling to a temperature not higher than Bs - 100°C, and then the forming may be finished. The control of the average cooling rate during forming can be achieved by a means of, for example, (a) controlling the temperature of a press tool (using a cooling medium shown in Fig. 1 above) or (b) controlling the thermal conductivity of a press tool (the same applies to the cooling in the method described below).

[0036] As another method for producing the press-formed product of the present invention, when a steel sheet is press formed with a press tool, the thin steel sheet may be heated to a temperature not lower than Ac_3 transformation point and not higher than 1000°C, and then the thin steel sheet is cooled to a temperature not higher than 700°C and not lower than 500°C at an average cooling temperature of 10°C/sec or lower, and then the forming of the thin steel sheet may be started, during which forming an average cooling rate of 20°C/sec or higher may be kept in the press tool, and which forming may be finished at a temperature not higher than (bainite transformation starting temperature Bs - 100°C). The reasons for defining the respective requirements in this process are as follows (the same as described above applies to the cooling finishing temperature):

[Heating a thin steel sheet to a temperature not lower than Ac_3 transformation point and not higher than 1000°C]

[0037] To properly adjust the structure of a hot press-formed product, the heating temperature should be controlled in a prescribed range. The proper control of the heating temperature makes it possible to cause transformation into a structure composed mainly of ferrite while securing a prescribed fraction of retained austenite in the subsequent cooling step to provide the final hot press-formed product with a desired structure. When the heating temperature of the thin steel sheet is lower than Ac_3 transformation point, a sufficient fraction of austenite cannot be obtained during heating, and therefore, a prescribed fraction of retained austenite cannot be secured in the final structure (the structure of a formed product). When the heating temperature of the thin steel sheet is higher than 1000°C, the grain size of austenite becomes increased during heating, and therefore, ferrite cannot be formed in the subsequent cooling.

[Cooling to a temperature not higher than 700°C and not lower than 500°C at an average cooling rate of 10°C/sec or lower, and then starting the forming]

[0038] This cooling step is an important step for forming ferrite during cooling. When the average cooling rate in this cooling step becomes higher than 10°C/sec, a prescribed fraction of ferrite cannot be secured. The average cooling rate may preferably be 7°C/sec or lower, more preferably 5°C/sec or lower. The cooling stopping temperature in this cooling step (this temperature may sometimes be referred to as the "cooling rate changing temperature") should be controlled to not higher than 700°C and not lower than 500°C. When the cooling stopping temperature becomes higher than 700°C, a sufficient fraction of ferrite cannot be secured. When the cooling stopping temperature becomes lower than 500°C, the fraction of ferrite becomes too high, and therefore, prescribed strength cannot be secured. The cooling stopping temperature may preferably be not higher than 680°C as the preferred upper limit (more preferably not higher than 660°C) and not lower than 520°C as the preferred lower limit (more preferably not lower than 550°C).

[0039] In any of these methods, the forming finishing temperature should be controlled to not higher than (Bs - 100°C), but may preferably be controlled in a temperature range of not lower than martensite transformation starting temperature Ms (a temperature in this range may sometimes be referred to as the "cooling temperature changing temperature), in which temperature range retention may preferably be carried out for 10 seconds or longer. The bainite transformation can proceed from super-cooled austenite to form a structure composed mainly of ferrite by retention in the above temperature range for 10 seconds or longer. The retention time may preferably be 50 seconds or longer (more preferably 100 seconds or longer). When the retention time becomes too long, austenite starts to decompose, so that the fraction of retained austenite cannot become secured. Therefore, the retention time may preferably be 1000 seconds or shorter (more preferably 800 seconds or shorter).

[0040] Retention as described above may be any of isothermal retention, monotonic cooling, and re-heating step, so long as it is in the above temperature range. With regard to a relationship between such retention and forming, retention as described above may be added at the stage when forming is finished. Alternatively, a retention step may be added within the above temperature range during the finish of forming. After forming is finished in such a manner, the steel sheet may be left as it is for cooling or cooled at a proper cooling rate to room temperature (25°C).

[0041] The process for producing the hot press-formed product of the present invention can be applied, not only to the case where a hot press-formed product having a simple shape as shown in Fig. 1 above is produced (i.e., direct method), but also to the case where a formed product having a relatively complicated shape is produced, even if any of the methods described above is adopted. However, in the case of a complicated product shape, it may be difficult to provide a product with the final shape by a single press forming step. In such a case, there can be used a method of cold press forming in a step prior to hot press forming (this method has been referred to as "indirect method"). This method includes previously forming a difficult-to-form portion into an approximate shape by cold processing and then hot press forming the other portions. When such a method is used to produce, for example, a formed product having three projections (profile peaks) by forming, two projections are formed by cold press forming and the third projection is then formed by hot press forming.

[0042] The present invention is intended for a hot press-formed product made of a high-strength steel sheet, the steel grade of which is acceptable, if it has an ordinary chemical element composition as a high-strength steel sheet, in which, however, C, Si, Mn, P, S, Al, and N contents may preferably be controlled in their respective proper ranges. From this viewpoint, the preferred ranges of these chemical elements and the grounds for limiting their ranges are as follows:

[C at 0.1% to 0.3%]

[0043] C is an important element for securing retained austenite. The concentration of austenite during heating at a temperature within two-phase region or at a temperature within single-phase region, which is not lower than Ac_3 transformation point, allows the formation of retained austenite after quenching. It further contributes to an increase of martensite fraction. When C content is lower than 0.1%, a prescribed fraction of retained austenite cannot be secured, making it impossible to obtain excellent ductility. When C content becomes higher than 0.3%, it results in that strength becomes too high. C content may more preferably be not lower than 0.15% as the more preferred lower limit (still more preferably not lower than 0.20%) and not higher than 0.27% as the more preferred upper limit (still more preferably not higher than 0.25%).

[Si at 0.5% to 3%]

[0044] Si suppresses austenite after heating at a temperature within two-phase region or at a temperature within single-phase region, which is not lower than Ac_3 transformation point, from being formed into cementite, and exhibits the action of increasing the fraction of retained austenite. It further exhibits the action of enhancing strength by solid solution enhancement without deteriorating ductility too much. When Si content is lower than 0.5%, retained austenite cannot be secured at a prescribed fraction, making it impossible to obtain excellent ductility. When Si content becomes higher than 3%, the degree of solid solution enhancement becomes too high, resulting in the drastic deterioration of ductility. Si content may more preferably be not lower than 1.15% as the more preferred lower limit (still more preferably not lower than 1.20%) and not higher than 2.7% as the more preferred upper limit (still more preferably not higher than 2.5%).

[Mn at 0.5% to 2%]

[0045] Mn is an element to stabilize austenite, and it contributes to an increase of retained austenite. To make such an effect exhibited, Mn may preferably be contained at 0.5% or higher. However, when Mn content becomes excessive, the formation of ferrite is prevented, thereby making it impossible to secure a prescribed fraction of ferrite, and therefore, Mn content may preferably be 2% or lower. In addition, a considerable improvement of austenite strength increases a hot rolling load, thereby making it difficult to produce steel sheets, and therefore, even from the viewpoint of productivity, it is not preferable that Mn is contained at higher than 2%. Mn content may more preferably be not lower than 0.7% as the more preferred lower limit (still more preferably not lower than 0.9%) and not higher than 1.8% as the more preferred higher limit (still more preferably not higher than 1.6%).

[P at 0.05% or lower (not including 0%)]

[0046] P is an element unavoidably contained in steel and deteriorates ductility. Therefore, P content may preferably be reduced as low as possible. However, extreme reduction causes an increase of steel production cost, and reduction to 0% is difficult in the actual production. Therefore, P content may more preferably be controlled to 0.05% or lower (not including 0%). P content may more preferably be not higher than 0.045% as the more preferred upper limit (still more preferably not higher than 0.040%).

[S at 0.05% or lower (not including 0%)]

[0047] S is also an element unavoidably contained in steel and deteriorates ductility, similarly to P. Therefore, S content may preferably be reduced as low as possible. However, extreme reduction causes an increase of steel production cost, and reduction to 0% is difficult in the actual production. Therefore, S content may preferably be controlled to 0.05% or lower (not including 0%). S content may more preferably be not higher than 0.045% as the more preferred upper limit (still more preferably not higher than 0.040%).

[Al at 0.01% to 0.1%]

[0048] Al is useful as a deoxidizing element and further useful for fixation of dissolved N in steel as AlN to improve ductility. To make such an effect effectively exhibited, Al content may preferably be controlled to 0.01% or higher. However, when Al content becomes higher than 0.1%, it results in the excessive formation of Al_2O_3 to deteriorate ductility. Al content may more preferably be not lower than 0.013% as the more preferred lower limit (still more preferably not lower than 0.015%) and not higher than 0.08% as the more preferred upper limit (still more preferably not higher than 0.06%).

[N at 0.001% to 0.01%]

[0049] N is an element unavoidably incorporated in steel, and a reduction of

[0050] N content may be preferred, which has, however, a limitation in actual process. Therefore, the lower limit of N content was set to 0.001%. When N content becomes excessive, ductility is deteriorated by strain aging, or the addition of B causes deposition of N as BN, thereby lowering the effect of improving hardenability by solid solution of B. Therefore, the upper limit of N content was set to 0.01%. N content may more preferably be not higher than 0.008% as the more preferred upper limit (still more preferably not higher than 0.006%).

[0051] The basic chemical components in the press-formed product of the present invention are as described above, and the remainder consists essentially of iron. The wording "consists essentially of iron" means that the press-formed product of the present invention can contain, in addition to iron, minor components (e.g., besides Mg, Ca, Sr, and Ba, REM such as La, and carbide-forming elements such as Zr, Hf, Ta, W, and Mo) in such a level that these minor components do not inhibit the characteristics of the steel sheet of the present invention, and can further contain unavoidable impurities (e.g., O, H) other than P, S, and N.

[0052] It is also useful to allow the press-formed product of the present invention to contain additional elements, when needed; for example, (a) B at 0.01% or lower (not including 0%) and Ti at 0.1% or lower (not including 0%); (b) one or more selected from the group consisting of Cu, Ni, Cr, and Mo at 1% or lower (not including 0%) in total; and (c) V and/or Nb at 0.1% or lower (not including 0%) in total. The press-formed product may have further improved characteristics depending on the kinds of elements contained. When these elements are contained, their preferred ranges and grounds for limitation of their ranges are as follows:

[B at 0.01% or lower (not including 0%) and Ti at 0.1% or lower (not including 0%)]

[0053] B is an element to prevent the formation of cementite during cooling after heating, thereby contributing to the securement of retained austenite. To make such an effect exhibited, B may preferably be contained at 0.0001% or higher, but even if B is contained beyond 0.01%, the effect is saturated. B content may more preferably be not lower than 0.0002% as the more preferred lower limit (still more preferably not lower than 0.0005%) and not higher than 0.008% as the more preferred upper limit (still more preferably not higher than 0.005%).

[0054] On the other hand, Ti fixes N and maintains B in solid solution state, thereby exhibiting the effect of improving hardenability. To make such an effect exhibited, Ti may preferably be contained at least 4 times higher than N content. However, when Ti content becomes excessive beyond 0.1%, it results in excessive formation of TiC, thereby causing an increase of strength by precipitation enhancement but a deterioration of ductility. Ti content may more preferably be not lower than 0.05% as the more preferred lower limit (still more preferably not lower than 0.06%) and not higher than 0.09% as the more preferred higher limit (still more preferably not higher than 0.08%).

[One or more selected from the group consisting of Cu, Ni, Cr, and Mo at 1% or lower (not including 0%) in total]

[0055] Cu, Ni, Cr, and Mo prevent the formation of cementite during cooling after heating, and effectively act the securement of retained austenite. To make such an effect exhibited, these elements may preferably be contained at 0.01% or higher in total. Taking only characteristics into consideration, their content may be preferable when it is higher, but may preferably be controlled to 1% or lower in total because of a cost increase by alloy element addition. In addition, these elements have the action of considerably enhancing the strength of austenite, thereby increasing a hot rolling load so that the production of steel sheets becomes difficult. Therefore, even from the viewpoint of productivity, their content may preferably be controlled to 1% or lower. These elements' content may more preferably be not lower than 0.05% as the more preferred lower limit (still more preferably not lower than 0.06%) in total and not higher than 0.9% as the more preferred upper limit (still more preferably not higher than 0.8%) in total.

[V and/or Nb at 0.1% or lower (not including 0%) in total]

[0056] V and Nb have the effect of forming fine carbide and make structure fine by pinning effect. To make such an effect exhibited, these elements may preferably be contained at 0.001% or higher in total. However, when these elements' content becomes excessive, it results in the formation of coarse carbide, which becomes the origin of fracture, thereby deteriorating ductility in contrast. Therefore, these elements' content may preferably be controlled to 0.1% or lower in total. These elements' content may more preferably be not lower than 0.005% as the more preferred lower limit (still more preferably not lower than 0.008%) in total and not higher than 0.08% as the more preferred upper limit (still more preferably not higher than 0.06%) in total.

[0057] The thin steel sheet for hot press forming of the present invention may be either a non-plated steel sheet or a plated steel sheet. When it is a plated steel sheet, the type of plating may be either ordinary galvanization or aluminium coating. The method of plating may be either hot-dip plating or electroplating. After the plating, alloying heat treatment may be carried out, or additional plating may be carried out as multilayer plating.

[0058] According to the present invention, the characteristics of formed products, such as strength and elongation, can be controlled by properly adjusting press forming conditions (heating temperature and cooling rate), and in addition, hot press-formed products having high ductility (retained ductility) can be obtained, so that they can be applied even to parts (e.g., energy-absorbing members), to which conventional hot press-formed products have hardly been applied; therefore, the present invention is extremely useful for extending the application range of hot press-formed products. The formed products, which can be obtained in the present invention, have further enhanced residual ductility as compared with formed products, of which structure was adjusted by ordinary annealing after cold press forming.

[0059] The following will describe the advantageous effects of the present invention more specifically by way of Examples, but the present invention is not limited to the Examples described below. The present invention can be put into practice after appropriate modifications or variations within a range capable of meeting the gist described above and below, all of which are included in the technical scope of the present invention.

[0060] The present application claims the benefit of priority based on Japanese Patent Application No. 2011-130636 filed on June 10, 2011. The entire contents of the specification of Japanese Patent Application No. 2011-130636 filed on June 10, 2011 are hereby incorporated by reference into the present application.

EXAMPLES

[0061] Steel materials having respective chemical element compositions shown in Table 1 below were formed into slabs for experimental use by a vacuum fusion method, after which the slabs were hot rolled, followed by cooling, and then wound. These rolled sheets were further cold rolled into thin steel sheets, followed by quench treatment so that they had respectively prescribed initial structures. In Table 1, Ac_1 transformation point, Ac_3 transformation point, Ms point, and (Bs - 100°C) were determined respectively on the basis of formulas (2) to (5) described below (see, e.g., the Japanese translation of "The Physical Metallurgy of Steels" originally written by William C. Leslie, published by Maruzen, 1985). Table 1 further shows the calculated values of (Ac_1 transformation point x 0.3 + Ac_3 transformation point x 0.7) (these calculated values may hereinafter be referred to as "A values").

$$Ac_1 \text{ transformation point } (°C) = 723 + 29.1 \times [Si] - 10.7 \times [Mn] + 16.9 \times [Cr] - 16.9 \times [Ni] \cdots (2)$$

$$Ac_3 \text{ transformation point } (°C) = 910 - 203 \times [C]^{1/2} + 44.7 \times [Si] - 30 \times [Mn] + 700 \times [P] + 400 \times [Al] + 400 \times [Ti] + 104 \times [V] - 11 \times [Cr] + 31.5 \times [Mo] - 20 \times [Cu] - 15.2 \times [Ni] \cdots (3)$$

$$Ms \text{ point } (°C) = 550 - 361 \times [C] - 39 \times [Mn] - 10 \times [Cu] - 17 \times [Ni] - 20 \times [Cr] - 5 \times [Mo] + 30 \times [Al] \cdots (4)$$

$$Bs \text{ point } (°C) = 830 - 270 \times [C] - 90 \times [Mn] - 37 \times [Ni] - 70 \times [Cr] - 83 \times [Mo] \cdots (5)$$

where [C], [Si], [Mn], [P], [Al], [Ti], [V], [Cr], [Mo], [Cu], and [Ni] indicate C, Si, Mn, P, Al, Ti, V, Cr, Mo, Cu, and Ni contents (% by mass), respectively. When some element indicated in a certain term of formulas (2) to (5) above is not contained, calculation is carried out under the assumption that the term does not exist in the formula.

[Table 1]

Steel grade	Chemical element composition* (% by mass)															Ac_1 transformation point (°C)	Ac_3 transformation point (°C)	Ms point (°C)	Bs – 100°C (°C)	A value (°C)
	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V	Nb	Ti	B	Al	N					
A	0.232	1.19	1.41	0.014	0.0021									0.053	0.0047	743	854	413	540	821
B	0.231	1.21	1.39	0.014	0.0021			0.21						0.053	0.0047	747	854	410	528	822
C	0.222	1.20	1.29	0.014	0.0021			0.21				0.027	0.0033	0.053	0.0047	748	869	417	539	832
D	0.225	1.31	1.33	0.014	0.0021	0.15						0.027	0.0033	0.053	0.0047	747	871	417	550	834
E	0.234	1.10	1.52	0.014	0.0021		0.22					0.027	0.0033	0.053	0.0047	735	854	404	522	818
F	0.229	1.04	1.41	0.014	0.0021	0.07		0.18				0.027	0.0033	0.053	0.0047	741	856	410	529	821
G	0.219	1.20	1.14	0.014	0.0021			0.15	0.03			0.027	0.0033	0.053	0.0047	748	876	425	555	837
H	0.225	1.23	1.26	0.014	0.0021				0.17			0.027	0.0033	0.053	0.0047	745	878	420	542	838
I	0.217	1.41	1.44	0.014	0.0021			0.20		0.03		0.027	0.0033	0.053	0.0047	752	878	413	528	840
J	0.230	0.89	1.37	0.014	0.0021			0.19			0.03	0.027	0.0033	0.053	0.0047	737	851	411	531	817
K	0.047	1.22	1.25	0.014	0.0021			0.19				0.027	0.0033	0.053	0.0047	748	923	482	592	870
L	0.230	0.01	1.22	0.014	0.0021			0.19				0.027	0.0033	0.053	0.0047	713	816	417	545	785
M	0.311	1.20	1.29	0.014	0.0021			0.21				0.027	0.0033	0.053	0.0047	748	851	385	515	820
N	0.232	0.18	1.41	0.014	0.0021			0.21				0.027	0.0033	0.053	0.0047	717	817	409	526	787

* The remainder consists of iron and unavoidable impurities other than P, S, and N.

[0062] The steel sheets thus obtained were heated under the respective conditions shown in Table 2 below, and then subjected to forming and cooling treatment using a high speed heat treatment testing system for steel sheets (CAS series, available from ULVAC-RIKO, Inc.), which can control an average cooling rate. The steel sheets to be subjected to cooling treatment had a size of 190 mm x 70 mm (and a sheet thickness of 1.4 mm). Test Nos. 1 to 14, 17 to 19, and 21 to 25 were the cases where hot-rolled steel sheets were used as steel sheets for forming. Test Nos. 15, 16, and 20 were the cases where cold-rolled steel sheets were used steel sheets for forming. The term "cooling 1" shown in Table 2 indicates cooling from a heating temperature to a temperature of 700°C to 500°C. The term "cooling 2" shown in Table 2 indicates cooling from then to a temperature range of [(Bs - 100°C) to Ms point] (In Test Nos. 19 to 23, forming was started at this stage). When needed, the steel sheet was subjected to hot-dip galvanization to obtain a hot-dip galvanized steel sheet (Test No. 25).

[0063] For the respective steel sheets after the above treatments (heating, forming, and cooling), measurement of tensile strength (TS) and elongation (total elongation EL), and observation of metallic structure (fraction of each structure), were carried out by the methods described below.

[Tensile strength (TS) and elongation (total elongation EL)]

[0064] JIS No. 5 specimens were used for tensile tests to measure tensile strength (TS) and elongation (EL). At that time, strain rate in the tensile tests was set to 10 mm/sec. In the present invention, the specimens were evaluated as "passing" when fulfilling any of the conditions that: (a) tensile strength (TS) is from 780 to 979 MPa and elongation (EL) is 25% or higher; and (b) tensile strength (TS) is from 980 to 1179 MPa and elongation (EL) is 15% or higher.

[Observation of metallic structure (fraction of each structure)]

[0065]

(1) For ferrite and bainitic ferrite structures in the steel sheets, the steel sheets were each subjected to nital etching, and then observed by SEM (with a magnification of 1000x or 2000x), in which ferrite and bainitic ferrite were distinguished to determine their respective fractions (area fractions).

(2) For the fraction (area fraction) of retained austenite in the steel sheets, the steel sheets were each measured by an X-ray diffraction method, after grinding to one-quarter thicknesses of the steel sheets and subsequent chemical polishing (see, e.g., ISJJ Int. Vol. 33 (1933), No. 7, p. 776).

(3) For the area fraction of martensite (as-quenched martensite), the steel sheets were each subjected to repera etching, and assuming white contrast as a mixed structure of martensite (as-quenched martensite) and retained austenite by SEM observation, the area fraction of the mixed structure was measured. The fraction of as-quenched martensite was calculated by subtracting the fraction of retained austenite, which had been determined by an X-ray diffraction method, from the area fraction of the mixed structure.

[0066] These results are shown in Table 3 below, together with the types of pre-forming steel sheets (fraction of ferrite, and reduction of cold-rolled steel sheet).

[Table 2]

Test No.	Steel grade	Production conditions								Plated or non-plated
		Steel sheet for forming		Heating temperature (°C)	Average cooling rate in cooling 1 (°C/sec)	Cooling rate changing temperature from cooling 1 to cooling 2 (°C)	Average cooling rate in cooling 2 (°C/sec)	Retention time at [Bs - 100°C to Ms point] (sec)	Forming finishing temperature (°C)	
		Fraction of ferrite (% by area)	Reduction (%)							
1	A	60	-	800	40	-	-	3.2	300	Non-plated
2	B	60	-	800	40	-	-	3.0	300	Non-plated
3	C	60	-	800	40	-	-	3.1	300	Non-plated
4	D	60	-	800	40	-	-	3.3	300	Non-plated
5	E	60	-	800	40	-	-	2.9	300	Non-plated
6	F	60	-	800	40	-	-	3.0	300	Non-plated
7	G	60	-	800	40	-	-	3.3	300	Non-plated
8	H	60	-	800	40	-	-	3.0	300	Non-plated
9	I	60	-	800	40	-	-	2.9	300	Non-plated
10	J	60	-	800	40	-	-	3.0	300	Non-plated
11	K	60	-	800	40	-	-	2.7	300	Non-plated
12	L	60	-	800	40	-	-	3.2	300	Non-plated
13	M	50	-	800	40	-	-	3.3	300	Non-plated
14	N	60	-	800	40	-	-	2.9	300	Non-plated
15	C	30	50	800	40	-	-	3.1	300	Non-plated
16	C	30	20	800	40	-	-	3.1	300	Non-plated
17	C	60	-	720	40	-	-	3.1	300	Non-plated
18	C	60	-	900	40	-	-	3.1	300	Non-plated
19	C	60	-	900	5	600	40	3.1	300	Non-plated
20	C	30	20	900	5	600	40	3.1	300	Non-plated
21	C	60	-	800	40	450	3	13.3	300	Non-plated

(continued)

Test No.	Steel grade	Production conditions								Plated or non-plated
		Steel sheet for forming		Heating temperature (°C)	Average cooling rate in cooling 1 (°C/sec)	Cooling rate changing temperature from cooling 1 to cooling 2 (°C)	Average cooling rate in cooling 2 (°C/sec)	Retention time at [Bs - 100°C to Ms point] (sec)	Forming finishing temperature (°C)	
		Fraction of ferrite (% by area)	Reduction (%)							
22	C	60	-	900	15	600	40	3.1	300	Non-plated
23	C	60	-	900	5	450	40	3.1	300	Non-plated
24	C	60	-	800	40	-	-	3.1	600	Non-plated
25	C	60	-	800	40	-	-	3.1	300	Plated

[Table 3]

Test No.	Steel grade	Structure of formed product (% by area)					Tensile strength TS (MPa)	Elongation EL (%)
		Ferrite	Bainitic ferrite	Martensite	Retained austenite	Others*		
1	A	41	25	26	8		994	17
2	B	43	29	22	6		1020	16
3	C	48	23	21	8		994	17
4	D	49	23	21	7		1002	17
5	E	49	24	20	7		1023	17
6	F	48	24	21	7		1031	17
7	G	44	25	23	8		1028	17
8	H	46	25	22	7		1011	17
9	I	45	24	23	8		1019	17
10	J	48	24	22	6		1018	17
11	K	49	26	24	1		1022	12
12	L	51	25	22	2		1302	14
13	M	36	28	28	8		1095	16
14	N	45	27	28	0		989	13
15	C	48	24	20	8		1023	17
16	C	25	45	25	5		1082	13
17	C	81	-	15	-	θ:4	745	14
18	C	-	-	95	5		1523	10
19	C	65	8	20	7		984	17
20	C	62	9	22	7		999	17
21	C	43	26	22	9		1032	18
22	C	12	61	20	7		1233	12
23	C	83	17	-	-		921	14
24	C	56	20	-	-	P:24	893	14
25	C	47	23	23	8		994	17

* θ and P indicate cementite and pearlite, respectively.

[0067] From these results, discussions can be made as follows: Test Nos. 1 to 10, 13, 15, 19 to 21, and 25 are Examples fulfilling the requirements defined in the present invention, thereby indicating that parts having satisfactory balance between strength and ductility were obtained.

[0068] In contrast, Test Nos. 11 to 12, 14, 16 to 18, and 22 to 24 are Comparative Examples not fulfilling any of the requirements defined in the present invention, thereby deteriorating any of the characteristics. More specifically, Test No. 11 was the case where steel having insufficient C content (steel grade K shown in Table 1) was used, so that retained austenite was not secured, thereby obtaining only low elongation (EL). Test No. 12 was the case where steel having insufficient Si content (steel grade L shown in Table 1), so that retained austenite was not secured, thereby obtaining only low elongation (EL).

[0069] Test No. 14 was intended for conventional 2MnB5 equivalent steel (steel grade N shown in Table 1), so that retained austenite was not secured, thereby obtaining only low elongation (EL), although high strength was obtained. Test No. 16 was the case where cold-rolled steel sheet having low reduction was used, so that the formed product had a structure containing ferrite at 25% by area, thereby lowering elongation (EL). Test No. 17 was the case where the heating temperature was lower than Ac_1 transformation point, so that the formed product had a structure containing ferrite at 81% by area (the remainder was martensite and cementite) and retained austenite was not secured, thereby lowering elongation (EL) and tensile strength. Test No. 18 was the case where the heating temperature was higher than A value, so that ferrite and bainitic ferrite were not secured by excessive formation of martensite, thereby lowering elongation (EL).

[0070] Test No. 22 was the case where the average cooling rate in cooling 1 was high, so that ferrite was not secured by the formation of bainitic ferrite, thereby lowering elongation (EL). Test No. 23 was the case where the average cooling rate in cooling 1 was low and the cooling rate changing temperature was low, so that the formed product had a structure containing ferrite at 83% by area (the remainder was bainitic ferrite) and retained austenite was not secured, thereby lowering elongation (EL). Test No. 24 was the case where the forming finishing temperature was high, so that pearlite was formed in the structure of the formed product and retained austenite was not secured, thereby lowing elongation (EL).

INDUSTRIAL APPLICABILITY

[0071] The present invention makes it possible to provide a hot press-formed product, including a steel sheet formed by a hot press-forming method, and having a metallic structure that contains ferrite at 30% to 80% by area, bainitic ferrite at lower than 30% by area (not including 0%), martensite at 30% by area or lower (not including 0%), and retained austenite at 3% to 20% by area, whereby balance between strength and elongation can be controlled in a proper range and high ductility can be achieved.

DESCRIPTION OF REFERENCE NUMERALS

[0072]

1 Punch
2 Die
3 Blank holder
4 Steel sheet (Blank)

Claims

1. A hot press-formed product, comprising a steel sheet formed by a hot press-forming method, and having a metallic structure that contains ferrite at 30% to 80% by area, bainitic ferrite at lower than 30% by area (not including 0% by area), martensite at 30% by area or lower (not including 0% by area), and retained austenite at 3% to 20% by area.

2. The hot press-formed product according to claim 1, having the following chemical element composition:

   C at 0.1% to 0.3% (where "%" means "% by mass", and the same applies to the below with respect to the chemical element composition);
   Si at 0.5% to 3%;
   Mn at 0.5% to 2%;
   P at 0.05% or lower (not including 0%);
   S at 0.05% or lower (not including 0%);
   Al at 0.01% to 0.1%; and
   N at 0.001% to 0.01%,

   and the remainder consisting of iron and unavoidable impurities.

3. The hot press-formed product according to claim 2, further comprising, as additional elements, B at 0.01% or lower (not including 0%) and Ti at 0.1% or lower (not including 0%).

4. The hot press-formed product according to claim 2 or 3, further comprising, as additional elements, one or more selected from the group consisting of Cu, Ni, Cr, and Mo at 1% or lower (not including 0%) in total.

5. The hot press-formed product according to claim 2 or 3, further comprising, as additional elements, V and/or Nb at 0.1% or lower (not including 0%) in total.

6. A process for producing a hot press-formed product as set forth in claim 1, comprising:

heating a hot-rolled steel sheet having a metallic structure that contains ferrite at 50% by area or higher, or heating a cold-rolled steel sheet at a reduction of 30% or higher, to a temperature not lower than Ac_1 transformation point and not higher than (Ac_1 transformation point x 0.3 + Ac_3 transformation point x 0.7); and then starting the forming of the hot-rolled steel sheet or the cold-rolled steel sheet with a press tool to produce the hot press-formed product, during which forming an average cooling rate of 20°C/sec or higher is kept in the press tool, and which forming is finished at a temperature not higher than (bainite transformation starting temperature Bs - 100°C).

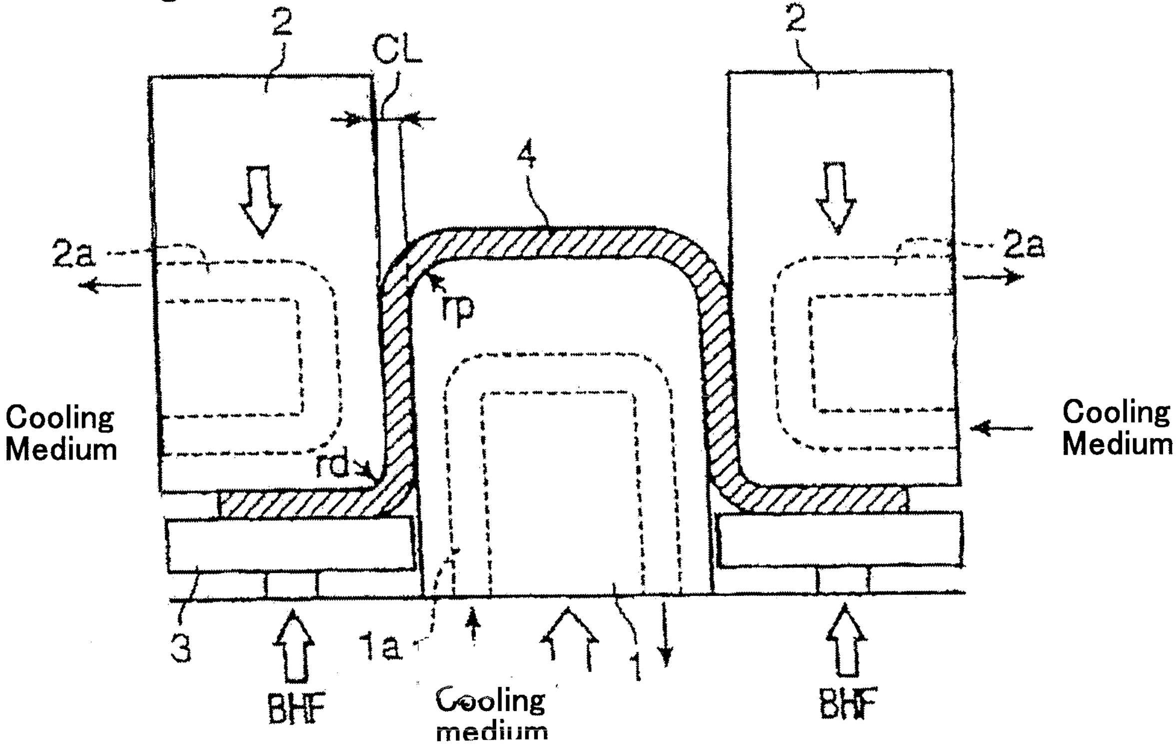
7. A process for producing a hot press-formed product as set forth in claim 1, comprising:

heating a thin steel sheet to a temperature not lower than Ac_3 transformation point and not higher than 1000°C; cooling the thin steel sheet to a temperature not higher than 700°C and not lower than 500°C at an average cooling rate of 10°C/sec or lower; and then
starting the forming of the thin steel sheet with a press tool to produce the hot press-formed product, during which forming an average cooling rate of 20°C/sec or higher is kept in the press tool, and which forming is finished at a temperature not higher than (bainite transformation starting temperature Bs - 100°C).

8. The process according to claim 6 or 7, wherein the forming finishing temperature is controlled in a temperature range of not higher than (bainite transformation starting temperature Bs - 100°C) and not lower than martensite transformation starting temperature Ms, in which temperature range the steel sheet is retained for 10 seconds or longer, followed by the forming.

9. A thin steel sheet for hot press forming, which is intended for use in producing a hot press-formed product as set forth in claim 1, and which is a hot-rolled steel sheet having a metallic structure that contains ferrite at 50% by area or higher, or a cold-rolled steel sheet at a reduction of 30% or higher.

Fig. 1


2
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INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER
C22C38/00(2006.01)i, *B21D22/20*(2006.01)i, *C21D1/18*(2006.01)i, *C21D9/00*(2006.01)i, *C22C38/60*(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)
C22C38/00, B21D22/20, C21D1/18, C21D9/00, C22C38/60

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	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

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 2007-16296 A (Nippon Steel Corp.), 25 January 2007 (25.01.2007), entire text (Family: none)	1-9
A	JP 9-143612 A (Kobe Steel, Ltd.), 03 June 1997 (03.06.1997), entire text (Family: none)	1-9
A	JP 2010-65292 A (JFE Steel Corp.), 25 March 2010 (25.03.2010), entire text (Family: none)	1-9

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

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Date of the actual completion of the international search	Date of mailing of the international search report
22 August, 2012 (22.08.12)	04 September, 2012 (04.09.12)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2011130636 A **[0060]**

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- Tailor made tool materials for the present and upcoming tooling solutions in hot sheet metal forming. **BEGONA CASAS ; DAVID LATRE ; NOEMI RODRIGUEZ ; ISAAC VALLS.** Proc, of 1st Int. Conf. on Hot Sheet Metal Forming of High-Performance steel. 2008, 23-35 **[0014]**
- The Physical Metallurgy of Steels. **WILLIAM C. LESLIE.** Japanese translation. Maruzen, 1985 **[0061]**
- *ISJJ Int.,* 1933, vol. 33 (7), 776 **[0065]**