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(54) **HOT-PRESSING STEEL PLATE, PRESS-MOLDED ARTICLE, AND METHOD FOR MANUFACTURING PRESS-MOLDED ARTICLE**

(57) Provided is a hot-pressing steel plate useful for obtaining a press-molded article having excellent anti-softening characteristics in heat-affected zones (HAZ) while attaining a press-molded article that can achieve a high level of balance between high strength and stretchability if uniform characteristics within the molded article are required, and a high level of balance between high strength and stretchability in respective regions if regions corresponding to shock-resistant portions and energy-absorbing portions are required within one molded article; molding and processing prior to hot-pressing being facilitated by the hot-pressing steel plate having a prescribed chemical composition, having the equivalent circular diameter of Ti-containing deposits included in the steel plate be 30 nm or less with the average equivalent circular diameter of the Ti-containing deposits being 6 nm or less, having the deposited Ti amount and the total Ti amount within the steel satisfy a prescribed relation, and having a metal structure with a proportion of ferrite of 30% by area or greater.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a steel sheet for hot-pressing to be used for an automotive structural component and suitable for hot-press forming, a press-formed article obtained from the steel sheet for hot-pressing, and a method for manufacturing a press-formed article. More specifically, the present invention relates to a steel sheet for hot-pressing which is useful, when forming a previously heated steel sheet (blank) into a predetermined shape, for the application to a hot-press forming method of imparting a shape, and applying a heat treatment to obtain a predetermined strength, a press-formed article, and a method useful for the manufacture of such a press-formed article.

BACKGROUND ART

[0002] As one of the measures for automotive fuel economy improvement triggered by global environmental problems, weight saving of a vehicle body is proceeding, and in turn, the strength of a steel sheet used for automobiles must be increased as much as possible. On the other hand, when the strength of a steel sheet is increased, the shape accuracy during press forming decreases.

[0003] For this reason, a component (press-formed article) is manufactured by employing a hot-press forming method where a steel sheet is heated to a given temperature (e.g., a temperature for forming an austenite phase) to lower the strength and then formed with a mold at a temperature (e.g., room temperature) lower than that of the steel sheet to impart a shape and, perform rapid-cooling heat treatment (quenching) by making use of a temperature difference therebetween so as to ensure the strength after forming. Such a hot-press forming method is referred to by various names such as hot forming method, hot stamping method, hot stamp method and die quenching method, in addition to hot-pressing method.

[0004] FIG. 1 is a schematic explanatory view showing the mold configuration for carrying out the above-described hot-press forming. In FIG. 1, 1 is a punch, 2 is a die, 3 is a blank holder, 4 is a steel sheet (blank), BHF is a blank holding force, rp is a punch shoulder radius, rd is a die shoulder radius, and CL is a punch-to-die clearance. Of these parts, the punch 1 and the die 2 are configured such that passages 1a and 2a allowing for passing of a cooling medium (e.g., water) are formed in respective insides and the parts are cooled by passing a cooling medium through the passage.

[0005] When hot-press forming (for example, hot deep drawing) is performed using such a mold, the forming is started in a state where the steel sheet (blank) 4 is softened by heating at a two-phase zone temperature of (Ac_1 transformation point to Ac_3 transformation point) or a single-phase zone temperature equal to or more than Ac_3 transformation point. More specifically, in the state of the steel sheet 4 at a high temperature being sandwiched between the die 2 and the blank holder 3, the steel sheet 4 is pushed into a hole of the die 2 (between 2 and 2 in FIG. 1) by the punch 1 and formed into a shape corresponding to the outer shape of the punch 1 while reducing the outer diameter of the steel sheet 4. In addition, heat is removed from the steel sheet 4 to the mold (the punch 1 and the die 2) by cooling the punch and the die in parallel with forming, and quenching of the material (steel sheet) is carried out by further holding and cooling the steel sheet at the forming bottom dead center (the point when the punch head is positioned at the deepest part: the state shown in FIG. 1). By carrying out such a forming method, a formed article of 1500 MPa class can be obtained with high dimensional accuracy and moreover, the forming load can be reduced as compared with a case of forming a component of the same strength class by cold working, so that the volume required of the pressing machine can be small.

[0006] As the steel sheet for hot-pressing which is widely used at present, a steel sheet using 22MnB5 steel as the material is known. This steel sheet has a tensile strength of 1,500 MPa and an elongation of approximately from 6 to 8% and is applied to an impact-resistant member (a member that undergoes as little a deformation as possible at the time of collision and is not fractured). However, its application to a component requiring a deformation, such as energy-absorbing member, is difficult because of low elongation (ductility).

[0007] As the steel sheet for hot-pressing which exerts good elongation, the techniques of, for example, Patent Documents 1 to 4 have also been proposed. In these techniques, the carbon content in the steel sheet is set in various ranges to adjust the fundamental strength class of respective steel sheets, and the elongation is enhanced by introducing a ferrite having high deformability and reducing the average particle diameters of ferrite and martensite. The techniques above are effective in enhancing the elongation but in view of elongation enhancement according to the strength of the steel sheet, it is still insufficient. For example, the elongation EL of a steel sheet having a tensile strength TS of 1,470 MPa or more is about 10.2% at the maximum, and further improvement is demanded.

[0008] On the other hand, a formed article of a low strength class as compared with hot-stamp formed articles which have been heretofore studied, for example, a formed article having a tensile strength TS of 980 MPa class or 1,180 MPa class, also has a problem with the forming accuracy in the cold pressing, and as an improvement measure thereof, there is a need for low-strength hot pressing. In this case, the energy absorption properties in a formed article must be greatly improved.

[0009] Particularly, in recent years, a technique for differentiating the strength within a single component is being developed. As such a technique, a technique of imparting high strength to a site that must be prevented from deforming (high strength side: impact resistant site-side) and imparting low strength and high ductility to a site that must absorb energy (low strength side: energy absorption site-side) has been proposed. For example, in a passenger car of middle or higher class, both functional sites of impact resistance and energy absorption are sometimes provided in a component of B-pillar or rear side member by taking into account the compatibility at the time of side collision and rear collision (a function of protecting also the counterpart side when involved in a collision with a small car). For manufacturing such a member, there have been proposed, for example, (a) a method where a steel sheet having low strength even when heated/mold quenched at the same temperature is joined to a normal steel sheet for hot-pressing (tailored weld blank: TWB), (b) a method where the cooling rate in the mold is differentiated to create a difference in the strength among respective regions of a steel sheet, (c) a method where a difference in the heating temperature is created among respective regions of a steel sheet to differentiate the strength.

[0010] In these techniques, a tensile strength of 1,500 MPa class is achieved on the high strength side (impact resistant site-side), but the low strength side (energy absorption site-side) stays at a maximum tensile strength of 700 MPa and an elongation EL of about 17% and in order to further improve the energy absorption properties, it is required to realize higher strength and higher ductility.

[0011] In addition, in order to realize a complicated shape by hot stamping, applicability to an approach of performing press forming at room temperature to create a shape to a certain degree and then performing hot stamping is required, or since a steel sheet for use in press forming of hot stamping is cut out, the strength of a steel sheet for hot-stamping is also required not to be excessively high.

[0012] In the meantime, an automotive component needs to be joined mainly by spot welding, but it is known that strength in the weld heat affected zone (HAZ) is reduced significantly and the welded joint is subject to a strength reduction (softening) (for example, Non-Patent Document 1).

RELATED ART

PATENT DOCUMENT

[0013]

Patent Document 1: JP-A-2010-65292
Patent Document 2: JP-A-2010-65293
Patent Document 3: JP-A-2010-65294
Patent Document 4: JP-A-2010-65295

NON-PATENT DOCUMENT

[0014] Non-Patent Document 1: Hirosue et al. "Nippon Steel Technical Report", No. 378, pp. 15-20 (2003)

SUMMARY OF THE INVENTION

PROBLEMS THAT THE INVENTION IS TO SOLVE

[0015] The present invention has been made under these circumstances, and an object thereof is to provide a steel sheet for hot-pressing which makes it possible to easily conduct forming or working before hot pressing, obtain a press-formed article capable of achieving a high-level balance between high strength and elongation when uniform properties are required in a formed article, achieve a high-level balance between high strength and elongation according to respective regions when regions corresponding to an impact resistant site and an energy absorption site are required in a single formed article, and moreover, improve the anti-softening property in HAZ; a press-formed article exerting the above-described properties; and a method useful for manufacturing such a press-formed article.

MEANS FOR SOLVING THE PROBLEMS

[0016] The steel sheet for hot-pressing in the present invention, which can attain the object above, contains:

C: from 0.15 to 0.5% (mass%; hereinafter, the same applies to the chemical component composition),
Si: from 0.2 to 3%,
Mn: from 0.5 to 3%,

P: 0.05% or less (exclusive of 0%),
S: 0.05% or less (exclusive of 0%),
Al: from 0.01 to 1%,
B: from 0.0002 to 0.01%,
Ti: equal to or more than 3.4[N]+0.01% and equal to or less than 3.4[N]+0.1 % (wherein [N] indicates a content (mass%) of N), and
N: from 0.0010 to 0.01 %, with the remainder being iron and unavoidable impurities, in which

an average equivalent-circle diameter of a Ti-containing precipitate having an equivalent-circle diameter of 30 nm or less among Ti-containing precipitates contained in the steel sheet is 6 nm or less, a precipitated Ti amount and a total Ti amount in a steel satisfy a relationship of the following formula (1), and a ferrite fraction in a metal microstructure is 30 area% or more. Here, the "equivalent-circle diameter" is the diameter of a circle having the same area as the size (area) of a Ti-containing precipitate (e.g., TiC) when the precipitate is converted to a circle ("the average equivalent-circle diameter" is the average value thereof).

$$\text{Precipitated Ti amount (mass\%)} - 3.4[N] < 0.5 \times [(\text{total Ti amount (mass\%)}) - 3.4[N]] \cdots (1)$$

(in the formula (1), [N] indicates the content (mass%) of N in the steel).

[0017] In the steel sheet for hot-pressing in the present invention, it is also useful to contain, as the other element(s), at least one of the following (a) to (c), if desired. The properties of the press-formed article are further improved according to the kind of the element that is contained according to need.

(a) One or more kinds selected from the group consisting of V, Nb and Zr, in an amount of 0.1% or less (exclusive of 0%) in total
(b) One or more kinds selected from the group consisting of Cu, Ni, Cr and Mo, in an amount of 1% or less (exclusive of 0%) in total
(c) One or more kinds selected from the group consisting of Mg, Ca and REM, in an amount of 0.01% or less (exclusive of 0%) in total

[0018] In the method for manufacturing a press-formed article in the present invention, which can attain the object above, the steel sheet for hot-pressing in the present invention is heated at a temperature equal to or more than Ac_1 transformation point+20°C and equal to or less than Ac_3 transformation point-20°C, then press forming of the steel sheet is started, and the steel sheet is cooled to a temperature equal to or less than a temperature 100°C below a bainite transformation starting temperature Bs while ensuring an average cooling rate of 20°C/sec or more in a mold during forming and after a completion of forming.

[0019] In the press-formed article in the present invention, the metal microstructure of the press-formed article includes retained austenite: from 3 to 20 area%, ferrite: from 30 to 80 area%, bainitic ferrite: less than 30 area% (exclusive of 0 area%), and martensite: 31 area% or less (exclusive of 0 area%), and an average equivalent-circle diameter of a Ti-containing precipitate having an equivalent-circle diameter of 30 nm or less among Ti-containing precipitates contained in the press-formed article is 10 nm or less, a precipitated Ti amount and a total Ti amount in a steel satisfy the relationship of the following formula (1), and a high-level balance between high strength and elongation can be achieved as uniform properties in the formed article.

$$\text{Precipitated Ti amount (mass\%)} - 3.4[N] < 0.5 \times [(\text{total Ti amount (mass\%)}) - 3.4[N]] \cdots (1)$$

(in the formula (1), [N] indicates the content (mass%) of N in the steel).

[0020] On the other hand, in another method for manufacturing a press-formed article in the present invention, which can attain the object above, the above steel sheet for hot-pressing is used, a heating region of the steel sheet is divided into at least two regions, one region of them is heated at a temperature of Ac_3 transformation point or more and 950°C or less, another region of them is heated at a temperature equal to or more than Ac_1 transformation point+20°C and equal to or less than Ac_3 transformation point-20°C, then press forming of both regions is started, and the steel sheet is cooled to a temperature equal to or less than a martensite transformation starting temperature Ms while ensuring an average cooling rate of 20°C/sec or more in a mold in both of the regions during forming and after a completion of forming.

[0021] Another press-formed article in the present invention is a press-formed article of a steel sheet having the chemical component composition above, and the press-formed article has a first region having a metal microstructure including retained austenite: from 3 to 20 area% and martensite: 80 area% or more and a second region having a metal microstructure including retained austenite: from 3 to 20 area%, ferrite: from 30 to 80 area%, bainitic ferrite: less than 30 area% (exclusive of 0 area%), and martensite: 31 area% or less (exclusive of 0 area%), and an average equivalent-circle diameter of a Ti-containing precipitate having an equivalent-circle diameter of 30 nm or less among Ti-containing precipitates contained in a steel of the second region is 10 nm or less, and a precipitated Ti amount and a total Ti amount in the steel satisfy the relationship of the following formula (1). In this press-formed article, a high-level balance between high strength and elongation can be achieved depending on respective regions, and regions corresponding to an impact resistant site and an energy absorption site are present in a single formed article, and moreover, when spot welding is performed in the second region, the anti-softening property of HAZ is improved.

$$\text{Precipitated Ti amount (mass\%)} - 3.4[\text{N}] < 0.5 \times [(\text{total Ti amount (mass\%)}) - 3.4[\text{N}]] \cdots (1)$$

(in the formula (1), [N] indicates the content (mass%) of N in the steel).

ADVANTAGE OF THE INVENTION

[0022] According to the present invention, a steel sheet where the chemical component composition is strictly specified and the size of the Ti-containing precipitate is controlled, and where the precipitation rate of Ti not forming TiN is controlled, and as to the metal microstructure, the ratio of ferrite is adjusted, is used, so that by hot-pressing the steel sheet under predetermined conditions, the strength-elongation balance of the press-formed article can be made to be a high-level balance. In addition, when hot-pressing is performed under different conditions among a plurality of regions, an impact resistant site and an energy absorption site can be formed in a single formed article, and a high-level balance between high strength and elongation can be achieved in respective sites, and moreover, the anti-softening property in HAZ is improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] [FIG. 1] A schematic explanatory view showing the mold configuration for carrying out hot-press forming.

MODE FOR CARRYING OUT THE INVENTION

[0024] The present inventors have made studies from various aspects to realize a steel sheet for hot-pressing which ensures that, in the manufacture of a press-formed article by heating a steel sheet at a predetermined temperature and then hot-press forming the steel sheet, a press-formed article exhibiting good ductility (elongation) is obtained while assuring high strength after press forming.

[0025] As a result, it has been found that when the chemical component composition of the steel sheet for hot-pressing is strictly specified and the size of the Ti-containing precipitate as well as the precipitated Ti amount are controlled and when a proper metal microstructure is created and the steel sheet is hot-press formed under predetermined conditions, a predetermined amount of retained austenite is ensured after press forming and a press-formed article having increased intrinsic ductility (residual ductility) is obtained. The present invention has been accomplished based on this finding.

[0026] In the steel sheet for hot-pressing in the present invention, the chemical component composition needs to be strictly specified, and the reason for limiting the range of each chemical component is as follows.

(C: from 0.15 to 0.5%)

[0027] C is an important element in achieving a high-level balance between high strength and elongation when uniform properties are required in a press-formed article, or in ensuring retained austenite particularly in the low strength/high ductility site when regions corresponding to an impact resistant site and an energy absorption site are required in a single formed article. In addition, C is enriched into austenite during heating in the hot press forming, so that retained austenite can be formed after quenching. Furthermore, this element contributes to increasing the amount of martensite and increases the strength. In order to exert such effects, the C content must be 0.15% or more.

[0028] However, if the C content is too large and exceeds 0.5%, the two-phase zone heating region becomes narrow, and when uniform properties are required in a formed article, the balance between high strength and elongation is not achieved at a high level, or when regions corresponding to an impact resistant site and an energy absorption site are required in a single formed article, adjustment to a metal microstructure (microstructure where predetermined amounts of ferrite, bainitic ferrite and martensite are ensured) targeted particularly in the low strength/high ductility site is difficult. The lower limit of the C content is preferably 0.17% or more (more preferably 0.20% or more), and the upper limit is preferably 0.45% or less (more preferably 0.40% or less).

(Si: from 0.2 to 3%)

[0029] Si exerts an effect of forming retained austenite by preventing martensite from being tempered during cooling of mold quenching to form cementite or by suppressing decomposition of untransformed austenite. In order to exert such an effect, the Si content must be 0.2% or more. If the Si content is too large and exceeds 3%, ferrite transformation is promoted during cooling after hot rolling, and TiC in the resulting ferrite is likely to be coarsely formed, and as a result, the anti-softening property in HAZ is not obtained. The lower limit of the Si content is preferably 0.5% or more (more preferably 1.0% or more), and the upper limit is preferably 2.5% or less (more preferably 2.0% or less).

(Mn: from 0.5 to 3%)

[0030] Mn is an element effective in enhancing the hardenability during quenching and suppressing the formation of a microstructure (e.g., ferrite, pearlite, bainite) other than martensite and retained austenite during cooling of mold quenching. In addition, Mn is an element capable of stabilizing austenite and is an element contributing to an increase in the retained austenite amount. In order to exert such effects, Mn must be contained in an amount of 0.5% or more. In the case of considering only the properties, the Mn content is preferably larger, but since the cost of alloying addition rises, the upper limit is set to 3% or less. The lower limit of the Mn content is preferably 0.7% or more (more preferably 1.0% or more), and the upper limit is preferably 2.5% or less (more preferably 2.0% or less).

(P: 0.05% or less (exclusive of 0%))

[0031] P is an element unavoidably contained in the steel but deteriorates the ductility and therefore, the P content is preferably reduced as much as possible. However, an extreme reduction causes an increase in the steelmaking cost, and it is difficult in terms of manufacture to reduce the content to 0%. For this reason, the upper limit is set to 0.05% or less (exclusive of 0%). The upper limit of the P content is preferably 0.045% or less (more preferably 0.040% or less).

(S: 0.05% or less (exclusive of 0%))

[0032] S is an element unavoidably contained in the steel, as with P, and deteriorates the ductility and therefore, the S content is preferably reduced as much as possible. However, an extreme reduction causes an increase in the steelmaking cost, and it is difficult in terms of manufacture to reduce the content to 0%. For this reason, the upper limit is set to 0.05% or less (exclusive of 0%). The upper limit of the S content is preferably 0.045% or less (more preferably 0.040% or less).

(Al: from 0.01 to 1%)

[0033] Al is useful as a deoxidizing element and allows the solute N present in the steel to be fixed as AlN, which is useful in enhancing the ductility. In order to effectively exert such an effect, the Al content must be 0.01% or more. However, if the Al content is too large and exceeds 1 %, Al_2O_3 is excessively produced to deteriorate the ductility. The lower limit of the Al content is preferably 0.02% or more (more preferably 0.03% or more), and the upper limit is preferably 0.8% or less (more preferably 0.6% or less).

(B: from 0.0002 to 0.01%)

[0034] B is an element having an action of suppressing ferrite transformation, pearlite transformation and bainite transformation on the high strength site-side and therefore, contributes to preventing the formation of ferrite, pearlite and bainite during cooling after heating at a two-phase zone temperature of (Ac_1 transformation point to Ac_3 transformation point), and ensuring retained austenite. In order to exert such effects, B must be contained in an amount of 0.0002% or more, but even when this element is contained excessively over 0.01%, the effects are saturated. The lower limit of the B content is preferably 0.0003% or more (more preferably 0.0005% or more), and the upper limit is preferably 0.008% or less (more preferably 0.005% or less).

(Ti: equal to or more than 3.4[N]+0.01% and equal to or less than 3.4[N]+0.1%: [N] is the content (mass%) of N)

[0035] Ti exerts an effect of improving the hardenability during quenching by fixing N and maintaining B in a solid solution state. In order to exert such an effect, it is important to contain this element in an amount larger than the stoichiometric ratio of Ti and N (3.4 times the N content) by 0.01% or more. In addition, when Ti added excessively relative to N is caused to be present in a solid solution state in a hot-stamp formed article and the precipitated compound is finely dispersed, the strength reduction in HAZ can be suppressed by virtue of precipitation strengthening due to formation, as TiC, of Ti dissolved in solid during welding of the hot-stamp formed article or by virtue of an effect such as delaying increase of the dislocation density due to the dislocation movement-preventing effect of TiC. However, if the Ti content is too large and exceeds 3.4[N]+0.1%, the Ti-containing precipitate (e.g., TiN) formed is coarsened to deteriorate the ductility of the steel sheet. The lower limit of the Ti content is preferably 3.4[N]+0.02% or more (more preferably 3.4[N]+0.05% or more), and the upper limit is preferably 3.4[N]+0.09% or less (more preferably 3.4[N]+0.08% or less).

(N: from 0.001 to 0.01%)

[0036] N is an element unavoidably mixed in, and the content thereof is preferably reduced as much as possible, but the reduction in an actual process is limited and therefore, the lower limit is set to 0.001%. If the N content is too large, the Ti-containing precipitate (e.g., TiN) formed is coarsened, and this precipitate works as a fracture origin to deteriorate the ductility of the steel sheet. For this reason, the upper limit is set to 0.01%. The upper limit of the N content is preferably 0.008% or less (more preferably 0.006% or less).

[0037] The basic chemical components in the steel sheet for hot-pressing in the present invention are as described above, and the remainder is iron and unavoidable impurities (e.g., O, H) other than P, S and N. In the steel sheet for hot-pressing in the present invention, it is also useful to further contain at least one of the following (a) to (c), if desired. The properties of the steel sheet for hot-pressing (i.e., press-formed article) are further improved according to the kind of the element that is contained according to need. In the case of containing such an element, the preferable range and the reason for limitation on the range are as follows.

(a) One or more kinds selected from the group consisting of V, Nb and Zr, in an amount of 0.1 % or less (exclusive of 0%) in total
(b) One or more kinds selected from the group consisting of Cu, Ni, Cr and Mo, in an amount of 1% or less (exclusive of 0%) in total
(c) One or more kinds selected from the group consisting of Mg, Ca and REM, in an amount of 0.01% or less (exclusive of 0%) in total

(One or more kinds selected from the group consisting of V, Nb and Zr, in an amount of 0.1 % or less (exclusive of 0%) in total)

[0038] V, Nb and Zr have an effect of forming fine carbide and refining the microstructure by a pinning effect. In order to exert such an effect, these elements are preferably contained in an amount of 0.001 % or more in total. However, if the content of these elements is too large, coarse carbide is formed and works out to a fracture origin to conversely deteriorate the ductility. For this reason, the content of these elements is preferably 0.1% or less in total. The lower limit of the content of these elements is more preferably 0.005% or more (still more preferably 0.008% or more) in total, and the upper limit is more preferably 0.08% or less (still more preferably 0.06% or less) in total.

(One or more kinds selected from the group consisting of Cu, Ni, Cr and Mo: 1% or less (exclusive of 0%) in total)

[0039] Cu, Ni, Cr and Mo suppress ferrite transformation, pearlite transformation and bainite transformation and therefore, effectively act to prevent the formation of ferrite, perlite and bainite during cooling after heating and ensure retained austenite. In order to exert such an effect, these are preferably contained in an amount of 0.01 % or more in total. In the case of considering only the properties, the content is preferably larger, but since the cost of alloying addition rises, the content is preferably 1 % or less in total. In addition, these elements have an action of greatly increasing the strength of austenite and put a large load on hot rolling, making it difficult to manufacture a steel sheet. Therefore, also from the standpoint of manufacturability, the content is preferably 1% or less. The lower limit of the content of these elements is more preferably 0.05% or more (still more preferably 0.06% or more) in total, and the upper limit is more preferably 0.5% or less (still more preferably 0.3% or less) in total.

(One or more kinds selected from the group consisting of Mg, Ca and REM (rare earth element), in an amount of 0.01% or less (exclusive of 0%) in total)

[0040] These elements refine the inclusion and therefore, effectively act to enhance the ductility. In order to exert such an effect, these elements are preferably contained in an amount of 0.0001% or more in total. In the case of considering only the properties, the content is preferably larger, but since the effect is saturated, the content is preferably 0.01% or less in total. The lower limit of the content of these elements is more preferably 0.0002% or more (still more preferably 0.0005% or more) in total, and the upper limit is more preferably 0.005% or less (still more preferably 0.003% or less) in total.

[0041] In the steel sheet for hot-pressing in the present invention, (A) the average equivalent-circle diameter of Ti-containing precipitates having an equivalent-circle diameter of 30 nm or less among Ti-containing precipitates contained in the steel sheet is 6 nm or less, (B) the relationship of "precipitated Ti amount (mass%)-3.4[N] < 0.5×[total Ti amount (mass%)-3.4[N]]" (the relationship of the formula (1)) is satisfied, and (C) the ferrite fraction in the metal microstructure is 30 area% or more, are also important requirements.

[0042] The Ti-containing precipitate and formula (1) is controlled for preventing softening of HAZ and such a control is originally a control required of a formed article, but these values are little changed between before and after hot-press forming. Therefore, the control needs to be already done at the stage before forming (the steel sheet for hot-pressing). When excessive Ti relative to N in the steel sheet before forming is cause to be present in a solid solution state or refined state, the Ti-containing precipitate can be maintained in a solid solution state or refined state during heating of hot pressing. As a result, the amount of Ti precipitated in the press-formed article can be controlled to not more than a predetermined amount, and softening in HAZ can be prevented, whereby the joint properties can be improved.

[0043] From such a standpoint, Ti-containing precipitates needs to be finely dispersed and to this end, the average equivalent-circle diameter of Ti-containing precipitates having an equivalent-circle diameter of 30 nm or less among Ti-containing precipitates contained in the steel sheet must be 6 nm or less (requirement of (A) above). Here, the equivalent-circle diameter of the target Ti-containing precipitate is specified to be 30 nm or less, because it is necessary to control Ti-containing precipitates excluding TiN that is formed coarsely in the melting stage and thereafter does not affect the microstructural change or properties. The size (average equivalent-circle diameter) of the Ti-containing precipitate is preferably 5 nm or less, more preferably 3 nm or less. Examples of the Ti-containing precipitate targeted in the present invention include TiC, TiN and other Ti-containing precipitates such as TiVC, TiNbC, TiVCN and TiNbCN.

[0044] As described later, the average equivalent-circle diameter of Ti-containing precipitates in the press-formed article is specified to be 10 nm or less, whereas that before forming (steel sheet for hot-pressing) is specified to be 6 nm or less. The reason why the size of the precipitate is specified to be larger in the formed article than in the steel sheet is that Ti is present as a fine precipitate or in a solid solution state in the steel sheet and when heated at near 800°C for 15 minutes or more, the Ti-containing precipitate is slightly coarsened. In order to ensure the properties as a formed article, the average equivalent-circle diameter of Ti-containing precipitates must be 10 nm or less, and for realizing this precipitation state in a hot-stamp formed article, it is necessary that in the state of the steel sheet for hot-stamping, the average equivalent-circle diameter of fine precipitates of 30 μm or less is adjusted to 6 nm or less and many of Ti is caused to be present in a solid solution state.

[0045] In addition, in the steel sheet for hot-pressing, the majority of Ti except for Ti to be used for precipitating and fixing N must be caused to be present in a solid solution state or refined state. To this end, the amount of Ti present as a precipitate other than TiN (i.e., precipitated Ti amount (mass%)-3.4[N]) needs to be an amount smaller than 0.5 times the remainder after deduction of Ti that forms TiN from total Ti (i.e., 0.5×[(total Ti amount (mass%))-3.4[N]]) (requirement of (B) above). The "precipitated Ti amount (mass%)-3.4[N]" is preferably 0.4×[(total Ti amount (mass%))-3.4[N]] or less, more preferably 0.3×[(total Ti amount (mass%))-3.4[N]] or less.

[0046] The steel material must be necessarily processed before hot stamping and is sometimes subjected to press forming, and in such a case, a predetermined amount of ferrite as soft microstructure needs to be ensured. From such a standpoint, the ferrite fraction in the steel sheet for hot-pressing must be 30 area% or more (requirement of (C) above). The ferrite fraction is preferably 50 area% or more, more preferably 70 area% or more.

[0047] In the steel sheet for hot-pressing, the remainder of the metal microstructure is not particularly limited but includes, for example, at least any one of pearlite, bainite, martensite and retained austenite.

[0048] For manufacturing the steel sheet (steel sheet for hot-pressing) in the present invention, a slab prepared by melting a steel material having the above-described chemical component composition may be hot-rolled at a heating temperature: 1,100°C or more (preferably 1,150°C or more) and 1,300°C or less (preferably 1,250°C or less) and a finish rolling temperature of 850°C or more (preferably 900°C or more) and 1,050°C or less (preferably 1,000°C or less), and immediately after that, it may be cooled (rapid cooling) at an average cooling rate of 20°C/sec or more (preferably 30°C/sec or more) until 650°C or less (preferably 625°C or less) and after that, it may be cooled at 10°C/sec or less (preferably 5°C/sec or less) from 620°C to 580°C, and then, it may be cooled at an average cooling rate of 10°C/sec or more, and thereafter, it may be wound at a temperature of 350°C or more (preferably 380°C or more) and 450°C or less (preferably 430°C or less).

[0049] In the method above, (1) rolling is terminated in a temperature region where a dislocation introduced into austenite by hot rolling remains, (2) rapid cooling is performed immediately thereafter to allow a Ti-containing precipitate such as TiC to be finely formed on the dislocation, and (3) two-stage cooling is further performed, followed by winding, whereby ferrite transformation is controlled to occur while ensuring the Ti-containing precipitate amount.

[0050] The steel sheet for hot-pressing which has the above-described chemical component composition, metal microstructure and Ti-precipitation state may be directly used for the manufacture by hot pressing or may be subjected to cold rolling at a rolling reduction of 60% or less (preferably 40% or less) after pickling and then used for the manufacture by hot pressing. In the steel sheet for hot-pressing in the present invention, the microstructure thereof may be produced during heat treatment of a hot rolling material in a continuous annealing furnace or in a continuous hot-dip galvanizing line. In short, as long as the required properties such as metal microstructure and Ti precipitation state are satisfied, the steel sheet is included in the steel sheet for hot-pressing in the present invention.

[0051] Using the above-described steel sheet for hot-pressing, the steel sheet is heated at a temperature equal to or more than Ac_1 transformation point+20°C (Ac_1+20°C) and equal to or less than Ac_3 transformation point-20°C (Ac_3-20°C) and after starting press forming, the steel sheet is cooled to a temperature equal to or less than a temperature 100°C below the bainite transformation starting temperature Bs (Bs-100°C) while ensuring an average cooling rate of 20°C/sec or more in a mold during forming as well as after the completion of forming, whereby an optimal microstructure as a formed article with low strength and high ductility can be produced in a press-formed article having a single property (hereinafter, sometimes referred to as "single-region formed article"). The reason for specifying each requirement in this forming method is as follows.

[0052] In a steel sheet containing a predetermined amount of ferrite, in order to cause a partial transformation to austenite while allowing part of the ferrite to remain, the heating temperature must be controlled to a predetermined range. If the heating temperature of the steel sheet is less than Ac_1 transformation point+20°C, a sufficient amount of austenite cannot be obtained during heating, and a predetermined amount of retained austenite cannot be ensured in the final microstructure (microstructure of a formed article). If the heating temperature of the steel sheet exceeds Ac_3 transformation point-20°C, the transformation amount to austenite is excessively increased during heating, and a predetermined amount of ferrite cannot be ensured in the final microstructure (microstructure of a formed article).

[0053] For allowing austenite formed in the heating step above to be a desired microstructure while impeding production of a microstructure such as ferrite or pearlite, the average cooling rate during forming as well as after forming and the cooling finishing temperature must be appropriately controlled. From such a standpoint, it is necessary that the average cooling rate during forming is 20°C/sec or more and the cooling finishing temperature is equal to or less than a temperature 100°C below the bainite transformation starting temperature Bs. The average cooling rate during forming is preferably 30°C/sec or more (more preferably 40°C/sec or more). When the cooling finishing temperature is equal to or less than a temperature 100°C below the bainite transformation starting temperature Bs, austenite present during heating is transformed to bainite or martensite while impeding production of a microstructure such as ferrite or pearlite, whereby fine austenite is caused to remain between bainite or martensite laths and a predetermined amount of retained austenite is assured while ensuring bainite and martensite.

[0054] If the cooling finishing temperature exceeds the temperature 100°C below the bainite transformation starting temperature Bs or the average cooling rate is less than 20°C/sec, a microstructure such as ferrite and pearlite is formed, and a predetermined amount of retained austenite cannot be ensured, resulting in deterioration of the elongation (ductility) in a formed article. The cooling finishing temperature is not particularly limited as long as it is equal to or less than a temperature 100°C below Bs, and the cooling finishing temperature may be, for example, equal to or less than the martensite transformation starting temperature Ms.

[0055] After reaching a temperature equal to or less than the temperature 100°C below the bainite transformation starting temperature Bs, fundamentally, the average cooling rate need not be controlled, but the steel sheet may be cooled to room temperature at an average cooling rate of, for example, 1°C/sec or more and 100°C/sec or less. Control of the average cooling rate during forming as well as after the completion of forming can be achieved by a technique of, for example, (a) controlling the temperature of the forming mold (the cooling medium shown in FIG. 1), or (b) controlling the thermal conductivity of the mold.

[0056] In the press-formed article (single-region formed article) manufactured by the above-described hot pressing, the metal microstructure includes retained austenite: from 3 to 20 area%, ferrite: from 30 to 80 area%: bainitic ferrite: less than 30 area% (exclusive of 0 area%), and martensite: 31 area% or less (exclusive of 0 area%), and a high-level balance between high strength and elongation can be achieved as a uniform property in a formed article. The reason for setting the range of each requirement (basic microstructure) in such a hot press-formed article is as follows.

[0057] Retained austenite has an effect of increasing the work hardening ratio (transformation induced plasticity) and enhancing the ductility of the press-formed article by undergoing transformation to martensite during plastic deformation. In order to exert such an effect, the retained austenite fraction must be 3 area% or more. The ductility is more improved as the retained austenite fraction is higher. In the composition to be used for an automotive steel sheet, the assurable retained austenite is limited, and the upper limit is about 20 area%. The lower limit of the retained austenite is preferably 5 area% or more (more preferably 7 area% or more).

[0058] When the main microstructure is fine ferrite having high ductility, the ductility (elongation) of a press-formed article can be enhanced. From such a standpoint, the ferrite fraction is 30 area% or more. However, if this fraction exceeds 80 area%, the strength of a formed article cannot be ensured. The lower limit of the ferrite fraction is preferably 35 area% or more (more preferably 40 area% or more), and the upper limit is preferably 75 area% or less (more preferably 70 area% or less).

[0059] The bainitic ferrite is a microstructure effective in enhancing the strength of a formed article but is a structure slightly lacking in ductility and therefore when present in a large amount, it deteriorates the elongation. From such a standpoint, the bainitic ferrite fraction is less than 30 area%. The upper limit of the bainitic ferrite fraction is preferably 25 area% or less (more preferably 20 area% or less).

[0060] The martensite (as-quenched martensite) is a microstructure effective in enhancing the strength of a formed article but is a structure lacking in ductility and therefore when present in a large amount, it deteriorates the elongation. From such a standpoint, the martensite fraction is 31 area% or less. The upper limit of the martensite fraction is preferably 25 area% or less (more preferably 20 area% or less).

[0061] The microstructure other than those described above is not particularly limited, and pearlite, etc. may be contained as a remainder microstructure, but such a microstructure is inferior to other microstructures in terms of contribution to strength or contribution to ductility, and it is fundamentally preferable not to contain such a microstructure (may be even 0 area%).

[0062] In the press-formed article (single-region formed article) above, the average equivalent-circle diameter of Ti-containing precipitates having an equivalent-circle diameter of 30 nm or less among Ti-containing precipitates contained in the press-formed article (i.e., in the steel sheet constituting the press-formed article) is 10 nm or less. When this requirement is satisfied, a press-formed article capable of achieving a high-level balance between high strength and elongation can be obtained. The average equivalent-circle diameter of the Ti-containing precipitate is preferably 8 nm or less, more preferably 6 nm or less.

[0063] In addition, in the press-formed article (single-region formed article), the amount of Ti present as a precipitate other than TiN (i.e., precipitated Ti amount-3.4[N]) is smaller than 0.5 times the remainder Ti after deduction of Ti that forms TiN from total Ti (i.e., smaller than 0.5×[total Ti amount (%)-3.4[N]]). When this requirement is satisfied, Ti dissolved in solid during welding is finely precipitated in HAZ or the existing fine Ti-containing precipitate suppresses recovery, etc. of the dislocation, and as a result, softening in HAZ is prevented, and the weldability is improved. The "precipitated Ti amount-3.4[N]" is preferably 0.4×[total Ti amount (mass%))-3.4[N]] or less, more preferably 0.3×[total Ti amount (mass%))-3.4[N]] or less.

[0064] When the steel sheet for hot-pressing in the present invention is used, the properties such as strength and elongation of a press-formed article can be controlled by appropriately adjusting the press-forming conditions (heating temperature and cooling rate) and moreover, a press-formed article having high ductility (residual ductility) is obtained, making its application possible to a site (e.g., energy absorption member) to which the conventional press-formed article can be hardly applied. This is very useful in expanding the application range of a press-formed article. In addition to the above-described single-region formed article, in the manufacture of a press-formed article by press-forming a steel sheet by use of a press-forming mold, when the heating temperature and the conditions in each region during forming are appropriately controlled and the microstructure of each region is thereby adjusted, a press-formed article exerting a strength-ductility balance depending on respective regions (hereinafter, sometimes referred to as "multiple-region formed article") is obtained.

[0065] When manufacturing a multiple-region formed article as described above by using the steel sheet for hot-pressing in the present invention, the manufacture may be performed by diving a heating region of the steel sheet into at least two regions, heating one region (hereinafter, referred to as first region) at a temperature of Ac_3 transformation point or more and 950°C or less, heating another region (hereinafter, referred to as second region) at a temperature equal to or more than Ac_1 transformation point+20°C and equal to or less than Ac_3 transformation point-20°C, then starting press forming of both the first and second regions, and cooling the steel sheet to a temperature equal to or less than the martensite transformation starting temperature Ms while ensuring an average cooling rate of 20°C/sec or more in a mold in both of the first and second regions during forming as well as after the completion of forming.

[0066] In the method above, a heating region of the steel sheet is divided into at least two regions (high strength-side region and low strength-side region), and the manufacturing conditions are controlled according to respective regions, whereby a press-formed article exerting a strength-ductility balance depending on respective regions is obtained. Out of two regions, the second region corresponds to the low strength-side region, and the manufacturing conditions, microstructure and properties in this region are basically the same as those of the above-described single-region formed article. In the following, the manufacturing conditions for forming the first region (corresponding to the high strength-side region) are described. Here, when conducting this manufacturing method, regions different in the heating temperature need to be formed in a single steel sheet, but the temperature can be controlled while keeping a temperature boundary portion of 50 mm or less, by using an existing heating furnace (e.g., far infrared furnace, electric furnace+shield).

(Manufacturing Conditions of First Region/High Strength-Side Region)

[0067] In order to appropriately adjust the microstructure of the press-formed article, the heating temperature must be controlled to a predetermined range. By appropriately controlling this heating temperature, in the subsequent cooling process, transformation to a microstructure mainly including martensite can be caused to occur while ensuring a predetermined amount of retained austenite, and a desired microstructure can be produced in the region of a final hot press-formed article. If the steel sheet heating temperature in this region is less than the Ac_3 transformation point, a sufficient amount of austenite cannot be obtained during heating, and a predetermined amount of retained austenite cannot be ensured in the final microstructure (the microstructure of a formed article). If the heating temperature of the steel sheet exceeds 950°C, the austenite grain size grows during heating, the martensite transformation starting temperature (Ms point) and the martensite transformation finishing temperature (Mf point) are elevated, retained austenite cannot be ensured during quenching, and good formability is not achieved. The heating temperature of the steel sheet is preferably Ac_3 transformation point+50°C or more and 930°C or less.

[0068] In order to allow austenite formed in the heating step above to be a desired microstructure while impeding production of a microstructure such as ferrite or pearlite, the average cooling rate during forming as well as after forming and the cooling finishing temperature must be appropriately controlled. From such a standpoint, the average cooling rate during forming needs to be 20°C/sec or more, and the cooling finishing temperature needs to be equal to or less than the martensite transformation starting temperature (Ms point). The average cooling rate during forming is preferably 30°C/sec or more (more preferably 40°C/sec or more). When the cooling finishing temperature is equal to or less than the martensite transformation starting temperature (Ms point), austenite present during heating is transformed to martensite while impeding production of a microstructure such as ferrite or pearlite, whereby martensite is ensured. Specifically, the cooling finishing temperature is 400°C or less, preferably 300°C or less.

[0069] In the press-formed article obtained by such a method, the metal microstructure, precipitate, etc. are different between the first region and the second region. In the first region, the metal microstructure includes retained austenite: from 3 to 20 area% (the action and effect of retained austenite are the same as above), and martensite: 80 area% or more. The second region satisfies the metal microstructure and Ti state (e.g., the average equivalent-circle diameter of Ti-containing precipitates, the value of "precipitated Ti amount (mass%)-3.4[N]") which are the same as in the above-described single-region formed article.

[0070] When the main microstructure of the first region is high-strength martensite containing a predetermined amount of retained austenite, a press-formed article can be assured of ductility in a specific region and high strength. From such a standpoint, the area fraction of martensite needs to be 80 area% or more. The martensite fraction is preferably 85 area% or more (more preferably 90 area% or more). The first region may partially contain ferrite, pearlite, bainite, etc. as a remainder microstructure.

[0071] The effects in the present invention are described more specifically below by referring to Examples, but the present invention is not limited to the following Examples, and all design changes made in light of the gist described above or later are included in the technical range in the present invention.

EXAMPLES

[Example 1]

[0072] Steel materials (Steel Nos. 1 to 16 and 18 to 32) having the chemical component composition shown in Tables 1 and 2 below were melted in vacuum to make an experimental slab, then hot-rolled to prepare a steel sheet, followed by cooling and subjecting to a treatment simulating the winding (sheet thickness: 1.6 mm or 3.0 mm). As to the method for treatment simulating the winding, the sample was cooled to a winding temperature, and put in a furnace heated at the winding temperature, followed by holding for 30 minutes and then cooling in the furnace. The manufacturing conditions of the steel sheets are shown in Tables 3 and 4 below. Here, in Tables 1 and 2, the Ac_1 transformation point, Ac_3 transformation point, Ms point, and Bs point were determined using the following formulae (2) to (5) (see, for example, The Physical Metallurgy of Steels, Leslie, Maruzen, (1985)). In addition, treatments (1) and (2) shown in Remarks of Table 3 mean that each treatment (rolling, cooling and alloying) described below was performed.

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

$$\text{Ac}_3 \text{ transformation point } (°C) = 910-203\times[C]^{1/2}+44.7\times[Si]-30\times[Mn]+700\times[P]+400\times[Al]+400\times[Ti]+104\times[V]-11\times[Cr]+31.5\times[Mo]-20\times[Cu]-15.2\times[Ni] \cdots (3)$$

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

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

wherein [C], [Si], [Mn], [P], [Al], [Ti], [V], [Cr], [Mo], [Cu] and [Ni] represent the contents (mass%) of C, Si, Mn, P, Al, Ti, V, Cr, Mo, Cu and Ni, respectively. In the case where the element shown in each term of formulae (2) to (5) is not contained, the calculation is done assuming that the term is not present.

[0073] Treatment (1): The hot-rolled steel sheet was cold-rolled (sheet thickness: 1.6 mm), then heated at 800°C for simulating continuous annealing in a heat treatment simulator, held for 90 seconds, cooled to 500°C at an average cooling rate of 20°C/sec, and held for 300 seconds.

[0074] Treatment (2): The hot-rolled steel sheet was cold-rolled (sheet thickness: 1.6 mm), then heated at 860°C for simulating a continuous hot-dip galvanizing line in a heat treatment simulator, cooled to 400°C at an average cooling rate of 30°C/sec, held, further held under the conditions of 500°C×10 seconds for simulating immersion in a plating bath and alloying treatment, and thereafter cooled to room temperature at an average cooling rate of 20°C/sec.

[Table 1]

Steel No.	Chemical Component Composition* (mass%)											
	C	Si	Mn	P	S	Al	B	Ti	N	V	Nb	Cu
1	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
2	0.150	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
3	0.220	0.05	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
4	0.220	0.25	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
5	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.024	0.0040	-	-	-
6	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
7	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
8	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
9	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
10	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
11	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
12	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
13	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
14	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
15	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
16	0.220	2.00	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-

*Remainder: Iron and unavoidable impurities except for P, S and N.

[Table 1] (continued)

Steel No.	Chemical Component Composition* (mass%)							Ac3-20°C (°C)	Ac1+20°C (°C)	Bs-100°C (°C)	Ms Point (°C)
	Ni	Zr	Mg	Ca	REM	Cr	Mo				
1	-	-	-	-	-	-	-	845	765	563	425
2	-	-	-	-	-	0.20	-	860	768	568	446
3	-	-	-	-	-	0.20	-	792	735	549	421
4	-	-	-	-	-	0.20	-	801	741	549	421
5	-	-	-	-	-	0.20	-	833	768	549	421
6	-	-	-	-	-	0.20	-	843	768	549	421
7	-	-	-	-	-	0.20	-	843	768	549	421
8	-	-	-	-	-	0.20	-	843	768	549	421
9	-	-	-	-	-	0.20	-	843	768	549	421
10	-	-	-	-	-	0.20	-	843	768	549	421
11	-	-	-	-	-	0.20	-	843	768	549	421
12	-	-	-	-	-	0.20	-	843	768	549	421
13	-	-	-	-	-	0.20	-	843	768	549	421
14	-	-	-	-	-	0.20	-	843	768	549	421
15	-	-	-	-	-	0.20	-	843	768	549	421
16	-	-	-	-	-	0.20	-	879	792	549	421

*Remainder: Iron and unavoidable impurities except for P, S and N.

[Table 2]

Steel No.	Chemical Component Composition* (mass%)										
	C	Si	Mn	P	S	Al	B	Ti	N	V	Nb	Cu
18	0.720	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
19	0.220	1.20	0.80	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
20	0.220	1.20	2.40	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
21	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.100	0.0040	-	-	-
22	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.200	0.0040	-	-	-
23	0.220	0.50	1.20	0.0050	0.0020	0.40	0.0020	0.044	0.0040	-	-	-
24	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	0.030	-	-
25	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	0.020	-
26	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	0.20
27	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
28	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
29	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
30	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
31	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-
32	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-

*Remainder: Iron and unavoidable impurities except for P, S and N.

[Table 2] (continued)

Steel No.	Chemical Component Composition* (mass%)							Ac_3-20°C (°C)	Ac_1+20°C (°C)	Bs-100°C (°C)	Ms Point (°C)
	Ni	Zr	Mg	Ca	REM	Cr	Mo				
18	-	-	-	-	-	0.20	-	766	768	414	240
19	-	-	-	-	-	0.20	-	855	773	585	436
20	-	-	-	-	-	0.20	-	807	756	441	374
21	-	-	-	-	-	0.20	-	866	768	549	421
22	-	-	-	-	-	0.20	-	906	768	549	421
23	-	-	-	-	-	0.20	-	960	748	549	432
24	-	-	-	-	-	0.20	-	846	768	549	421
25	-	-	-	-	-	0.20	-	843	768	549	421
26	-	-	-	-	-	0.20	-	839	768	549	419
27	0.20	-	-	-	-	0.20	-	840	765	541	417
28	-	-	-	-	-	0.20	0.20	849	768	532	420
29	-	0.015	-	-	-	0.20	-	843	768	549	421
30	-	-	0.002	-	-	0.20	-	843	768	549	421
31	-	-	-	0.002	-	0.20	-	843	768	549	421
32	-	-	-	-	0.002	0.20	-	843	768	549	421

*Remainder: Iron and unavoidable impurities except for P, S and N.

[Table 3]

Steel No.	Steel Sheet Manufacturing Conditions						
	Heating Temperature (°C)	Finish Rolling Temperature (°C)	Average Cooling Rate from Finish Rolling Temperature to 620°C(°C/sec)	Average Cooling Rate from 620°C to 580°C (°C/sec.)	Average Cooling Rate from 580°C to Winding Temperature (°C/sec.)	Winding Temperature (°C)	Remarks
1	1200	950	50	3.3	50	400	-
2	1200	950	50	3.3	50	400	-
3	1200	950	50	3.3	50	400	-
4	1200	950	50	3.3	50	400	-
5	1200	950	50	3.3	50	400	-
6	1200	950	50	3.3	50	400	-
7	1200	800	50	3.3	50	400	-
8	1200	950	50	50	50	400	-
9	1200	950	50	3.3	50	500	-
10	1200	950	50	3.3	50	400	treatment (1)
11	1200	950	50	3.3	50	400	treatment (2)
12	1200	950	50	3.3	50	400	-
13	1200	950	50	3.3	50	400	-
14	1200	950	50	3.3	50	400	-
15	1200	950	50	3.3	50	400	-
16	1200	950	50	3.3	50	400	-

[Table 4]

Steel No.	Steel Sheet Manufacturing Conditions						
	Heating Temperature (°C)	Finish Rolling Temperature (°C)	Average Cooling Rate from Finish Rolling Temperature to 620°C (°C/sec)	Average Cooling Rate from 620°C to 580°C (°C/sec.)	Average Cooling Rate from 580°C to Winding Temperature (°C/sec.)	Winding Temperature (°C)	Remarks
18	1200	950	50	3.3	50	400	-
19	1200	950	50	3.3	50	400	-
20	1200	950	50	3.3	50	400	-
21	1200	950	50	3.3	50	400	-
22	1200	950	50	3.3	50	400	-
23	1200	950	50	3.3	50	400	-
24	1200	950	50	3.3	50	400	-
25	1200	950	50	3.3	50	400	-
26	1200	950	50	3.3	50	400	-
27	1200	950	50	3.3	50	400	-
28	1200	950	50	3.3	50	400	-
29	1200	950	50	3.3	50	400	-
30	1200	950	50	3.3	50	400	-
31	1200	950	50	3.3	50	400	-
32	1200	950	50	3.3	50	400	-

[0075] With respect to the steel sheets (steel sheets for press-forming) obtained, analysis of the Ti precipitation state and observation of the metal microstructure (the fraction of each microstructure) were performed in the following manner. In addition, the tensile strength (TS) of each steel sheet was measured by the later-described method. The results obtained are shown in Tables 5 and 6 below together with the calculated value of 0.5×[total Ti amount (mass%)-3.4[N]] [indicated as 0.5×[total Ti amount-3.4[N]].

(Analysis of Ti Precipitation State of Steel Sheet)

[0076] An extraction replica sample was prepared, and a transmission electron microscope image (magnifications: 100,000 times) of Ti-containing precipitates was photographed using a transmission electron microscope (TEM). At this time, the Ti-containing precipitate (those having an equivalent-circle diameter of 30 nm or less) was identified by the composition analysis of precipitates by means of an energy dispersive X-ray spectrometer (EDX). At least 100 pieces of Ti-containing precipitates were measured for the area by image analysis, the equivalent-circle diameter was determined therefrom, and the average value thereof was defined as the precipitate size (average equivalent-circle diameter of Ti-containing precipitates). As for the "precipitated Ti amount (mass%)-3.4[N]" (the amount of Ti present as a precipitate), extraction residue analysis was performed using a mesh having a mesh size of 0.1 μm (during extraction treatment, a fine precipitate resulting from aggregation of precipitates could also be measured), and the "precipitated Ti amount (mass%)-3.4[N]" (in Tables 5 and 6, indicated as "Precipitated Ti Amount-3.4[N]") was determined. In the case where the Ti-containing precipitate partially contained V or Nb, the contents of these precipitates were also measured.

(Observation of Metal Microstructure (Fraction of Each Microstructure))

[0077]

(1) As to the microstructures of ferrite, bainitic ferrite, pearlite and martensite in the steel sheet, the steel sheet was corroded with nital and after distinguishing ferrite, bainitic ferrite, pearlite and martensite from each other by SEM observation (magnifications: 1,000 times or 2,000 times), the fraction (area ratio) of each microstructure was determined.

(2) The retained austenite fraction in the steel sheet was measured by X-ray diffraction method after the steel sheet was ground to 1/4 thickness and then subjected to chemical polishing (for example, ISJJ Int. Vol. 33. (1933), No. 7, P. 776).

[Table 5]

Steel No.	Steel Sheet for Press-Forming					
	Precipitated Ti Amount-3.4[N] (mass %)	0.5×[Total Ti Amount-3.4[N] (mass %)	Average Equivalent-Circle Diameter of Ti-Containing Precipitates (nm)	Ferrite Fraction (area%)	Remainder Microstructure*	Tensile Strength (MPa)
1	0.008	0.015	3.8	40	B	799
2	0.007	0.015	2.7	38	B	808
3	0.007	0.015	3.0	43	P+B	785
4	0.007	0.015	2.7	43	P+B	787
5	0.001	0.003	3.2	45	B	776
6	0.008	0.015	2.7	36	B	822
7	0.018	0.015	9.2	39	B	807
8	0.007	0.015	3.7	0	B	1150
9	0.010	0.015	7.2	42	B	789
10	0.008	0.015	2.8	40	B	799
11	0.008	0.015	2.8	40	B	799

(continued)

Steel No.	Steel Sheet for Press-Forming					
	Precipitated Ti Amount-3.4[N] (mass %)	0.5×[Total Ti Amount-3.4[N] (mass %)	Average Equivalent-Circle Diameter of Ti-Containing Precipitates (nm)	Ferrite Fraction (area%)	Remainder Microstructure*	Tensile Strength (MPa)
12	0.008	0.015	2.8	40	B	799
13	0.008	0.015	2.8	40	B	799
14	0.008	0.015	2.8	40	B	799
15	0.008	0.015	2.8	40	B	799
16	0.006	0.015	3.1	43	B	787
*B: Bainitic ferrite, P: pearlite.						

[Table 6]

Steel No.	Steel Sheet for Press-Forming					
	Precipitated Ti Amount-3.4[N] (mass %)	0.5×[Total Ti Amount-3.4[N] (mass %)	Average Equivalent-Circle Diameter of Ti-Containing Precipitates (nm)	Ferrite Fraction (area%)	Remainder Microstructure*	Tensile Strength (MPa)
18	0.007	0.015	3.9	0	B+M	1277
19	0.009	0.015	3.1	45	P+B	777
20	0.007	0.015	2.1	40	B+M	798
21	0.025	0.043	2.6	39	B	804
22	0.166	0.093	12.8	44	B	780
23	0.007	0.015	3.4	43	B	785
24	0.007	0.015	3.7	44	B	779
25	0.008	0.015	2.1	42	B	789
26	0.009	0.015	2.9	38	B	809
27	0.008	0.015	2.3	41	B	796
28	0.008	0.015	3.5	41	B	794
29	0.007	0.015	2.8	42	B	780
30	0.007	0.015	2.7	40	B	785
31	0.007	0.015	2.9	40	P+B	790
32	0.007	0.015	2.7	42	P+B	785
*B: Bainitic ferrite, P: pearlite, M: Martensite.						

[0078] Each of the steel sheets above (1.6 mm^t×150 mmx200 mm) (the thickness t of those other than the treatment (1) and (2) was adjusted to 1.6 mm by hot rolling) was heated at a predetermined temperature in a heating furnace, followed by subjecting to press forming and cooling treatment using a hat-shaped mold (FIG. 1) to obtain a formed article. The press forming conditions (heating temperature, average cooling rate, and rapid cooling finishing temperature during press forming) are shown in Table 7 below.

[Table 7]

Steel No.	Press-Forming Conditions		
	Heating Temperature (°C)	Average Cooling Rate (°C/sec)	Rapid Cooling Finishing Temperature (°C)
1	810	40	300
2	810	40	300
3	760	40	300
4	770	40	300
5	800	40	300
6	810	40	300
7	810	40	300
8	810	40	300
9	810	40	300
10	810	40	300
11	810	40	300
12	900	40	300
13	810	5	300
14	810	40	600
15	810	40	100
16	840	40	300
18	770	40	300
19	810	40	300
20	780	40	300
21	820	40	300
22	840	40	300
23	850	40	300
24	810	40	300
25	810	40	300
26	800	40	300
27	800	40	300
28	810	40	300
29	810	40	300
30	810	40	300
31	810	40	300
32	810	40	300

[0079] With respect to the press-formed articles obtained, the tensile strength (TS), elongation (total elongation EL), observation of metal microstructure (fraction of each microstructure), and hardness reduction amount after heat treatment were measured by the following methods, and the Ti precipitation state was analyzed by the method described above.

(Measurement of Tensile Strength (TS) and Elongation (Total Elongation EL))

[0080] A tensile test was performed using a JIS No. 5 test piece, and the tensile strength (TS) and elongation (EL) were measured. At this time, the strain rate in the tensile test was set to 10 mm/sec. In the present invention, the test piece was rated "passed" when a tensile strength (TS) of 980 MPa or more and an elongation (EL) of 16% or more were satisfied and the strength-elongation balance (TS×EL) was 16,000 (MPa·%) or more.

(Observation of Metal Microstructure (Fraction of Each Microstructure))

[0081]

(1) With respect to the microstructures of ferrite, bainitic ferrite and pearlite in the steel sheet, the steel sheet was corroded with nital and after distinguishing ferrite, bainitic ferrite and pearlite from each other (including distinguishing between ferrite and acicular ferrite) by SEM observation (magnifications: 1,000 times or 2,000 times), the fraction (area ratio) of each microstructure was determined.
(2) The retained austenite fraction in the steel sheet was measured by X-ray diffraction method after the steel sheet was ground to 1/4 thickness and then subjected to chemical polishing (for example, ISJJ Int. Vol. 33. (1933), No. 7, P. 776).
(3) As to the fraction of martensite (as-quenched martensite), after LePera corrosion of the steel sheet, the area ratio of a white contrast regarded as a mixed microstructure of as-quenched martensite and retained austenite was measured, and the retained austenite fraction determined by X-ray diffraction was subtracted therefrom, whereby the martensite fraction was calculated.

(Hardness Reduction Amount After Heat Treatment)

[0082] As the heat history based on spot welding, the hardness reduction amount (ΔHv) relative to the original hardness (Vickers hardness) was measured after heating to 700°C at an average heating rate of 50°C/sec in a heat treatment simulator and then cooling at an average cooling rate of 50°C/sec. The anti-softening property in HAZ was judged as good when the hardness reduction amount (ΔHv) was 50 Hv or less.
[0083] The observation results (Ti precipitation state, fraction of each microstructure, and precipitated Ti amount-3.4[N]) of the metal microstructure are shown in Tables 8 and 9 below. In addition, the mechanical properties (tensile strength TS, elongation EL, TS×EL, and hardness reduction amount ΔHv) of the formed article are shown in Table 10 below. Here, the value of "precipitated Ti amount-3.4[N]" in the formed article is slightly different from the value of "precipitated Ti amount-3.4[N]" in the steel sheet for press-forming, but this is a measurement error.

[Table 8]

Steel No.	Metal Microstructure of Press-Formed Article						
	Ferrite Fraction (area %)	Bainitic Ferrite Fraction (area%)	Martensite Fraction (area%)	Retained Austenite Fraction (area %)	Precipitated Ti Amount-3.4[N] (mass%)	Average Equivalent-Circle Diameter of Ti-Containing Precipitates (nm)	Others
1	54	18	20	8	0.010	3.7	-
2	64	20	8	8	0.012	4.0	-
3	46	15	39	0	0.009	3.9	-
4	50	16	30	4	0.013	3.9	-
5	54	16	23	7	0.000	3.6	-
6	46	17	29	8	0.011	2.2	-
7	47	17	29	7	0.022	8.9	-
8	53	18	21	8	0.010	3.4	out of ferrite, acicular ferrite: 48%
9	51	18	24	7	0.014	11.0	-
10	50	18	26	6	0.009	3.4	-

(continued)

Steel No.	Metal Microstructure of Press-Formed Article						
	Ferrite Fraction (area %)	Bainitic Ferrite Fraction (area%)	Martensite Fraction (area%)	Retained Austenite Fraction (area %)	Precipitated Ti Amount-3.4[N] (mass%)	Average Equivalent-Circle Diameter of Ti-Containing Precipitates (nm)	Others
11	52	16	26	6	0.008	3.4	-
12	0	0	95	5	0.002	3.4	-
13	82	0	10	8	0.009	2.2	-
14	65	0	10	0	0.010	2.5	pearlite: 25%
15	50	16	27	7	0.009	2.3	-
16	46	18	27	9	0.012	3.2	-

[Table 9]

Steel No.	Metal Microstructure of Press-Formed Article						
	Ferrite Fraction (area %)	Bainitic Ferrite Fraction (area%)	Martensite Fraction (area%)	Retained Austenite Fraction (area %)	Precipitated Ti Amount-3.4[N] (mass%)	Average Equivalent-Circle Diameter of Ti-Containing Precipitates (nm)	Others
18	8	0	80	12	0.009	2.8	-
19	62	18	12	8	0.011	2.8	-
20	46	17	30	7	0.011	3.0	-
21	47	18	28	7	0.035	2.3	-
22	51	19	22	8	0.175	15.3	-
23	45	17	31	7	0.011	2.0	-
24	54	16	23	7	0.013	3.0	-
25	51	17	25	7	0.011	2.2	-
26	48	20	25	7	0.011	3.3	-
27	46	19	28	7	0.011	2.0	-
28	54	19	20	7	0.012	2.6	-
29	54	18	20	8	0.008	3.8	-
30	52	20	20	8	0.009	4.0	-
31	50	18	24	8	0.009	4.0	-
32	53	19	20	8	0.009	3.8	-

[Table 10]

Steel No.	Mechanical Properties of Press-Formed Article			
	Tensile Strength TS (MPa)	Elongation EL (%)	TS×EL (MPa·%)	Hardness Reduction Amount ΔHv (Hv)
1	1031	17.1	17630	25

(continued)

Steel No.	Mechanical Properties of Press-Formed Article			
	Tensile Strength TS (MPa)	Elongation EL (%)	TS×EL (MPa·%)	Hardness Reduction Amount ΔHv (Hv)
2	1065	17.7	18851	25
3	981	10.8	10595	22
4	983	19.3	18972	22
5	1003	18.7	18756	26
6	1029	18.2	18728	23
7	1070	19.0	20330	57
8	1006	22.2	22333	24
9	1003	19.4	19458	55
10	1057	17.5	18498	25
11	1050	17.6	18480	25
12	1500	10.3	15450	23
13	889	19.8	17602	25
14	811	15.2	12327	23
15	1028	18.1	18607	23
16	1015	18.9	19184	22
18	1682	6.5	10933	24
19	1044	17.9	18688	24
20	1038	18.1	18788	24
21	1077	17.7	19063	28
22	1043	18.4	19191	62
23	1076	17.6	18938	22
24	1063	17.6	18709	23
25	1070	18.1	19367	25
26	1071	17.6	18850	25
27	1006	19.1	19215	26
28	1048	17.7	18550	23
29	1028	18.9	19429	22
30	1030	19.2	19776	19
31	1050	18.3	19215	18
32	1050	18.8	19740	19

[0084] These results allow for the following consideration. It is found that in the case of Steel Nos. 1, 2, 4 to 6, 10, 11, 15, 16, 19 to 21, and 23 to 32, which are Examples satisfying the requirements specified in the present invention, a component having a good strength-ductility balance and a good anti-softening property is obtained.

[0085] On the other hand, in the case of Steel Nos. 3, 7 to 9, 12 to 14, 18 and 22, which are Comparative Examples failing in satisfying any of the requirements specified in the present invention, any of the properties is deteriorated. More specifically, in the case of Steel No. 3 where a steel sheet for press-forming which has a small Si content is used, the retained austenite fraction is not ensured in the press-formed article and due to low elongation, the strength-elongation balance is deteriorated. In the case of Steel No. 7 where the finish rolling temperature in the manufacture of a steel sheet is low, the Ti-containing precipitate in a steel sheet for press-forming is coarsened, the relationship of the formula (1) is not satisfied in both of the stage of the steel sheet for press-forming and the stage of the press-formed article, and the anti-softening property is deteriorated.

[0086] In the case of Steel No. 8 where the cooling rate in the range from 620°C to 580°C in the manufacture of a steel sheet is high, ferrite transformation does not sufficiently proceeds, failing in ensuring the ferrite fraction in a steel sheet for press-forming, and it is expected that the strength is increased to make the forming or working before press forming difficult. In the case of Steel No. 9 where the winding temperature in the manufacture of a steel sheet is high, the Ti-containing precipitate in a steel sheet for press-forming is coarsened and when press forming is performed using this steel sheet, the anti-softening property is deteriorated despite appropriate forming conditions and good strength-ductility balance.

[0087] In the case of Steel No. 12 where the heating temperature during press forming is high, ferrite is not produced, though martensite is produced, and the elongation is reduced, and the strength-elongation balance (TS×EL) is deteriorated. In the case of Steel No. 13 where the cooling rate during press forming is low, the ferrite fraction at the stage of a press-formed article is increased, and the strength is reduced.

[0088] In the case of Steel No. 14 where the cooling finishing temperature during press forming is high, pearlite is produced, retained austenite is not ensured, and the strength and elongation are reduced to deteriorate the strength-elongation balance (TSxEL). In the case of Steel No. 18 where a steel sheet for press-forming which has an excessive C content is used, due to a failure in ensuring the ferrite fraction of a steel sheet, the ferrite fraction in a press-formed article cannot be ensured, and as a result, only low elongation EL is obtained, and the strength-elongation balance (TS×EL) is deteriorated. In the case of Steel No. 22 where a steel sheet for press-forming which has an excessive Ti content is used, the relationship of the formula (1) is not satisfied in both of the stage of the steel sheet for press-forming and the stage of the press-formed article, and not only the Ti-containing precipitate is coarsened but also the anti-softening property is deteriorated.

[Example 2]

[0089] Steel materials (Steel Nos. 33 to 37) having the chemical component composition shown in Table 11 below were melted in vacuum to make an experimental slab, and then it was hot-rolled, followed by cooling and winding (sheet thickness: 3.0 mm). The steel sheet manufacturing conditions here are shown in Table 12 below.

[Table 11]

Steel No.	Chemical Component Composition* (mass%)															Ac_3-20°C (°C)	Ac_1+20°C (°C)	Bs-100°C (°C)	Ms Point (°C)
	C	Si	Mn	P	S	Al	B	Ti	N	V	Nb	Cu	Ni	Cr	Mo				
33	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
34	0.350	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	818	768	514	374
35	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
36	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	-	-	845	765	563	425
37	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421

*Remainder: Iron and unavoidable impurities except for P, S and N.

[Table 12]

Steel No.	Steel Sheet Manufacturing Conditions						
	Heating Temperature (°C)	Finish Rolling Temperature (°C)	Average Cooling Rate from Finish Rolling Temperature to 620°C (°C/sec)	Average Cooling Rate from 620°C to 580°C (°C/sec)	Average Cooling Rate from 580°C to Winding Temperature (°C/sec)	Winding Temperature (°C)	Remarks
33	1200	950	50	3.3	50	400	-
34	1200	950	50	3.3	50	400	-
35	1200	950	50	3.3	50	400	treatment (1)
36	1200	950	50	3.3	50	400	-
37	1200	950	50	3.3	50	400	-

[0090] With respect to the steel sheets (steel sheets for press-forming) obtained, analysis of the precipitation state of Ti precipitates, observation of the metal microstructure (the fraction of each microstructure), and measurement of the tensile strength were performed in the same manner as in Example 1. The results are shown in Table 13 below.

[Table 13]

Steel No.	Steel Sheet for Press-Forming					
	Precipitated Ti Amount -3.4 [N] (mass%)	0.5×[Total Ti Amount-3.4 [N] (mass%)	Average Equivalent-Circle Diameter of Ti-Containing Precipitates (nm)	Ferrite Fraction (area%)	Remainder Microstructure*	Tensile Strength (MPa)
33	0.006	0.015	3.2	36	B	789
34	0.023	0.015	3.4	37	B	830
35	0.009	0.015	3.6	42	B	702
36	0.008	0.015	3.4	37	B	830
37	0.008	0.015	3.4	37	B	830
*B: Bainitic ferrite.						

[0091] Each of the steel sheets above (3.0 mm^t×150 mmx200 mm) was heated at a predetermined temperature in a heating furnace and then subjected to press forming and cooling treatment in a hat-shaped mold (FIG. 1) to obtain a formed article. At this time, the steel sheet was placed in an infrared furnace, and a temperature difference was created by applying an infrared ray directly to a portion intended to have high strength (the steel sheet portion corresponding to the first region) so that the portion could be heated at a high temperature, and by putting a cover on a portion intended to have low strength (the steel sheet portion corresponding to the first region) so that the portion could be heated at a low temperature by blocking part of the infrared ray. Accordingly, the formed article has regions differing in the strength in a single component. The press forming conditions (heating temperature, average cooling rate, and rapid cooling finishing temperature of each region during press forming) are shown in Table 14 below.

[Table 14]

Steel No.	Region	Press Forming Conditions		
		Heating Temperature (°C)	Average Cooling Rate (°C/sec)	Rapid Cooling Finishing Temperature (°C)
33	low strength side	810	40	300
	high strength side	920	40	300
34	low strength side	800	40	300
	high strength side	920	40	300
35	low strength side	820	40	300
	high strength side	920	40	300
36	low strength side	800	40	300
	high strength side	920	40	300

(continued)

Steel No.	Region	Press Forming Conditions		
		Heating Temperature (°C)	Average Cooling Rate (°C/sec)	Rapid Cooling Finishing Temperature (°C)
37	low strength side	800	40	300
	high strength side	850	40	300

[0092] With respect to the press-formed articles obtained, the tensile strength (TS), elongation (total elongation EL), observation of metal microstructure (fraction of each microstructure), and hardness reduction amount (ΔHv), in each region, were determined in the same manner as in Example 1.

[0093] The observation results (fraction of each microstructure) of the metal microstructure and the analysis results of Ti precipitation state are shown in Table 15 below. In addition, the mechanical properties (tensile strength TS, elongation EL, TS$\times$EL, and hardness reduction amount ΔHv) of the press-formed article are shown in Table 16 below. Here, the test piece was rated "passed" when a tensile strength (TS) of 1,470 MPa or more and an elongation (EL) of 8% or more were satisfied on the high strength side and the strength-elongation balance (TS$\times$EL) was 14,000 (MPa·%) or more (the evaluation criteria of the low strength side are the same as in Example 1).

[Table 15]

Steel No.	Region	Metal Microstructure of Press-Formed Article						
		Ferrite Fraction (area %)	Bainitic Ferrite Fraction (area%)	Martensite Fraction (area%)	Retained Austenite Fraction (area %)	Precipitated Ti Amount - 3.4 Amount - [N] (mass%)	Average Equivalent-Circle Diameter of Ti-Containing Precipitates (nm)	Others
33	low strength side	54	18	21	7	0.013	3.0	-
	high strength side	0	0	94	6	0.010	3.3	-
34	low strength side	50	16	27	7	0.011	3.0	-
	high strength side	0	0	95	5	0.009	3.0	-
35	low strength side	54	16	22	8	0.010	4.0	-
	high strength side	0	0	94	6	0.010	3.2	-

(continued)

Steel No.	Region	Metal Microstructure of Press-Formed Article						
		Ferrite Fraction (area %)	Bainitic Ferrite Fraction (area%)	Martensite Fraction (area%)	Retained Austenite Fraction (area %)	Precipitated Ti Amount - 3.4 Amount - [N] (mass%)	Average Equivalent-Circle Diameter of Ti-Containing Precipitates (nm)	Others
36	low strength side	50	16	27	7	0.011	3.0	-
	high strength side	0	0	95	5	0.010	3.4	-
37	low strength side	50	16	27	7	0.011	3.2	-
	high strength side	25	0	70	5	0.010	3.3	-

[Table 16]

Steel No.	Region	Mechanical Properties of Press-Formed Article			
		Tensile Strength TS (MPa)	Elongation EL (%)	TS×EL (MPa•%)	Hardness Reduction Amount ΔHv (Hv)
33	low strength side	1078	17.6	18973	25
	high strength side	1511	10.2	15412	37
34	low strength side	1192	18.1	21575	26
	high strength side	1820	10.3	18746	38
35	low strength side	1043	18.4	19191	26
	high strength side	1499	10.1	15140	38
36	low strength side	1035	17.2	17802	26
	high strength side	1520	10.2	15504	44
37	low strength side	1052	17.2	18094	26
	high strength side	1302	11.8	15364	41

[0094] These results allow for the following consideration. It is found that in the case of Steel Nos. 33 to 36, which are Examples satisfying the requirements specified in the present invention, a press-formed article having a good strength-ductility balance in each region is obtained. On the other hand, in the case of Steel No. 37 where the heating temperature during press forming is low, the martensite fraction on the high strength side is insufficient, and the strength on the high strength side is reduced (the difference in the strength from the low strength side is less than 300 MPa).

INDUSTRIAL APPLICABILITY

[0095] In the present invention, the steel sheet has a predetermined chemical component composition, the average equivalent-circle diameter of Ti-containing precipitates having an equivalent-circle diameter of 30 nm or less among Ti-containing precipitates contained in the steel sheet is 6 nm or less, the precipitated Ti amount and the total Ti amount in the steel satisfy a predetermined relationship, and the ferrite fraction in the metal microstructure is 30 area% or more, whereby there can be realized a steel sheet for hot-pressing which is useful to obtain a press-formed article with good anti-softening property in HAZ and ensuring that forming or working before hot pressing is facilitated, a press-formed article capable of achieving a high-level balance between high strength and elongation when uniform properties are required in the formed article can be obtained, and the press-formed article can achieve a high-level balance between high strength and elongation according to respective regions when regions corresponding to an impact resistant site and an energy absorption site are required in a single formed article.

DESCRIPTION OF REFERENCE NUMERALS AND SIGNS

[0096]

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

Claims

1. A steel sheet for hot-pressing, comprising:

C: from 0.15 to 0.5% (mass%; hereinafter, the same applies to the chemical component composition),
Si: from 0.2 to 3%,
Mn: from 0.5 to 3%,
P: 0.05% or less (exclusive of 0%),
S: 0.05% or less (exclusive of 0%),
Al: from 0.01 to 1%,
B: from 0.0002 to 0.01%,
Ti: equal to or more than 3.4[N]+0.01% and equal to or less than 3.4[N]+0.1% (wherein [N] indicates a content (mass%) of N), and
N: from 0.001 to 0.01 %, with the remainder being iron and unavoidable impurities, wherein
an average equivalent-circle diameter of a Ti-containing precipitate having an equivalent-circle diameter of 30 nm or less among Ti-containing precipitates contained in the steel sheet is 6 nm or less, a precipitated Ti amount and a total Ti amount in a steel satisfy a relationship of the following formula (1), and a ferrite fraction in a metal microstructure is 30 area% or more:

$$\text{Precipitated Ti amount (mass\%)} - 3.4[N] < 0.5\times[(\text{total Ti amount (mass\%)}) - 3.4[N]] \cdots (1)$$

(in the formula (1), [N] indicates the content (mass%) of N in the steel).

2. The steel sheet for hot-pressing according to claim 1, comprising, as the other element(s), at least one of the following (a) to (c):

(a) one or more kinds selected from the group consisting of V, Nb and Zr, in an amount of 0.1% or less (exclusive of 0%) in total;

(b) one or more kinds selected from the group consisting of Cu, Ni, Cr and Mo, in an amount of 1% or less (exclusive of 0%) in total; and

(c) one or more kinds selected from the group consisting of Mg, Ca and REM, in an amount of 0.01% or less (exclusive of 0%) in total.

3. A method for manufacturing a press-formed article, wherein the steel sheet for hot-pressing as defined in claim 1 or 2 is heated at a temperature equal to or more than Ac_1 transformation point+20°C and equal to or less than Ac_3 transformation point-20°C, and then press forming of the steel sheet is started, and the steel sheet is cooled to a temperature equal to or less than a temperature 100°C below a bainite transformation starting temperature Bs while ensuring an average cooling rate of 20°C/sec or more in a mold during forming and after a completion of forming.

4. A press-formed article of a steel sheet having a chemical component composition as defined in claim 1 or 2, wherein a metal microstructure of the press-formed article includes retained austenite: from 3 to 20 area%, ferrite: from 30 to 80 area%, bainitic ferrite: less than 30 area% (exclusive of 0 area%), and martensite: 31 area% or less (exclusive of 0 area%), and an average equivalent-circle diameter of a Ti-containing precipitate having an equivalent-circle diameter of 30 nm or less among Ti-containing precipitates contained in the press-formed article is 10 nm or less, and a precipitated Ti amount and a total Ti amount in a steel satisfy the relationship of the following formula (1):

$$\text{Precipitated Ti amount (mass\%)}-3.4[N] < 0.5\times[(\text{total Ti amount (mass\%)})-3.4[N]] \cdots (1)$$

(in the fonnula (1), [N] indicates the content (mass%) ofN in the steel).

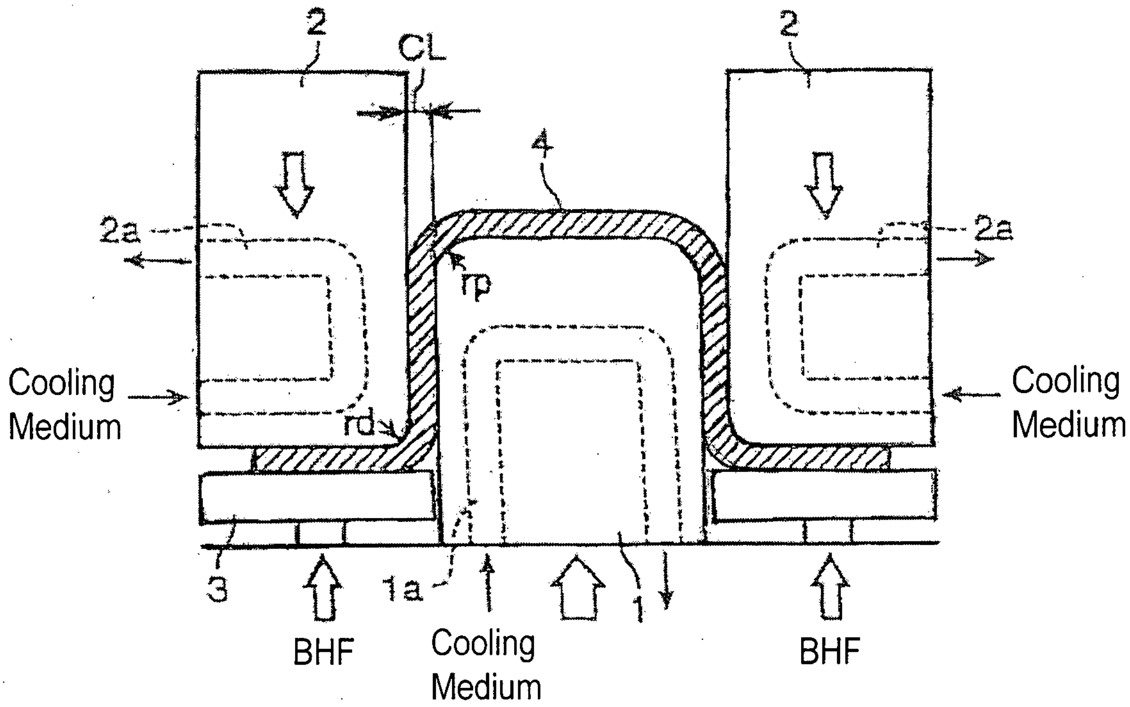
5. A method for manufacturing a press-formed article, wherein the steel sheet for hot-pressing as defined in claim 1 or 2 is used, a heating region of the steel sheet is divided into at least two regions, one region of them is heated at a temperature of A_c3 transformation point or more and 950°C or less, another region of them is heated at a temperature equal to or more than Ac_1 transformation point+20°C and equal to or less than Ac_3 transformation point-20°C, and then press forming of both regions is started, and the steel sheet is cooled to a temperature equal to or less than a martensite transformation starting temperature Ms while ensuring an average cooling rate of 20°C/sec or more in a mold in both of the regions during forming and after a completion of forming.

6. A press-formed article of a steel sheet having a chemical component composition as defined in claim 1 or 2, which has a first region having a metal microstructure including retained austenite: from 3 to 20 area% and martensite: 80 area% or more and a second region having a metal microstructure including retained austenite: from 3 to 20 area%, ferrite: from 30 to 80 area%, bainitic ferrite: less than 30 area% (exclusive of 0 area%), and martensite: 31 area% or less (exclusive of 0 area%), and an average equivalent-circle diameter of a Ti-containing precipitate having an equivalent-circle diameter of 30 nm or less among Ti-containing precipitates contained in a steel of the second region is 10 nm or less, and a precipitated Ti amount and a total Ti amount in the steel satisfy the relationship of the following formula (1):

$$\text{Precipitated Ti amount (mass\%)}-3.4[N] < 0.5\times[(\text{total Ti amount (mass\%)})-3.4[N]] \cdots (1)$$

(in the formula (1), [N] indicates the content (mass%) of N in the steel).

FIG. 1


2
CL
2
4
2a
2a
rp
Cooling
Medium
Cooling
Medium
rd
3
1a
1
BHF
Cooling
Medium
BHF

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/074426

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, *C21D9/46*(2006.01)n

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, C21D9/46

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	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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	WO 2012/169639 A1 (Kobe Steel, Ltd.), 13 December 2012 (13.12.2012), claims; paragraph [0060] & JP 2013-14841 A	1-6
A	WO 2012/169640 A1 (Kobe Steel, Ltd.), 13 December 2012 (13.12.2012), claims; paragraph [0053] & JP 2013-79441 A	1-6
A	JP 2010-43323 A (Sumitomo Metal Industries, Ltd.), 25 February 2010 (25.02.2010), claims; tables 1 to 3 (Family: none)	1-6

☒ 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
15 November, 2013 (15.11.13)

Date of mailing of the international search report
26 November, 2013 (26.11.13)

Name and mailing address of the ISA/
Japanese Patent Office

Facsimile No.

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Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2013/074426

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 2009-61473 A (Sumitomo Metal Industries, Ltd.), 26 March 2009 (26.03.2009), claims; paragraph [0024] (Family: none)	1-6
A	JP 2006-183139 A (JFE Steel Corp.), 13 July 2006 (13.07.2006), claims; paragraph [0050] (Family: none)	1-6
E,X	JP 2013-185247 A (Kobe Steel, Ltd.), 19 September 2013 (19.09.2013), entire text (Family: none)	1-6

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2010065293 A **[0013]**
- JP 2010065294 A **[0013]**
- JP 2010065295 A **[0013]**

Non-patent literature cited in the description

- **HIROSUE et al.** *Nippon Steel Technical Report,* 2003, 15-20 **[0014]**
- *ISJJ Int.,* 1933, vol. 33 (7), 776 **[0077]**
- *ISJJ Int.,* 1933, vol. 33, 776 **[0081]**