(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 366 798 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
29.08.2018 Bulletin 2018/35

(21) Application number: **16857080.2**

(22) Date of filing: **03.10.2016**

(51) Int Cl.:
C22C 38/00 *(2006.01)*
B21D 22/02 *(2006.01)*
B21D 22/20 *(2006.01)*
B21D 24/00 *(2006.01)*
C21D 1/18 *(2006.01)*
C21D 9/00 *(2006.01)*
C21D 9/46 *(2006.01)*
C22C 38/60 *(2006.01)*

(86) International application number:
PCT/JP2016/004459

(87) International publication number:
WO 2017/068757 (27.04.2017 Gazette 2017/17)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **19.10.2015 JP 2015205752**

(71) Applicant: **JFE Steel Corporation**
Tokyo 100-0011 (JP)

(72) Inventors:
- **NAKAGAWA, Koichi**
  Tokyo 100-0011 (JP)
- **KANEKO, Shinjiro**
  Tokyo 100-0011 (JP)
- **YOKOTA, Takeshi**
  Tokyo 100-0011 (JP)
- **SETO, Kazuhiro**
  Tokyo 100-0011 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) HOT PRESS MEMBER AND METHOD FOR PRODUCING SAME

(57) A hot pressed member including: a first region having a tensile property of 1500 MPa or more in tensile strength TS and 6.0 % or more in uniform elongation uEl; and a second region having a tensile property of 780 MPa or more in tensile strength TS and 15.0 % or more in uniform elongation uEl is provided. The hot pressed member comprises: a predetermined chemical composition (in particular, low C of 0.090 % or more and less than 0.30 % and high Mn of 3.5 % or more and less than 11.0 %); a first region having: a microstructure including a martensite phase of 80.0 % or more in volume fraction and a retained austenite phase of 3.0 % or more and 20.0 % or less in volume fraction; and a dislocation density of $1.0 \times 10^{16}/m^2$ or more; and a second region having a microstructure including a ferrite phase of 30.0 % or more and 60.0 % or less in volume fraction, a retained austenite phase of 10.0 % or more and 70.0 % or less in volume fraction, and a martensite phase of 30.0 % or less in volume fraction.

Printed by Jouve, 75001 PARIS (FR)

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a member obtained by hot press forming a thin steel sheet, i.e. a hot pressed member, and a method of manufacturing the same.

BACKGROUND

[0002] Recent years have seen strong demand to improve the fuel efficiency of vehicles, for global environment protection. This has led to intense need for lighter automotive bodies. To ensure safety even with thinner automotive members, steel sheets as blank sheets of such members needs to be strengthened. However, strengthening a steel sheet typically leads to lower formability. Hence, problems such as difficulty in forming and degraded shape fixability arise in the manufacture of members using high strength steel sheets as blank sheets.

[0003] In view of such problems, a technique of manufacturing a high strength automotive member by applying a hot press process to a steel sheet has been put into actual use. In the hot press process, after heating a steel sheet to an austenite region, the steel sheet is conveyed to a press machine. In the press machine, the steel sheet is formed into a member of a desired shape using a press tool, and simultaneously quenched. In this cooling process (quenching) in the press tool, the microstructure of the member undergoes phase transformation from austenite phase to martensite phase. A high strength member of a desired shape is thus obtained.

[0004] Demand to improve the anti-crash property of automotive members has also been growing recently, in order to ensure the safety of drivers and passengers. To meet this demand, increasing the uniform elongation of an automotive member is effective in enhancing the ability to absorb energy upon collision (collision energy absorbing performance). There has thus been strong demand for hot pressed members having excellent uniform elongation as well as high strength.

[0005] To meet this demand, JP 2013-79441 A (PTL 1) proposes a hot press formed part obtained by forming a thin steel sheet by a hot press forming method. The hot press formed part proposed in PTL 1 includes: a chemical composition containing, in mass%, C: 0.15 % to 0.35 %, Si: 0.5 % to 3 %, Mn: 0.5 % to 2 %, P: 0.05 % or less, S: 0.05 % or less, Al: 0.01 % to 0.1 %, Cr: 0.01 % to 1 %, B: 0.0002 % to 0.01 %, Ti: (N content) × 4 % to 0.1 %, and N: 0.001 % to 0.01 %, with a balance consisting of Fe and incidental impurities; and a microstructure including, in area ratio, martensite: 80 % to 97 %, retained austenite: 3 % to 20 %, and a balance: 5 % or less. PTL 1 states that, with the proposed technique, a metallic microstructure with an appropriate amount of retained austenite can be obtained, and a hot pressed member having higher ductility can be realized.

[0006] JP 2010-65293 A (PTL 2) proposes a hot pressed member having excellent ductility. The hot pressed member described in PTL 2 includes: a composition containing, in mass%, C: 0.20 % to 0.40 %, Si: 0.05 % to 3.0 %, Mn: 1.0 % to 4.0 %, P: 0.05 % or less, S: 0.05 % or less, Al: 0.005 % to 0.1 %, and N: 0.01 % or less, with a balance consisting of Fe and incidental impurities; and a microstructure in which the area ratio of ferrite phase is 5 % to 55 % and the area ratio of martensite phase is 45 % to 95 % with respect to the whole microstructure, and the mean grain size of ferrite phase and martensite phase is 7 μm or less. The hot pressed member has high strength of 1470 MPa to 1750 MPa in tensile strength TS, and high ductility of 8 % or more in total elongation El.

[0007] Furthermore, hot pressed members having two sites that differ in mechanical property in the same member and manufacturing methods therefor have been developed in recent years, and receiving attention as a technique for further enhancing the performance of parts such as B-pillars and rear side members. JP 2013-194248 A (PTL 3) describes a hot press formed part including: a chemical composition containing, in mass%, C: 0.1 % to 0.3 %, Si: 0.5 % to 3 %, Mn: 0.5 % to 2 %, P: 0.05 % or less, S: 0.05 % or less, Al: 0.01 % to 0.1 %, and N: 0.001 % to 0.01 % with a balance consisting of Fe and incidental impurities; a first region having a metallic microstructure including martensite: 80 area% to 97 area%, retained austenite: 3 area% to 20 area%, and a balance: 5 area% or less; and a second region having a metallic microstructure including ferrite: 30 area% to 80 area%, bainitic ferrite: less than 30 area%, martensite: 30 % or less, and retained austenite: 3 area% to 20 area%.

CITATION LIST

Patent Literatures

[0008]

PTL 1: JP 2013-79441 A

PTL 2: JP 2010-65293 A

PTL 3: JP 2013-194248 A

SUMMARY

(Technical Problem)

[0009] With the techniques described in PTL 1 and PTL 2, high strength of 1500 MPa or more in tensile strength TS is achieved by strengthening martensite phase by C, but there is a problem of insufficient uniform elongation in terms of enhancing collision energy absorbing performance.

[0010] The technique described in PTL 3 has a problem of constrained robustness for the forming start temperature in hot press for forming two sites having different mechanical properties.

[0011] A hot pressed member is typically subjected to a baking finish after the production. Heat treatment in this baking finish increases yield stress YS. To enhance anti-crash property, not only high uniform elongation but also high YS is important. Accordingly, a hot pressed member that has excellent heat treatment hardenability so that YS increases as high as possible as a result of the heat treatment in the baking finish is desired. The techniques described in PTL 1, PTL 2, and PTL 3 are, however, not concerned with such heat treatment hardenability.

[0012] It could therefore be helpful to provide a hot pressed member including: a first region having a tensile property of 1500 MPa or more in tensile strength TS and 6.0 % or more in uniform elongation uEl, and excellent heat treatment hardenability of increasing in yield stress YS by 150 MPa or more when subjected to heat treatment (baking finish); and a second region having a tensile property of 780 MPa or more in tensile strength TS and 15.0 % or more in uniform elongation uEl, and a hot pressed member manufacturing method capable of manufacturing a hot pressed member having the above-mentioned properties in a condition of high robustness for the forming start temperature in hot press. In this description, "excellent heat treatment hardenability" means a property that, when a hot pressed member is heat treated, the difference (hereafter denoted by "ΔYS") between the yield stress YS after the heat treatment and the yield stress YS before the heat treatment is 150 MPa or more. Since a lot of mobile dislocations form in martensite phase, martensite phase is low in YS. Therefore, increasing YS in the first region having martensite as the main phase is considered to be effective in solving the problem stated above.

(Solution to Problem)

[0013] As a result of conducting extensive study on various factors that influence uniform elongation uEl and YS in the first region in a hot pressed member including a first region having high strength of 1500 MPa or more in tensile strength TS and a second region having strength of 780 MPa or more in tensile strength TS, we discovered the following.

(A) To achieve high uniform elongation uEl of 6.0 % or more in the first region and high uniform elongation uEl of 15.0 % or more in the second region, a microstructure having an appropriate amount of retained austenite is necessary. To obtain a microstructure having an appropriate amount of retained austenite with less than 0.30 mass% C, the Mn content needs to be 3.5 % or more. Mn contributes to increased strength, so that high strength can be ensured even with less than 0.30 % C.

(B) An appropriate amount of retained austenite can be generated by, before hot pressing a steel sheet containing 3.5 % or more Mn as mentioned above, performing heat treatment of heating the steel sheet to a ferrite-austenite dual phase temperature range and retaining the steel sheet at a predetermined temperature in the temperature range for 1 hr or more and 48 hr or less beforehand to cause Mn to concentrate in austenite.

(C) The dislocation density and ΔYS of the hot pressed member correlate with each other. To achieve ΔYS of 150 MPa or more, the dislocation density of the hot pressed member needs to be $1.0 \times 10^{16}/\mathrm{m}^2$ or more.

(D) If the Mn content is 3.5 mass% or more, austenite formed in a heating process immediately before a hot press forming process for the blank steel sheet does not newly undergo ferrite transformation during cooling performed following the heating process, at a cooling rate of air cooling or more. This is because Mn has the effect of delaying ferrite transformation of austenite in cooling. This eliminates constraints on the forming start temperature for yielding the first region and the second region having the desired properties, and contributes to enhanced robustness as compared with conventional techniques.

[0014] The present disclosure is based on these discoveries. We thus provide:

(1) A hot pressed member comprising: a chemical composition containing (consisting of), in mass%, C: 0.090 % or more and less than 0.30 %, Mn: 3.5 % or more and less than 11.0 %, Si: 0.01 % to 2.5 %, P: 0.05 % or less, S: 0.05 % or less, Al: 0.005 % to 0.1 %, and N: 0.01 % or less, with a balance consisting of Fe and incidental impurities; a first region having: a microstructure including a martensite phase of 80.0 % or more in volume fraction and a retained

austenite phase of 3.0 % or more and 20.0 % or less in volume fraction; a tensile property of 1500 MPa or more in tensile strength TS and 6.0 % or more in uniform elongation uEl; and a dislocation density of $1.0 \times 10^{16}/m^2$ or more; and a second region having: a microstructure including a ferrite phase of 30.0 % or more and 60.0 % or less in volume fraction, a retained austenite phase of 10.0 % or more and 70.0 % or less in volume fraction, and a martensite phase of 30.0 % or less in volume fraction; and a tensile property of 780 MPa or more in tensile strength TS and 15.0 % or more in uniform elongation uEl.

(2) The hot pressed member according to (1), wherein, in the microstructure in the second region, a mean grain size of the ferrite phase is 10 μm or less, a mean grain size of a secondary phase is 10 μm or less, and Mns/Mnα is 1.5 or more, where Mns is a Mn concentration in the secondary phase and Mnα is a Mn concentration in the ferrite phase.

(3) The hot pressed member according to (1) or (2), wherein the chemical composition further contains, in mass%, one or more groups selected from A group: one or more selected from Ni: 0.01 % to 5.0 %, Cu: 0.01 % to 5.0 %, Cr: 0.01 % to 5.0 %, and Mo: 0.01 % to 3.0 %, B group: one or more selected from Ti: 0.005 % to 3.0 %, Nb: 0.005 % to 3.0 %, V: 0.005 % to 3.0 %, and W: 0.005 % to 3.0 %, C group: one or more selected from REM: 0.0005 % to 0.01 %, Ca: 0.0005 % to 0.01 %, and Mg: 0.0005 % to 0.01 %, D group: Sb: 0.002 % to 0.03 %, and E group: B: 0.0005 % to 0.05 %.

(4) The hot pressed member according to any one of (1) to (3), comprising a coated layer on a surface thereof.

(5) The hot pressed member according to (4), wherein the coated layer is any of a zinc or zinc alloy coated layer and an aluminum or aluminum alloy coated layer.

(6) The hot pressed member according to (5), wherein the zinc or zinc alloy coated layer contains Ni: 10 mass% to 25 mass%.

(7) A method of manufacturing a hot pressed member, the method comprising: heating a steel sheet to a first temperature that is an Ac1 point or more and an Ac3 point or less, retaining the steel sheet at the first temperature for 1 hr or more and 48 hr or less, and then cooling the steel sheet to obtain a blank steel sheet, the steel sheet having a chemical composition containing, in mass%, C: 0.090 % or more and less than 0.30 %, Mn: 3.5 % or more and less than 11.0 %, Si: 0.01 % to 2.5 %, P: 0.05 % or less, S: 0.05 % or less, Al: 0.005 % to 0.1 %, and N: 0.01 % or less, with a balance consisting of Fe and incidental impurities; performing a heating process of separately heating a first region of the blank steel sheet to a second temperature that is the Ac3 point or more and 1000 °C or less and heating a second region of the blank steel sheet to a third temperature that is the Ac1 point or more and not more than a temperature obtained by subtracting 20 °C from the Ac3 point; and thereafter performing a hot press forming process of simultaneously press forming and quenching the blank steel sheet using a press tool for forming, to obtain a hot pressed member.

(8) The method of manufacturing a hot pressed member according to (7), wherein the chemical composition further contains, in mass%, one or more groups selected from A group: one or more selected from Ni: 0.01 % to 5.0 %, Cu: 0.01 % to 5.0 %, Cr: 0.01 % to 5.0 %, and Mo: 0.01 % to 3.0 %, B group: one or more selected from Ti: 0.005 % to 3.0 %, Nb: 0.005 % to 3.0 %, V: 0.005 % to 3.0 %, and W: 0.005 % to 3.0 %, C group: one or more selected from REM: 0.0005 % to 0.01 %, Ca: 0.0005 % to 0.01 %, and Mg: 0.0005 % to 0.01 %, D group: Sb: 0.002 % to 0.03 %, and E group: B: 0.0005 % to 0.05 %.

(9) The method of manufacturing a hot pressed member according to (7) or (8), further comprising forming a coated layer on a surface of the blank steel sheet, before the heating process.

(10) The method of manufacturing a hot pressed member according to (9), wherein the coated layer is any of a zinc or zinc alloy coated layer and an aluminum or aluminum alloy coated layer.

(11) The method of manufacturing a hot pressed member according to (10), wherein the zinc or zinc alloy coated layer contains Ni: 10 mass% to 25 mass%.

(12) The method of manufacturing a hot pressed member according to any one of (9) to (11), wherein a coating weight of the coated layer is 10 g/m^2 to 90 g/m^2 per side.

(Advantageous Effect)

[0015] The hot pressed member according to the present disclosure includes: a first region having a tensile property of 1500 MPa or more in tensile strength TS and 6.0 % or more in uniform elongation uEl, and excellent heat treatment hardenability of increasing in yield stress YS by 150 MPa or more when subjected to heat treatment (baking finish); and a second region having a tensile property of 780 MPa or more in tensile strength TS and 15.0 % or more in uniform elongation uEl. With the method of manufacturing a hot pressed member according to the present disclosure, a hot pressed member having these properties can be manufactured in a condition of high robustness for the forming start temperature in hot press.

DETAILED DESCRIPTION

[0016] A hot pressed member according to one of the disclosed embodiments includes: a first region having a tensile property of 1500 MPa or more and preferably less than 2300 MPa in tensile strength TS and 6.0 % or more and substantially 20 % or less in uniform elongation uEl; and a second region having a tensile property of 780 MPa or more and preferably less than 1320 MPa in tensile strength TS and 15.0 % or more and substantially 40 % or less in uniform elongation uEl. The first region (high strength and high ductility site) is a collision resistance site that exhibits a certain degree of collision energy absorbing performance but does not allow deformation upon collision. The second region (low strength and ultrahigh ductility site) is an energy absorbing site that allows deformation but exhibits very high collision energy absorbing performance upon collision. By including two regions having different properties in the same hot pressed member in this way, the hot pressed member can be suitably used as a structural member required to have high collision energy absorbing performance, such as an impact beam, a center pillar, or a bumper of a vehicle.

[0017] The positional relationship of the first and second regions in the hot pressed member is not limited, and may be determined depending on the use of the member. For example, in the case of using the member in a center pillar, the upper portion and the lower portion may be set respectively as the first region and the second region.

(Chemical composition)

[0018] The chemical composition of a hot pressed member according to one of the disclosed embodiments is described below. In the following description, "mass%" is simply written as "%" unless otherwise noted.

C: 0.090 % or more and less than 0.30 %

[0019] C is an element that increases the strength of the steel. In addition, in heat treatment for the hot pressed member, yield stress is increased by dislocation locking of solute C. To achieve the effects and ensure a tensile strength TS of 1500 MPa or more, the C content is 0.090 % or more. If the C content is 0.30 % or more, the degree of solid solution strengthening by C increases, which makes it difficult to adjust the tensile strength TS of the hot pressed member to less than 2300 MPa.

Mn: 3.5 % or more and less than 11.0 %

[0020] Mn is an element that increases the strength of the steel and also concentrates in austenite to improve the stability of austenite, and is the most important element in the present disclosure. To achieve the effects and ensure a tensile strength TS of 1500 MPa or more and a uniform elongation uEl of 6.0 % or more in the first region, the Mn content is 3.5 % or more. If the Mn content is 11.0 % or more, the degree of solid solution strengthening by Mn increases, which makes it difficult to adjust the tensile strength TS of the hot pressed member to less than 2300 MPa.

[0021] If the C content and the Mn content are in the respective ranges mentioned above, a hot pressed member having tensile property of 6.0 % or more in uniform elongation can be yielded stably, with a tensile strength TS of 1500 MPa or more and preferably less than 2300 MPa in the first region. In more detail, to ensure a strength of 1500 MPa or more and less than 1700 MPa in tensile strength TS in the first region, it is preferable to set C: 0.090 % or more and less than 0.12 % and Mn: 4.5 % or more and less than 6.5 %, or C: 0.12 % or more and less than 0.18 % and Mn: 3.5 % or more and less than 5.5 %. To ensure a strength of 1700 MPa or more and less than 1900 MPa in tensile strength TS in the first region, it is preferable to set C: 0.090 % or more and less than 0.12 % and Mn: 6.5 % or more and less than 8.5 %, or C: 0.12 % or more and less than 0.18 % and Mn: 5.5 % or more and less than 7.5 %. To ensure a strength of 1800 MPa or more and less than 1980 MPa in tensile strength TS in the first region, it is preferable to set C: 0.18 % or more and less than 0.30 % and Mn: 3.5 % or more and less than 4.5 %. To ensure a strength of 2000 MPa or more and less than 2300 MPa in tensile strength TS in the first region, it is preferable to set C: 0.090 % or more and less than 0.12 % and Mn: 8.5 % or more and less than 11.0 %, C: 0.12 % or more and less than 0.18 % and Mn: 7.5 % or more and less than 11.0 %, or C: 0.18 % or more and less than 0.30 % and Mn: 4.5 % or more and less than 6.5 %.

[0022] In the second region, although C and Mn influence the mechanical property of the region, the desired property of 780 MPa or more in tensile strength TS and 15.0 % or more in uniform elongation uEl is ensured as a result of the below-mentioned Mn concentration heat treatment and heating process immediately before hot press, in the above-mentioned range of C: 0.090 % or more and less than 0.30 % and Mn: 3.5 % or more and less than 11.0 %. Thus, the mechanical property in the second region is strongly influenced by the heating temperature T1 in the Mn concentration heat treatment and the heating temperature T3 in the heating immediately before hot press (described later).

Si: 0.01 % to 2.5 %

[0023] Si is an element that increases the strength of the steel by solid solution strengthening. To achieve the effect, the Si content is 0.01 % or more. If the Si content is more than 2.5 %, surface defects called red scale occur significantly in hot rolling, and also the rolling load increases. The Si content is therefore 0.01 % or more and 2.5 % or less. The Si content is preferably 0.02 % or more. The Si content is preferably 1.5 % or less.

P: 0.05 % or less

[0024] P is an element that exists in the steel as an incidental impurity, and segregates to crystal grain boundaries and like and causes adverse effects such as a decrease in the toughness of the member. The P content is therefore desirably as low as possible, but 0.05 % or less P is allowable. Accordingly, the P content is 0.05 % or less, and more preferably 0.02 % or less. Excessive dephosphorization leads to higher refining cost, and so the P content is desirably 0.0005 % or more.

S: 0.05 % or less

[0025] S is contained in the steel incidentally. S exists in the steel as a sulfide inclusion, and decreases the ductility, toughness, and the like of the hot pressed member. The S content is therefore desirably as low as possible, but 0.05 % or less S is allowable. Accordingly, the S content is 0.05 % or less, and more preferably 0.005 % or less. Excessive desulfurization leads to higher refining cost, and so the S content is desirably 0.0005 % or more.

Al: 0.005 % to 0.1 %

[0026] Al is an element that acts as a deoxidizer. To achieve the effect, the Al content is 0.005 % or more. If the Al content is more than 0.1 %, Al combines with nitrogen to form a large amount of nitride. This causes a decrease in the blanking workability and quench hardenability of the steel sheet as a blank sheet. The Al content is therefore 0.005 % or more and 0.1 % or less. The Al content is preferably 0.02 % or more. The Al content is preferably 0.05 % or less.

N: 0.01 % or less

[0027] N is typically contained in the steel incidentally. If the N content is more than 0.01 %, nitrides such as AlN form during heating in hot rolling or hot press. This causes a decrease in the blanking workability and quench hardenability of the steel sheet as a blank sheet. The N content is therefore 0.01 % or less. The N content is more preferably 0.0030 % or more. The N content is more preferably 0.0050 % or less. In the case where N is contained incidentally without adjustment, the N content is approximately less than 0.0025 %. To prevent an increase in refining cost, the N content is desirably 0.0025 % or more.

[0028] In addition to the basic components described above, the chemical composition may contain the following optional components.

[0029] A group: one or more selected from Ni: 0.01 % to 5.0 %, Cu: 0.01 % to 5.0 %, Cr: 0.01 % to 5.0 %, and Mo: 0.01 % to 3.0 %

[0030] Ni, Cu, Cr, and Mo are each an element that increases the strength of the steel and improves quench hardenability. One or more of them may be selected and added according to need. To achieve the effect, the content of each element is 0.01 % or more. To prevent an increase in material cost, the Ni, Cu, and Cr contents are each 5.0 % or less, and the Mo content is 3.0 % or less. The content of each element is preferably 0.01 % or more and 1.0 % or less.

B group: one or more selected from Ti: 0.005 % to 3.0 %, Nb: 0.005 % to 3.0 %, V: 0.005 % to 3.0 %, and W: 0.005 % to 3.0 %

[0031] Ti, Nb, V, and W are each an element that increases the strength of the steel by precipitation strengthening, and also improves toughness by crystal grain refinement. One or more of them may be selected and added according to need.

[0032] Ti has not only the effect of increasing strength and improving toughness, but also the effect of forming a nitride more preferentially than B and improving quench hardenability by solute B. To achieve the effects, the Ti content is 0.005 % or more. If the Ti content is more than 3.0 %, the rolling load increases extremely in hot rolling, and also the toughness of the hot pressed member decreases. Accordingly, in the case of containing Ti, the Ti content is 0.005 % or more and 3.0 % or less. The Ti content is preferably 0.01 % or more. The Ti content is preferably 1.0 % or less.

[0033] To achieve the above-mentioned effect by Nb, the Nb content is 0.005 % or more. If the Nb content is more than 3.0 %, the amount of carbonitride increases, and ductility and lagging destruction resistance decrease. Accordingly, in the case of containing Nb, the Nb content is 0.005 % or more and 3.0 % or less. The Nb content is preferably 0.01 % or more. The Nb content is preferably 0.05 %.

[0034] V has not only the effect of increasing strength and improving toughness, but also the effect of precipitating as a precipitate or a crystallized product and improving hydrogen embrittlement resistance as a hydrogen trap site. To achieve the effects, the V content is 0.005 % or more. If the V content is more than 3.0 %, the amount of carbonitride increases considerably, and ductility decreases. Accordingly, in the case of containing V, the V content is 0.005 % or more and 3.0 % or less. The V content is preferably 0.01 % or more. The V content is preferably 2.0 % or less.

[0035] W has not only the effect of increasing strength and improving toughness, but also the effect of improving hydrogen embrittlement resistance. To achieve the effects, the W content is 0.005 % or more. If the W content is more than 3.0 %, ductility decreases. Accordingly, in the case of containing W, the W content is 0.005 % or more and 3.0 % or less. The W content is preferably 0.01 % or more. The W content is preferably 2.0 % or less.

C group: one or more selected from REM: 0.0005 % to 0.01 %, Ca: 0.0005 % to 0.01 %, and Mg: 0.0005 % to 0.01 %

[0036] REM, Ca, and Mg are each an element that improves ductility and hydrogen embrittlement resistance by morphological control of an inclusion. One or more of them may be selected and added according to need. To achieve the effect, the content of each element is 0.0005 % or more. To prevent a decrease in hot workability, the REM content and the Ca content are each 0.01 % or less. To prevent a decrease in ductility caused by the formation of a coarse oxide or sulfide, the Mg content is 0.01 % or less. The content of each element is preferably 0.0006 % to 0.01 %.

D group: Sb: 0.002 % to 0.03 %

[0037] Sb inhibits the formation of a decarburized layer in the steel sheet surface layer when heating or cooling the steel sheet, and so may be added according to need. To achieve the effect, the Sb content is 0.002 % or more. If the Sb content is more than 0.03 %, the rolling load increases, and productivity decreases. Accordingly, in the case of containing Sb, the Sb content is 0.002 % or more and 0.03 % or less. The Sb content is preferably 0.002 % or more and 0.02 % or less.

E group: B: 0.0005 % to 0.05 %

[0038] B improves quench hardenability during hot press and toughness after hot press, and so may be added according to need. To achieve the effect, the B content is 0.0005 % or more. If the B content is more than 0.05 %, the rolling load in hot rolling increases. Besides, martensite phase or bainite phase may form after hot rolling, and cause cracking in the steel sheet. Accordingly, in the case of containing B, the B content is 0.0005 % or more and 0.05 % or less, and preferably 0.0005 % or more and 0.01 % or less.

[0039] The balance other than the components described above consists of Fe and incidental impurities. As the incidental impurities, O (oxygen): 0.0100 % or less is allowable.

(Microstructure)

[0040] The microstructure of the hot pressed member in this embodiment is described below.

Martensite phase in first region: 80.0 % or more in volume fraction

[0041] To ensure a tensile strength TS of 1500 MPa or more in the first region, martensite phase of 80.0 % or more in volume fraction needs to be the main phase. To contain the desired amount of retained austenite phase, martensite phase is preferably 97 % or less.

Retained austenite phase in first region: 3.0 % to 20.0 % in volume fraction

[0042] Retained austenite phase enhances uniform elongation by a transformation induced plasticity (TRIP) effect upon deformation, and is the most important microstructure in the present disclosure. In this embodiment, the volume fraction of retained austenite phase is 3.0 % or more, to achieve a uniform elongation uEl of 6.0 % or more in the first region. If the volume fraction of retained austenite phase is more than 20.0 %, hard martensite phase transformed after the TRIP effect is developed increases excessively, and toughness decreases. The volume fraction of retained austenite phase is therefore 3.0 % or more and 20.0 % or less. The volume fraction of retained austenite phase is preferably 5.0 or more. The volume fraction of retained austenite phase is preferably 18.0 % or less.

[0043] As the balance other than martensite phase and retained austenite phase in the first region, 10 % or less (including 0 %) bainite phase, ferrite phase, cementite, and pearlite in volume fraction in total is allowable.

Ferrite phase in second region: 30.0 % or more and 60.0 % or less in volume fraction

[0044] Ferrite phase is soft, and has a function of increasing the ductility of the hot pressed member. If the volume fraction of ferrite phase is less than 30.0 %, a uniform elongation of 15.0 % or more cannot be ensured. If the volume fraction of ferrite phase is more than 60.0 %, a tensile strength TS of 780 MPa or more cannot be ensured. The volume fraction of ferrite phase is therefore 30.0 % or more and 60.0 % or less, and preferably 35.0 % or more and 55.0 % or less.

Retained austenite phase in second region: 10.0 % or more and 70.0 % or less in volume fraction

[0045] Retained austenite phase enhances uniform elongation by a transformation induced plasticity (TRIP) effect upon deformation, and is the most important microstructure in the second region, too. If the volume fraction of retained austenite phase is less than 10.0 %, a uniform elongation uEl of 15.0 % or more cannot be ensured. If the volume fraction of retained austenite phase is more than 70.0 %, hard martensite phase transformed after the TRIP effect is developed increases excessively, and toughness decreases. The volume fraction of retained austenite phase is therefore 10.0 % or more and 70.0 % or less. The volume fraction of retained austenite phase is preferably 15.0 % or more. The volume fraction of retained austenite phase is preferably 65.0 % or less.

Martensite phase in second region: 30.0 % or less in volume fraction

[0046] Martensite phase is hard, and has a function of increasing strength. To achieve a tensile strength TS of 780 MPa or more, the volume fraction of martensite phase is 30.0 % or less (including 0 %). If the volume fraction of martensite is more than 30.0 %, a uniform elongation uEl of 15.0 % or more cannot be ensured. The volume fraction of martensite phase is therefore 30.0 % or less (including 0 %).

[0047] As the balance other than ferrite phase, retained austenite phase, and martensite phase in the second region, 10 % or less (including 0 %) bainite phase, cementite, and pearlite in volume fraction in total is allowable.

[0048] In both of the first and second regions, for the formation of the above-mentioned appropriate amount of retained austenite phase, it is important to use a steel sheet containing an appropriate amount of Mn, subject the steel sheet to predetermined heat treatment before hot press to cause Mn to concentrate in austenite, and appropriately adjusting a heating process in hot press.

[0049] In the present disclosure, the volume fraction of each phase is determined as follows.

[0050] The volume fraction of retained austenite is determined by the following method. An X-ray diffraction test piece is cut out of the first or second region of the hot pressed member, mechanically polished and chemically polished so that the measurement plane is at a position of 1/4 of the thickness, and then subjected to X-ray diffraction. Using CoKα radiation as an incident X-ray, the peak integrated intensity for the retained austenite (γ) planes of {200}, {220}, and {311} and the peak integrated intensity for the ferrite (α) planes of {200} and {211} are measured. For a total of six patterns of α\{200\} - γ\{200\}, α\{200\} - γ\{220\}, α\{200\} - γ\{311\}, α\{211\} - γ\{200\}, α\{211\} - γ\{220\}, and α\{211\} - γ\{311\}, the retained γ volume fraction obtained from each integrated intensity ratio is calculated. Their mean value is set as "the volume fraction of retained austenite phase".

[0051] The volume fraction of ferrite phase and balance is determined by the following method. A microstructure observation test piece is collected from the first or second region of the hot pressed member so that the observation plane is parallel to the rolling direction and perpendicular to the rolling plane. The observation plane is polished, and etched with a 3 vol% nital solution to expose the microstructure. The microstructure at a position of 1/4 of the sheet thickness is observed using a scanning electron microscope (at 1500 magnifications) and photographed. From the obtained micrograph, the microstructure is identified and the microstructure proportion is calculated by image analysis. A phase observed as black with a relatively smooth surface is identified as ferrite phase. A phase observed as white in film or lump form in crystal grain boundaries is identified as cementite. A phase in which ferrite phase and cementite form in layers is identified as pearlite. A phase in which a carbide forms between laths and a phase made of bainitic ferrite having no carbide in grains are identified as bainite phase. The occupancy area ratio of each phase in the micrograph is calculated, and the area ratio is set as the volume fraction on the assumption that the microstructure is homogeneous three-dimensionally.

[0052] The volume fraction of martensite phase is calculated by subtracting the volume fraction of the balance and the volume fraction of the retained austenite phase from 100 %.

Mean grain size of ferrite phase in second region: 10 μm or less

[0053] Refining the crystal grain size of ferrite in the second region improves TS. To ensure the desired TS, the mean grain size of ferrite phase is preferably 10 μm or less, and more preferably 5 μm or less. No lower limit is placed on the mean grain size of ferrite, but the lower limit is preferably about 0.2 μm in industrial terms.

Mean grain size of secondary phase in second region: 10 μm or less

[0054] Coarse secondary phase in the second region causes a decrease in ductility. Accordingly, the mean grain size of secondary phase is preferably 10 μm or less, and more preferably 5 μm or less. No lower limit is placed on the mean grain size of secondary phase, but the lower limit is preferably about 0.2 μm in industrial terms. Secondary phase in the second region is the balance other than ferrite, and is mainly retained austenite and martensite but also includes martensite, pearlite, and bainite.

[0055] The mean grain size of ferrite and the mean grain size of secondary phase are determined by the following method. From a micrograph of the second region obtained by the above-mentioned method, the microstructure is identified by the above-mentioned method. The mean grain size of each of ferrite and secondary phase is calculated according to linear analysis described in JIS G 0551 (2005).

Mns/Mnα in second region: 1.5 or more

[0056] Mns/Mnα is preferably 1.5 or more, where Mns is the Mn concentration in secondary phase and Mnα is the Mn concentration in ferrite phase. Secondary phase in the second region is mainly retained austenite. A state of having high Mn concentration, i.e. a Mn-concentrated state, indicates that the stability of retained austenite is high. Retained austenite having high stability has a high transformation induced plasticity (TRIP) effect upon deformation, and enhances uniform elongation. To ensure favorable ductility, Mns/Mnα of 1.5 or more, i.e. a state of high Mn concentration in secondary phase, is necessary. Mns/Mnα is preferably 1.6 or more. No upper limit is placed on Mns/Mnα, but Mns/Mnα is substantially 10.0 or less.

[0057] Mns/Mnα in secondary phase is determined by the following method. A microstructure observation test piece is collected. Its observation plane is then polished, and etched with a 3 vol% nital solution to expose the microstructure. The microstructure at a position of 1/4 of the sheet thickness is observed using an electron probe microanalyzer (EPMA), and quantitative analysis of Mn is performed on 30 particles for each of ferrite and secondary phase. Regarding the Mn quantitative analysis results, the mean value of ferrite is set as Mnα, the mean value of secondary phase is set as Mns, and the value obtained by dividing the mean value Mns of secondary phase by the mean value Mnα of ferrite is set as Mns/Mnα.

(Dislocation density)

Dislocation density in first region: $1.0 \times 10^{16}/m^2$ or more

[0058] The dislocation density of the hot pressed member influences ΔYS, and is the most important index in the present disclosure. It is considered that, when the hot pressed member is subjected to heat treatment (baking finish), solute C locks to mobile dislocations, as a result of which yield stress YS increases. To achieve ΔYS of 150 MPa or more, the dislocation density of the hot pressed member needs to be $1.0 \times 10^{16}/m^2$ or more. The upper limit of the dislocation density is substantially $5.0 \times 10^{16}/m^2$. The dislocation density of the hot pressed member is preferably $1.2 \times 10^{16}/m^2$ or more. The dislocation density of the hot pressed member is preferably $4.5 \times 10^{16}/m^2$ or less. In particular, martensite in the first region typically has low YS, because of the formation of mobile dislocations. Therefore, improving YS in the first region is effective for the effects of the part properties.

[0059] In the present disclosure, the dislocation density is determined by the following method. An X-ray diffraction test piece is cut out of the first region of the hot pressed member, mechanically polished and chemically polished so that the measurement plane is at a position of 1/4 of the thickness, and then subjected to X-ray diffraction. Using CoKα_1 radiation as an incident X-ray, the peak half-value widths of α{110}, α{211}, and α{220} are measured. The measured peak half-value widths of α{110}, α{211}, and α{220} are corrected to true half-value widths using a strain-free standard test piece (Si), and then strain (ε) is calculated based on the Willaimson-Hall method. The dislocation density (ρ) is calculated using the strain (ε) and the Burgers vector (b = 0.286 nm), according to the following expression:

$$\rho = 14.4 \times \varepsilon^2/b^2.$$

(Coated layer)

[0060] The hot pressed member in this embodiment preferably has a coated layer.

[0061] In the case where the steel sheet used as a blank sheet of the hot pressed member is a coated steel sheet, a coated layer remains in the surface layer of the yielded hot pressed member. In such a case, scaling is suppressed during heating in hot press. The hot pressed member can thus be put to use without descaling the surface, which contributes to improved productivity.

[0062] The coated layer is preferably a zinc or zinc alloy coated layer or an aluminum or aluminum alloy coated layer. In the case where corrosion resistance is required, a zinc or zinc alloy coated layer is better than an aluminum or aluminum alloy coated layer, because the corrosion rate of the steel substrate can be reduced by the sacrificial protection effect of zinc. Moreover, in the case of hot pressing the coated steel sheet, a zinc oxide film forms in the initial stage of heating in the hot press process, so that evaporation of Zn can be prevented in the subsequent treatment of the hot pressed member.

[0063] Examples of the zinc or zinc alloy coating include typical hot-dip galvanizing (GI), galvannealing (GA), and Zn-Ni-based coating. Zn-Ni-based coating is particularly preferable. A Zn-Ni-based coated layer can remarkably suppress scaling during hot press heating, and also prevent liquid metal embrittlement cracking. To achieve the effects, the Zn-Ni-based coated layer preferably contains 10 mass% to 25 mass% Ni. If more than 25 % Ni is contained, the effects are saturated.

[0064] Examples of the aluminum or aluminum alloy coated layer include Al-10 mass% Si coating.

(Manufacturing method)

[0065] A method of manufacturing a hot pressed member in this embodiment is described below. First, a slab having the above-mentioned chemical composition is heated, and hot rolled to obtain a hot rolled steel sheet. The hot rolled steel sheet is then subjected to predetermined heat treatment (Mn concentration heat treatment) (described later), to obtain a first blank steel sheet. After this, the first blank steel sheet is optionally cold rolled to obtain a cold rolled steel sheet. The cold rolled steel sheet is then subjected to predetermined annealing, to obtain a second blank steel sheet.

[0066] The first blank steel sheet or the second blank steel sheet obtained in this way is subjected to a predetermined heating process and a hot press forming process, to obtain a hot pressed member. Each process is described in detail below.

<Obtainment of steel sheet>

[0067] The obtainment of the steel sheet is not limited, and may be performed according to a usual method. It is preferable to obtain molten steel having the above-mentioned chemical composition by steelmaking in a converter or the like, and process the molten steel into a slab by a continuous casting method in order to prevent macrosegregation. An ingot casting method or a thin slab continuous casting method may be used instead of the continuous casting method.

[0068] The obtained slab is cooled to the room temperature, and then charged into a heating furnace for reheating. Alternatively, an energy saving process such as a process of charging the slab into the heating furnace as a warm slab without cooling the slab to the room temperature or a process of heat-retaining the slab for a short time and then immediately hot rolling the slab may be used.

[0069] The obtained slab is heated to a predetermined heating temperature, and then hot rolled to obtain a hot rolled steel sheet. The heating temperature is, for example, 1000 °C to 1300 °C. The heated slab is typically hot rolled at a finisher entry temperature of 1100 °C or less and a finisher delivery temperature of 800 °C to 950 °C, cooled at an average cooling rate of 5 °C/s or more, and coiled at a coiling temperature of 300 °C to 750 °C, to obtain a hot rolled steel sheet.

[0070] The hot rolled steel sheet is then preferably cold rolled to obtain a cold rolled steel sheet, because a cold rolled steel sheet can be easily thinned and has high sheet thickness accuracy. To prevent abnormal grain growth in the subsequent annealing or the heating process immediately before the hot press, the reduction ratio in the cold rolling is preferably 30 % or more, and more preferably 50 % or more. To prevent an increase in rolling load and a decrease in productivity, the reduction ratio is preferably 85 % or less. In the case where the rolling load increases significantly, the hot rolled steel sheet may be subjected to softening annealing before cold rolling. The softening annealing is preferably performed in a batch annealing furnace, a continuous annealing furnace, or the like.

<Mn concentration heat treatment>

[0071] Following this, the hot rolled steel sheet or preferably the cold rolled steel sheet is heated to a first temperature that is Ac1 point or more and Ac3 point or less, retained at the first temperature for 1 hr or more and 48 hr or less, and then cooled to obtain a blank steel sheet. This process causes Mn to concentrate in austenite, and is the most important process for manufacturing a hot pressed member that has the appropriate amount of retained austenite to achieve a uniform elongation uEl of 6.0 % or more and has a dislocation density of $1.0 \times 10^{16}/m^2$ or more to achieve ΔYS of 150

MPa or more in the first region.

Heating temperature (first temperature TI): Ac1 point or more and Ac3 point or less

[0072] The hot rolled steel sheet or preferably the cold rolled steel sheet is heated to a ferrite-austenite dual phase temperature range, to cause Mn to concentrate in austenite. In Mn-concentrated austenite, the martensite transformation end temperature is the room temperature or less, and the formation of retained austenite is facilitated. If the heating temperature is less than Ac1 point, austenite does not form, and Mn cannot be concentrated in austenite. If the heating temperature is more than Ac3 point, the temperature is in an austenite single phase temperature range, and Mn does not concentrate in austenite. In both of the case where the heating temperature is less than Ac1 point and the case where the heating temperature is more than Ac3 point, a hot pressed member having a dislocation density of $1.0 \times 10^{16}/m^2$ or more in the first region cannot be obtained. The heating temperature is therefore Ac1 point or more and Ac3 point or less. The heating temperature is preferably (Ac1 point + 20 °C) or more. The heating temperature is preferably (Ac3 point - 20 °C) or less.

[0073] Ac1 point (°C) and Ac3 point (°C) are calculated according to the following expressions:

$$\text{Ac1 point } (^\circ\text{C}) = 751 - 16\text{C} + 11\text{Si} - 28\text{Mn} - 5.5\text{Cu} - 16\text{Ni} + 13\text{Cr} + 3.4\text{Mo}$$

$$\text{Ac3 point } (^\circ\text{C}) = 910 - 203\text{C}^{1/2} + 44.7\text{Si} - 4\text{Mn} + 11\text{Cr}$$

where C, Si, Mn, Ni, Cu, Cr, and Mo are each the content (mass%) of the corresponding element. In the case where the element is not contained, the content of the element is assumed to be 0.

Heating retention time: 1 hr or more and 48 hr or less

[0074] The concentration of Mn in austenite progresses with the passage of the heating retention time. If the heating retention time is less than 1 hr, the concentration of Mn in austenite is insufficient, and the desired uniform elongation in the first region cannot be obtained. Besides, if the heating retention time is less than 1 hr, the concentration of Mn is insufficient, and Ms point does not decrease in the hot press process, so that a hot pressed member having a dislocation density of $1.0 \times 10^{16}/m^2$ or more in the first region cannot be obtained. If the heating retention time is more than 48 hr, pearlite forms, making it impossible to achieve the desired uniform elongation in the first region. Moreover, a hot pressed member having a dislocation density of $1.0 \times 10^{16}/m^2$ or more in the first region cannot be obtained. The heating retention time is therefore 1 hr or more and 48 hr or less. The heating retention time is preferably 1.5 hr or more. The heating retention time is preferably 24 hr or less.

[0075] Ms point (°C) is calculated according to the following expression:

$$\text{Ms point } (^\circ\text{C}) = 539 - 423\text{C} - 30.4\text{Mn} - 17.7\text{Ni} - 12.1\text{Cr} - 7.5\text{Mo}$$

where C, Mn, Ni, Cr, and Mo are each the content (mass%) of the corresponding element. In the case where the element is not contained, the content of the element is assumed to be 0.

[0076] The cooling after the heating retention is not limited. It is preferable to appropriately perform the cooling by natural cooling (gradual cooling) or controlled cooling depending on the heating furnace used and the like.

[0077] The Mn concentration heat treatment is preferably performed in a batch annealing furnace or a continuous annealing furnace. The treatment conditions in the batch annealing furnace other than the above-mentioned conditions are not limited. For example, it is preferable to set the heating rate to 40 °C/hr or more and the cooling rate after the heating retention to 40 °C/hr or more, in terms of Mn concentration. The treatment conditions in the continuous annealing furnace other than the above-mentioned conditions are not limited. For example, it is preferable to, after performing the above-mentioned heating retention, cool the hot rolled steel sheet or the cold rolled steel sheet at an average cooling rate of 10 °C/s or more to a cooling stop temperature in a temperature range of 350 °C to 600 °C, cause the hot rolled steel sheet or the cold rolled steel sheet to stay in the temperature range for 10 sec to 300 sec, and then cool and coil the steel sheet, in terms of manufacturability.

[0078] The blank steel sheet produced in this way can be used as a steel sheet for hot press.

<Coating>

[0079] In the case where no coated layer is formed on the surface of the blank steel sheet, descaling treatment such as shot blasting needs to be performed on the hot pressed member after the hot press. In the case where a coated layer is formed on the surface of the blank steel sheet, on the other hand, scaling is suppressed during heating in the hot press, so that descaling treatment after the hot press is unnecessary. This improves productivity.

[0080] The coating weight of the coated layer is preferably 10 g/m^2 to 90 g/m^2 per side, and more preferably 30 g/m^2 to 70 g/m^2 per side. If the coating weight is 10 g/m^2 or more, the effect of suppressing scaling during heating is sufficient. If the coating weight is 90 g/m^2 or less, productivity is not hampered. The components of the coated layer are as described above.

<Heating process>

[0081] Following this, a heating process of separately heating the first region of the blank steel sheet to a second temperature that is Ac3 point or more and 1000 °C or less and heating the second region of the blank steel sheet to a third temperature that is Ac1 point or more and (Ac3 point - 20 °C) or less is performed.

Heating temperature (second temperature T2) of first region: Ac3 point or more and 1000 °C or less

[0082] In the first region, the blank steel sheet is heated to Ac3 point or more which is in an austenite single phase region. If the heating temperature is less than Ac3 point, austenitization is insufficient. As a result, the desired amount of martensite in the first region of the hot pressed member cannot be ensured, and the desired tensile strength cannot be achieved. Besides, the hot pressed member cannot have a dislocation density of $1.0 \times 10^{16}/m^2$ or more in the first region, making it impossible to achieve ΔYS of 150 MPa or more. If the heating temperature is more than 1000 °C, Mn concentrated in austenite is made uniform. Consequently, the desired amount of retained austenite in the first region cannot be ensured, and the desired uniform elongation cannot be achieved. Moreover, uniform Mn makes it impossible to decrease Ms point, so that the hot pressed member cannot have a dislocation density of $1.0 \times 10^{16}/m^2$ or more and ΔYS of 150 MPa or more cannot be achieved. The heating temperature is therefore Ac3 point or more and 1000 °C or less. The heating temperature is preferably (Ac3 point + 20 °C) or more. The heating temperature is preferably 950 °C or less.

Heating temperature (third temperature T3) of second region: Ac1 point or more and (Ac3 point - 20 °C) or less

[0083] If the heating temperature of the second region is more than (Ac3 point - 20 °C), the desired amounts of ferrite phase and retained austenite phase cannot be obtained, and a uniform elongation uEl of 15.0 % or more cannot be achieved. If the heating temperature of the second region is less than Ac1 point, the volume fraction of ferrite increases, and the strength decreases. The heating temperature of the second region is therefore Ac1 point or more and (Ac3 point - 20 °C) or less. The heating temperature of the second region is preferably (Ac1 point + 10 °C) or more. The heating temperature of the second region is preferably (Ac3 point - 30 °C) or less.

[0084] The mechanical property of the second region is influenced by the heating temperature T3 in this heating process and the heating temperature T1 in the above-mentioned Mn concentration heat treatment, as follows. In the case where T3 is more than T1 and (Ac3 point - 20 °C) or less, the mechanical property of the second region is strongly influenced by T3. In the case where T3 is T1 or less, the mechanical property of the second region is strongly influenced by T1. This is because, regarding the microstructure formed by the Mn concentration heat treatment, the volume fraction of secondary phase is unchanged in the case where T3 is T1 or less, and increases in the case where T3 is more than T1.

[0085] The heating rate to the heating temperature (second temperature and third temperature) is not limited, but is preferably 1 °C/s to 400 °C/s, and more preferably 10 °C/s to 150 °C/s. If the heating rate is 1 °C/s or more, productivity is not hampered. If the heating rate is 400 °C/s or less, stable temperature control is ensured.

Retention time: 900 sec or less (including 0 sec)

[0086] With the passage of the retention time at the heating temperature (second temperature and third temperature), concentrated Mn diffuses around and is made uniform. Accordingly, if the retention time is more than 900 sec, the desired amount of retained austenite cannot be ensured, and the desired uniform elongation cannot be achieved. Besides, uniform Mn makes it impossible to decrease Ms point, so that the hot pressed member cannot have a dislocation density of $1.0 \times 10^{16}/m^2$ or more in the first region and ΔYS of 150 MPa or more cannot be achieved. The retention time is therefore 900 sec or less. The retention time may be 0 sec, that is, the heating may be stopped immediately after the second temperature is reached.

[0087] The heating method is not limited, and may be any typical heating method such as an electric furnace, a gas furnace, infrared heating, high frequency heating, or direct current heating. The atmosphere is not limited, and may be any of an air atmosphere and an inert gas atmosphere.

[0088] The method of separately heating the first and second regions is not limited. Any of a method of placing a cover over part of the blank steel sheet, a method of spraying a cooling medium such as gas to part of the blank steel sheet, a method of excluding part of the blank steel sheet from the heating zone (e.g. placing part of the blank steel sheet outside the high frequency coil, or adjusting the electrode clamp position in direct current heating), and the like may be used.

<Hot press forming process>

[0089] In the hot press forming process, the blank steel sheet which has undergone the heating process is simultaneously press formed and quenched using a press tool for forming, to obtain a hot pressed member of a predetermined shape. Hot press forming is a process of press forming a heated thin steel sheet using a press tool and simultaneously quenching it, and is also referred to as "hot forming", "hot stamping", "die quenching", etc.

[0090] The forming start temperature in the press machine is not limited. If the Mn content is 3.5 mass% or more, austenite formed in the heating process immediately before the hot press forming process for the blank steel sheet does not newly undergo ferrite transformation during cooling performed following the heating process, at a cooling rate of air cooling or more. This is because Mn has the effect of delaying ferrite transformation of austenite in cooling. This eliminates constraints on the forming start temperature for yielding the first region and the second region having the desired properties, and contributes to enhanced robustness as compared with conventional techniques. In terms of the forming load, however, the press forming start temperature in the first region is, for example, preferably 500 °C or more. The conveyance of the blank steel sheet before the forming start is typically performed with air cooling. Accordingly, the upper limit of the forming start temperature is the heating temperature in the immediately previous heating process in the manufacturing process. In the case where the blank steel sheet is conveyed in an environment where the cooling rate is accelerated by a refrigerant such as gas or liquid, the cooling rate is preferably decreased by a heat insulation jig such as a heat retention box.

[0091] The cooling rate in the press tool is not limited. In terms of productivity, the average cooling rate to 200 °C is preferably 20 °C/s or more, and more preferably 40 °C/s or more.

[0092] The removal time from the press tool and the cooling rate after the removal are not limited. As the cooling method, for example, a punch press tool is held at the bottom dead center for 1 sec to 60 sec, and the hot pressed member is cooled using a die press tool and the punch press tool. After this, the hot pressed member is removed from the press tool, and cooled. The cooling in the press tool and the cooling after the removal from the press tool may be performed in combination with a cooling method using a refrigerant such as gas or liquid. This improves productivity.

EXAMPLES

[0093] Molten steel having the chemical composition (the balance consisting of Fe and incidental impurities) listed in Tables 1 and 4 was obtained by steelmaking in a small vacuum melting furnace, to yield a slab. The slab was heated to 1250 °C, and further subjected to hot rolling including rough rolling and finish rolling, to obtain a hot rolled steel sheet. The finisher entry temperature was 1100 °C, and the finisher delivery temperature was 850 °C. The cooling rate after the hot rolling end was 15 °C/s on average from 800 °C to 600 °C, and the coiling temperature was 650 °C. The obtained hot rolled steel sheet was pickled, and cold rolled at a reduction ratio of 54 %, to obtain a cold rolled steel sheet (sheet thickness: 1.6 mm).

[0094] The obtained cold rolled steel sheet was heated to the heating temperature T1 (first temperature) listed in Tables 2 and 5, retained at the temperature for the time listed in Tables 2 and 5, and then cooled to obtain a blank steel sheet.

[0095] As listed in Tables 2 and 5, in some test examples, the blank steel sheet was subjected to coating treatment. In Tables 2 and 5, "GI" denotes a hot-dip galvanized layer, "GA" denotes a galvannealed layer, "Zn-Ni" denotes a Zn-12 mass% Ni coated layer, and "Al-Si" denotes a Al-10 mass% Si coated layer. The coating weight of each coated layer was 60 g/m^2 per side.

[0096] The blank steel sheet obtained in this way was subjected to a heating process under the conditions listed in Tables 3 and 6 and a hot press forming process, to obtain a hat-shaped hot pressed member. The hot press was performed using a punch press tool having a width of 70 mm and a shoulder radius R of 6 mm and a die press tool having a shoulder radius R of 7.6 mm, with a forming depth of 30 mm.

[0097] The heating process before the hot press forming process was performed using an electric heating furnace in the air atmosphere, where the heating rate from the room temperature to 750 °C was 7.5 °C/s on average in the first region. The second region was covered with a heat-resisting cover of 10 mm in thickness. Hence, the heating temperature

T2 of the first region and the heating temperature T3 of the second region were as listed in Tables 3 and 6. The retention time in the heating process is also listed in Tables 3 and 6. The hot pressing start temperature in the first region is also listed in Tables 3 and 6. The steel sheet was cooled to 150 °C or less by a combination of: clamping the steel sheet using the die press tool and the punch press tool with the punch press tool being held at the bottom dead center for 15 sec; and air cooling on the die after release from the clamping. The average cooling rate from the hot pressing start temperature to 200 °C was 100 °C/s.

[0098] A JIS No. 5 tensile test piece (parallel portion width: 25 mm, parallel portion length: 60 mm, GL = 50 mm) was collected from a hat top portion in each of the first and second regions of the obtained hot pressed member, and a tensile test was conducted according to JIS Z 2241 to determine the tensile strength TS, the total elongation tEl, and the uniform elongation uEl. For the first region, the yield stress YS was also determined. The results are listed in Tables 3 and 6.

[0099] Moreover, the volume fraction of martensite phase, the volume fraction of retained austenite phase, and the volume fraction of the balance in the first region of the obtained hot pressed member and the volume fraction of ferrite phase, the volume fraction of retained austenite phase, the volume fraction of martensite phase, the volume fraction of the balance, the mean grain size of ferrite phase, the mean grain size of secondary phase, and Mns/Mna in the second region of the obtained hot pressed member were measured by the above-mentioned methods. The results are listed in Tables 3 and 6.

[0100] The obtained hot pressed member was heat treated (low temperature heat treatment) at 170 °C for 20 min. This corresponds to the baking finish condition in a typical automotive member manufacturing process. After the low temperature heat treatment, a JIS No. 5 tensile test piece (parallel portion width: 25 mm, parallel portion length: 60 mm, GL = 50 mm) was collected from the first region of the hat top portion, and a tensile test was conducted according to JIS Z 2241 to determine the yield stress YS, the tensile strength TS, the total elongation tEl, and the uniform elongation uEl. The results are listed in Tables 3 and 6.

Table 1

Steel No.	C (mass%)	Mn (mass%)	Si (mass%)	P (mass%)	S (mass%)	Al (mass%)	N (mass%)	Ac1 point (°C)	Ac3 point (°C)	Category
A	0.220	4.15	0.25	0.012	0.002	0.032	0.003	634	809	Conforming steel
B	0.225	6.20	0.25	0.013	0.002	0.035	0.003	577	800	Conforming steel
C	0.148	6.20	0.23	0.013	0.002	0.032	0.003	578	817	Conforming steel
D	0.152	10.20	0.23	0.013	0.002	0.030	0.003	465	800	Conforming steel
E	0.274	4.35	0.25	0.015	0.003	0.035	0.003	628	798	Conforming steel
F	0.291	4.20	0.20	0.015	0.002	0.035	0.003	631	793	Conforming steel
G	0.320	4.20	0.24	0.012	0.002	0.035	0.003	631	789	Comparative steel
H	0.078	4.15	0.26	0.012	0.002	0.032	0.003	636	848	Comparative steel
I	0.290	12.00	0.20	0.015	0.002	0.035	0.003	413	762	Comparative steel
J	0.152	3.20	0.25	0.013	0.002	0.030	0.003	662	829	Comparative steel

Table 2

Blank steel sheet No.	Steel No.	Heating temperature T1 (°C)	Retention time (hr)	Surface treatment of blank steel sheet	Category
A1	A	675	2.0	None	Example
A2	A	640	3.5	Zn-Ni	Example
A3	A	725	3.1	GA	Example
A4	A	675	47.0	GI	Example
A5	A	675	25.0	Zn-Ni	Example
A6	A	850	2.3	None	Comparative Example
A7	A	550	2.3	None	Comparative Example
A8	A	670	50.5	GA	Comparative Example
A9	A	672	0.2	None	Comparative Example
B1	B	670	2.0	None	Example
B2	B	672	2.3	Zn-Ni	Example
B3	B	671	2.5	None	Example
B4	B	674	2.4	Al-Si	Example
B5	B	678	2.0	None	Comparative Example
B6	B	675	2.1	None	Comparative Example
B7	B	672	2.0	None	Comparative Example
B8	B	674	2.2	None	Comparative Example
C1	C	625	2.0	Zn-Ni	Example
D1	D	620	2.0	Zn-Ni	Example
E1	E	634	3.5	GA	Example
E2	E	635	3.2	Al-Si	Example
E3	E	675	3.5	GI	Example
E4	E	675	3.4	None	Example
F1	F	715	3.0	Zn-Ni	Example
F2	F	675	3.6	Zn-Ni	Example
F3	F	680	3.7	None	Example
F4	F	684	3.8	None	Example
G1	G	670	3.0	None	Comparative Example
H1	H	670	2.0	None	Comparative Example

(continued)

Blank steel sheet No.	Steel No.	Heating temperature T1 (°C)	Retention time (hr)	Surface treatment of blank steel sheet	Category
I1	I	675	3.0	None	Comparative Example
J1	J	615	2.0	None	Comparative Example

Table 3

Hot pressed member No.	Blank steel sheet No.	Retention time (s)	First region						Second region							
			Heating temp. T2 (°C)	Forming start temp. (°C)	Volume fraction of RA (%)	Volume fraction of M (%)	Volume fraction of balance (%)	Dislocation density ($\times 10^{16}/m^2$)	Heating temp. T3 (°C)	Volume fraction of RA (%)	Volume fraction of α (%)	Volume fraction of M (%)	Volume fraction of balance (%)	Mean grain size of ferrite (μm)	Mean grain size of secondary phase (μm)	Mns /Mnα
1-1	A1	20	850	700	8.2	91.8	---	1.9	700	27.7	57.4	14.9	---	3.2	3.0	2.3
1-2	A2	25	852	700	9.5	90.5	---	1.9	705	28.8	55.7	15.5	---	3.6	3.6	2.5
1-3	A3	22	865	705	9.4	90.6	---	1.5	703	28.3	56.4	15.3	---	4.5	3.4	1.8
1-4	A4	24	843	703	10.3	89.7	---	1.8	702	28.1	56.7	15.1	---	3.2	3.7	3.6
1-5	A5	22	843	765	11.2	88.8	---	2.0	702	34.6	46.7	18.6	---	3.3	3.0	3.1
1-6	A6	20	852	700	1.5	98.5	---	0.9	700	34.2	47.4	18.4	---	3.5	3.5	2.5
1-7	A7	22	850	700	1.2	98.8	---	0.8	705	35.3	45.7	19.0	---	3.2	3.3	2.3
1-8	A8	20	854	705	2.1	85.4	P: 12.5	0.6	700	33.6	47.4	18.9	---	3.5	3.7	2.4
1-9	A9	25	853	700	2.0	98.0	---	0.8	702	34.6	46.7	18.6	---	3.6	3.6	2.4
2-1	B1	25	835	705	10.2	89.8	---	2.4	682	44.4	31.7	23.9	---	3.5	4.5	2.5
2-2	B2	45	815	720	11.2	88.8	---	2.1	650	38.8	40.3	20.9	---	3.5	4.3	2.1
2-3	B3	60	985	715	10.0	90.0	---	1.8	653	39.3	39.5	21.2	---	3.6	4.4	2.5
2-4	B4	495	950	730	10.3	89.7	---	2.0	654	39.5	392	21.3	---	3.4	4.3	2.4
2-5	B5	20	1052	715	1.9	98.1	---	0.8	685	44.9	30.9	24.2	---	3.6	4.4	2.6
2-6	B6	25	720	652	51.0	27.5	α: 21.5	0.4	683	44.6	31.4	24.0	---	3.7	4.2	2.7
2-7	B7	22	835	705	8.0	92.0	---	2.1	799	7.5	1.0	91.5	---	2.5	15.0	1.2
2-8	B8	20	832	702	10.3	89.7	---	2.2	550	7.3	67.1	1.5	P: 24.1	2.5	4.5	1.0
3	C1	22	823	702	7.8	922	---	21	620	32.9	49.4	17.7	---	4.5	4.5	3.2
4	D1	20	810	700	8.2	91.8	---	2.5	615	43.4	33.2	23.4	---	42	7.3	4.2
5-1	E1	190	815	704	9.5	90.5	---	2.1	735	50.6	22.1	27.3	---	4.1	7.5	4.1
5-2	E2	165	815	702	9.6	90.4	---	2.0	635	27.7	57.4	149	---	4.0	76	4.0

(continued)

Hot pressed member No.	Blank steel sheet No.	Retention time (s)	First region						Second region							
			Heating temp. T2 (°C)	Forming start temp. (°C)	Volume fraction of RA (%)	Volume fraction of M (%)	Volume fraction of balance (%)	Dislocation density ($\times 10^{16}/m^2$)	Heating temp. T3 (°C)	Volume fraction of RA (%)	Volume fraction of α (%)	Volume fraction of M (%)	Volume fraction of balance (%)	Mean grain size of ferrite (μm)	Mean grain size of secondary phase (μm)	Mns /Mnα
5-3	E3	165	820	706	99	90.1	---	1.8	640	28.9	55.6	15.5	---	4.2	7.8	4.5
5-4	E4	195	825	705	8.4	91.6	---	2.0	638	28.4	56.3	15.3	---	4.5	7.7	4.3
6-1	F1	25	850	695	12.5	87.5	---	2.1	695	41.4	36.2	22.3	---	2.5	3.0	2.6
6-2	F2	215	855	650	13.4	86.6	---	2.1	680	37.8	41.8	20.4	---	2.5	3.2	2.6
6-3	F3	210	852	420	11.5	88.5	---	2.0	685	39.0	39.9	21.0	---	2.6	3.2	2.8
6-4	F4	220	853	350	10.6	89.4	---	1.9	683	38.6	40.7	20.8	---	22	3.3	29
7	G1	20	852	710	80	920	---	1.8	705	44.3	31.9	23.8	---	3.5	30	2.5
8	H1	25	850	712	7.2	92.8	---	1.4	712	39.9	38.6	21.5	---	3.6	3.0	2.6
9	I1	25	852	696	12.0	88.0	---	2.6	690	57.0	12.3	30.7	---	3.9	86	3.2
10	J1	20	815	704	8.0	92.0	---	0.8	610	14.0	78.5	7.5	---	3.6	2.3	1.6

In the table, RA denotes retained austenite, M denotes martensite, α denotes ferrite, and P denotes pearlite

First region				Second region			Mechanical property of first region after low temperature heat treatment					Scaling	Category
YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	ΔYS (MPa)		
1194	1845	7.5	10.5	1185	19.0	27.5	1386	1882	7.7	10.6	192	Scaling	Example
1159	1850	7.6	109.0	1182	18.5	26.7	1352	1887	7.8	110.1	193	No scaling	Example
1129	1852	7.3	10.5	1932	19.2	28.2	1294	1889	7.4	10.6	165	No scaling	Example
1098	1854	82	11.5	1910	19.7	28.9	1293	1891	8.4	11.6	195	No scaling	Example

(continued)

First region				Second region			Mechanical property of first region after low temperature heat treatment					Scaling	Category
YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	ΔYS (MPa)		
1182	1852	8.2	10.8	1182	19.7	28.6	1378	1889	8.4	10.9	196	No scaling	Example
1164	1880	4.2	6.3	1180	19.5	22.1	1303	1918	4.3	64	139	Scaling	Comparative Example
1042	1820	4.1	6.4	1185	19.6	22.2	1159	1856	4.2	6.5	117	Scaling	Comparative Example
1105	1856	4.6	6.5	1184	19.5	22.3	1220	1893	4.7	6.6	115	No scaling	Comparative Example
1065	1854	4.0	6.3	1185	19.4	22.2	1194	1891	4.1	6.4	129	Scaling	Comparative Example
1227	2013	10.1	12.5	1250	22.0	30.2	1434	2053	10.3	12.6	207	Scaling	Example
1222	2114	10.1	12.3	1238	22.0	30.5	1407	2156	10.3	12.4	185	No scaling	Example
1322	2050	10.5	12.6	1250	23.1	30.3	1525	2091	10.7	12.7	203	Scaling	Example
1253	2030	10.8	12.9	1287	23.8	30.8	1435	2070	11.0	13.0	182	No scaling	Example
1229	2015	4.5	6.3	1254	21.8	23.7	1329	2055	4.6	6.4	100	Scaling	Comparative Example
845	1320	20.5	24.7	1250	20.8	22.5	934	1346	20.9	24.9	89	Scaling	Comparative Example
1164	2015	10.2	123	1980	7.8	10.2	1352	2055	10.4	12.4	188	Scaling	Comparative Example
1121	2013	10.1	11.8	1005	13.5	15.5	1329	2053	10.3	11.9	208	Scaling	Comparative Example
1023	1820	7.2	10.2	1185	21.0	28.2	1227	1856	7.3	10.3	204	No scaling	Example
1306	2025	10.2	11.5	812	28.6	36.8	1516	2066	10.4	11.6	210	No scaling	Example
1290	2023	10.1	11.5	1082	29.4	38.3	1491	2063	10.3	11.6	201	No scaling	Example

(continued)

First region				Second region			Mechanical property of first region after low temperature heat treatment					Scaling	Category
YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	ΔYS (MPa)		
1170	2015	10.3	11.4	1095	21.0	29.9	1382	2055	10.5	11.5	212	No scaling	Example
1177	2035	10.1	11.4	1096	22.3	29.5	1357	2076	10.3	11.5	180	No scaling	Example
1311	2042	10.5	11.6	1094	21.8	30.7	1525	2083	10.7	11.7	214	Scaling	Example
1213	2035	7.7	8.7	1230	22.0	29.2	1428	2076	7.9	8.8	215	No scaling	Example
1126	2015	8.1	8.9	1229	20.5	29.4	1342	2055	8.3	9.0	216	No scaling	Example
1175	2020	7.5	8.9	1243	20.4	27.6	1368	2060	7.7	9.0	193	Scaling	Example
1185	2014	7.3	8.4	1215	20.6	27.8	1376	2054	7.4	8.5	191	Scaling	Example
1418	2412	5.2	8.5	1262	21.3	25.6	1613	2460	5.3	8.6	195	Scaling	Comparative Example
712	1256	8.5	10.9	798	29.8	32.5	894	1281	8.7	11.0	182	Scaling	Comparative Example
1467	2521	4.8	6.4	1182	21.6	24.1	1688	2571	4.9	6.5	221	Scaling	Comparative Example
759	1331	5.3	7.2	685	24.5	27.9	879	1358	5.4	7.3	120	Scaling	Comparative Example

Table 4

Steel No.	C (mass%)	Mn (mass%)	Si (mass%)	(mass%)	S (mass%)	Al (mass%)	N (mass%)	Ac1 point (°C)	Ac3 point (°C)	Others (mass%)	Category
K	0.223	4.24	0.02	0.012	0.003	0.030	0.004	628	798	Ni: 0.03	Conforming steel
L	0.220	4.25	0.02	0.012	0.004	0.032	0.003	629	799	Cu: 0.02	Conforming steel
M	0.221	4.22	0.03	0.012	0.003	0.031	0.004	633	802	Cr: 0.25	Conforming steel
N	0.220	4.24	0.03	0.012	0.004	0.032	0.004	630	799	Mo: 0.2	Conforming steel
O	0.215	6.35	0.02	0.031	0.004	0.035	0.005	570	791	Ti: 0.03	Conforming steel
P	0.210	6.30	0.03	0.035	0.003	0.030	0.003	572	793	Nb: 0.03	Conforming steel
Q	0.202	6.50	0.05	0.036	0.005	0.031	0.004	566	795	V: 0.02	Conforming steel
R	0.205	6.55	0.06	0.035	0.002	0.034	0.006	565	795	W: 0.02	Conforming steel
S	0.225	4.30	0.20	0.013	0.004	0.035	0.004	629	806	Ti: 0.02, B: 0.002	Conforming steel
T	0.235	6.65	0.25	0.015	0.003	0.036	0.003	564	796	Ti: 0.02, B: 0.002	Conforming steel
U	0.154	6.20	0.10	0.015	0.002	0.048	0.007	576	810	REM: 0.001	Conforming steel
V	0.154	6.15	0.15	0.035	0.003	0.053	0.008	578	812	B: 0.002	Conforming steel
W	0.162	6.30	0.20	0.030	0.004	0.068	0.002	574	812	Ca: 0.003	Conforming steel
X	0.148	6.25	0.15	0.030	0.003	0.070	0.008	575	814	Mg: 0.003	Conforming steel

(continued)

Steel No.	C (mass%)	Mn (mass%)	Si (mass%)	(mass%)	S (mass%)	Al (mass%)	N (mass%)	Ac1 point (°C)	Ac3 point (°C)	Others (mass%)	Category
Y	0.210	4.25	0.12	0.034	0.003	0.052	0.005	630	805	Sb: 0.009	Conforming steel

Table 5

Blank steel sheet No.	Steel No.	Heating temperature T1 (°C)	Retention time (hr)	Surface treatment of blank steel sheet	Category
K1	K	675	2	None	Example
L1	L	675	2	Al-Si	Example
M1	M	675	2	Zn-Ni	Example
N1	N	675	2	GA	Example
O1	O	632	1	Zn-Ni	Example
P1	P	630	5	GI	Example
Q1	Q	632	1	GI	Example
R1	R	630	5	Zn-Ni	Example
S1	S	675	2	Zn-Ni	Example
T1	T	625	3	None	Example
U1	U	630	5	Al-Si	Example
V1	V	625	15	Zn-Ni	Example
W1	W	620	10	GA	Example
X1	X	620	10	GA	Example
Y1	Y	670	8	Zn-Ni	Example

Table 6

Hot pressed member No.	Blank steel sheet No.	Retention time (s)	First region						Second region							
			Heating temp. T2 (°C)	Forming start temp. (°C)	Volume fraction of RA (%)	Volume fraction of M (%)	Volume fraction of balance (%)	Dislocation density ($\times 10^{16}/m^2$)	Heating temp. T3 (°C)	Volume fraction of RA (%)	Volume fraction of α (%)	Volume fraction of M (%)	Volume fraction of balance (%)	Mean grain size of ferrite (μm)	Mean grain size of secondary phase (μm)	Mns /Mnα
11	K1	25	860	700	10.5	89.5	---	2.0	700	30.3	54.8	14.9	---	3.2	3.1	2.5
12	L1	440	865	700	10.0	90.0	---	2.0	695	29.1	56.6	14.3	---	3.2	3.1	2.6
13	M1	20	860	715	10.0	90.0	---	2.1	715	33.7	49.8	16.6	---	3.1	3.0	2.6
14	N1	140	862	700	11.0	89.0	---	1.9	700	30.2	55.0	14.9	---	3.5	3.1	2.4
15	O1	30	840	705	15.0	85.0	---	2.5	675	32.5	51.5	16.0	---	3.5	4.6	3.5
16	P1	240	835	705	14.5	85.5	---	2.5	660	29.4	56.1	14.5	---	3.6	4.5	3.2
17	Q1	265	835	700	14.0	86.0	---	2.4	670	31.6	52.8	15.6	---	3.6	4.7	3.6
18	R1	35	840	700	15.0	85.0	---	2.4	665	30.9	53.9	15.2	---	3.5	4.7	3.6
19	S1	25	860	685	11.5	88.5	---	2.0	705	30.7	54.2	15.1	---	3.6	3.1	3.4
20	T1	30	862	670	15.2	84.8	---	2.3	702	37.3	44.3	18.4	---	3.5	4.8	3.2
21	U1	490	825	720	6.9	93.1	---	2.4	665	28.7	57.2	14.1	---	3.5	4.5	3.5
22	V1	15	825	715	6.5	93.5	---	2.3	683	31.4	53.1	15.5	---	3.2	4.4	3.7
23	W1	160	825	715	6.3	93.7	---	2.3	675	30.4	54.6	15.0	---	3.1	4.5	3.6
24	X1	155	830	720	7.5	92.5	---	2.2	670	29.4	56.2	14.5	---	3.5	4.5	3.5
25	Y1	30	860	705	11.2	88.8	---	2.1	710	31.7	52.6	15.6	---	3.6	3.1	2.7

In the table, RA denotes retained austenite. M denotes martensite, and α denotes ferrite.

First region				Second region			Mechanical property of first region after low temperature heat treatment					Scaling	Category
YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	ΔYS (MPa)		
1135	1900	7.7	10.8	1221	19.6	28.1	1327	1938	7.9	10.9	192	Scaling	Example

(continued)

First region				Second region			Mechanical property of first region after low temperature heat treatment					Scaling	Category
YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	ΔYS (MPa)		
1185	1919	7.8	10.8	1244	20.0	27.2	1378	1957	8.0	10.9	193	No scaling	Example
1042	1882	7.7	11.0	1232	19.0	26.0	1236	1920	7.9	11.1	194	No scaling	Example
1220	1937	7.9	10.9	1232	19.8	26.8	1415	1976	8.0	11.0	195	No scaling	Example
1338	2114	10.6	13.0	1300	22.9	31.4	1557	2156	10.8	13.1	219	No scaling	Example
1315	2053	10.3	12.9	1300	23.1	30.3	1531	2094	10.5	13.0	216	No scaling	Example
1368	2114	10.4	12.5	1313	23.3	30.3	1581	2156	10.6	12.6	213	No scaling	Example
1186	2073	10.5	12.9	1300	23.1	30.1	1398	2115	10.7	13.0	212	No scaling	Example
1049	1856	8.2	11.5	1225	20.5	27.5	1249	1893	8.4	11.6	200	No scaling	Example
1258	2230	12.5	13.5	1228	20.3	28.8	1459	2275	12.8	13.6	201	Scaling	Example
1049	1875	7.5	10.5	1232	22.1	29.3	1262	1912	7.6	10.6	213	No scaling	Example
1201	1893	7.6	10.6	1244	22.1	29.3	1404	1931	7.7	10.7	203	No scaling	Example
1073	1875	7.4	10.5	1232	21.8	29.0	1277	1912	7.6	10.6	204	No scaling	Example
1177	1893	7.5	10.5	1232	22.1	30.6	1382	1931	7.6	10.6	205	No scaling	Example

(continued)

First region				Second region			Mechanical property of first region after low temperature heat treatment					Scaling	Category
YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	YS (MPa)	TS (MPa)	Uniform elongation (%)	Total elongation (%)	ΔYS (MPa)		
1122	1911	7.6	10.6	1244	22.3	29.5	1328	1949	7.7	10.7	206	No scaling	Example

[0101] All Examples achieved a tensile strength TS of 1500 MPa or more, a uniform elongation uEl of 6.0 % or more, and ΔYS of 150 MPa or more in the first region, and a tensile strength TS of 780 MPa or more and a uniform elongation uEl of 15.0 % or more in the second region. Comparative Examples, on the other hand, failed to satisfy at least one of the properties.

INDUSTRIAL APPLICABILITY

[0102] The hot pressed member according to the present disclosure is suitable as a structural member required to have high collision energy absorbing performance, such as an impact beam, a center pillar, or a bumper of a vehicle.

Claims

1. A hot pressed member comprising:

a chemical composition containing, in mass%,
C: 0.090 % or more and less than 0.30 %,
Mn: 3.5 % or more and less than 11.0 %,
Si: 0.01 % to 2.5 %,
P: 0.05 % or less,
S: 0.05 % or less,
Al: 0.005 % to 0.1 %, and
N: 0.01 % or less,
with a balance consisting of Fe and incidental impurities;
a first region having: a microstructure including a martensite phase of 80.0 % or more in volume fraction and a retained austenite phase of 3.0 % or more and 20.0 % or less in volume fraction; a tensile property of 1500 MPa or more in tensile strength TS and 6.0 % or more in uniform elongation uEl; and a dislocation density of $1.0 \times 10^{16}/m^2$ or more; and
a second region having: a microstructure including a ferrite phase of 30.0 % or more and 60.0 % or less in volume fraction, a retained austenite phase of 10.0 % or more and 70.0 % or less in volume fraction, and a martensite phase of 30.0 % or less in volume fraction; and a tensile property of 780 MPa or more in tensile strength TS and 15.0 % or more in uniform elongation uEl.

2. The hot pressed member according to claim 1,
wherein, in the microstructure in the second region, a mean grain size of the ferrite phase is 10 μm or less, a mean grain size of a secondary phase is 10 μm or less, and Mns/Mnα is 1.5 or more, where Mns is a Mn concentration in the secondary phase and Mnα is a Mn concentration in the ferrite phase.

3. The hot pressed member according to claim 1 or 2,
wherein the chemical composition further contains, in mass%, one or more groups selected from
A group: one or more selected from Ni: 0.01 % to 5.0 %, Cu: 0.01 % to 5.0 %, Cr: 0.01 % to 5.0 %, and Mo: 0.01 % to 3.0 %,
B group: one or more selected from Ti: 0.005 % to 3.0 %, Nb: 0.005 % to 3.0 %, V: 0.005 % to 3.0 %, and W: 0.005 % to 3.0 %,
C group: one or more selected from REM: 0.0005 % to 0.01 %, Ca: 0.0005 % to 0.01 %, and Mg: 0.0005 % to 0.01 %,
D group: Sb: 0.002 % to 0.03 %, and
E group: B: 0.0005 % to 0.05 %.

4. The hot pressed member according to any one of claims 1 to 3, comprising
a coated layer on a surface thereof.

5. The hot pressed member according to claim 4,
wherein the coated layer is any of a zinc or zinc alloy coated layer and an aluminum or aluminum alloy coated layer.

6. The hot pressed member according to claim 5,
wherein the zinc or zinc alloy coated layer contains Ni: 10 mass% to 25 mass%.

7. A method of manufacturing a hot pressed member, the method comprising:

heating a steel sheet to a first temperature that is an Ac1 point or more and an Ac3 point or less, retaining the steel sheet at the first temperature for 1 hr or more and 48 hr or less, and then cooling the steel sheet to obtain a blank steel sheet, the steel sheet having a chemical composition containing, in mass%,
C: 0.090 % or more and less than 0.30 %,
Mn: 3.5 % or more and less than 11.0 %,
Si: 0.01 % to 2.5 %,
P: 0.05 % or less,
S: 0.05 % or less,
Al: 0.005 % to 0.1 %, and
N: 0.01 % or less,
with a balance consisting of Fe and incidental impurities;
performing a heating process of separately heating a first region of the blank steel sheet to a second temperature that is the Ac3 point or more and 1000 °C or less and heating a second region of the blank steel sheet to a third temperature that is the Ac1 point or more and not more than a temperature obtained by subtracting 20 °C from the Ac3 point; and
thereafter performing a hot press forming process of simultaneously press forming and quenching the blank steel sheet using a press tool for forming, to obtain a hot pressed member.

8. The method of manufacturing a hot pressed member according to claim 7,
wherein the chemical composition further contains, in mass%, one or more groups selected from
A group: one or more selected from Ni: 0.01 % to 5.0 %, Cu: 0.01 % to 5.0 %, Cr: 0.01 % to 5.0 %, and Mo: 0.01 % to 3.0 %,
B group: one or more selected from Ti: 0.005 % to 3.0 %, Nb: 0.005 % to 3.0 %, V: 0.005 % to 3.0 %, and W: 0.005 % to 3.0 %,
C group: one or more selected from REM: 0.0005 % to 0.01 %, Ca: 0.0005 % to 0.01 %, and Mg: 0.0005 % to 0.01 %,
D group: Sb: 0.002 % to 0.03 %, and
E group: B: 0.0005 % to 0.05 %.

9. The method of manufacturing a hot pressed member according to claim 7 or 8, further comprising
forming a coated layer on a surface of the blank steel sheet, before the heating process.

10. The method of manufacturing a hot pressed member according to claim 9,
wherein the coated layer is any of a zinc or zinc alloy coated layer and an aluminum or aluminum alloy coated layer.

11. The method of manufacturing a hot pressed member according to claim 10,
wherein the zinc or zinc alloy coated layer contains Ni: 10 mass% to 25 mass%.

12. The method of manufacturing a hot pressed member according to any one of claims 9 to 11,
wherein a coating weight of the coated layer is 10 g/m^2 to 90 g/m^2 per side.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/004459

A. CLASSIFICATION OF SUBJECT MATTER
C22C38/00(2006.01)i, *B21D22/02*(2006.01)i, *B21D22/20*(2006.01)i, *B21D24/00*(2006.01)i, *C21D1/18*(2006.01)i, *C21D9/00*(2006.01)i, *C21D9/46*(2006.01)i, *C22C38/60*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22C38/00-38/60

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2004-211147 A (Kobe Steel, Ltd.), 29 July 2004 (29.07.2004), (Family: none)	1-12
A	WO 2013/038637 A1 (JFE Steel Corp.), 21 March 2013 (21.03.2013), & US 2014/0230971 A1 & EP 2757169 A1 & CN 103797145 A & KR 10-2014-0060574 A & TW 201323625 A	1-12
A	WO 2013/047821 A1 (Nippon Steel & Sumitomo Metal Corp.), 04 April 2013 (04.04.2013), & US 2014/0234660 A1 & EP 2762582 A1 & CA 2850340 A1 & CN 103842541 A & KR 10-2014-0052072 A & MX 2014003718 A & RU 2014117645 A & TW 201329251 A	1-12

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

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

Date of the actual completion of the international search 01 December 2016 (01.12.16)	Date of mailing of the international search report 13 December 2016 (13.12.16)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/004459

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 2015-503023 A (Posco), 29 January 2015 (29.01.2015), & US 2014/0308156 A1 & WO 2013/069937 A1 & EP 2778247 A1 & KR 10-2013-0050138 A & CN 103917681 A	1-12
A	JP 2008-144233 A (Kobe Steel, Ltd.), 26 June 2008 (26.06.2008), (Family: none)	1-12
A	JP 62-17125 A (Nippon Steel Corp.), 26 January 1987 (26.01.1987), (Family: none)	1-12
A	WO 2013/137453 A1 (Kobe Steel, Ltd.), 19 September 2013 (19.09.2013), & US 2015/0000802 A1 & EP 2826880 A1 & CN 104204252 A & KR 10-2014-0129128 A	1-12
P,A	WO 2015/182596 A1 (Nippon Steel & Sumitomo Metal Corp.), 03 December 2015 (03.12.2015), & TW 201608039 A	1-12

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2013079441 A **[0005] [0008]**
- JP 2010065293 A **[0006] [0008]**
- JP 2013194248 A **[0007] [0008]**