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(54) **STEEL SHEET FOR HOT PRESSING USE, PRESS-MOLDED ARTICLE, AND METHOD FOR PRODUCING PRESS-MOLDED ARTICLE**

(57) A steel sheet for hot pressing use according to the present invention has a specified chemical component composition, wherein some of Ti-containing precipitates contained in the steel sheet, each of which having an equivalent circle diameter of 30 nm or less, have an average equivalent circle diameter of 3 nm or more, the precipitated Ti amount and the total Ti amount in the steel fulfill the relationship represented by formula (1) shown below, and the sum total of the fraction of bainite and the fraction of martensite in the metal microstructure is 80 area% or more.

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

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

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Description

[Technical Field]

[0001] The present invention relates to a steel sheet for hot pressing use used in manufacturing structural components of an automobile and suitable for hot press forming, a press-formed product obtained from such a steel sheet for hot pressing use, and a method for manufacturing the press-formed product, and relates more specifically to a steel sheet for hot pressing use that is useful in being applied to a hot press forming method securing a predetermined strength by being subjected to heat treatment simultaneously with impartation of the shape in forming a pre-heated steel sheet (blank) into a predetermined shape, a press-formed product, and a useful method for manufacturing such a press-formed product.

[Background Art]

[0002] As one of the fuel economy improvement measures of an automobile triggered by global environment problems, weight reduction of the vehicle body is advancing, and it is necessary to high-strengthen a steel sheet used for an automobile as much as possible. On the other hand, when a steel sheet is high-strengthened, shape accuracy in press forming comes to deteriorate.

[0003] On this account, a hot press forming method has been employed for manufacturing components in which a steel sheet is heated to a predetermined temperature (for example, a temperature at which a state of an austenitic phase is achieved), the strength is lowered, the steel sheet is thereafter formed using a tool of a temperature (room temperature for example) lower than the steel sheet, thereby impartation of a shape and rapid heat treatment (quenching) utilizing the temperature difference of the both are executed simultaneously, and the strength after forming is secured. Also, such a hot-press forming method is referred to by various names such as a hot forming method, hot stamping method, hot stamp method, die quench method, and the like in addition to the hot press method.

[0004] Fig. 1 is a schematic explanatory drawing showing a tool configuration for executing hot press forming described above, 1 in the drawing is a punch, 2 is a die, 3 is a blank holder, 4 is a steel sheet (blank), BHF is a blank holding force, r_p is punch shoulder radius, r_d is die shoulder radius, and CL is punch/die clearance respectively. Also, out of these components, in the punch 1 and the die 2, passages 1a, 2a through which a cooling medium (water for example) can pass are formed inside of each, and it is configured that these members are cooled by making the cooling medium pass through these passages.

[0005] In hot press forming (hot deep drawing for example) using such a tool, forming is started in a state the steel sheet (blank) 4 is heated to a two-phase zone temperature (between Ac_1 transformation point and Ac_3 transformation point) or a single-phase zone temperature of Ac_3 transformation point or above and is softened. That is, in a state the steel sheet 4 in a high temperature state is sandwiched between the die 2 and the blank holder 3, the steel sheet 4 is pressed in to the inside of a hole of the die 2 by the punch 1, and is formed into a shape corresponding to the shape of the outer shape of the punch 1 while reducing the outside diameter of the steel sheet 4. Also, by cooling the punch 1 and the die 2 in parallel with forming, heat removal from the steel sheet 4 to the tools (the punch 1 and the die 2) is executed, holding and cooling are further executed at a forming bottom dead point (the temporal point the tip of the punch is positioned at the deepest point: the state shown in Fig. 1), and thereby quenching of the raw material is executed. By executing such a forming method, a formed product of 1,500 MPa class with excellent dimensional accuracy can be obtained, the forming load can be reduced compared with a case a component of a same strength class is cold-formed, and therefore less capacity of the press machine is needed.

[0006] As a steel sheet for hot pressing use widely used at present, one using 22Mn-B5 steel as a raw material is known. The steel sheet has the tensile strength of approximately 1,500 MPa and the elongation of approximately 6-8%, and is applied to a shock resistant member (a member not causing deformation as much as possible and not causing breakage in collision). However, application to a component requiring deformation such as an energy absorption member is difficult because elongation (ductility) is low.

[0007] As a steel sheet for hot pressing use exerting excellent elongation, technologies such as the patent literatures 1-4 for example have also been proposed. According to these technologies, the basic strength class of each steel sheet is adjusted by setting the carbon content in the steel sheet to various ranges, and elongation is improved by introducing ferrite with high deformability and reducing the average grain size of ferrite and martensite. Although these technologies are effective in improving elongation, they are still insufficient from the viewpoint of improving elongation matching the strength of the steel sheet. For example, those having 1,470 MPa or more of the tensile strength TS have the elongation EL of approximately 10.2% at the maximum, and further improvement is required.

[0008] On the other hand, even the formed product having a lower strength class compared to the hot stamp formed product, 980 MPa class or 1,180 MPa class of the tensile strength TS for example, having been studied until now has a problem in forming accuracy of cold press forming, and there are needs for low-strength hot press forming as an

improvement measure therefor. At that time, it is necessary to largely improve energy absorption properties in the formed product.

[0009] Particularly, in recent years, development of the technology for differentiating the strength within a single component is proceeding. As such a technology, a technology has been proposed in which the portion that must be prevented from deforming has high strength (high strength side: shock resistant portion side), and the portion that needs energy absorption has low strength and high ductility (low strength side: energy absorption portion side). For example, in a passenger car of the middle class or above, there is a case that portions having both functions of shock resistant property and energy absorption property are provided within a component of a B-pillar and rear side member considering compatibility in a side collision and a rear collision (a function for protecting the counterpart side also when a small-sized car collides with). For the purpose of manufacturing such members, (a) a method of joining a steel sheet becoming of low strength even in being heated to a same temperature and tool-quenched to a normal steel sheet for hot pressing use (tailored weld blank: TWB), (b) a method for differentiating the strength for each region of a steel sheet by differentiating the cooling rate in the tool, (c) a method for differentiating the strength by differentiating the heating temperature for each region of a steel sheet, and the like have been proposed.

[0010] Although the tensile strength: 1,500 MPa class is achieved on the high strength side (shock resistant portion side) according to these technologies, the maximum tensile strength is 700 MPa and the elongation EL is approximately 17% on the low strength side (energy absorption portion side), and achievement of higher strength and higher ductility are required in order to further improve the energy absorption properties.

[Citation List]

[Patent Literature]

[0011]

[Patent Literature 1] JP-A 2010-065292

[Patent Literature 2] JP-A 2010-065293

[Patent Literature 3] JP-A 2010-065294

[Patent Literature 4] JP-A 2010-065295

[Summary of Invention]

[Technical Problems]

[0012] The present invention has been developed in view of such circumstances as described above, and its object is to provide a steel sheet for hot pressing use capable of obtaining a hot press-formed product that can achieve the balance of high strength and elongation with a high level when uniform property is required within a formed product and is useful in obtaining a press-formed product that can achieve the balance of high strength and elongation with a high level according to each region when regions corresponding to a shock resistant portion and an energy absorption portion are required within a single formed product, a press-formed product exerting the properties described above, and a useful method for manufacturing such a hot press-formed product.

[Solution to Problems]

[0013] The steel sheet for hot pressing use of the present invention which could achieve the object described above contains:

C: 0.15-0.5% (means mass%, hereinafter the same with respect to the chemical component composition);

Si: 0.2-3%;

Mn: 0.5-3%;

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

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

Al: 0.01-1%;

B: 0.0002-0.01%;

Ti: $3.4[N] + 0.002\%$ or more and $3.4[N] + 0.1\%$ or less ([N] expresses N content (mass%)), and

N: 0.001-0.01% respectively, with the remainder consisting of iron and inevitable impurities, in which

some of Ti-containing precipitates contained in the steel sheet, each of which having an equivalent circle diameter of

30 nm or less, have an average equivalent circle diameter of 3 nm or less, the precipitated Ti amount and the total Ti amount in the steel fulfill the relationship represented by formula (1) shown below, and the sum total of the fraction of bainite and the fraction of martensite in the metal microstructure is 80 area% or more. Also, "equivalent circle diameter" is the diameter of an imaginary circle having an area same to the size (area) of Ti containing precipitates (TiC for example) ("the average equivalent circle diameter" is the average value thereof).

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

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

[0014] In the steel sheet for hot pressing use of the present invention, according to the necessity, it is also useful to contain, as other elements, (a) at least one element selected from the group consisting of V, Nb and Zr by 0.1% or less (exclusive of 0%) in total, (b) at least one element selected from the group consisting of Cu, Ni, Cr and Mo by 1% or less (exclusive of 0%) in total, (c) at least one element selected from the group consisting of Mg, Ca and REM by 0.01% or less (exclusive of 0%) in total, and the like, and the properties of the press-formed product is improved further according to the kind of the elements contained.

[0015] The method for manufacturing a press-formed product of the present invention which could achieve the object described above includes the steps of using such a steel sheet for hot pressing use of the present invention as described above, heating the steel sheet to a temperature of Ac_1 transformation point + 20°C or above and Ac_3 transformation point - 20°C or below, thereafter starting press forming, and executing cooling to a temperature or below, the temperature being lower than the bainite transformation starting temperature B_s by 100°C, while securing the average cooling rate of 20°C/s or more within a tool during forming and after completion of forming.

[0016] In the press-formed product obtained by the method for manufacturing, the metal microstructure includes retained austenite: 3-20 area%, annealed martensite and/or annealed bainite: 30-87 area%, and martensite as quenched: 10-67 area%, the amount of carbon in the retained austenite is 0.60% or more, and the balance of high strength and elongation can be achieved with a high level and as a uniform property within the formed product. Also, the area ratio of annealed martensite and/or annealed bainite means the total area ratio of both microstructures when both microstructures are included, and means, when either one microstructure is included, the area ratio of the microstructure.

[0017] Also, another method for manufacturing a press-formed product of the present invention which could achieve the object described above includes the steps of using such a steel sheet for hot pressing use of the present invention as described above, dividing a heating region of the steel sheet into two regions, heating one region thereof to a temperature of Ac_3 transformation point or above and 950°C or below, heating the other region to a temperature of Ac_1 transformation point + 20°C or above and Ac_3 transformation point - 20°C or below, thereafter starting press forming, and executing cooling to a temperature of martensite transformation starting temperature M_s or below while securing the average cooling rate of 20°C/s or more within a tool during forming and after completion of forming.

[0018] In the press-formed product obtained by the method for manufacturing, a first region whose metal microstructure includes retained austenite: 3-20 area% and martensite: 80 area% or more and a second region whose metal microstructure includes retained austenite: 3-20 area%, annealed martensite and/or annealed bainite: 30-87 area%, and martensite as quenched: 10-67 area% with the amount of carbon in the retained austenite being 0.60% or more are included, the balance of high strength and elongation can be achieved with a high level according to each region, and regions corresponding to a shock resistant portion and an energy absorption portion are present within a single formed product.

[Advantageous Effects of Invention]

[0019] According to the present invention, because a steel sheet is used in which the chemical component composition is strictly stipulated, the size of Ti-containing precipitates is controlled, the precipitation rate is controlled for Ti that does not form TiN, and the ratio of tempered hard phase (martensitic phase, bainitic phase and the like), hard phase (as-quenched martensite phase) and retained austenite phase is adjusted with respect to the metal microstructure, by hot-pressing the steel sheet under a predetermined condition, high strength-elongation balance of the press-formed product can be made a high level. Also, when hot-pressing is executed under different conditions in plural regions, the shock resistant portion and the energy absorption portion can be formed within a single formed product, the balance of high strength and elongation can be achieved with a high level for each portion.

[Brief Description of Drawings]

[0020] [Fig. 1] Fig. 1 is a schematic explanatory drawing showing a tool configuration for executing hot press forming.

[Description of Embodiments]

[0021] The present inventors carried out studies from various aspects in order to achieve such a steel sheet for hot pressing use that can obtain a press-formed product exhibiting excellent ductility (elongation) also while securing high strength after press-forming in manufacturing the press-formed product by heating a steel sheet to a predetermined temperature and thereafter executing hot press forming.

[0022] As a result of the studies, it was found out that, when the chemical component composition of the steel sheet for hot pressing use was strictly stipulated, the size of Ti-containing precipitates and precipitated Ti amount were controlled and the metal microstructure was made an appropriate one, by hot press forming of the steel sheet under a predetermined condition, a press-formed product in which retained austenite of a predetermined amount was secured after press forming and intrinsic ductility (residual ductility) was enhanced could be obtained, and the present invention was completed.

[0023] In the steel sheet for hot pressing use of the present invention, it is necessary to strictly stipulate the chemical component composition, and the reasons for limiting the range of each chemical component are as follows.

[C: 0.15-0.5%]

[0024] C is an important element in achieving the balance of high strength and elongation of a case uniform properties are required within a formed product with a high level or in securing retained austenite particularly in the low strength/high ductility portion of a case the regions corresponding to a shock resistant portion and an energy absorption portion are required within a single formed product. Also, by concentration of C to austenite in heating of hot press forming, retained austenite can be formed after quenching. Also, C contributes to increase of the amount of martensite, and increases the strength. In order to exert such effects, C content should be 0.15% or more.

[0025] However, when C content becomes excessive and exceeds 0.5%, two phase zone heating range becomes narrow, and the balance of high strength and elongation of a case uniform properties are required within a formed product is not achieved with a high level, or it becomes hard to adjust the metal microstructure to that targeted particularly in the low strength/high ductility portion (a microstructure in which a predetermined amount of annealed martensite and/or annealed bainite is secured) of a case the regions corresponding to a shock resistant portion and an energy absorption portion are required within a single formed product. Preferable lower limit of C content is 0.17% or more (more preferably 0.20% or more), and more preferable upper limit is 0.45% or less (further more preferably 0.40% or less).

[Si: 0.2-3%]

[0026] Si exerts an effect of forming retained austenite by suppressing that martensite is tempered during cooling of tool-quenching and cementite is formed, or that untransformed austenite is disintegrated. In order to exert such an effect, Si content should be 0.2% or more. Also, when Si content becomes excessive and exceeds 3%, ferrite is liable to be formed, formation of single-phase microstructure becomes hard in heating, and required fractions of bainite and martensite cannot be secured in a steel sheet for hot pressing use. Preferable lower limit of Si content is 0.5% or more (more preferably 1.0% or more), and preferable upper limit is 2.5% or less (more preferably 2.0% or less).

[Mn: 0.5-3%]

[0027] Mn is an element effective in enhancing quenchability and suppressing formation of a microstructure (ferrite, pearlite, bainite and the like) other than martensite and retained austenite during cooling of tool-quenching. Also, Mn is an element stabilizing austenite, and is an element contributing to increase of retained austenite amount. In order to exert such effects, Mn should be contained by 0.5% or more. Although Mn content is preferable to be as much as possible when only properties are considered, because the cost of adding alloy increases, Mn content is made 3% or less. Preferable lower limit of Mn content is 0.7% or more (more preferably 1.0% or more), and preferable upper limit is 2.5% or less (more preferably 2.0% or less).

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

[0028] Although P is an element inevitably included in steel, because P deteriorates ductility, P is preferable to be reduced as much as possible. However, because extreme reduction causes increase of the steel making cost and to make it 0% is difficult in manufacturing, P content is made 0.05% or less (exclusive of 0%). Preferable upper limit of P

content is 0.045% or less (more preferably 0.040% or less).

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

5 **[0029]** Similar to P, S is also an element inevitably included in steel, S deteriorates ductility, and therefore S is preferable to be reduced as much as possible. However, because extreme reduction causes increase of the steel making cost and to make it 0% is difficult in manufacturing, S content is made 0.05% or less (exclusive of 0%). Preferable upper limit of S content is 0.045% or less (more preferably 0.040% or less).

10 [Al: 0.01-1%]

[0030] Al is useful as a deoxidizing element, fixes solid-solution N present in steel as AlN, and is useful in improving ductility. In order to effectively exert such an effect, Al content should be 0.01% or more. However, when Al content becomes excessive and exceeds 1%, Al_2O_3 is formed excessively, and ductility is deteriorated. Also, preferable lower limit of Al content is 0.02% or more (more preferably 0.03% or more), and preferable upper limit is 0.8% or less (more preferably 0.6% or less).

[B: 0.0002-0.01%]

20 **[0031]** B is an element contributing to prevention of formation of ferrite, pearlite and bainite during cooling after heating to a two-phase zone temperature of (Ac_1 transformation point - Ac_3 transformation point) because B has an action of suppressing ferrite transformation, pearlite transformation and bainite transformation on the high strength portion side, and to secure retained austenite. In order to exert such effects, B should be contained by 0.0002% or more, however, even when B is contained excessively exceeding 0.01%, the effects saturate. Preferable lower limit of B content is 0.0003% or more (more preferably 0.0005% or more), and preferable upper limit is 0.008% or less (more preferably 0.005% or less).

[Ti: $3.4[N]+0.01\%$ or more and $3.4[N]+0.1\%$ or less: [N] expresses N content (mass%)]

30 **[0032]** Ti develops improvement effect of quenchability by fixing N and holding B in a solid solution state. In order to exert such an effect, it is important to contain Ti more than the stoichiometric ratio of Ti and N (3.4 times of N content) by 0.01% or more. However, when Ti content becomes excessive to be more than $3.4[N]+0.1\%$, Ti-containing precipitates formed are finely dispersed and impede the growth of martensite during cooling after heating to the two phase zone temperature, a lath (lath-like martensite) with a small aspect ratio is formed, discharging of carbon (C) to retained austenite between the laths becomes slow, and the carbon amount in the retained austenite reduces. Preferable lower limit of Ti content is $3.4[N]+0.02\%$ or more (more preferably $3.4[N]+0.05\%$ or more), and preferable upper limit is $3.4[N]+0.09\%$ or less (more preferably $3.4[N]+0.08\%$ or less).

[N: 0.001-0.01%]

40 **[0033]** N is an element inevitably mixed in and is preferable to be reduced, however, because there is a limit in reducing N in an actual process, 0.001% is made the lower limit. Also, when N content becomes excessive, the ductility deteriorates because of time aging, N precipitates as BN, the quenchability improvement effect by solid-dissolved B is deteriorated, and therefore the upper limit is made 0.01%. Preferable upper limit of N content is 0.008% or less (more preferably 0.006% or less).

[0034] The basic chemical composition in the steel sheet for hot pressing use of the present invention is as described above, and the remainder is iron and inevitable impurities other than P, S (O, H and the like for example). Further, in the steel sheet for hot pressing use of the present invention, according to the necessity, it is also useful to further contain (a) at least one element selected from the group consisting of V, Nb and Zr by 0.1% or less (exclusive of 0%) in total, (b) at least one element selected from the group consisting of Cu, Ni, Cr and Mo by 1% or less (exclusive of 0%) in total, (c) at least one element selected from the group consisting of Mg, Ca and REM (rare earth elements) by 0.01% or less (exclusive of 0%) in total, and the like, and the properties of the steel sheet for hot pressing use are improved further according to the kind of the element contained. Preferable range when these elements are contained and reasons for limiting the range are as follows.

[At least one element selected from the group consisting of V, Nb and Zr by 0.1% or less (exclusive of 0%) in total]

[0035] V, Nb and Zr have effects of forming fine carbide and miniaturizing the microstructure by a pinning effect. In

order to exert such effects, it is preferable to contain them by 0.001% or more in total. However, when the content of these elements becomes excessive, coarse carbide is formed and becomes a start point of breakage, and ductility is deteriorated adversely. Therefore, it is preferable to contain these elements by 0.1% or less in total. More preferable lower limit of the content of these elements in total is 0.005% or more (further more preferably 0.008% or more), and more preferable upper limit in total is 0.08% or less (further more preferably 0.06% or less).

[At least one element selected from the group consisting of Cu, Ni, Cr and Mo: 1% or less (exclusive of 0%) in total]

[0036] Cu, Ni, Cr and Mo suppress ferrite transformation, pearlite transformation and bainite transformation, therefore prevent formation of ferrite, pearlite and bainite during cooling after heating, and act effectively in securing retained austenite. In order to exert such effects, it is preferable to contain them by 0.01% or more in total. Although the content is preferable to be as much as possible when only the properties are considered, because the cost for adding alloys increases, 1% or less in total is preferable. Also, because there is an action of largely increasing the strength of austenite, the load of hot rolling increases, manufacturing of the steel sheet becomes difficult, and therefore 1% or less is also preferable from the viewpoint of manufacturability. More preferable lower limit of these elements in total is 0.05% or more (further more preferably 0.06% or more), and more preferable upper limit in total is 0.5% or less (further more preferably 0.3% or less).

[At least one element selected from the group consisting of Mg, Ca and REM by 0.01% or less (exclusive of 0%) in total]

[0037] Because these elements miniaturize inclusions, they act effectively in improving ductility. In order to exert such effects, it is preferable to contain them by 0.0001% or more in total. Although the content is preferable to be as much as possible when only the properties are considered, because the effects saturate, 0.01% or less in total is preferable. More preferable lower limit of these elements in total is 0.0002% or more (further more preferably 0.0005% or more), and more preferable upper limit in total is 0.005% or less (further more preferably 0.003% or less).

[0038] In the steel sheet for hot pressing use of the present invention, (A) some of Ti-containing precipitates contained in the steel sheet, each of which having an equivalent circle diameter of 30 nm or less, have an average equivalent circle diameter of 3 nm or less, (B) relationship of precipitated Ti amount (mass%)- $3.4[N] > 0.5 \times [(total\ Ti\ amount\ (mass\ \%)) - 3.4[N]]$ (the relationship of the formula (1) described above) is fulfilled, and (C) the metal microstructure contains at least either one of bainite and martensite, and the sum total of the fraction of bainite and the fraction of martensite is 80 area% or more, are also important requirements.

[0039] When Ti that is excessive with respect to N is dispersed finely or majority thereof is present in a solid solution state in the steel sheet before hot press forming, much amount of Ti comes to be present while it is fine in heating of hot press forming. Thus, in martensite transformation that occurs during rapid cooling within the tool after heating, the growth of martensite lath in the longitudinal direction is impeded, the growth in the width direction is promoted, and the aspect ratio reduces. As a result, discharge of carbon from the martensite lath to surrounding retained austenite delays, the carbon amount in retained austenite reduces, the stability of retained austenite deteriorates, and therefore the improvement effect of the elongation cannot be obtained sufficiently.

[0040] From such a viewpoint, Ti-containing precipitates should be dispersed coarsely, and, for that purpose, it is necessary that some of Ti-containing precipitates contained in the steel sheet, each of which having an equivalent circle diameter of 30 nm or less, have an average equivalent circle diameter of 3 nm or more (the requirement of (A) described above). Also, the reason the equivalent circle diameter of the Ti-containing precipitates of the object is stipulated to be 30 nm or less is that it is necessary to control the Ti-containing precipitates and excluding TiN formed coarsely in the melting stage that does not affect microstructure change and properties thereafter. The size of the Ti-containing precipitates (the average equivalent circle diameter of the Ti-containing precipitates whose equivalent circle diameter is 30 nm or less) is preferably 5 nm or more, more preferably 10 nm or more. Further, the Ti-containing precipitates of the object of the present invention also include precipitates containing Ti such as TiVC, TiNbC, TiVCN, TiNbCN and the like in addition to TiC and TiN.

[0041] Also, in the steel sheet for hot pressing use, it is necessary that, out of Ti, majority of Ti other than that used for precipitating and fixing N is present in the precipitated state. For that purpose, it is necessary that the Ti amount present as the precipitates other than TiN (that is, precipitated Ti amount (mass%)- $3.4[N]$) is more than 0.5 times of the balance obtained by deducting Ti that forms TiN from total Ti (that is, more than $0.5 \times [(total\ Ti\ amount\ (mass\ \%)) - 3.4[N]]$) (the requirement of (B) described above). Precipitated Ti amount (mass%)- $3.4[N]$ is preferably $0.6 \times [(total\ Ti\ amount\ (mass\ \%)) - 3.4[N]]$ or more, more preferably $0.7 \times [(total\ Ti\ amount\ (mass\ \%)) - 3.4[N]]$ or more.

[0042] Although control of the metal microstructure is intrinsically necessary for achieving desired strength-elongation balance in the formed product, the metal microstructure cannot be controlled only by the hot pressing condition, and it is necessary to control the microstructure of the raw material steel thereof (the steel sheet for hot pressing use) beforehand. In order to secure the proper amount of annealed martensite and annealed bainite which are fine and largely contributing

to ductility in the press forming steel sheet, it is necessary to make the sum total of the fraction of bainite and the fraction of martensite in the steel sheet 80 area% or more. When the sum total of the fraction of bainite and the fraction of martensite is less than 80 area%, the fraction of annealed martensite and/or annealed bainite targeted is hardly secured, and the amount of other microstructure (ferrite for example) increases to deteriorate the strength-elongation balance.

The sum total of the fraction of bainite and the fraction of martensite is preferably 90 area% or more, more preferably 95 area% or more.

[0043] Further, in the steel sheet for hot pressing use of the present invention, although the remainder of the metal microstructure is not particularly limited, at least any of ferrite, pearlite or retained austenite can be cited for example.

[0044] The steel sheet (the steel sheet for hot pressing use) of the present invention as described above can be manufactured by that a billet obtained by melting steel having the chemical component composition as described above is subjected to hot rolling with the heating temperature: 1,100°C or above (preferably 1,150°C or above) and 1,300°C or below (preferably 1,250°C or below) and the finish rolling temperature of 750°C or above (preferably 780°C or above) and 850°C or below (preferably 830°C or below), cooling thereafter (slow cooling: intermediate cooling) so as to stay for 10 s or more (preferably 50 s or more) between 700-750°C (preferably 720-740°C), cooling (rapid cooling) thereafter to 450°C or below (preferably 350°C or below) at 20°C/s or more (preferably 30°C/s or more), and winding at 100°C or above (preferably 150°C or above) and 450°C or below (preferably 400°C or below).

[0045] The method described above is for executing control so that (1) rolling is finished at a temperature range where dislocation introduced by hot rolling remains within austenite, (2) Ti-containing precipitates such as TiC and the like are formed finely on the dislocation by rapid cooling immediately thereafter, and (3) bainite transformation or martensite transformation is caused by rapid cooling and winding thereafter.

[0046] The steel sheet for hot pressing use having the chemical component composition, metal microstructure and Ti-precipitation state as described above may be used as it is for manufacturing by hot press forming, and may be subjected to cold rolling with the draft: 10-80% (preferably 20-70%) after pickling. Further, the steel sheet for hot pressing use or the material obtained by cold rolling thereof may be subjected to such heat treatment of heating to such a temperature range where TiC is not dissolved by 100% (1,000°C or below: for example 870-900°C), rapidly cooling thereafter to 450°C or below (preferably 400°C or below) at a cooling rate of 20°C/s or more (preferably 30°C/s or more), and holding thereafter at 450°C or below for 10 s or more and 1,000 s or less or tempering at a temperature of 450°C or below. Also, the steel sheet for hot pressing use of the present invention may be subjected to plating containing at least one element out of Al, Zn, Mg and Si on the surface thereof (the surface of the base steel sheet).

[0047] By using the steel sheet for hot pressing use as described above, executing heating to a temperature of A_{c1} transformation point+20°C or above and A_{c3} transformation point-20°C or below, thereafter starting press-forming, and executing cooling to a temperature or below, the temperature being lower than the bainite transformation starting temperature B_s by 100°C, while securing the average cooling rate of 20°C/s or more within the tool during forming and after completion of forming, the press formed product having a single property (may be hereinafter referred to as "single region formed product") can have an optimum microstructure of low strength and high ductility. The reasons for stipulating each requirement in this forming method are as described below.

[0048] In order to form austenite between laths of martensite and bainite within the steel sheet and to form annealed martensite and annealed bainite excellent in ductility by annealing martensite and bainite, the heating temperature should be controlled to a predetermined range. When the heating temperature of the steel sheet is below A_{c1} transformation point+20°C, sufficient amount of austenite cannot be secured in heating, and a predetermined amount of retained austenite cannot be secured in the final microstructure (the microstructure of the formed product). Also, when the heating temperature of the steel sheet exceeds A_{c3} transformation point-20°C, the transformation amount to austenite increases excessively in heating, and a predetermined amount of annealed martensite and annealed bainite cannot be secured in the final microstructure (the microstructure of the formed product).

[0049] In order to make austenite formed in the heating step described above a desired microstructure while preventing formation of the microstructure such as ferrite or pearlite, it is necessary to properly control the average cooling rate and the cooling finishing temperature during forming and after forming. From such a viewpoint, it is necessary to make the average cooling rate during forming 20°C/s or more and to make the cooling finishing temperature a temperature or below, the temperature being lower than the bainite transformation starting temperature B_s by 100°C. The average cooling rate during forming is preferably 30°C/s or more (more preferably 40°C/s or more). By transforming austenite having been present in heating to bainite and martensite while preventing formation of the microstructure such as ferrite or martensite by making the cooling finishing temperature a temperature equal to or below the bainite transformation starting temperature B_s , fine austenite is made remain between the laths of bainite and martensite, and a predetermined amount of retained austenite is secured while securing bainite and martensite.

[0050] When the cooling finishing temperature becomes higher than the temperature that is lower than the bainite transformation starting temperature B_s by 100°C and the average cooling rate is less than 20°C/s, the microstructure such as ferrite, pearlite and the like is formed, a predetermined amount of retained austenite cannot be secured, and elongation (ductility) in the formed product deteriorates.

[0051] Although control of the average cooling rate basically becomes unnecessary at the stage the temperature becomes equal to or below the temperature lower than the bainite transformation starting temperature B_s by 100°C, cooling may be executed to the room temperature with the average cooling rate of 1°C/s or more and 100°C/s or less for example. Also, control of the average cooling rate during forming and after completion of forming can be achieved by means such as (a) to control the temperature of the forming tool (the cooling medium shown in Fig. 1 above), and (b) to control the thermal conductivity of the tool.

[0052] In the press-formed product manufactured by hot press forming as described above, the metal microstructure is formed of retained austenite: 3-20 area%, annealed martensite and/or annealed bainite: 30-87 area%, and martensite as quenched: 10-67 area%, the carbon amount in the retained austenite is 0.60% or more, and the balance of high strength and elongation can be achieved with a high level and as a uniform property within the formed product. The reasons for setting the range of each requirement (the basic microstructure and the carbon amount in the retained austenite) in such a hot press-formed product are as described below.

[0053] Retained austenite has an effect of increasing the work hardening ratio (transformation induced plasticity) and improving ductility of the press-formed product by being transformed to martensite during plastic deformation. In order to exert such an effect, the fraction of retained austenite should be made 3 area% or more. Ductility becomes more excellent as the fraction of retained austenite is higher. In the composition used for a steel sheet for an automobile, retained austenite that can be secured is limited, and approximately 20 area% becomes the upper limit. Preferable lower limit of retained austenite is 5 area% or more (more preferably 7 area% or more).

[0054] By making the main microstructure annealed martensite and/or annealed bainite which is fine and has low dislocation density, ductility (elongation) of the press-formed product can be enhanced while securing a predetermined strength. From such a viewpoint, the fraction of annealed martensite and/or annealed bainite is made 30 area% or more. However, when this fraction exceeds 87 area%, the fraction of retained austenite becomes insufficient, and ductility (residual ductility) deteriorates. Preferable lower limit of annealed martensite and/or annealed bainite is 40 area% or more (more preferably 50 area% or more), and preferable upper limit is less than 80 area% (more preferably less than 70 area%).

[0055] Because martensite as quenched is a microstructure inferior in ductility, when much amount thereof is present, elongation is deteriorated, however, in order to achieve high strength of over 100 kg/mm² class in a microstructure with low matrix strength such as annealed martensite, it is necessary to secure a predetermined amount of martensite as quenched. From such a viewpoint, the fraction of martensite as quenched is made 10 area% or more. However, when the fraction of martensite as quenched increases excessively, strength increases excessively and elongation becomes insufficient, and therefore the fraction thereof should be 67 area% or less. Preferable lower limit of the fraction of martensite as quenched is 20 area% or more (more preferably 30 area% or more), and preferable upper limit is 60 area% or less (more preferably 50 area% or less).

[0056] With respect to the microstructure other the above, ferrite, pearlite, bainite and the like may be included as the remainder microstructure, however, these microstructures are inferior in contribution to strength and contribution to ductility compared to other microstructures, and it is basically preferable not to be contained (it may also be 0 area%). However, up to 20 area% is allowable. The remainder microstructure is preferably 10 area% or less, more preferably 5 area% or less.

[0057] The carbon amount in retained austenite affects the timing of work induced transformation of retained austenite to martensite at the time of deformation such as the tensile test and the like, and enhances the transformation induced plasticity (TRIP) effect by causing the work induced transformation at a higher strain zone as the carbon amount is higher. In the case of the process of the present invention, carbon is discharged during cooling from the martensite lath formed to surrounding austenite. At that time, if Ti-carbide or carbonitride dispersed in steel is dispersed coarsely, growth of the martensite lath in the longitudinal direction proceeds without being impeded, and therefore the martensite lath narrow in the width, long, and having a large aspect ratio is obtained. As a result, carbon is easily discharged from the martensite lath to the width direction, the carbon amount in retained austenite increases, and the ductility improves. From such a viewpoint, in the press-formed product of the present invention, the carbon amount in retained austenite in steel was stipulated to be 0.60% or more. Further, although the carbon amount in retained austenite can be concentrated to approximately 0.70%, approximately 1.0% is the limit.

[0058] When the steel sheet for hot pressing use of the present invention is used, by properly adjusting the press forming condition (heating temperature and cooling rate), the properties such as strength, elongation and the like of the press-formed product can be controlled, the press-formed product with high ductility (residual ductility) is obtained, and therefore application to a portion (energy absorption member for example) to which it has been difficult to apply conventional press-formed products becomes also possible which is very useful in expanding the application range of the press-formed product. Also, not only the single region formed product described above, a press-formed product exerting strength-ductility balance according to each region (may be hereinafter referred to as "plural region formed product") is obtained when the heating temperature and the condition of each region in forming are properly controlled and the microstructure of each region is adjusted in manufacturing the press-formed product by press forming of a steel sheet

using a press-forming tool.

[0059] The plural region formed product can be manufactured as described above using the steel sheet for hot pressing use of the present invention by dividing a heating region of the steel sheet into at least two regions, heating one region thereof (hereinafter referred to as the first region) to a temperature of Ac_3 transformation point or above and $950^{\circ}C$ or below, heating another region (hereinafter referred to as the second region) to a temperature of Ac_1 transformation point+ $20^{\circ}C$ or above and Ac_3 transformation point- $20^{\circ}C$ or below, thereafter starting press forming of both of the first and second regions, and executing cooling to a temperature of martensite transformation starting temperature M_s or below while securing the average cooling rate of $20^{\circ}C/s$ or more within a tool in both of the first and second regions during forming and after forming.

[0060] According to the method described above, by dividing the heating region of the steel sheet into at least two regions (high strength side region and low strength side region) and controlling the manufacturing condition according to each region, such a press-formed product that strength-ductility balance according to each region is exerted is obtained. The second region out of two regions corresponds to the low strength side region, and the manufacturing condition, microstructure and properties in this region is basically same to those of the single region formed product described above. Below, the manufacturing condition for forming the other first region (corresponding to the high strength side region) will be described. Also, in executing this manufacturing method, it is required to form regions with different heating temperature by a single steel sheet, however, by using an existing heating furnace (for example, far infrared furnace, electric furnace+shield), controlling while making the boundary section of the temperature 50 mm or less is possible.

(Manufacturing condition of the first region/high strength side region)

[0061] In order to properly adjust the microstructure of the press-formed product, it is necessary to control the heating temperature to a predetermined range. By properly controlling this heating temperature, transformation to a microstructure mainly of martensite is caused while securing a predetermined amount of retained austenite in the cooling step after heating, and a desired microstructure can be achieved within the range of the final hot press-formed product. When the steel sheet heating temperature in this region is below Ac_3 transformation point, a sufficient amount of austenite cannot be obtained in heating, and a predetermined amount of retained austenite cannot be secured in the final microstructure (the microstructure of the formed product). Also, when the heating temperature of the steel sheet exceeds $950^{\circ}C$, the grain size of austenite becomes large in heating, martensite transformation starting temperature (M_s point) and martensite transformation finishing temperature (M_f point) rise, retained austenite cannot be secured in quenching, and excellent formability is not achieved. The heating temperature of the steel sheet is preferably Ac_3 transformation point+ $50^{\circ}C$ or above and $900^{\circ}C$ or below.

[0062] In order to make austenite formed in the heating step described above a desired microstructure while preventing formation of the microstructure such as ferrite or pearlite, it is necessary to properly control the average cooling rate and the cooling finishing temperature during forming and after forming. From such a viewpoint, the average cooling rate during forming should be $20^{\circ}C/s$ or more and the cooling finishing temperature should be martensite transformation starting temperature (M_s point) or below. The average cooling rate during forming is preferably $30^{\circ}C/s$ or more (more preferably $40^{\circ}C/s$ or more). By transforming austenite having been present in heating to martensite while preventing formation of the microstructure such as ferrite or pearlite by making the cooling finishing temperature the martensite transformation starting temperature (M_s point) or below, martensite is secured. Specifically, the cooling finishing temperature is $400^{\circ}C$ or below, preferably $300^{\circ}C$ or below.

[0063] In the press-formed product obtained by such a method, the metal microstructure, precipitates and the like are different between the first region and the second region. In the first region, the metal microstructure is of retained austenite: 3-20 area% (the action and effect of retained austenite are same to the above), and martensite: 80 area% or more. In the second region, the metal microstructure same to that of the single region formed product described above and 0.60% or more of the carbon amount in retained austenite are fulfilled.

[0064] By making the main microstructure of the first region martensite with high strength containing a predetermined amount of retained austenite, ductility and high strength in a specific region in the hot press-formed product can be secured. From such a viewpoint, the area fraction of martensite should be 80 area% or more. The fraction of martensite is preferably 85 area% or more (more preferably 90 area% or more). Also, as the microstructure in the first region, ferrite, pearlite, bainite and the like may be included in a part thereof.

[0065] Although the effect of the present invention will be shown below more specifically by examples, the examples described below do not limit the present invention, and any of the design alterations judging from the purposes described above and below is to be included in the technical range of the present invention.

[Examples]

[Example 1]

[0066] Steel (steel Nos. 1-32) having the chemical component composition shown in Table 1 below was molten in vacuum, was made a slab for experiment, was thereafter made a steel sheet by hot rolling, was thereafter cooled, and was subjected to a treatment that simulates winding (sheet thickness: 3.0 mm). The winding simulated treatment method included cooling to the winding temperature, putting the sample thereafter into a furnace heated to the winding temperature, holding for 30 min, and cooling in the furnace. The manufacturing condition for the steel sheet at that time is shown in Table 2 below. Also, Ac_1 transformation point, Ac_3 transformation point, Ms point, and Bs point in Table 1 were obtained using the formula (2)-formula (5) below (refer to "The physical Metallurgy of Steels", Leslie, Maruzen Company, Limited (1985) for example). Also, the treatments (1)-(3) shown in the remarks column in Table 2 express that each treatment (rolling, cooling, alloying) shown below was executed.

$$Ac_1 \text{ transformation point } (^{\circ}C)$$

$$=723+29.1 \times [Si]-10.7 \times [Mn]+16.9 \times [Cr]-16.9 \times [Ni] \quad \cdots (2)$$

$$Ac_3 \text{ transformation point } (^{\circ}C)$$

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

$$Ms \text{ point } (^{\circ}C)$$

$$=550-361 \times [C]-39 \times [Mn]-10 \times [Cu]-17 \times [Ni]-20 \times [Cr]-5 \times [Mo]+30 \times [Al] \quad \cdots (4)$$

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

wherein $[C]$, $[Si]$, $[Mn]$, $[P]$, $[Al]$, $[Ti]$, $[V]$, $[Cr]$, $[Mo]$, $[Cu]$ and $[Ni]$ represent the content (mass%) of C, Si, Mn, P, Al, Ti, V, Cr, Mo, Cu and Ni respectively. Also, when the element shown in each term of the formulae (2)-(5) above is not contained, calculation is done assuming that the term is null.

[0067] Treatment (1): After finish rolling, cooling was executed to $650^{\circ}C$ with the average cooling rate of $50^{\circ}C/s$, cooling was thereafter executed for 10 s from $650^{\circ}C$ with the average cooling rate of $5^{\circ}C/s$, and cooling was thereafter executed to the winding temperature with the average cooling rate of $50^{\circ}C/s$. The front and back surfaces were thereafter polished and the thickness was reduced to 1.6 mm so as to match the thickness to that of the treatments (2) and (3).

[0068] Treatment (2): The hot-rolled steel sheet was cold-rolled, was heated thereafter to $860^{\circ}C$ simulating continuous annealing, was cooled thereafter to $400^{\circ}C$ with the average cooling rate of $30^{\circ}C/s$, and was held.

[0069] Treatment (3): The hot-rolled steel sheet was cold-rolled, was heated thereafter to $860^{\circ}C$ for simulating continuous hot dip galvanizing line, was cooled thereafter to $400^{\circ}C$ with the average cooling rate of $30^{\circ}C/s$, was held, was thereafter heated further by ($500^{\circ}C \times 10$ s), and was cooled thereafter.

[Table 1]

Steel No.	Chemical component composition* (mass%)															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				
1	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	-	-	845	765	563	425
2	0.150	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	860	768	568	446
3	0.220	0.05	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	792	735	549	421
4	0.220	0.50	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	812	748	549	421
5	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
6	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
7	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
8	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
9	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
10	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
11	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
12	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
13	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
14	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
15	0.220	2.00	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	879	792	549	421
16	0.350	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	818	768	514	374
17	0.450	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	802	768	487	338
18	0.720	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	766	768	414	240
19	0.220	1.20	0.80	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	855	773	585	436
20	0.220	1.20	2.40	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	807	756	441	374
21	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.100	0.0040	-	-	-	-	0.20	-	866	768	549	421
22	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.200	0.0040	-	-	-	-	0.20	-	906	768	549	421
23	0.220	0.50	1.20	0.0050	0.0020	0.40	0.0020	0.044	0.0040	-	-	-	-	0.20	-	960	748	549	432
24	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	0.030	-	-	-	0.20	-	846	768	549	421
25	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	0.020	-	-	0.20	-	843	768	549	421
26	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	0.20	-	0.20	-	839	768	549	419
27	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	0.20	0.20	-	840	765	541	417
28	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	0.20	849	768	532	420

*The remainder: iron and inevitable impurities other than P, S, N.

[Table 2]

Steel No.	Steel sheet manufacturing condition					
	Heating temperature (°C)	Finish rolling temperature (°C)	Cooling time of 750-700°C (s)	Average cooling rate of 700°C-450°C (°C/s)	Winding temperature (°C)	Remarks
1	1200	800	15	50	200	-
2	1200	800	15	50	200	-
3	1200	800	15	50	200	-
4	1200	800	15	50	200	-
5	1200	800	15	50	200	-
6	1200	800	15	50	200	-
7	1200	800	15	50	200	-
8	1200	800	15	50	200	-
9	1200	800	1	17	200	Treatment (1)
10	1200	900	1	17	450	Treatment (1)
11	1200	800	15	50	400	Cold rolling: 20%
12	1200	800	15	50	400	Treatment (2)
13	1200	800	15	50	400	Treatment (3)
14	1200	800	15	50	580	-
15	1200	800	15	50	200	-
16	1200	800	15	50	200	-
17	1200	800	15	50	200	-
18	1200	800	15	50	200	-
19	1200	800	15	50	200	-
20	1200	800	15	50	200	-
21	1200	800	15	50	200	-
22	1200	800	15	50	200	-
23	1200	800	15	50	200	-
24	1200	800	15	50	200	-
25	1200	800	15	50	200	-
26	1200	800	15	50	200	-
27	1200	800	15	50	200	-
28	1200	800	15	50	200	-

[Analysis of precipitation state of Ti of steel sheet]

[0071] 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, by composition analysis of the precipitates using an energy dispersion type X-ray spectrometer (EDX), Ti-containing precipitates were identified. The area of the Ti-containing precipitates of at least 100 pieces was measured by image analysis, those having the equivalent circle diameter of 30 nm or less were extracted, and the average value thereof was made the size of the precipitates. Also, in the table, the size is shown as "average equivalent circle diameter of Ti-containing precipitates". Further, with respect to precipitated Ti amount (mass%)-3.4[N] (the Ti amount present as the precipitates), extraction residue analysis (in extraction treatment, the precipitates coagulate, and fine precipitates also can be measured) was executed using a mesh with mesh diameter: 0.1 μ m, and precipitated Ti amount (mass%)-3.4[N] (expressed as "precipitated Ti amount-3.4[N]" in Table 3) was obtained. Also, when the Ti-containing precipitates partly contained V and Nb, the contents of these precipitates were also measured.

[Observation of metal microstructure (fraction of each microstructure)]

[0072]

(1) With respect to the microstructure of martensite and bainite in the steel sheet, the steel sheet was corroded by nital, martensite and bainite were distinguished from each other by SEM observation (magnifications: 1,000 times or 2,000 times), and each fraction (area ratio) was obtained.

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

[0073]

[Table 3]

Steel No.	Steel sheet for press forming use					
	Precipitated Ti amount - 3.4[N] (mass%)	0.5 x (total Ti amount - 3.4[N]) (mass%)	Average equivalent circle diameter of Ti-containing precipitates (nm)	Fraction of martensite (area%)	Fraction of bainite (area%)	Others
1	0.024	0.015	10.0	100	0	-
2	0.024	0.015	10.0	100	0	-
3	0.025	0.015	10.0	100	0	-
4	0.027	0.015	10.0	100	0	-
5	0.029	0.015	10.0	100	0	-
6	0.026	0.015	10.0	100	0	-
7	0.023	0.015	10.0	100	0	-
8	0.026	0.015	10.0	100	0	-
9	0.006	0.015	5.0	100	0	-
10	0.012	0.015	2.0	0	100	-
11	0.026	0.015	10.0	0	100	-
12	0.030	0.015	10.0	0	100	-
13	0.027	0.015	10.0	0	100	-
14	0.025	0.015	10.0	0	0	Ferrite + Pearlite: 100%
15	0.028	0.015	10.0	100	0	-
16	0.023	0.015	10.0	90	0	Retained austenite 10%

(continued)

Steel No.	Steel sheet for press forming use					
	Precipitated Ti amount - 3.4[N] (mass%)	0.5 x (total Ti amount - 3.4[N]) (mass%)	Average equivalent circle diameter of Ti-containing precipitates (nm)	Fraction of martensite (area%)	Fraction of bainite (area%)	Others
17	0.026	0.015	10.0	80	0	Retained austenite 20%
18	0.030	0.015	10.0	60	0	Retained austenite 40%
19	0.023	0.015	10.0	100	0	-
20	0.023	0.015	10.0	100	0	-
21	0.084	0.043	10.0	100	0	-
22	0.144	0.093	18.0	100	0	-
23	0.029	0.015	10.0	100	0	-
24	0.024	0.015	10.0	100	0	-
25	0.024	0.015	10.0	100	0	-
26	0.026	0.015	10.0	100	0	-
27	0.028	0.015	10.0	100	0	-
28	0.024	0.015	10.0	100	0	-

[0074] Each steel sheet described above (1.6 mm^t×150 mm×200 mm) (with respect to those other than the treatments of (1)-(3) described above, the thickness was adjusted to 1.6 mm by hot rolling) was heated to a predetermined temperature in a heating furnace, and was thereafter subjected to press forming and cooling treatment using the tool (Fig. 1 above) of a hat shape to obtain the press-formed product. The press forming conditions (heating temperature, average cooling rate, and rapid cooling finishing temperature in press forming) are shown in Table 4 below.

[0075]

[Table 4]

Steel No.	Press forming condition		
	Heating temperature (°C)	Average cooling rate (°C/s)	Rapid cooling finishing temperature (°C)
1	790	40	300
2	800	40	300
3	760	40	300
4	770	40	300
5	810	40	300
6	950	40	300
7	820	5	300
8	800	40	600
9	800	40	300
10	810	40	300
11	800	40	300

(continued)

Steel No.	Press forming condition		
	Heating temperature (°C)	Average cooling rate (°C/s)	Rapid cooling finishing temperature (°C)
12	820	40	300
13	810	40	300
14	800	40	300
15	830	40	300
16	790	40	300
17	790	40	300
18	770	40	300
19	800	40	300
20	780	40	300
21	810	40	300
22	820	40	300
23	830	40	300
24	800	40	300
25	810	40	300
26	800	40	300
27	810	40	300
28	820	40	300

[0076] With respect to the formed product obtained, tensile strength (TS), elongation (total elongation EL), and observation of the metal microstructure (the fraction of each microstructure) were measured by methods described below.

[Measurement of tensile strength (TS) and elongation (total elongation EL)]

[0077] The tensile test was executed using JIS No. 5 test specimen, and the tensile strength (TS) and the elongation (EL) were measured. At this time, the strain rate of the tensile test was made 10 mm/s. In the present invention, the case 980-1, 179 MPa of the tensile strength (TS) and 20% or more of the elongation (EL) were satisfied and the strength-elongation balance (TS×EL) was 24,000 (MPa · %) or more was evaluated to have passed.

(Observation of metal microstructure (fraction of each microstructure))

[0078]

- (1) With respect to the microstructure of annealed martensite, bainite and annealed bainite in the steel sheet, the steel sheet was corroded by nital, annealed martensite, bainite and annealed bainite were distinguished from each other by SEM observation (magnifications: 1,000 times or 2,000 times), and each fraction (area ratio) was obtained.
- (2) The retained austenite fraction in the steel sheet was measured by X-ray diffraction method after the steel sheet was ground up to 1/4 thickness thereof and was thereafter subjected to chemical polishing (for example, ISJJ Int. Vol. 33. (1933), No. 7, P.776). At this time, the carbon amount in retained austenite was also measured.
- (3) With respect to the fraction of martensite as quenched, the steel sheet was LePera-corroded, the area ratio of the white contrast was measured as the mixture microstructure of martensite as quenched and retained austenite, the retained austenite fraction obtained by X-ray diffraction was deducted therefrom, and the fraction of martensite as quenched was calculated.

[0079] The observation results (fraction of each microstructure) of the metal microstructure are shown in Table 5 below. Also, the mechanical properties (tensile strength TS, elongation EL, and TS×EL) of the formed product are shown

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in Table 6 below.

[0080]

[Table 5]

Steel No.	Metal microstructure of formed product				
	Fraction of annealed martensite and/or annealed bainite (area%)	Fraction of martensite as quenched (area%)	Fraction of retained austenite (area%)	Carbon amount in retained austenite (mass%)	Others
1	70	23	7	0.65	-
2	67	23	7	0.65	Ferrite 3%
3	70	28	2	0.45	-
4	70	25	5	0.65	-
5	70	23	7	0.65	-
6	70	23	7	0.65	-
7	70	2	0	0.65	Pearlite 18%, Ferrite 10%
8	70	6	3	0.65	Pearlite 12%, Ferrite 9%
9	70	23	7	0.65	-
10	70	23	7	0.65	-
11	70	23	7	0.65	-
12	70	23	7	0.65	-
13	70	23	7	0.65	-
14	-	33	7	0.52	Ferrite 60%
15	70	23	9	0.65	-
16	60	29	11	0.65	-
17	55	32	13	0.65	-
18	16	62	22	0.65	-
19	70	25	5	0.68	-
20	70	21	9	0.61	-
21	70	23	7	0.65	-
22	70	23	7	0.65	-
23	70	23	7	0.65	-
24	70	23	7	0.65	-
25	70	23	7	0.65	-
26	70	23	7	0.65	-
27	70	23	7	0.65	-
28	70	23	7	0.65	-

[0081]

[Table 6]

Steel No.	Mechanical properties of formed product		
	Tensile strength TS (MPa)	Elongation EL (%)	TS×EL (MPa·%)
1	1074	23.5	25239
2	1022	26.1	26674
3	1014	12.0	26364
4	983	25.5	25067
5	1016	26.2	26619
6	1524	11.3	17221
7	781	19.7	15386
8	856	19.0	16264
9	1026	22.6	23188
10	1044	22.0	22968
11	1051	25.9	27221
12	1018	25.3	25755
13	1039	24.1	25040
14	1063	19.9	21154
15	1038	25.6	26573
16	1192	23.5	28012
17	1260	28.0	35280
18	1321	10.2	13474
19	1031	24.3	25053
20	1021	29.0	29609
21	1045	25.9	27066
22	1045	18.1	18915
23	1013	26.1	26439
24	1049	24.0	25176
25	1033	26.0	26858
26	1007	26.1	26283
27	1059	25.2	26687
28	1045	24.2	25289

[0082] From these results, following consideration can be made. Those of the steel Nos. 1, 2, 4, 5, 11-13, 15-17, 19-21, 23-32 are examples fulfilling the requirements stipulated in the present invention, and it is known that components excellent in strength-elongation balance have been obtained.

[0083] On the other hand, those of the steel Nos. 3, 6-10, 14, 18, 22 are the comparative examples not fulfilling any of the requirements stipulated in the present invention, and any of the properties is deteriorated. That is, in that of the steel No. 3, a steel sheet with low Si content is used, the fraction of retained austenite in the formed product is not secured, the carbon amount in the retained austenite drops, and the elongation is not enough. In that of the steel No. 6, the heating temperature in forming is high, only low elongation EL is obtained, and the strength-elongation balance (TS×EL) also deteriorates.

[0084] In that of the steel No. 7, the average cooling rate in press forming is slow, pearlite and ferrite are formed, the

fraction of martensite as quenched cannot be secured, and the strength-elongation balance (TS×EL) is deteriorated. In that of the steel No. 8, the rapid cooling finishing temperature is high, pearlite and ferrite are formed, the fraction of martensite as quenched cannot be secured, only low elongation is obtained, and the strength-elongation balance (TS×EL) is also deteriorated.

[0085] In those of the steel Nos. 9, 10, the condition in manufacturing the steel is not appropriate, the amount of precipitated Ti is insufficient (steel Nos. 9, 10), Ti-containing precipitates are small (steel No. 10), and, when press forming is executed using such a steel sheet, the strength-elongation balance (TS×EL) is deteriorated even if the forming condition is appropriate.

[0086] In that of the steel No. 14, a steel sheet whose metal microstructure is of ferrite+pearlite of 100 area% which is caused by the winding temperature is used, the fraction of annealed martensite and/or annealed bainite during forming cannot be secured, and the strength-elongation balance (TS×EL) is deteriorated. In that of the steel No. 18, the steel sheet with excessive C content is used, the strength becomes high, and only low elongation EL is obtained. In that of the steel No. 22, the steel sheet with excessive Ti content is used, and the strength-elongation balance (TS×EL) is deteriorated.

[Example 2]

[0087] Steel (steel Nos. 33-37) having the chemical component composition shown in Table 7 below was molten in vacuum, was made a slab for experiment, was thereafter hot-rolled, and was thereafter cooled and wound (sheet thickness: 3.0 mm). The manufacturing condition for the steel sheet at that time is shown in Table 8 below.

[0088]

[Table 7]

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				
29	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
30	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
31	0.350	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	818	768	514	374
32	0.220	1.20	1.20	0.0050	0.0020	0.030	0.0020	0.044	0.0040	-	-	-	-	0.20	-	843	768	549	421
*The remainder: iron and inevitable impurities other than P, S, N.																			

[0089]

[Table 8]

Steel No.	Steel sheet manufacturing condition					
	Heating temperature (°C)	Finish rolling temperature (°C)	Cooling time of 750-700°C (s)	Average cooling rate of 700°C-450°C (°C/s)	Winding temperature (°C)	Remarks
29	1200	800	15	50	200	-
30	1200	800	15	50	200	-
31	1200	800	15	50	200	-
32	1200	800	1	17	200	Treatment (1)

[0090] With respect to the steel sheet obtained, analysis of the precipitation state of Ti-containing precipitates and observation of the metal microstructure (the fraction of each microstructure) were executed similarly to Example 1. The result is shown in Table 9 below.

[0091]

[Table 9]

Steel No.	Steel sheet for press forming use					
	Precipitated Ti amount - 3.4[N] (mass%)	0.5 x (total Ti amount - 3.4[N]) (mass%)	Average equivalent circle diameter of Ti-containing precipitates (nm)	Fraction of martensite (area%)	Fraction of bainite (area%)	Others
29	0.030	0.015	10.0	100	0	-
30	0.023	0.015	10.0	100	0	-
31	0.028	0.015	10.0	90	0	Retained austenite 10%
32	0.006	0.015	2.3	100	0	-

[0092] Each steel sheet described above (3.0 mm^t×150 mm×200 mm) was heated to a predetermined temperature in a heating furnace, and was subjected thereafter to press forming and cooling treatment using the tool (Fig. 1 above) of a hat shape to obtain the formed product. At this time, the steel sheet was put in an infrared furnace and the portion intended to be high-strengthened (the steel sheet portion corresponding to the first region) was configured so that infrared rays directly hit so as to allow high temperature heating, whereas the portion intended to be low-strengthened (the steel sheet portion corresponding to the second region) was shielded with a cover so that a part of the infrared rays was blocked so as to allow low temperature heating, and thereby the heating temperature was differentiated. Therefore, the formed product has the regions with different strength within a single component. The press forming conditions (heating temperature, average cooling rate, and rapid cooling finishing temperature of each region in press forming) are shown in Table 10 below.

[0093]

[Table 10]

Steel No.	Region	Press forming condition		
		Heating temperature (°C)	Average cooling rate (°C/s)	Rapid cooling finishing temperature (°C)
29	Low strength side	810	40	300
	High strength side	920	40	300
30	Low strength side	800	40	300
	High strength side	850	40	300
31	Low strength side	790	40	300
	High strength side	920	40	300
32	Low strength side	810	40	300
	High strength side	920	40	300

[0094] With respect to the formed product obtained, tensile strength (TS), elongation (total elongation EL), observation of the metal microstructure (the fraction of each microstructure), and the carbon amount in retained austenite in each region were obtained similarly to Example 1.

[0095] The observation results (fraction of each microstructure) of the metal microstructure are shown in Table 11 below. Also, the mechanical properties (tensile strength TS, elongation EL, and TS×EL) of the formed product are shown in Table 12 below. Further, the case 1,470 MPa or more of the tensile strength (TS) and 8% or more of the elongation (EL) were fulfilled and the strength-elongation balance (TS×EL) was 14,000 (MPa · %) or more on the high strength side was evaluated to have passed (the evaluation criteria of the low strength side are same to those of Example 1).

[0096]

[Table 11]

Steel No.	Region	Metal microstructure of formed product				
		Fraction of annealed martensite and/or annealed bainite (area%)	Fraction of martensite as quenched (area%)	Fraction of retained austenite (area%)	Carbon amount in retained austenite (mass%)	Others
29	Low strength side	70	23	7	0.65	-
	High strength side	0	94	6	0.55	-
30	Low strength side	70	23	7	0.65	-
	High strength side	0	61	6	0.52	Ferrite 33%

(continued)

Steel No.	Region	Metal microstructure of formed product				
		Fraction of annealed martensite and/or annealed bainite (area%)	Fraction of martensite as quenched (area%)	Fraction of retained austenite (area%)	Carbon amount in retained austenite (mass%)	Others
31	Low strength side	60	29	11	0.65	-
	High strength side	-	95	5	0.53	-
32	Low strength side	70	23	7	0.65	-
	High strength side	0	94	6	0.54	-

[0097]

[Table 12]

Steel No.	Region	Mechanical properties of formed product		
		Tensile strength TS (MPa)	Elongation EL (%)	TS × EL (MPa·%)
29	Low strength side	1058	24.1	25498
	High strength side	1511	11.0	16621
30	Low strength side	1063	23.9	25406
	High strength side	1278	13.0	16614
31	Low strength side	1192	25.0	29800
	High strength side	1820	10.1	18382
32	Low strength side	1049	21.5	22554
	High strength side	1499	11.0	16489

[0098] From this result, following consideration can be made. Those of the steel Nos. 33, 35, 37 are examples fulfilling the requirements stipulated in the present invention, and it is known that components excellent in the strength-elongation balance in each region have been obtained.

[0099] On the other hand, those of the steel Nos. 34, 36 are the comparative examples not fulfilling any of the requirements stipulated in the present invention, and any of the properties is deteriorated. That is, in that of the steel No. 34, the heating temperature in press forming is low, and the strength on the high strength side drops. In that of the steel No. 36, a steel sheet with small size of Ti-containing precipitates is used, only low strength is obtained on the high strength side, and the strength-elongation balance (TS×EL) is deteriorated on the low strength side.

[0100] Although the present invention has been described in detail and referring to specific embodiments, it is obvious for a person with an ordinary skill in the art that various alterations and amendments can be effected without departing from the spirit and the range of the present invention.

[0101] The present application is based on Japanese Patent Application (JP-A-No. 2012-053844) applied on March 9, 2012, and the contents thereof are hereby incorporated by reference.

[Industrial Applicability]

[0102] The present invention is suitable to a steel sheet for hot pressing use that is used in manufacturing structural components of an automobile.

[Reference Signs List]

[0103]

- 1...punch
- 2...die
- 3...blank holder
- 4...steel sheet (blank)

Claims

1. A steel sheet for hot pressing use comprising:

C: 0.15-0.5% (means mass%, hereinafter the same with respect to the chemical component composition);
 Si: 0.2-3%;
 Mn: 0.5-3%;
 P: 0.05% or less (exclusive of 0%);
 S: 0.05% or less (exclusive of 0%);
 Al: 0.01-1%;
 B: 0.0002-0.01%;
 Ti: $3.4[N] + 0.01\%$ or more and $3.4[N] + 0.1\%$ or less ([N] expresses N content (mass%)); and
 N: 0.001-0.01% respectively, with the remainder consisting of iron and inevitable impurities, wherein

some of Ti-containing precipitates contained in the steel sheet, each of which having an equivalent circle diameter of 30 nm or less, have an average equivalent circle diameter of 3 nm or more, the precipitated Ti amount and the total Ti amount in the steel fulfill the relationship represented by formula (1) shown below, and the sum total of the fraction of bainite and the fraction of martensite in the metal microstructure is 80 area% or more.

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

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

2. The steel sheet for hot pressing use according to claim 1 further comprising at least one of (a)-(c) below as other elements:

- (a) at least one element selected from the group consisting of V, Nb and Zr by 0.1% or less (exclusive of 0%) in total;
- (b) at least one element selected from the group consisting of Cu, Ni, Cr and Mo by 1% or less (exclusive of 0%) in total; and
- (c) at least one element selected from the group consisting of Mg, Ca and REM by 0.01% or less (exclusive of 0%) in total.

3. A method for manufacturing a press-formed product comprising the steps of:

using a steel sheet for hot pressing use according to claim 1 or 2;
 heating the steel sheet to a temperature of Ac_1 transformation point + 20°C or above and Ac_3 transformation point - 20°C or below;
 thereafter starting press forming; and
 executing cooling to a temperature or below, the temperature being lower than the bainite transformation starting

temperature Bs by 100°C, while securing the average cooling rate of 20°C/s or more within a tool during forming and after completion of forming.

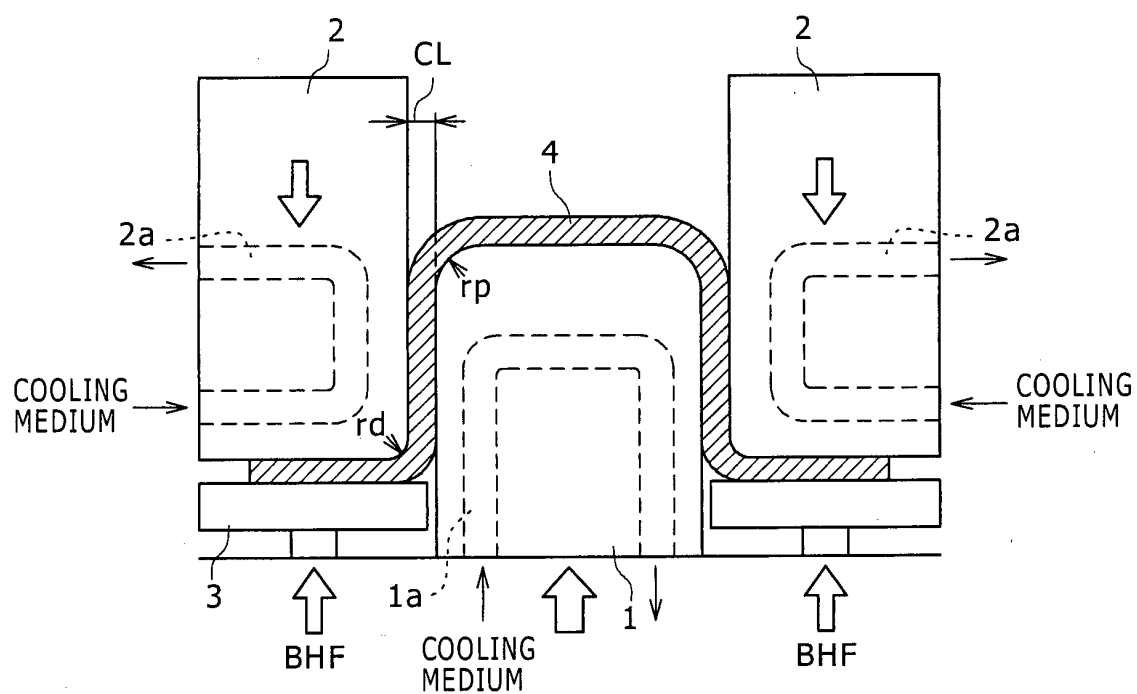
4. A press-formed product obtained by the method for manufacturing according to claim 3, wherein metal microstructure comprises retained austenite: 3-20 area%, annealed martensite and/or annealed bainite: 30-87 area%, and martensite as quenched: 10-67 area%, and the amount of carbon in the retained austenite is 0.60% or more.

5. A method for manufacturing a press-formed product comprising the steps of:

using the steel sheet for hot pressing use according to claim 1 or 2;
dividing a heating region of the steel sheet into two regions;
heating one region thereof to a temperature of Ac₃ transformation point or above and 950°C or below;
heating the other region to a temperature of Ac₁ transformation point+20°C or above and Ac₃ transformation point-20°C or below;
thereafter starting press forming; and
executing cooling to a temperature of martensite transformation starting temperature Ms or below while securing the average cooling rate of 20°C/s or more within a tool during forming and after completion of forming.

6. A press-formed product obtained by the method for manufacturing according to claim 5 comprising a first region whose metal microstructure comprises retained austenite: 3-20 area% and martensite: 80 area% or more, and a second region whose metal microstructure comprises retained austenite: 3-20 area%, annealed martensite and/or annealed bainite: 30-87 area%, and martensite as quenched: 10-67 area% with the amount of carbon in the retained austenite being 0.60% or more.

FIG. 1



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/055680

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/00(2006.01)i, B21D22/20(2006.01)i, C21D9/00(2006.01)i, C22C38/60(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22C38/00, B21D22/20, C21D9/00, C22C38/60

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
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	JP 2005-97725 A (Nippon Steel Corp.), 14 April 2005 (14.04.2005), tables 1, 2 (Family: none)	1-6
A	Heping Liu et al., Enhanced mechanical properties of a hot stamped advanced high- strength steel treated by quenching and partitioning process, Scripta Materialia, Vol.64 No.8, 2011.04, Page.749-752	1-6
A	L.Xu et al., Improved mechanical properties in Ti-bearing martensitic steel by precipitation and grain refinement, Journal of Material Science, Vol.46 No.19, 2011.10, Page.6384-6389	1-6

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

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search
15 April, 2013 (15.04.13)Date of mailing of the international search report
23 April, 2013 (23.04.13)Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/055680

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 2012-12701 A (JFE Steel Corp.), 19 January 2012 (19.01.2012), tables 1 to 3 & WO 2011/152541 A1	1-6
A	JP 2006-274335 A (JFE Steel Corp.), 12 October 2006 (12.10.2006), tables 1, 2 (Family: none)	1-6
A	JP 7-197186 A (Kobe Steel, Ltd.), 01 August 1995 (01.08.1995), paragraph [0025]; tables 1 to 3 (Family: none)	1-6
A	JP 2009-61473 A (Sumitomo Metal Industries, Ltd.), 26 March 2009 (26.03.2009), entire text (Family: none)	1-6

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

REFERENCES CITED IN THE DESCRIPTION

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- JP 2010065293 A [0011]
- JP 2010065294 A [0011]
- JP 2010065295 A [0011]
- JP 2012053844 A [0101]

Non-patent literature cited in the description

- *ISJJ Int.*, 1933, vol. 33 (7), 776 [0072] [0078]