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(54) HIGH-STRENGTH STEEL SHEET

(57) A high-strength steel sheet having high stretch flangeability after working and corrosion resistance after painting is provided. The steel sheet contains, on the basis of mass percent, C: 0.02% to 0.20%, Si: 0.3% or less, Mn: 0.5% to 2.5%, P: 0.06% or less, S: 0.01% or less, Al: 0.1% or less, Ti: 0.05% to 0.25%, and V: 0.05% to 0.25%, the remainder being Fe and incidental impurities. The steel sheet has a substantially ferritic single phase, the ferritic single phase containing precipitates having a size of less than 20 nm, the precipitates containing 200 to 1750 mass ppm Ti and 150 to 1750 mass ppm V, V dissolved in solid solution being 200 or more but less than 1750 mass ppm.

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Description

Technical Field

[0001] The present invention relates to a high-strength steel sheet having high stretch flangeability after working and corrosion resistance after painting.

Background Art

[0002] Automobile parts, such as chassis and truck frames, require formability (mainly elongation and stretch flangeability), and steel having a tensile strength on the order of 590 MPa has been used for such applications. However, to reduce the effects of automobiles on the environment and to improve crashworthiness of automobiles, use of higher-strength automotive steel sheets has been promoted in recent years, and use of steel having a tensile strength on the order of 780 MPa is being investigated.

[0003] In general, steel materials having higher strength have lower workability. High-strength high-workability steel sheets have therefore been studied. For example, Patent Documents 1 to 6 describe techniques for improving elongation and stretch flangeability.

[0004] Patent Document 1 discloses a technique relating to high-workability high-strength steel sheet having a tensile strength of 590 MPa or more, wherein the steel sheet has a substantially ferritic single phase in which carbide containing Ti and Mo having an average particle size of less than 10 nm is dispersedly precipitated.

[0005] Patent Document 2 discloses a technique relating to a high-strength hot-rolled steel sheet having a strength of 880 MPa or more and a yield ratio of 0.80 or more. The steel sheet has a steel structure that contains, on the basis of mass, C: 0.08% to 0.20%, Si: 0.001% or more but less than 0.2%, Mn: more than 1.0% but not more than 3.0%, Al: 0.001% to 0.5%, V: more than 0.1% but not more than 0.5%, Ti: 0.05% or more but less than 0.2%, and Nb: 0.005% to 0.5%, provided that the following three formulae are satisfied, the remainder being Fe and incidental impurities, and that contains 70% by volume or more ferrite having an average particle size of 5 μm or less and a hardness of 250 Hv or more.

$$\text{(Formula 1)}\quad (Ti/48 + Nb/93) \times C/12 \leq 4.5 \times 10^{-5}$$

$$\text{(Formula 2)}\quad 0.5 \leq (V/51 + Ti/48 + Nb/93)/(C/12) \leq 1.5$$

$$\text{(Formula 3)}\quad V + Ti \times 2 + Nb \times 1.4 + C \times 2 + Mn \times 0.1 \geq 0.80$$

[0006] Patent Document 3 discloses a technique relating to a hot-rolled steel sheet that contains, on the basis of mass, C: 0.05% to 0.2%, Si: 0.001% to 3.0%, Mn: 0.5 to 3.0, P: 0.001% to 0.2%, Al: 0.001% to 3%, and V: more than 0.1% but not more than 1.5%, the remainder being Fe and impurities, and has a structure mainly composed of ferrite phase having an average particle size in the range of 1 to 5 μm, the ferrite particles containing carbonitride of V having an average particle size of 50 nm or less.

[0007] Patent Document 4 discloses a thermally stable high-strength thin steel sheet that contains precipitated carbide in the steel structure. In the thin steel sheet, carbide has a NaCl-type crystal structure represented by MC wherein M denotes a metallic element composed of at least two metals, and the at least two metals are regularly spaced in a crystal lattice, forming a superlattice.

[0008] Patent Document 5 discloses the following hot-rolled steel sheet. The steel sheet has a composition of C: 0.0002% to 0.25%, Si: 0.003% to 3.0%, Mn: 0.003% to 3.0%, and Al: 0.002% to 2.0% on the basis of mass percent, the remainder being Fe and incidental impurities, the impurities containing 0.15% or less P, 0.05% or less S, and 0.01% or less N. A ferrite phase accounts for 70% by area or more of the metal structure and has an average grain size of 20 μm or less and an aspect ratio of 3 or less. Seventy percent or more of ferrite grain boundaries are high-angle grain boundaries. Among ferrite phases defined by high-angle grain boundaries, the area percentage of precipitates having a maximum diameter of 30 μm or less and a minimum diameter of 5 nm or more is 2% or less of the metal structure. Second phases having the largest area percentage among phases other than the ferrite phases and the precipitates have an average grain size of 20 μm or less. High-angle grain boundaries of ferrite phases are disposed between the nearest second

phases.

[0009] Patent Document 6 discloses a drawable high-strength thin steel sheet that has excellent shape fixability and burring characteristics, wherein the thin steel sheet contains, on the basis of mass percent, C: 0.01% to 0.1%, S ≤ 0.03%, N ≤ 0.005%, and Ti: 0.05% to 0.5%, the Ti content satisfying Ti-48/12C-48/14N-48/32S ≥ 0%, the remainder being Fe and incidental impurities, at least the mean values of X-ray random intensity ratios in a plane at half the thickness of the steel sheet are 3 or more for {100}<011> to {223}<110> orientations and 3.5 or less for three orientations of {554}<225>, {111}<112>, and {111}<110>, the arithmetical mean roughness Ra of at least one of the surfaces of the steel sheet ranges from 1 to 3.5, and the steel sheet is coated with a lubricating composition.

[0010] However, the related art described above has the following problems.

[0011] Because the steel sheet contains Mo in Patent Documents 1 and 4, a recent increase in the cost of Mo has resulted in a marked increase in the cost of the steel sheet.

[0012] With the increasing globalization of the automobile industry, automotive steel sheets are being used under severe corrosion conditions, and therefore steel sheets require higher corrosion resistance after painting. However, the addition of Mo prevents the formation or growth of crystals during chemical conversion, thereby lowering the corrosion resistance of a steel sheet after painting. The addition of Mo therefore cannot satisfy this requirement. Thus, the steel described in Patent Documents 1 and 4 does not have corrosion resistance after painting that satisfies recent requirements of the automobile industry.

[0013] With recent advances in pressing techniques, processing such as drawing or stretch forming → piercing → flange forming is increasingly employed. Flanges of steel sheets formed by such processing require stretch flangeability after drawing or stretch forming and piercing, that is, stretch flangeability after working. However, in Patent Documents 2, 3, and 4, a TS of 780 MPa or more is not always compatible with sufficient stretch flangeability after working. The addition of Nb in Patent Document 3 significantly retards the recrystallization of austenite after hot rolling. Deformed austenite therefore remains in a steel sheet, thereby lowering workability. The addition of Nb also disadvantageously increases rolling load in hot rolling.

[0014] Patent Document 5 discloses single-phase ferritic steel sheets having a tensile strength TS of 422 MPa or less (for example, test numbers 1 to 5 in Table 6 and test number 45 in Table 8 in Examples) and multiphase steel sheets composed of a ferrite phase and a second phase and having a tensile strength TS of 780 MPa or more (for example, test numbers 33 to 36 in Table 6 and test number 49 in Table 8 in Examples). These steel sheets described in Patent Document 5 mainly take advantage of solid-solution strengthening due to Si or Mn and transformation hardening utilizing a hard second phase. These steel sheets must therefore be cooled to a temperature in the range of 600°C to 800°C at an average cooling rate of 30°C/s or more within two seconds after finish rolling, air-cooled for 3 to 15 seconds, and then water-cooled at an average cooling rate of 30°C/s or more before coiling. This promotes two-phase separation during ferrite transformation, allowing the steel sheets to have a mixed structure of the ferrite phase and the second phase. The finish-rolling temperature ranges from (Ae3 point + 100°C) to Ae3 point, which is lower than the temperature range suitable for manufacture according to the present invention described below. For example, the finish-rolling temperature for multiphase steel sheets having a tensile strength TS of 780 MPa or more (test numbers 33 to 36 in Table 6 in Examples) ranged from 871°C to 800°C. A low finish-rolling temperature results in a decrease in the solubility limit of a carbide-forming element, such as Ti, in an austenite phase. Furthermore, because rolling introduces precipitation sites, precipitates having a size of 20 nm or more are formed. This phenomenon is referred to as strain-induced precipitation. In the steel sheets and the method for manufacturing the steel sheets described in Patent Document 5, strain-induced precipitation increases the amount of precipitates having a size of 20 nm or more.

[0015] Patent Document 5 also discloses a technique in which a ferritic single phase can be manufactured by greatly decreasing the C content and decreasing the amount of austenite forming element, Mn, in a steel composition (see steel numbers AA to AE in Table 2 in Examples). However, a decrease in the amount of Mn, which is also a solid-solution strengthening element, lowers the solid-solution strengthening level. A decrease in C content results in a decrease in the amount of precipitated carbide, for example, of Ti or Nb, which has precipitation hardening effects, thereby lowering the precipitation hardening level. Thus, even with a combination of the solid-solution strengthening level and the precipitation hardening level, a single-phase ferritic steel sheet cannot have a strength of 780 MPa or more (see test numbers 1 to 5 in Table 6 and test number 45 in Table 8 in Examples). For these reasons, an object of the present invention, that is, a steel sheet that has a substantially ferritic single phase, a tensile strength of 780 MPa or more, and other characteristics cannot be manufactured by the technique described in Patent Document 5.

[0016] Patent Document 6 discloses steel sheets having a tensile strength σ_B of 780 MPa or more (for example, steel symbols A-4, A-8, A-10, C, E, and H in Table 2 in Examples). The YRs of these steel sheets (YR represents σ_Y/σ_B x 100 (%)) are as low as 69% to 74%, indicating that these steel sheets contain a hard second phase, such as a martensite phase.

[0017] As in Patent Document 5, the possible basic ideas behind the design of a steel sheet having a strength of 780 MPa or more according to Patent Document 6 mainly take advantage of solid-solution strengthening due to Si or Mn and transformation hardening utilizing a hard second phase. As described in Patent Document 5, therefore, rolling at a

total reduction of 25% or more must be performed at a finish-rolling temperature (Ar3 point + 100°C or less) lower than the temperature range suitable for manufacture according to the present invention described below. For example, according to an example of Patent Document 6, the finish-rolling temperature for a steel sheet having a tensile strength σ_B of 780 MPa or more ranged from 800°C to 890°C. In the steel sheets and the method for manufacturing the steel sheets described in Patent Document 6, as described in Patent Document 5, strain-induced precipitation increases the amount of precipitates having a size of 20 nm or more. Consequently, an object of the present invention, that is, a steel sheet that has a substantially ferritic single phase, a tensile strength of 780 MPa or more, and other characteristics cannot be manufactured.

Patent Document 1: Japanese Patent No. 3591502
Patent Document 2: Japanese Unexamined Patent Application Publication No. 2006-161112
Patent Document 3: Japanese Unexamined Patent Application Publication No. 2004-143518
Patent Document 4: Japanese Unexamined Patent Application Publication No. 2003-321740
Patent Document 5: Japanese Unexamined Patent Application Publication No. 2003-293083
Patent Document 6: Japanese Unexamined Patent Application Publication No. 2003-160836

Disclosure of Invention

[0018] In view of the situations described above, it is an object of the present invention to provide a high-strength steel sheet having high stretch flangeability after working and corrosion resistance after painting.

[0019] As a result of investigations to develop a high-strength hot-rolled steel sheet that has high stretch flangeability after working, corrosion resistance after painting, and a tensile strength of 780 MPa or more, the present inventors obtain the following findings.

i) To manufacture a high-strength steel sheet having high corrosion resistance after painting, precipitates must remain fine (less than 20 nm), and the percentage of fine precipitates (having a size less than 20 nm) must be increased. Although precipitates containing Ti-Mo or Ti-V remain fine, mixed precipitation of Ti and V is useful in improving corrosion resistance after painting.
ii) Solid solution of V is important in improving stretch flangeability after working. There is an optimum V content of solid solution for an improvement in characteristics.

[0020] The present invention has been accomplished on the basis of these findings and is summarized as follows:

[1] A high-strength steel sheet containing, on the basis of mass percent, C: 0.02% to 0.20%, Si: 0.3% or less, Mn: 0.5% to 2.5%, P: 0.06% or less, S: 0.01% or less, Al: 0.1% or less, Ti: 0.05% to 0.25%, and V: 0.05% to 0.25%, the remainder being Fe and incidental impurities, wherein the steel sheet has a substantially ferritic single phase, the ferritic single phase containing precipitates having a size of less than 20 nm, the precipitates containing 200 to 1750 mass ppm Ti and 150 to 1750 mass ppm V, V dissolved in solid solution being 200 or more but less than 1750 mass ppm.
[2] In [1], the steel sheet further contains, on the basis of mass percent, any one or two or more of Cr: 0.01% to 0.5%, W: 0.005% to 0.2%, and Zr: 0.0005% to 0.05%.
[3] In [1] or [2], the high-strength steel sheet has a tensile strength TS of 780 MPa or more.
[4] In [1] or [2], the high-strength steel sheet has a one-side maximum peel width of 3.0 mm or less after a tape peel test in a warm salt water immersion test.
[5] In [3], the high-strength steel sheet has a one-side maximum peel width of 3.0 mm or less after a tape peel test in a warm salt water immersion test.
[6] In [1] or [2], the high-strength steel sheet has a stretch flangeability λ_{10} of 60% or more after rolling at an elongation percentage of 10%.
[7] In [3], the high-strength steel sheet has a stretch flangeability λ_{10} of 60% or more after rolling at an elongation percentage of 10%.

[0021] In the present specification, the percentages and ppm of components of steel are based on mass percent and mass ppm. High-strength steel sheets according to the present invention have a tensile strength (hereinafter also referred to as TS) of 780 MPa or more and include hot-rolled steel sheets and surface-treated steel sheets, which are high-strength steel sheets subjected to surface treatment, such as plating.

[0022] Target characteristics of the present invention include a stretch flangeability (λ_{10}) of 60% or more after rolling at an elongation percentage of 10% and a one-side maximum peel width of 3.0 mm or less after a tape peel test in a warm salt water immersion test (SDT) described below.

[0023] The present invention provides a high-strength hot-rolled steel sheet that has high stretch flangeability after working, corrosion resistance after painting, and a TS of 780 MPa or more. The present invention has these advantages without the addition of Mo and can therefore reduce costs.

[0024] For example, use of a high-strength hot-rolled steel sheet according to the present invention in automobile chassis and truck frames should allow thickness reduction, reduce the effects of automobiles on the environment, and markedly improve crashworthiness of automobiles.

Best Modes for Carrying Out the Invention

[0025] The present invention will be described in detail below.

(1) First, the reason to limit the chemical components (composition) of steel according to the present invention will be described below.

C: 0.02% to 0.20%

[0026] C can be precipitated in ferrite as carbide with Ti or V, thereby contributing to high strength of a steel sheet. 0.02% or more C is required to achieve a TS of 780 MPa or more. However, more than 0.20% C results in coarsening of precipitates and the formation of a second phase, lowering stretch flangeability after working. Thus, the C content ranges from 0.02% to 0.20%, preferably 0.03% to 0.15%.

Si: 0.3% or less

[0027] Although Si can contribute to solid-solution strengthening, the addition of more than 0.3% Si results in the formation of cementite at grain boundaries, lowering stretch flangeability after working. Thus, the Si content is 0.3% or less, preferably 0.001% to 0.2%.

Mn: 0.5% to 2.5%

[0028] Mn can contribute to solid-solution strengthening. However, the TS is less than 780 MPa at a Mn content of less than 0.5%. The addition of more than 2.5% Mn markedly lowers weldability. Thus, the Mn content ranges from 0.5% to 2.5%, preferably 0.6% to 2.0%.

P: 0.06% or less

[0029] P can segregate at prior austenite grain boundaries, lowering workability and low-temperature toughness. Thus, the P content is preferably minimized and is 0.06% or less, preferably in the range of 0.001% to 0.055%.

S: 0.01% or less

[0030] S can segregate at prior austenite grain boundaries or can be precipitated as MnS. The segregation or a large amount of MnS lowers low-temperature toughness. S also markedly lowers stretch flangeability, regardless of the presence or absence of working. Thus, the S content is preferably minimized and is 0.01% or less, preferably in the range of 0.0001% to 0.005%.

Al: 0.1% or less

[0031] Al can be added to steel as a deoxidizer and effectively improves the cleanliness of the steel. Preferably, 0.001% or more Al is added to steel to produce this effect. However, more than 0.1% Al results in the generation of a large number of inclusions, causing flaws in a steel sheet. Thus, the Al content is 0.1% or less, preferably 0.01% to 0.04%.

Ti: 0.05% to 0.25%

[0032] Ti is very important for the precipitation hardening of ferrite and is an important factor for the advantages of the present invention. A required strength is difficult to achieve at a Ti content of less than 0.05%. However, the effects of Ti become saturated at a Ti content of more than 0.25%, and more than 0.25% Ti only increases costs. Thus, the Ti content ranges from 0.05% to 0.25%, preferably 0.08% to 0.20%.

V: 0.05% to 0.25%

[0033] V can contribute to an improvement in strength by precipitation hardening or solid-solution strengthening. Like Ti, V is therefore an important factor for the advantages of the present invention. A proper amount of V, together with Ti, tends to be precipitated as fine Ti-V carbide having a particle size (hereinafter also referred to as "size") of less than 20 nm. Unlike Mo, V does not lower corrosion resistance after painting. Less than 0.05% V is insufficient for the effects described above. However, the effects of V become saturated at a V content of more than 0.25%, and more than 0.25% V only increases costs. Thus, the V content ranges from 0.05% to 0.25%, preferably 0.06% to 0.20%.

[0034] With these essential additive elements, steel according to the present invention can have target characteristics. In addition to the essential additive elements, any one or two or more of Cr: 0.01% to 0.5%, W: 0.005% to 0.2%, and Zr: 0.0005% to 0.05% may be added for the following reasons.

Cr: 0.01% to 0.5%, W: 0.005% to 0.2%, and Zr: 0.0005% to 0.05%

[0035] Like V, Cr, W, and Zr can strengthen ferrite as a precipitate or solid solution. Less than 0.01% Cr, less than 0.005% W, or less than 0.0005% Zr makes a negligible contribution to high strength of steel. However, more than 0.5% Cr, more than 0.2% W, or more than 0.05% Zr lowers workability. Thus, when any one or two or more of Cr, W, and Zr are added, their amounts are Cr: 0.01% to 0.5%, W: 0.005% to 0.2%, and Zr: 0.0005% to 0.05%, preferably Cr: 0.03% to 0.3%, W: 0.01% to 0.18%, and Zr: 0.001% to 0.04%.

[0036] The remainder consists of Fe and incidental impurities. As an incidental impurity, for example, O forms a non-metallic inclusion and has adverse effects on the quality of steel. O is therefore desirably decreased to 0.003% or less. In the present invention, 0.1% or less Cu, Ni, Sn, and/or Sb may be contained as a trace element without compromising the operational advantages of the present invention.

(2) The structure of a high-strength steel sheet according to the present invention will be described below.

Substantially Ferritic Single Phase

[0037] To achieve a TS of 780 MPa or more and improve stretch flangeability after working, ferrite having a low dislocation density is effective, and a single phase is effective. In particular, a highly ductile ferritic single phase has a marked improving effect on stretch flangeability after working. However, a completely ferritic single phase is not necessary, and even a substantially ferritic single phase can sufficiently produce the effect. A substantially ferritic single phase, as used herein, refers to allowance for a minute amount of another phase or precipitate other than carbide of the present invention, and the volume percentage of ferrite is preferably 95% or more. A substantially ferritic single phase may contain up to 5% by volume of cementite, pearlite, and/or bainite without affecting the characteristics of the present invention.

[0038] The volume percentage of ferrite can be determined by exposing a microstructure in the vertical cross-section parallel to the rolling direction using 3% nital, observing the microstructure at a quarter thickness in the depth direction with a scanning electron microscope (SEM) at a magnification of 1500, and determining the ferrite area ratio, for example, using an image-processing software "Ryusi Kaiseki (particle analysis) II" from Sumitomo Metal Technology, Inc.

200 to 1750 ppm Ti and 150 to 1750 ppm V in Precipitates Having a Size below 20 nm in a Ferritic Single Phase

[0039] In a high-strength steel sheet according to the present invention, precipitates containing Ti and/or V exist in ferrite mainly as carbides. This is probably because the solubility limit of C in ferrite is low, and supersaturated C is therefore easily precipitated in ferrite as carbide. Such a precipitate increases the hardness (strength) of soft ferrite, thereby achieving a TS of 780 MPa or more. Such a precipitate also increases YS, achieving YR (= YS/YR) of 83% or more.

[0040] As described above, to manufacture a high-strength steel sheet, it is important that precipitates remain fine (less than 20 nm), and the percentage of fine precipitates (having a size less than 20 nm) is increased. A precipitate having a size of 20 nm or more has a small effect in preventing dislocation movement and cannot sufficiently increase the hardness of ferrite, sometimes resulting in low strength.

[0041] A further investigation revealed that a fine precipitate size is important for corrosion resistance after painting. In conventional Ti (addition of Ti alone) HSLA steel, a precipitate have a tendency to become coarse with increasing Ti content. In such a steel sheet, therefore, corrosion resistance after painting also has a tendency to decrease with decreasing strength. Although the reason for a deterioration in corrosion resistance after painting associated with coarsening of a precipitate is not clear, a coarse precipitate should prevent the formation or growth of crystals during chemical conversion.

[0042] Thus, a precipitate preferably has a size of less than 20 nm. A fine precipitate having a size of less than 20 nm

can be formed by the addition of both Ti and V. V forms a complex carbide mainly with Ti. Although there is no clear reason, these precipitates remain stable and fine at high temperatures within the coiling temperature within the scope of the present invention for a long period of time.

[0043] It is important to control the Ti content and the V content of precipitates having a size of less than 20 nm. When the Ti content and the V content of precipitates having a size of less than 20 nm are less than 200 ppm and less than 150 ppm, respectively, the number density of the precipitates is small, and the distance between precipitates increases. The precipitates therefore have a small effect in preventing dislocation movement. Thus, the precipitates cannot sufficiently increase the hardness of ferrite, and therefore the TS cannot be 780 MPa or more. When the Ti content and the V content of precipitates having a size of less than 20 nm are 200 ppm or more and less than 150 ppm, respectively, the precipitates have a tendency to become coarse, and therefore the TS may be less than 780 MPa. When the Ti content and the V content of precipitates having a size of less than 20 nm are less than 200 ppm and 150 ppm or more, respectively, the precipitation efficiency of V decreases, and therefore the TS may be less than 780 MPa. When the Ti content or the V content of precipitates having a size of less than 20 nm is more than 1750 ppm, the corrosion resistance after painting decreases, and therefore the target characteristics cannot be achieved. This is probably because a large number of fine precipitates prevent the formation or growth of crystals on the surface of a steel sheet during chemical conversion. Thus, the amounts of precipitated Ti and V in precipitates having a size of less than 20 nm must be satisfactorily controlled.

[0044] When the ratio of the Ti content to the V content of precipitates having a size of less than 20 nm satisfies $0.4 \leq (Ti/48)/(V/51) \leq 2.5$, the TS can be 785 MPa or more, thus achieving more suitable conditions. Although there is no clear reason, optimization of the ratio of Ti to V should improve heat stability.

[0045] Thus, the Ti content and the V content of precipitates having a size of less than 20 nm range from 200 to 1750 ppm and 150 to 1750 ppm, respectively. Furthermore, the ratio of the Ti content to the V content of precipitates having a size of less than 20 nm preferably satisfies $0.4 \leq (Ti/48)/(V/51) \leq 2.5$.

[0046] A precipitate and/or an inclusion is hereinafter also collectively referred to as a precipitate or the like.

[0047] The Ti content and the V content can be controlled by the coiling temperature. The coiling temperature preferably ranges from 500°C to 700°C. At a coiling temperature above 700°C, precipitates become coarse, and the amounts of precipitated Ti and V in precipitates having a size of less than 20 nm are less than 200 ppm and less than 150 ppm, respectively, and the TS cannot be 780 MPa or more. At a coiling temperature below 500°C, the amounts of precipitated Ti and V in precipitates having a size of less than 20 nm are also less than 200 ppm and less than 150 ppm, respectively. Such a low coiling temperature should result in insufficient diffusion of Ti and V.

[0048] The Ti content and the V content of precipitates having a size of less than 20 nm can be determined by the following method.

[0049] After a predetermined amount of sample is electrolyzed in an electrolyte, the sample is removed from the electrolyte and is immersed in a dispersive solution. Precipitates in the solution is filtered with a filter having a pore size of 20 nm. Precipitates in filtrate passing through the filter having a pore size of 20 nm have a size of less than 20 nm. The filtrate after filtration is appropriately analyzed by inductively coupled plasma (ICP) emission spectroscopic analysis, ICP mass spectrometry, atomic absorption spectrometry, or the like to determine the Ti content and the V content of precipitates having a size of less than 20 nm.

Structure Containing 200 ppm or More but Less Than 1750 ppm V in Solid Solution

[0050] In the present invention, V in solid solution is the most important factor. Solid solution of V is important in improving stretch flangeability after working. Less than 200 ppm V in solid solution has an insufficient effect, and 200 ppm or more V in solid solution is required to produce the effect described above. 1750 ppm or more V in solid solution exhibits a saturated effect and is considered as an upper limit.

[0051] Thus, the amount of V in solid solution is 200 ppm or more but less than 1750 ppm. Although the workability of steel according to the present invention slightly deteriorates with increasing strength, when the Ti content and the V content of precipitates having a size of less than 20 nm are both 1750 ppm or less, 200 ppm or more V in solid solution can sufficiently ensure target stretch flangeability after working.

[0052] 200 ppm or more but less than 1750 ppm V in solid solution can be measured, for example, by the following method.

[0053] After a predetermined amount of sample is electrolyzed in a nonaqueous solvent electrolyte, the electrolyte is subjected to elementary analysis. The analysis method may be inductively coupled plasma (ICP) emission spectroscopic analysis, ICP mass spectrometry, or atomic absorption spectrometry.

(3) A method for manufacturing a high-strength steel sheet according to the present invention will be described below.

[0054] For example, a high-strength steel sheet according to the present invention can be manufactured by heating

a steel slab adjusted within the chemical component ranges described above at a temperature in the range of 1150°C to 1350°C, hot-rolling the steel slab at a finish-rolling temperature in the range of 850°C to 1100°C, and coiling the rolled steel at a temperature in the range of 500°C to 700°C. Conditions suitable for these processes will be described in detail below.

Steel Slab Heating Temperature: 1150°C to 1350°C

[0055] A carbide-forming element, such as Ti or V, is mostly present as a precipitate in a steel slab. To be precipitated as desired in a ferrite phase after hot rolling, a precipitate in the form of carbide must be temporarily dissolved before hot rolling. A precipitate must therefore be heated at 1150°C or more.

[0056] At a temperature below 1150°C, carbide having a size of 20 nm or more, which does not contribute to precipitation hardening or corrosion resistance after painting, remains. This reduces the amount of Ti and V involved in the formation of fine precipitates having a size of less than 20 nm required for the advantages of the present invention. A target amount of precipitates having a size of less than 20 nm cannot therefore be obtained in coiling described below. In a method for manufacturing a steel sheet according to the present invention, most desirably, carbide containing Ti or V remains dissolved during slab heating and finish rolling, and is precipitated as fine carbide containing Ti or V during coiling after finish rolling. The heating temperature is therefore more preferably 1170°C or more so that carbide can be dissolved almost completely.

[0057] However, heating at a temperature above 1350°C excessively increases the crystal grain size, lowering stretch flangeability and elongation after working. Taking subsequent heat-treatment conditions into consideration, an increase in crystal grain size can be almost completely prevented at a heating temperature of 1300°C or less.

[0058] Thus, the slab heating temperature preferably ranges from 1150°C to 1350°C, more preferably 1170°C to 1300°C.

Finish-Rolling Temperature in Hot Rolling: 850°C to 1100°C

[0059] The control of finish-rolling temperature is important in ensuring the Ti content and the V content of precipitates having a size of less than 20 nm according to the present invention. Preferably, a steel slab after working is hot-rolled at a finish-rolling temperature in the range of 850°C to 1100°C, which is the final temperature of hot rolling. At a finish-rolling temperature below 850°C, a steel slab is rolled in a ferrite + austenite region and has an elongated ferrite phase. This may lower stretch flangeability or elongation after working. Even if a steel slab is heated at a temperature of 1150°C or more to temporarily dissolve a carbide precipitate before rolling, carbide containing Ti or V is precipitated at a finish-rolling temperature below 850°C because of strain-induced precipitation. This reduces the amount of Ti and V involved in the formation of fine precipitates having a size of less than 20 nm required for the advantages of the present invention. A target amount of precipitates having a size of less than 20 nm cannot therefore be obtained in coiling described below. Thus, it is important to perform the subsequent coiling process while carbide containing Ti or V temporarily dissolved during the slab heating described above remains dissolved in finish rolling as much as possible. The finish-rolling temperature is more preferably 935°C or more such that carbide remains dissolved.

[0060] A finish-rolling temperature above 1100°C may result in coarsening of ferrite particles and a TS below 780 MPa. The finish-rolling temperature is more preferably 990°C or less to prevent coarsening of ferrite particles.

[0061] Thus, the finish-rolling temperature preferably ranges from 850°C to 1100°C, more preferably 935°C to 990°C.

Coiling Temperature: 500°C to 700°C

[0062] The control of coiling temperature is important in ensuring the Ti content and the V content of precipitates having a size of less than 20 nm in the present invention. As described above, this is because, in the most desirable manufacturing form, this coiling process yields a large number of precipitation sites from which carbide is precipitated, thus preventing carbide grains from growing to 20 nm or more. The coiling temperature preferably ranges from 500°C to 700°C so that steel has a substantially ferritic single phase and the characteristics of the present invention can be achieved.

[0063] In the present invention, a coiling temperature below 500°C may result in an insufficient amount of precipitated carbide containing Ti and/or V and reduced strength. Furthermore, a bainite phase may be formed in place of a ferritic single phase.

[0064] To form a large number of precipitation sites and produce carbide from these precipitation sites, the coiling temperature is preferably 500°C or more, more preferably 550°C or more.

[0065] A coiling temperature above 700°C may result in coarsening of precipitated carbide and reduced strength. A coiling temperature above 700°C may also promote the formation of a pearlite phase, lowering stretch flangeability after working. The coiling temperature is more preferably 650°C or less to prevent coarsening of precipitated carbide without fail.

[0066] Thus, the coiling temperature preferably ranges from 500°C to 700°C, more preferably 550°C to 650°C.

[0067] Steel sheets according to the present invention include surface-treated steel sheets and surface-coated steel sheets. In particular, a steel sheet according to the present invention may be subjected to hot-dip galvanizing to form a galvanized steel sheet, and the present invention can be suitably applied to such a galvanized steel sheet. Because a steel sheet according to the present invention has excellent workability, such a galvanized steel sheet can also have excellent workability. Hot-dip galvanizing is zinc and zinc-based (approximately 90% or more) hot dipping and includes hot dipping including an alloying element, such as Al or Cr, as well as zinc. Hot-dip galvanizing may be performed alone or followed by alloying.

[0068] A steel melting method is not particularly limited, and any known melting method may be suitable. For example, a suitable melting method involves melting in a converter or an electric furnace and secondary refining in a vacuum degassing furnace. A casting method is preferably continuous casting in terms of productivity and quality. After casting, hot direct rolling may be performed immediately or after concurrent heating, without compromising the advantages of the present invention. Furthermore, a hot-rolled material may be heated after rough rolling and before finish rolling, continuous hot rolling in which rolled materials are joined may be performed after rough rolling, or heating and continuous rolling of a heating material of a rolled material may be performed simultaneously. These do not compromise the advantages of the present invention.

EXAMPLES

EXAMPLE 1

[0069] Steel having a composition shown in Table 1 was melted in a converter and was formed into a steel slab by continuous casting. The steel slab was subjected to heating, hot rolling, and coiling under conditions shown in Table 2 to form a hot-rolled steel sheet having a thickness of 2.0 mm.

Table 1

Type of steel	Composition (mass%)								Note
	C	Si	Mn	P	S	Al	Ti	V	
A	0.040	0.01	1.45	0.01	0.0015	0.03	0.105	0.120	Conforming steel
B	0.120	0.02	1.20	0.02	0.0008	0.03	0.240	0.100	Conforming steel
C	0.100	0.02	1.20	0.01	0.0080	0.03	0.110	0.245	Conforming steel
D	0.150	0.02	1.40	0.03	0.0020	0.03	0.230	0.224	Conforming steel
E	0.050	0.01	2.02	0.01	0.0020	0.03	0.120	0.120	Conforming steel
F	0.050	0.01	0.65	0.01	0.0015	0.03	0.110	0.136	Conforming steel
G	0.045	0.02	1.34	0.02	0.0007	0.02	0.060	0.110	Conforming steel
H	0.050	0.02	1.30	0.01	0.0008	0.02	0.110	0.052	Conforming steel
I	0.030	0.01	1.32	0.01	0.0007	0.02	0.080	0.070	Conforming steel
J	0.040	0.01	1.40	0.02	0.0015	0.03	0.126	0.152	Conforming steel
K	0.250	0.01	1.20	0.02	0.0020	0.03	0.120	0.130	Nonconforming
L	0.001	0.01	1.19	0.02	0.0020	0.03	0.120	0.130	Nonconforming
M	0.080	0.50	1.30	0.01	0.0012	0.03	0.070	0.070	Nonconforming
N	0.050	0.01	0.35	0.02	0.0015	0.03	0.080	0.080	Nonconforming
O	0.050	0.01	3.00	0.02	0.0014	0.03	0.080	0.080	Nonconforming
P	0.150	0.01	1.60	0.02	0.0015	0.03	0.040	0.120	Nonconforming
Q	0.160	0.01	1.60	0.02	0.0016	0.02	0.070	0.032	Nonconforming
R	0.152	0.01	1.62	0.02	0.0015	0.03	0.280	0.120	Nonconforming
S	0.161	0.01	1.61	0.02	0.0014	0.03	0.150	0.300	Nonconforming
X	0.090	0.06	1.35	0.04	0.0014	0.05	0.150	0.160	Conforming steel

[0070] The microstructure of the hot-rolled steel sheet was analyzed by the following method to determine the Ti content and the V content of precipitates having a size of less than 20 nm and the amount of V in solid solution. The tensile strength TS, the stretch flangeability after working λ_{10}, and the corrosion resistance after painting (SDT one-side maximum peel width) were measured.

Analysis of Microstructure

[0071] The hot-rolled steel sheet thus formed was cut into an appropriate size. Approximately 0.2 g of hot-rolled steel sheet was subjected to constant-current electrolysis at an electric current density of 20 mA/cm^2 in 10% AA electrolyte (10% by volume acetylacetone-1% by mass tetramethylammonium chloride-methanol).

Measurement of the Ti Content and the V Content of Precipitates Having a Size of Less Than 20 nm

[0072] After electrolysis, a test piece on which a precipitate was deposited was removed from the electrolyte and was immersed in aqueous sodium hexametaphosphate (500 mg/l) (hereinafter referred to as aqueous SHMP). Ultrasonic vibration was applied to the test piece to detach and extract the precipitate from the test piece in aqueous SHMP. The aqueous SHMP containing the precipitate was then passed through a filter having a pore size of 20 nm. The filtrate was analyzed with an ICP spectrometer to measure the absolute amounts of Ti and V in the filtrate. The absolute amounts of Ti and V were divided by the weight of the electrolyzed sample to calculate the Ti content and the V content of precipitates having a size of less than 20 nm. The weight of electrolyzed sample was calculated by subtracting the sample weight after the detachment of the precipitate from the sample weight before electrolysis.

Measurement of the Amount of V in Solid Solution

[0073] After electrolysis, the concentrations of V and a comparative element Fe in the electrolyte were measured by ICP mass spectrometry. On the basis of the concentrations thus measured, the ratio of the concentration of V to the concentration of Fe was calculated. The ratio was multiplied by the Fe content of the sample to calculate the amount of V in solid solution. The Fe content of the sample can be calculated by subtracting the summation of compositions other than Fe from 100%.

TS

[0074] A tensile test according to JIS Z 2241 was performed with a JIS No. 5 specimen in the tensile direction parallel to the rolling direction to measure TS.

Stretch flangeability after Working: λ_{10}

[0075] After rolling at an elongation percentage of 10%, a hole expanding test according to the Japan Iron and Steel Federation Standard JFS T 1001 was performed to measure λ_{10}. Corrosion Resistance after Painting: SDT One-Side Maximum Peel Width

[0076] A chemical conversion treatment was performed under more adverse temperature and concentration conditions than the standard conditions using a degreasing agent, Surfcleaner EC090, a surface conditioner, Surffine 5N-10, and a chemical conversion treatment agent, Surfdine SD2800, all manufactured by Nippon Paint Co., Ltd. As an example of standard conditions, a degreasing process included a concentration of 16 g/l, a treatment temperature in the range of 42°C to 44°C, a treatment time of 120 s, and spray degreasing, and a surface conditioning process included a total alkalinity in the range of 1.5 to 2.5 points, a free acidity in the range of 0.7 to 0.9 points, an accelerator concentration in the range of 2.8 to 3.5 points, a treatment temperature of 44°C, and a treatment time of 120 s. Under adverse conditions, a treatment temperature in a chemical conversion treatment process was decreased to 38°C. Subsequently, electrodeposition coating was performed using an electrodeposition paint, V-50, manufactured by Nippon Paint Co., Ltd. The target amount of deposited chemical conversion film ranged from 2 to 2.5 g/m^2, and the target film thickness in electrodeposition coating was 25 μm.

[0077] Corrosion resistance after painting was determined in a warm salt water immersion test (SDT). A crosscut was formed with a cutter in a sample subjected to chemical conversion treatment and electrodeposition coating. The sample was immersed in warm salt water (5% NaCl at 55°C) for 10 days, was then washed with water, and was dried. Tape peeling on the crosscut was performed to measure the maximum peel width on the left and right sides of the crosscut. A one-side maximum peel width of 3.0 mm or less was considered as high corrosion resistance after painting.

[0078] Table 2 shows the results, together with manufacturing conditions.

Table 2

No	Type of steel	Slab heating temperature (°C)	Finish-rolling temperature (°C)	Coiling temperature (°C)	TS (MPa)	Elongation after prestraining (%)	Stretch flangeability after working: λ_{10} (%)	Precipitated Ti content for <20 nm (mass ppm)	Precipitated V content for <20 nm (mass ppm)	Amount of V in solid solution (mass ppm)	One-side maximum peel width (mm)	Phase	Note
1	A	1250	920	630	812	20	87	752	818	340	1.7	Ferrite: 100%	Example
2	B	1300	926	632	952	18	79	1580	765	231	2.5	Ferrite: 100%	Example
3	C	1270	911	650	966	17	81	703	1700	380	2.2	Ferrite: 100%	Example
4	C	1270	900	580	865	17	95	635	657	1350	1.2	Ferrite: 99%, Remainder: Cementite 1%	Example
5	D	1270	917	603	1190	16	61	1700	1682	213	2.2	Ferrite: 98%, Remainder: Bainite 2%	Example
6	E	1250	921	611	940	18	92	808	658	476	1.2	Ferrite: 100%	Example
7	F	1250	900	590	834	20	98	727	735	540	1.4	Ferrite: 100%	Example
8	G	1250	918	670	815	19	82	230	450	420	1.4	Ferrite: 100%	Example
9	H	1250	920	580	802	18	93	352	167	272	1.2	Ferrite: 100%	Example

(continued)

No	Type of steel	Slab heating temperature (°C)	Finish-rolling temperature (°C)	Coiling temperature (°C)	TS (MPa)	Elongation after prestraining (%)	Stretch flangeability after working: λ_{10} (%)	Precipitated Ti content for <20 nm (mass ppm)	Precipitated V content for <20 nm (mass ppm)	Amount of V in solid solution (mass ppm)	One-side maximum peel width (mm)	Phase	Note
10	I	1160	905	625	785	22	97	532	372	306	1.2	Ferrite: 100%	Example
11	J	1250	920	630	936	18	83	863	1129	274	2.0	Ferrite: 100%	Example
12	A	1250	920	480	760	19	63	150	121	934	2.0	Ferrite: 100%	Comparative Example
13	G	1250	920	720	765	18	90	220	98	330	5.2	Ferrite: 100%	Comparative Example
14	G	1250	915	750	760	15	78	140	80	908	5.1	Ferrite: 100%	Comparative Example
15	K	1250	923	590	851	20	45	821	702	568	0.8	Ferrite: 90%, Remainder: Pearlite 10%	Comparative Example
16	L	1250	918	585	659	25	60	50	45	568	1.1	Ferrite: 100%	Comparative Example
17	M	1250	918	595	850	17	40	480	353	330	0.8	Ferrite: 92%, Remainder: Cementite 8%	Comparative Example
18	N	1250	920	575	765	18	75	560	540	247	1.0	Ferrite: 100%	Comparative Example

(continued)

No	Type of steel	Slab heating temperature (°C)	Finish-rolling temperature (°C)	Coiling temperature (°C)	TS (MPa)	Elongation after prestraining (%)	Stretch flangeability after working: λ_{10} (%)	Precipitated Ti content for <20 nm (mass ppm)	Precipitated V content for <20 nm (mass ppm)	Amount of V in solid solution (mass ppm)	One-side maximum peel width (mm)	Phase	Note
19	O	1250	916	565	851	14	43	560	432	350	1.1	Ferrite: 100%	Comparative Example
20	P	1160	921	575	653	23	75	180	324	832	1.2	Ferrite: 100%	Comparative Example
21	Q	1160	922	650	765	16	73	490	14	223	1.2	Ferrite: 100%	Comparative Example
22	Q	1160	920	510	782	16	50	502	220	90	1.1	Ferrite: 100%	Comparative Example
23	R	1250	910	605	1280	13	93	2065	602	580	5.5	Ferrite: 100%	Comparative Example
24	S	1250	900	610	1290	14	91	971	1890	530	5.3	Ferrite: 100%	Comparative Example
29	A	1250	935	600	825	19	70	800	825	340	2.0	Ferrite: 100%	Example
30	A	1260	980	580	820	19	68	802	830	355	2.1	Ferrite: 100%	Example
31	A	1260	1020	630	826	18	73	801	824	349	2.1	Ferrite: 100%	Example
32	J	1260	940	620	982	17	63	923	1120	270	2.6	Ferrite: 100%	Example
33	C	1260	960	600	983	17	65	812	1702	375	2.5	Ferrite: 100%	Example
34	X	1300	965	600	1005	16	62	1205	1108	305	2.8	Ferrite: 100%	Example

[0079] Table 2 shows that the working examples had a TS of 780 MPa or more, λ_{10} of 60% or more, and an SDT one-side maximum peel width of 3.0 mm or less, indicating that the hot-rolled steel sheets had high stretch flangeability after working and corrosion resistance after painting.

[0080] In contrast, the comparative examples had a low TS (strength), small λ_{10} (stretch flangeability after working), and/or a large SDT one-side maximum peel width (corrosion resistance after painting).

EXAMPLE 2

[0081] Steel having a composition shown in Table 3 was melted in a converter and was formed into a steel slab by continuous casting. The steel slab was subjected to heating, hot rolling, and coiling under conditions shown in Table 4 to form a hot-rolled steel sheet having a thickness of 2.0 mm.

Table 3

Type of steel	Composition (mass%)											Note
	C	Si	Mn	P	S	Al	Ti	V	Cr	W	Zr	
T	0.040	0.01	1.40	0.01	0.0014	0.03	0.100	0.115	0.10	-	-	Conforming steel
U	0.040	0.02	1.43	0.01	0.0015	0.03	0.104	0.105	-	0.150	-	Conforming steel
V	0.041	0.01	1.42	0.01	0.0014	0.03	0.102	0.105	-	-	0.0030	Conforming steel
W	0.040	0.02	1.40	0.01	0.0014	0.03	0.101	0.115	0.20	0.140	0.0050	Conforming steel

[0082] In the same way as in Example 1 the microstructure of the hot-rolled steel sheet thus formed was analyzed to determine the Ti content and the V content of precipitates having a size of less than 20 nm and the amount of V in solid solution. In the same way as in Example 1, the tensile strength TS, the stretch flangeability after working λ_{10}, and the corrosion resistance after painting (SDT one-side maximum peel width) were measured.

[0083] Table 4 shows the results.

Table 4

No	Type of steel	Slab heating temperature (°C)	Finish-rolling temperature (°C)	Coiling temperature (°C)	TS (MPa)	Elongation after prestraining (%)	Stretch flangeability after working: λ_{10}(%)	Precipitated Ti content for <20 nm (mass ppm)	Precipitated V content for <20 nm (mass ppm)	Amount of V in solid solution (mass ppm)	One-side maximum peel width (mm)	Phase	Note
25	T	1250	921	625	832	17	99	750	815	250	2.5	Ferrite: 100%	Example
26	U	1250	918	620	830	18	90	753	760	252	2.2	Ferrite: 100%	Example
27	V	1250	920	621	829	17	93	753	770	250	2.0	Ferrite: 100%	Example
28	W	1250	921	620	842	18	98	760	823	251	2.6	Ferrite: 100%	Example
35	T	1250	940	600	835	18	92	780	820	240	2.2	Ferrite: 100%	Example
36	T	1270	960	630	840	17	93	782	823	244	2.1	Ferrite: 100%	Example
37	T	1300	980	620	837	18	95	788	830	245	2.3	Ferrite: 100%	Example

[0084] Table 4 shows that the working examples had a TS of 780 MPa or more, λ_{10} of 60% or more, and an SDT one-side maximum peel width of 3.0 mm or less, indicating that the hot-rolled steel sheets had high stretch flangeability after working and corrosion resistance after painting.

[0085] As compared with the steel sheet No. 1 (Table 2), the steel sheets Nos. 25 to 28 and 35 to 37, which further contained Cr, W, or Zr, had an improved TS.

Industrial Applicability

[0086] A steel sheet according to the present invention had high strength, high stretch flangeability after working, and high corrosion resistance after painting, and is therefore most suitable for, for example, automobile and truck frames, and components that require elongation and stretch flangeability.

Claims

1. A high-strength steel sheet comprising, on the basis of mass percent, C: 0.02% to 0.20%, Si: 0.3% or less, Mn: 0.5% to 2.5%, P: 0.06% or less, S: 0.01% or less, Al: 0.1% or less, Ti: 0.05% to 0.25%, and V: 0.05% to 0.25%, the remainder being Fe and incidental impurities, wherein the steel sheet has a substantially ferritic single phase, the ferritic single phase containing precipitates having a size of less than 20 nm, the precipitates containing 200 to 1750 mass ppm Ti and 150 to 1750 mass ppm V, V dissolved in solid solution being 200 or more but less than 1750 mass ppm.

2. The high-strength steel sheet according to Claim 1,
wherein the steel sheet further comprises, on the basis of mass percent, any one or two or more of Cr: 0.01% to 0.5%, W: 0.005% to 0.2%, and Zr: 0.0005% to 0.05%.

3. The high-strength steel sheet according to Claim 1 or 2, wherein the steel sheet has a tensile strength TS of 780 MPa or more.

4. The high-strength steel sheet according to Claim 1 or 2, wherein the steel sheet has a one-side maximum peel width of 3.0 mm or less after a tape peel test in a warm salt water immersion test.

5. The high-strength steel sheet according to Claim 3,
wherein the steel sheet has a one-side maximum peel width of 3.0 mm or less after a tape peel test in a warm salt water immersion test.

6. The high-strength steel sheet according to Claim 1 or 2,
wherein the steel sheet has a stretch flangeability λ_{10} of 60% or more after rolling at an elongation percentage of 10%.

7. The high-strength steel sheet according to Claim 3,
wherein the steel sheet has a stretch flangeability λ_{10} of 60% or more after rolling at an elongation percentage of 10%.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/064175

A. CLASSIFICATION OF SUBJECT MATTER
C22C38/14(2006.01)i, *C22C38/38*(2006.01)i, *C21D8/02*(2006.01)n, *C21D9/46*(2006.01)n

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22C38/00-38/60, C21D8/00-8/04, C21D9/46-9/48

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 1996-2008
Kokai Jitsuyo Shinan Koho 1971-2008 Toroku Jitsuyo Shinan Koho 1994-2008

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2007-70647 A (Nippon Steel Corp.), 22 March, 2007 (22.03.07), Claims; tables 1 to 3 (Family: none)	1-7
A	JP 2005-120430 A (JFE Steel Corp.), 12 May, 2005 (12.05.05), Claims; Par. Nos. [0060] to [0063], [0072]; tables 2, 3 (Family: none)	1-7
A	JP 2002-161340 A (Nippon Steel Corp.), 04 June, 2002 (04.06.02), Claims; Par. Nos. [0040], [0041]; tables 1, 2 (Family: none)	1-7

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 October, 2008 (28.10.08)	11 November, 2008 (11.11.08)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/064175

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	JP 2007-247049 A (Nippon Steel Corp.), 27 September, 2007 (27.09.07), Claims; Par. Nos. [0086] to [0089]; tables 1, 2 (Family: none)	1-7
P,A	JP 2007-231352 A (JFE Steel Corp.), 13 September, 2007 (13.09.07), Claims; tables 1 to 3 (Family: none)	1-7

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

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