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(54) COLD-ROLLED STEEL SHEET, GALVANIZED COLD-ROLLED STEEL SHEET, AND METHOD FOR MANUFACTURING THE SAME

KALTGEWALZTES STAHLBLECH, GALVANISIERTES KALTGEWALZTES STAHLBLECH UND VERFAHREN ZUR HERSTELLUNG DAVON

TÔLE D’ACIER LAMINÉE À FROID, TÔLE D’ACIER LAMINÉE À FROID ET GALVANISÉE, ET PROCÉDÉ DE FABRICATION DE CELLE-CI

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Description

TECHNICAL FIELD

[0001] The present invention relates to a cold-rolled steel sheet and a galvanized cold-rolled steel sheet excellent in press formability, and a method of manufacturing the same.

BACKGROUND ART

[0002] Various steel sheets are used for a vehicle, and a steel sheet with strength over 980 MPa is used for framework components. This is to enable reduction in weight of a vehicle body to improve mileage of a vehicle while securing collision safety. Improvement in strength is required also for a steel sheet for panel components to enable both the reduction in weight of the vehicle body and the collision safety, and press formability is very important for the steel sheet for panel components depending on usage thereof.

[0003] For example, an ultralow carbon steel sheet where Ti and Nb are added is used for outer plate components where the press formability is required, and in particular, a BH (bake hardening) steel sheet is used for an outer plate panel of a door to supply a dent resistance property. Further, a steel sheet with a low yield strength is used from a viewpoint of avoiding a plane defect called as a surface strain, which occurs in press forming. As stated above, high strength as same as the framework component is not required and high ductility as same as a mild steel sheet is required due to restrictions such as the surface strain generated in press forming as for the steel sheet used for a complicated shaped component such as an inner plate or the outer plate component even for the steel sheet for the panel component.

[0004] A TRIP (transformation-induced plasticity) steel sheet where a transformation-induced plasticity effect is used is known as a steel sheet including ductility and high-strength. For example, a high-strength hot-dip galvanized steel sheet for outer plate and a method of manufacturing the same are disclosed in Patent Literature 1.

[0005] However, it is difficult for a conventional TRIP steel sheet including a steel sheet disclosed in Patent Literature 1 to obtain more excellent ductility and hole expandability while obtaining strength of 380 MPa to 630 MPa, which is suitable for a panel component. Various steel sheets are also disclosed in Patent Literatures 2 to 5, but it is difficult to obtain the more excellent ductility and hole expandability while obtaining the strength of 380 MPa to 630 MPa. Patent Literature 6 discloses a steel plate excellent in shape freezing property and Patent Literature 7 discloses a transformation-induced plastic plated steel sheet excellent in ductility.

CITATION LIST

PATENT LITERATURE

[0006]

Patent Literature 1: Japanese Laid-open Patent Publication No. 2012-117148
Patent Literature 2: Japanese Laid-open Patent Publication No. 2005-8961
Patent Literature 3: International Publication No. 2011/148490
Patent Literature 4: Japanese Laid-open Patent Publication No. 2000-290745
Patent Literature 5: Japanese Laid-open Patent Publication No. 2009-249676
Patent Literature 6: US 2003/196735 A1
Patent Literature 7: JP 2001/355041 A

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0007] An object of the present invention is to provide a cold-rolled steel sheet and a galvanized cold-rolled steel sheet capable of obtaining excellent ductility and hole expandability while having appropriate strength, and a method of manufacturing the same.

SOLUTION TO PROBLEM

[0008] The present inventors came up to various modes of the invention described below by the repeated various hard studies for solving the problems.

(1) A cold-rolled steel sheet, including:

a chemical composition expressed by, in mass%:

Si: 0.01% to 0.50%;
Mn or Cr, or both thereof: 0.70% to 1.50% in total;
C: 0.030% to 0.060% when Cr: "0" (zero)% or more and less than 0.30%,
0.030% to 0.080% when Cr: 0.30% or more and 1.50% or less;
Al: 0.800% to 2.000%;
P: 0.030% or less;
S: 0.0100% or less;
Mo: 0.10% to 0.50%;
O: 0.0070% or less;
N: 0.0070% or less;
B: "0" (zero)% to 0.0020%;
Ti: "0" (zero)% to 0.050%;
Nb: "0" (zero)% to 0.050%;
V: "0" (zero)% to 0.050%;
Ni: "0" (zero)% to 1.00%;
Cu: "0" (zero)% to 1.00%;
Ca or REM, or both thereof: "0" (zero)% to 0.0300% in total;
W: "0" (zero)% to 1.000%;
Mg: "0" (zero)% to 0.010%;
Zr: "0" (zero)% to 0.200%;
As: "0" (zero)% to 0.500%;
Co: "0" (zero)% to 1.000%;
Sn: "0" (zero)% to 0.200%;
Pb: "0" (zero)% to 0.200%;
Y: "0" (zero)% to 0.200%;
Hf: "0" (zero)% to 0.2000%; and
the balance: Fe and impurities; and

a structure expressed by:

an area fraction of ferrite: 95% or more;
an area fraction of retained austenite and an area fraction of martensite: 1% to 3% in total;
a product of the area fraction of retained austenite and a carbon concentration in retained austenite: 1 or more;
a value of I(111)/{I(100) + I(110)} at a region where a depth from a surface is 1/4 of a thickness of the cold-rolled steel sheet when intensity of a (hkl) plane is expressed by I(hkl): 2 or less;
a quotient ($V_B/V_{\gamma R}$) where an area fraction of bainite (V_B) is divided by the area fraction of retained austenite ($V_{\gamma R}$) : 0.6 or less.

(2) The cold-rolled steel sheet according to (1), wherein the chemical composition satisfies:

Cr: 0.30% to 0.80%; or
Mn: 0.40% to 1.00%; or

both thereof.

(3) The cold-rolled steel sheet according to (1) or (2), wherein the chemical composition satisfies:

B: 0.0003% to 0.0020%;
Ti: 0.005% to 0.050%;
Nb: 0.005% to 0.050%; or
V: 0.005% to 0.050%; or

any combination thereof.

(4) The cold-rolled steel sheet according to any one of (1) to (3), wherein the chemical composition satisfies:

Ni: 0.01% to 1.00%; or
Cu: 0.01% to 1.00%; or

both thereof.

(5) The cold-rolled steel sheet according to any one of (1) to (4), wherein the chemical composition satisfies Ca or REM, or both thereof: 0.0005% to 0.0300% in total.

(6) The cold-rolled steel sheet according to any one of (1) to (5), wherein the chemical composition satisfies:

W: 0.001% to 1.000%;
Mg: 0.0001% to 0.010%;
Zr: 0.0001% to 0.200%;
As: 0.0001% to 0.500%;
Co: 0.0001% to 1.000%;
Sn: 0.0001% to 0.200%;
Pb: 0.0001% to 0.200%;
Y: 0.0001% to 0.200%; or
Hf: 0.0001% to 0.2000%; or

any combination thereof.

(7) A galvanized cold-rolled steel sheet, including:

the cold-rolled steel sheet according to any one of (1) to (6); and
a hot-dip galvanized layer or an alloyed hot-dip galvanized layer on a surface of the cold-rolled steel sheet.

(8) A method of manufacturing a cold-rolled
performing hot-rolling of a slab heated to a temperature of 1250°C or less to obtain a hot-rolled sheet;
coiling the hot-rolled sheet at a temperature of 650°C or less;
then, performing cold-rolling of the hot-rolled sheet with a reduction ratio of 70% or more to obtain a cold-rolled sheet; and
performing continuous annealing of the cold-rolled sheet at a temperature of 750°C to 900°C,
wherein
the performing the hot-rolling includes performing finish-rolling at a temperature of 850°C to 1000°C under a state in which two phases of ferrite and austenite exist,
a total reduction ratio at last three stands is 60% or more in the finish-rolling,
cooling is started within one second from an end of the finish-rolling, and
the slab includes a chemical composition expressed by, in mass%,

Si: 0.01% to 0.50%;
Mn or Cr, or both thereof: 0.70% to 1.50% in total;
C: 0.030% to 0.060% when Cr: "0" (zero)% or more and less than 0.30%,
0.030% to 0.080% when Cr: 0.30% or more and 1.50% or less;
Al: 0.800% to 2.000%;
P: 0.030% or less;
S: 0.0100% or less;
Mo: 0.10% to 0.50%;
O: 0.0070% or less;
N: 0.0070% or less;
B: "0" (zero)% to 0.0020%;
Ti: "0" (zero)% to 0.050%;
Nb: "0" (zero)% to 0.050%;
V: "0" (zero)% to 0.050%;
Ni: "0" (zero)% to 1.00%;
Cu: "0" (zero)% to 1.00%;

Ca or REM, or both of them: "0" (zero)% to 0.0300% in total;
W: "0" (zero)% to 1.000%;
Mg: "0" (zero)% to 0.010%;
Zr: "0" (zero)% to 0.200%;
As: "0" (zero)% to 0.500%;
Co: "0" (zero)% to 1.000%;
Sn: "0" (zero)% to 0.200%;
Pb: "0" (zero)% to 0.200%;
Y: "0" (zero)% to 0.200%;
Hf: "0" (zero)% to 0.2000%; and

the balance: Fe and impurities.

(9) The method of manufacturing the cold-rolled steel sheet according to (8), wherein in the chemical composition satisfies:

Cr: 0.30% to 0.80%; or
Mn: 0.40% to 1.00%; or

both thereof.

(10) The method of manufacturing the cold-rolled steel sheet according to (8) or (9), wherein the chemical composition satisfies:

B: 0.0003% to 0.0020%;
Ti: 0.005% to 0.050%;
Nb: 0.005% to 0.050%; or
V: 0.005% to 0.050%; or

any combination thereof.

(11) The method of manufacturing the cold-rolled steel sheet according to any one of (8) to (10), wherein the chemical composition satisfies:

Ni: 0.01% to 1.00%; or
Cu: 0.01% to 1.00%; or

both thereof.

(12) The method of manufacturing the cold-rolled steel sheet according to any one of (8) to (11), wherein the chemical composition satisfies
Ca or REM, or both thereof: 0.0005% to 0.0300% in total.

(13) The method of manufacturing the cold-rolled steel sheet according to any one of (8) to (12), wherein the chemical composition satisfies:

W: 0.001% to 1.000%;
Mg: 0.0001% to 0.010%;
Zr: 0.0001% to 0.200%;
As: 0.0001% to 0.500%;
Co: 0.0001% to 1.000%;
Sn: 0.0001% to 0.200%;
Pb: 0.0001% to 0.200%;
Y: 0.0001% to 0.200%; or
Hf: 0.0001% to 0.2000%; or

any combination thereof.

(14) A method of manufacturing a galvanized cold-rolled steel sheet, including:

manufacturing a cold-rolled steel sheet by the method according to any one of (8) to (13); and
forming a hot-dip galvanized layer or an alloyed hot-dip galvanized layer on a surface of the cold-rolled steel sheet.

ADVANTAGEOUS EFFECTS OF INVENTION

[0009] According to the present invention, it is possible to obtain excellent ductility and hole expandability while having an appropriate strength. Besides, improvement in deep drawability can be expected owing to a TRIP effect.

DESCRIPTION OF EMBODIMENTS

[0010] Hereinafter, embodiments of the present invention are described.

[0011] First, a structure of a cold-rolled steel sheet according to the embodiment is described. The cold-rolled steel sheet according to the embodiment includes a structure expressed by: an area fraction of ferrite (V_F): 95% or more, an area fraction of retained austenite ($V_{\gamma R}$) and an area fraction of martensite (V_M): 1% to 3% in total, a product of the area fraction of retained austenite ($V_{\gamma R}$) and a carbon concentration in retained austenite ($C_{\gamma R}$): 1 or more, a value of I(111)/{I(100) + I(110)} at a region where a depth from a surface is 1/4 of a thickness of the cold-rolled steel sheet when intensity of a (hkl) plane is expressed by I(hkl): 2 or less.

(Area Fraction of Ferrite (V_F (%)): 95% or more)

[0012] Ferrite exhibits excellent deformability, and improves ductility. When the area fraction of ferrite is less than 95%, sufficient ductility cannot be obtained. Accordingly, the area fraction of ferrite is 95% or more.

(Area Fraction of Retained Austenite ($V_{\gamma R}$ (%)) and Area Fraction of Martensite (V_M (%)): 1% to 3% in total)

[0013] Retained austenite and martensite contribute to secure strength. When a sum of the area fraction of retained austenite and the area fraction of martensite is less than 1%, sufficient strength cannot be obtained. When the sum of the area fraction of retained austenite and the area fraction of martensite is over 3%, sufficient hole expandability cannot be obtained. Therefore, the area fraction of retained austenite and the area fraction of martensite are 1% to 3% in total.

(Product of Area Fraction of Retained Austenite ($V_{\gamma R}$ (%)) and Carbon Concentration in Retained Austenite ($C_{\gamma R}$ (mass%)): 1 or more)

[0014] Characteristics of retained austenite are largely affected by the carbon concentration in the retained austenite itself. When the product of the area fraction of retained austenite and the carbon concentration in retained austenite ($V_{\gamma R} \times C_{\gamma R}$) is less than 1, the sufficient ductility, for example, elongation of 40% or more cannot be obtained. Accordingly, the product of the area fraction of retained austenite and the carbon concentration in retained austenite is 1 or more.

(Value of I(111)/{I(100) + I(110)} at Region where Depth from Surface is 1/4 of Thickness of Cold-Rolled Steel Sheet: 2 or less)

[0015] The value of I(111)/{I(100) + I(110)}, namely, a plane intensity ratio is reflected by a form of a texture of ferrite. When the plane intensity ratio at the region where the depth from the surface is 1/4 of the thickness of the cold-rolled steel sheet (sheet thickness 1/4t part) is over 2, in-plane anisotropy is too large, and therefore, the sufficient hole expandability cannot be obtained. The plane intensity ratio at the sheet thickness 1/4t part is preferably 1 or less. Intensity of an (hkl) plane (I(hkl)) may be obtained by an electron backscattered diffraction pattern (EBSD) method using a field emission scanning electron microscope (FESEM) or an X-ray diffractometry. Namely, it is possible to grasp the characteristics of the texture of ferrite with the FESEM-EBSD method or the X-ray diffractometry. Intensity of a (111) plane, intensity of a (100) plane, and intensity of a (110) plane were found by the FESEM-EBSD method in examples described later.

[0016] Identification of ferrite, retained austenite, martensite, and bainite, confirmation of positions thereof, and measurement of area fractions thereof may be performed by observing a cross section in parallel with the rolling direction and the thickness direction, or a cross section orthogonal to the rolling direction. Observation of a cross-section may be performed by, for example, etching the cross-section with a Nital reagent, and observing it at a magnification of 1000 times to 100000 times with a scanning electron microscope (SEM) or a transmission electron microscope (TEM). Other etchants may be used instated of the Nital reagent. An example of usable etchant is described in Japanese Laid-open

Patent Publication No. 59-219473. The etchant described in Japanese Laid-open Patent Publication No. 59-219473 is "a color etching solution characterized by consisting of a pretreatment solution and a post-treatment solution, in which the pretreatment solution is prepared by mixing a solution A in which 1 to 5 g of picric acid is dissolved into 100 mL of ethanol, with a solution B in which 1 to 25 g of sodium thiosulfate and 1 to 5 g of citric acid are dissolved into 100 mL of water, in a proportion of 1 : 1, and thereafter adding 1.5 to 4% of nitric acid to the solution, and the post-treatment solution is prepared by mixing 10% of the pretreating solution with a 2% Nital solution, or mixing 2 to 5% of nitric acid with 100ml of ethanol." Crystal orientation analysis may also be performed by the EBSD method using FESEM to identify structures, confirm positions thereof, and measure area fractions thereof.

[0017] The area fraction of martensite (V_M), the area fraction of ferrite (V_F), the area fraction of retained austenite ($V_{\gamma R}$), and the area fraction of bainite (V_B) may also be measured as described below. For example, a sample is taken which has a cross-section in parallel with the rolling direction and the thickness direction of a steel sheet as an observation surface, the observation surface is electropolished, a portion of the steel sheet at a depth of 1/8 to 3/8 thickness thereof from the surface is observed with an FESEM, and the area fraction is measured by the EBSD method. In such an occasion, each measurement is performed at a magnification of 5000 times in 10 visual fields, the area fraction is assumed to be an average value thereof. "OIM-Analysis 5" manufactured by TSL solutions Co., Ltd. may be used for the analysis.

[0018] Effects of the embodiment may be obtained, even if bainite and pearlite are contained as long as a sum of area fractions of these is less than 1%.

[0019] The carbon concentration ($C_{\gamma R}$) in retained austenite may be specified as described below. First, a lattice constant is found from a midpoint of full width at half maximum of a plane intensity as for each of a (200) plane, a (220) plane, and a (311) plane of retained austenite by the X-ray diffraction whose target is Fe. An average value of these lattice constants is defined as a lattice constant (a_0) of austenite, and the carbon concentration ($C_{\gamma R}$) is calculated from the following expression 1. In the expression 1, "%Al" is an Al content of the cold-rolled steel sheet, and a coefficient (0.0087) thereof is a value found from Table 1 in a document (C. M. Chu et.al.:Scr. Metal. et Mater., Vol.30, p.505-508) by the multiple regression.

$$a_0 = 3.572 + 0.033 \times (C_{\gamma R}) + 0.0087 \times (\%Al) \ldots \text{(expression 1)}$$

[0020] When these conditions are satisfied, amounts of retained austenite and martensite which are adjacent to bainite are extremely small, and the excellent ductility and hole expandability can be obtained. Besides, a quotient ($V_B/V_{\gamma R}$) where the area fraction of bainite (V_B) is divided by the area fraction of retained austenite ($V_{\gamma R}$) is 0.6 or less. Reasons why the excellent ductility and hole expandability can be obtained when the amounts of retained austenite and martensite which are adjacent to bainite are extremely small is not known, but it is supposed to be as follows. In general, formability is more improved owing to ferrite, which is easy to be deformed, existing around retained austenite or martensite. When the amount of bainite around retained austenite is small, a shape of retained austenite is like a sphere, and therefore, concentration of distortion is difficult to occur, and retained austenite remains up to a latter stage even if working such as press forming is performed. Accordingly, the effect of the TRIP is kept, and the excellent ductility and hole expandability are obtained. A sum (f_N) of the area fraction of retained austenite and the area fraction of martensite which are adjacent to bainite is preferable to be as smaller as possible. The sum (f_N) of the area fractions is preferably three out of ten or less relative to the sum of the area fraction of martensite and the area fraction of retained austenite, and more preferably two out of ten or less.

[0021] Next, a chemical composition of the cold-rolled steel sheet according to the embodiment of the present invention and a slab used for manufacturing the same is described. Details will be described later, but the cold-rolled steel sheet according to the embodiment of the present invention is manufactured through hot-rolling of the slab, cooling, coiling, cold-rolling, continuous annealing, and so on. Accordingly, the chemical composition of the cold-rolled steel sheet and the slab are ones in consideration of not only characteristics of the cold-rolled steel sheet but also the above-stated processes. In the following description, "%" being a unit of a content of each element contained in the cold-rolled steel sheet and the slab used for the manufacturing the same means "mass%" unless otherwise specified. The cold-rolled steel sheet according to the embodiment and the slab used for the manufacturing the same each include a chemical composition expressed by: Si: 0.01% to 0.50%; Mn or Cr, or both thereof: 0.70% to 1.50% in total; C: 0.030% to 0.060% when Cr: "0" (zero)% or more and less than 0.30%, 0.030% to 0.080% when Cr: 0.30% or more and 1.50% or less; Al: 0.800% to 2.000%; P: 0.030% or less; S: 0.0100% or less; Mo: 0.10% to 0.50%; O: 0.0070% or less; N: 0.0070% or less; B: "0" (zero)% to 0.0020%; Ti: "0" (zero)% to 0.050%; Nb: "0" (zero)% to 0.050%; V: "0" (zero)% to 0.050%; Ni: "0" (zero)% to 1.00%; Cu: "0" (zero)% to 1.00%; Ca or REM, or both thereof: "0" (zero)% to 0.0300% in total; W: "0" (zero)% to 1.000%; Mg: "0" (zero)% to 0.010%; Zr: "0" (zero)% to 0.200%; As: "0" (zero)% to 0.500%; Co: "0" (zero)%

to 1.000%; Sn: "0" (zero)% 0.200%; Pb: "0" (zero)% to 0.200%; Y: "0" (zero)% to 0.200%; Hf: "0" (zero)% to 0.2000%; and the balance: Fe and impurities. As the impurities, those contained in raw materials such as ores and scraps, and those introduced in the production process are exemplified.

(Si: 0.01% to 0.50%)

[0022] Si contributes to improve the strength of the cold-rolled steel sheet, and stabilizes retained austenite by suppressing precipitation of cementite. When a Si content is less than 0.01%, these effects cannot be sufficiently obtained. Therefore, the Si content is 0.01% or more. Significant cost is sometimes required to reduce the Si content. When the Si content is over 0.50%, the strength is too high due to solid solution strengthening, and sufficient press formability cannot be obtained. Accordingly, the Si content is 0.50% or less, and preferably 0.10% or less. When the Si content is excessive, sufficient plating wettability cannot be sometimes obtained in forming a hot-dip galvanized layer.

(Mn or Cr, or both thereof: 0.70% to 1.50% in total)

[0023] Mn and Cr secure hardenability, and contribute to secure an appropriate amount of retained austenite. When a sum of a Mn content and a Cr content is less than 0.70%, ferrite and pearlite are excessively formed, and a desired area fraction of retained austenite cannot be obtained. Thus, the sum of the Mn content and the Cr content is 0.70% or more. When the sum of the Mn content and the Cr content is over 1.50%, the strength is too high, and the sufficient press formability cannot be obtained. Troubles such that a casted slab cracks are easy to occur due to embrittlement caused by segregation of Mn and/or Cr. Weldability is sometimes lowered. Strength of a hot-rolled sheet is sometimes excessively high, and it may be difficult to secure a high reduction ratio in cold-rolling. Therefore, the sum of the Mn content and the Cr content is 1.50% or less. When the sum of the Mn content and the Cr content is 0.70% to 1.50%, there is no problem if one of Mn and Cr is not contained.

[0024] The Cr content is preferably 0.30% to 0.80%, and the Mn content is preferably 0.40% to 1.00%. Cr of 0.30% or more and Mn of 0.40% or more contribute to further improve the hardenability. When the Cr content is over 0.80% or the Mn content is over 1.00%, the embrittlement caused by segregation may be easy to occur, and cold-rollability may be sometimes lowered because the strength of the hot-rolled sheet is high. As it is described later, when the Cr content is less than 0.30%, the sufficient press formability cannot be obtained when a C content is over 0.060%, but the sufficient press formability may be obtained when the Cr content is 0.30% or more even if the C content is over 0.060%.

(C: 0.030% to 0.060% (when Cr: "0" (zero)% or more and less than 0.30%), or 0.030% to 0.080% (when Cr: 0.30% or more and 1.50% or less))

[0025] C contributes to improve the strength of the cold-rolled steel sheet, and stabilizes retained austenite. When the C content is less than 0.030%, these effects cannot be sufficiently obtained. Accordingly, the C content is 0.030% or more, and preferably 0.040% or more. When the C content is over 0.060% in a case where the Cr content is "0" (zero)% or more and less than 0.30%, the strength is too high, and the sufficient press formability cannot be obtained. Therefore, the C content is 0.060% or less, preferably 0.050% or less in the case where the Cr content is "0" (zero)% or more and less than 0.30%. On the other hand, when the C content is 0.080% or less, a sufficient press formability can be obtained even when the C content is over 0.060% in a case where the Cr content is 0.30% or more and 1.50% or less. Therefore, the C content is 0.080% or less, preferably 0.060% or less in the case where the Cr content is 0.30% or more and 1.50% or less. Reasons why the sufficient press formability can be obtained even when the C content is over 0.060% is not known, but it is supposed that carbide remains without being dissolved in annealing due to a function of Cr, generations of hard structures such as retained austenite and martensite are suppressed, and excessive increase in the strength is suppressed. Besides, a fact that solid-solution hardenability of Cr is lower than that of Mn is also supposed to be a cause that the sufficient press formability can be obtained.

(Al: 0.800% to 2.000%)

[0026] Al has a function deoxidizing molten steel, stabilizes retained austenite, and contributes to secure high ductility. When an Al content is less than 0.800%, sufficient ductility cannot be obtained. Therefore, the Al content is 0.800% or more. When the Al content is over 2.000%, a lot of oxide remains in the cold-rolled steel sheet, and mechanical properties, in particular, local deformability may deteriorate, and variation of characteristics may be large. The effect to stabilize retained austenite is saturated when the Al content is over 2.000%. Therefore, the Al content is 2.000% or less. The Al content is preferably 1.700% or less from a viewpoint of avoiding nozzle clogging or the like in casting.

(P: 0.030% or less)

[0027] P is not an essential element, and is contained, for example, as an impurity in the steel. P is easy to segregate to a center part in the thickness direction of the steel sheet, and embrittles a welded part. The segregation of P leads to lower the hole expandability. Accordingly, the lower a P content is, the better. In particular, the lowering of the hole expandability and the embrittlement of the welded part are remarkable when the P content is over 0.030%. Therefore, the P content is 0.030% or less. Significant cost may be required to make the P content to be less than 0.001%. It takes cost to reduce the P content, and the cost remarkably increases to reduce to be less than 0.001%. Accordingly, the P content may be 0.001% or more.

(S: 0.0100% or less)

[0028] S is not an essential element, and is contained, for example, as an impurity in the steel. Manufacturability in casting and manufacturability in hot-rolling are lowered as an S content is higher. Therefore, the lower the S content is, the better.

[0029] In particular, the lowering of the manufacturability is remarkable when the S content is over 0.0100%. Accordingly, the S content is 0.0100% or less. It takes cost to reduce the S content, and the cost remarkably increases to reduce to less than 0.0001%. Therefore, the S content may be 0.0001% or more.

(Mo: 0.10% to 0.50%)

[0030] Mo contributes to secure retained austenite, in particular, to secure retained austenite when a hot-dip galvanizing treatment is performed. When a Mo content is less than 0.10%, this effect cannot be sufficiently obtained. Accordingly, the Mo content is 0.10% or more. When the Mo content is over 0.50%, this effect is saturated, and the cost just increases. Besides, the effect to stabilize retained austenite is saturated when the Mo content is over 0.50%. Therefore, the Mo content is 0.50% or less, and preferably 0.30% or less from a viewpoint of cost.

(O: 0.0070% or less)

[0031] O is not an essential element, and is contained, for example, as an impurity in the steel. O forms oxide, and deteriorates the hole expandability. Besides, the oxide existing in a vicinity of a surface of the cold-rolled steel sheet may be a cause of a surface flaw, and deteriorates an appearance grade. When the oxide exists at a cut surface, a flaw in a cutout state is formed at the cut surface, and the hole expandability deteriorates. Therefore, the lower an O content is, the better. In particular, the deterioration of the hole expandability or the like is remarkable when the O content is over 0.0070%. Therefore, the O content is 0.0070% or less. It takes cost to reduce the O content, and the cost remarkably increases to reduce to less than 0.0001%. Therefore, the O content may be 0.0001% or more.

(N: 0.0070% or less)

[0032] N is not an essential element, and is contained, for example, as an impurity in the steel. N forms coarse nitride, and deteriorates the ductility and the hole expandability. N may be a cause of occurrence of blowholes in welding. Therefore, the lower an N content is, the better. In particular, the deteriorations or the like of bendability, the hole expandability are remarkable when the N content is over 0.0070%. It takes cost to reduce the N content, and the cost remarkably increases to reduce to less than 0.0010%. Therefore, the N content may be 0.0010% or more.

[0033] B, Ti, Nb, V, Ni, Cu, Ca, REM, W, Mg, Zr, As, Co, Sn, Pb, Y, and Hf are not essential elements, and are arbitrary elements which may be contained with a predetermined amount as a limit in the cold-rolled steel sheet.

(B: "0" (zero)% to 0.0020%; Ti: "0" (zero)% to 0.050%; Nb: "0" (zero)% to 0.050%; V: "0" (zero)% to 0.050%)

[0034] B contributes to improve the hardenability. However, when a B content is over 0.0020%, an iron-based boride is easy to be precipitated, and the effect of improvement in the hardenability cannot be obtained. Therefore, the B content is 0.0020% or less. Ti is bonded to N to form TiN, to thereby contribute to suppress nitriding of B. However, when a Ti content is over 0.050%, Ti iron-based carbide is formed, and carbon, which contributes to stabilize retained austenite, decreases, and the ductility is lowered. Therefore, the Ti content is 0.050% or less. Nb and V contribute to increase the strength and improve toughness by refining of grains. However, when Nb is over 0.050%, Nb iron-based carbide is formed, and carbon, which contributes to the stabilization of retained austenite, decreases, and the ductility is lowered. Therefore, an Nb content is 0.050% or less. Similarly, when V is over 0.050%, V iron-based carbide is formed, and carbon, which contributes to the stabilization of retained austenite, decreases, and therefore the ductility is lowered.

Therefore, a V content is 0.050% or less. The B content is preferably 0.0003% or more, and the Ti content, the Nb content, and the V content are each preferably 0.005% or more to surely obtain the effects owing to the above-stated functions. Namely, it is preferable that "B: 0.0003% to 0.0020%", "Ti: 0.005% to 0.050%", "Nb: 0.005% to 0.050%" or "V: 0.005% to 0.050%", or any combination thereof is satisfied.

(Ni: "0" (zero)% to 1.00%, Cu: "0" (zero)% to 1.00%)

[0035] Ni and Cu contribute to secure the hardenability. However, when a content of Ni and/or Cu is over 1.00%, the weldability, hot workability, and so on are deteriorated. Therefore, the Ni content is 1.00% or less, and the Cu content is 1.00% or less. The Ni content and the Cu content are both preferably 0.01% or more, and more preferably 0.05% or more to surely obtain the effects owing to the above-stated actions. Namely, it is preferable that "Ni: 0.01% to 1.00%", or "Cu: 0.01% to 1.00%", or any combination thereof is satisfied.

(Ca or REM, or both thereof: "0" (zero)% to 0.0300% in total)

[0036] Ca and REM contribute to improve the strength and to improve the toughness owing to refinement of structure. However, when a sum of a Ca content and a REM content is over 0.0300%, castability and the hot workability are deteriorated. Therefore, the sum of the Ca content and the REM content is 0.0300% or less. The sum of the Ca content and the REM content is preferably 0.0005% or more to surely obtain the effects owing to the above-stated functions. Namely, it is preferable that "Ca or REM, or both thereof: 0.0005% to 0.0300%" is satisfied. REM indicates Sc, Y and elements which belong to lanthanoid series, and the "REM content" means a total content of these elements. Lanthanoid is often added industrially as a misch metal, for example, and a plurality of kinds of elements such as La and Ce are contained. A metal element which belongs to REM such as metal La or metal Ce may be individually added.

(W: "0" (zero)% to 1.000%; Mg: "0" (zero)% to 0.010%; Zr: "0" (zero)% to 0.200%; As: "0" (zero)% to 0.500%; Co: "0" (zero)% to 1.000%; Sn: "0" (zero)% to 0.200%; Pb: "0" (zero)% to 0.200%; Y: "0" (zero)% to 0.200%; Hf: "0" (zero)% to 0.2000%)

[0037] W, Mg, and Zr contribute to suppress lowering of local ductility due to inclusions. For example, Mg contributes to reduce negative effect of the inclusions. However, when a W content is over 1.000%, workability is lowered. Therefore, the W content is 1.000% or less. When a Mg content is over 0.010%, cleanliness deteriorates. Therefore, the Mg content is 0.010% or less. When a Zr content is over 0.200%, the workability is lowered. Therefore, the Zr content is 0.200% or less. As contributes to improve the mechanical strength and to improve materials. However, when an As content is over 0.500%, the workability is lowered. Therefore, the As content is 0.500% or less. Co accelerates bainite transformation. In the TRIP steel, the bainite transformation is used, and therefore, Co is useful. However, when a Co content is over 1.000%, the weldability is worse. Therefore, the Co content is 1.000% or less. Sn and Pb contribute to improve the plating wettability and adhesiveness of a plating layer. However, when a content of Sn and/or Pb is over 0.200%, flaws are easy to occur in manufacturing, and the toughness is lowered. Therefore, the Sn content is 0.200% or less, and the Pb content is 0.200% or less. Y and Hf contribute to improve corrosion resistance. Y forms oxide in the steel, adsorbs hydrogen in the steel to thereby reduce diffusible hydrogen, and therefore, contributes to improve hydrogen embrittlement resistance. However, when an Y content is over 0.200% or an Hf content is over 0.2000%, the hole expandability deteriorates. Therefore, the Y content is 0.200% or less, and the Hf content is 0.2000% or less.

[0038] The W content is preferably 0.001% or more, the Mg content, the Zr content, the As content, the Co content, the Sn content, the Pb content, the Y content, and the Hf content are each preferably 0.0001% or more to surely obtain the effects owing to the above-stated functions. Namely, it is preferable that "W: 0.001% to 1.000%", "Mg: 0.0001% to 0.010%", "Zr: 0.0001% to 0.200%", "As: 0.0001% to 0.500%", "Co: 0.0001% to 1.000%", "Sn: 0.0001% to 0.200%", "Pb: 0.0001% to 0.2%, "Y: 0.0001% to 0.200%" or "Hf: 0.0001% to 0.2000%", or any combination thereof is satisfied.

[0039] Next, an example of a method of manufacturing the cold-rolled steel sheet according to the embodiment is described. According to the method described here, it is possible to manufacture the cold-rolled steel sheet according to the embodiment, but the method of manufacturing the cold-rolled steel sheet according to the embodiment is not limited thereto. Namely, a cold-rolled steel sheets manufactured by another method is within a scope of the embodiment as long as it includes the above-stated structure and chemical composition.

[0040] In this manufacturing method, hot-rolling of a slab heated to a temperature of 1250°C or less is performed to obtain a hot-rolled sheet, the hot-rolled sheet is coiled at a temperature of 650°C or less, cold-rolling of the hot-rolled sheet is performed with a reduction ratio of 70% or more to obtain a cold-rolled sheet, and continuous annealing of the cold-rolled sheet is performed at a temperature of 750°C to 900°C. In the performing the hot-rolling, finish-rolling is performed at a temperature of 850°C to 1000°C under a state in which two phases of ferrite and austenite exist. A total reduction ratio at the last three stands is 60% or more in the finish-rolling, and cooling is started within one second from the end of the finish-rolling.

[0041] As the slab supplied for the hot-rolling, one which is casted from molten steel whose composition is adjusted such that the chemical composition is within the above-stated range is used. As the slab, a continuous casting slab and a slab made by a thin slab caster may be used. A process such as a continuous casting-direct rolling (CC-DR) process, in which hot rolling is performed immediately after a slab is cast, may be applied.

[0042] The slab heating temperature is 1250°C or less. When the slab heating temperature is excessively high, not only the productivity deteriorates but also the manufacturing cost increases. The slab heating temperature is preferably 1200°C or less. The slab heating temperature is preferably 1050°C or more. When the slab heating temperature is less than 1050°C, a finish-rolling temperature is sometimes lowered, and a rolling load in the finish-rolling is sometimes high. The increase of the rolling load may incur the deterioration of rolling ability and a defective shape of the steel sheet (hot-rolled sheet) after the rolling.

[0043] When the hot-rolling is performed, the finish-rolling is performed at the temperature of 850°C to 1000°C under the state in which the two phases of ferrite and austenite exist. When the temperature of the finish-rolling (finish-rolling temperature) is less than 850°C, the rolling load may be high to incur the deterioration of the rolling ability and the defective shape of the hot-rolled sheet. The finish-rolling temperature is 1000°C or less. This is because a grain diameter in the hot-rolled sheet is made small as much as possible. In the finish-rolling, a total reduction ratio from two stands prior to the last stand to the last stand, namely, the total reduction ratio at the last three stands is 60% or more, and cooling, for example, water cooling is started within one second from the end of the finish-rolling. When the total reduction ratio is less than 60%, the grain diameter in the hot-rolled sheet becomes coarse. When it takes a time over one second from the end of the finish-rolling to the start of the cooling, the grain diameter in the hot-rolled sheet becomes coarse.

[0044] The coiling of the hot-rolled sheet is performed at the temperature of 650°C or less. When this temperature (coiling temperature) is 650°C, a thickness of oxide formed on a surface of the hot-rolled sheet excessively increases, and picklability deteriorates. The coiling temperature is preferably 500°C or more. When the coiling temperature is less than 500°C, strength of the hot-rolled sheet may excessively increase, and cracks and defective shape sometimes occur during the cold-rolling.

[0045] Rough-rolled sheets after rough rolling may be joined together during hot-rolling to perform finish-rolling in a continuous manner. Further, finish-rolling may be performed after once coiling the rough-rolled sheet.

[0046] After the hot-rolled sheet is coiled, pickling of the hot-rolled sheet is preferably performed. Oxide on the surface of the hot-rolled sheet is removed by the pickling. Therefore, the pickling is extremely effective to improve galvanizing characteristics when a hot-dip galvanized layer or an alloyed hot-dip galvanized layer is formed later. The pickling may be performed once or divided into plural times.

[0047] Thereafter, the cold-rolling of the hot-rolled sheet is performed with a reduction ratio of 70% or more to obtain a cold-rolled sheet. When the reduction ratio of the cold-rolling is less than 70%, a recrystallization temperature is high and the sufficient ductility is not obtained. Besides, it is difficult to keep a shape of the steel sheet to be flat, and the ductility of the cold-rolled steel sheet being a final product deteriorates. The reduction ratio is preferably 90% or less. When the reduction ratio is over 90%, the rolling load becomes too large, and it becomes difficult to perform the cold-rolling. When the reduction ratio is over 90%, anisotropy may be large, and the hole expandability sometimes deteriorates. When the reduction ratio is 90% or less, the plane intensity ratio (the value of I(111)/{I(100) + I(110)}) of 2 or less can be obtained. The number of times of a rolling pass and a reduction ratio by each pass do not affect on the effects of the embodiment, and are not particularly limited.

[0048] After the cold-rolling, the continuous annealing of the cold-rolled sheet is performed at the temperature of 750°C to 900°C. Owing to this continuous annealing, it is possible to lower the strength of the cold-rolled sheet which is raised by the cold-rolling to an appropriate level, and to obtain a desired structure containing an appropriate amount of retained austenite. Namely, dislocation introduced during the cold-rolling is freed by recovery, recrystallization or phase transformation, and stable retained austenite can be obtained by the continuous annealing. When the temperature of the continuous annealing is less than 750°C, non-recrystallized grains remain, and the sufficient ductility cannot be obtained. When the temperature of the continuous annealing is over 900°C, an excessive load is applied on a continuous annealing furnace. When the temperature of the continuous annealing is 750°C or more, the area fraction of retained austenite ($V_{\gamma R}$) and the area fraction of martensite (V_M) of 1% or more in total can be obtained, and the product of the area fraction of retained austenite ($V_{\gamma R}$) and the carbon concentration in retained austenite ($C_{\gamma R}$) of 1 or more can be obtained.

[0049] The cold-rolled steel sheet may be manufactured as stated above.

[0050] When a galvanized cold-rolled steel sheet is manufactured, a hot-dip galvanized layer or an alloyed hot-dip galvanized layer is formed on a surface of the cold-rolled steel sheet. The hot-dip galvanized layer or the alloyed hot-dip galvanized layer is formed by performing a hot-dip galvanizing treatment after the continuous annealing or subsequent to the continuous annealing. Effects of suppression of formation of scales and improvement in corrosion resistance are obtained by the hot-dip galvanizing treatment. When the alloyed hot-dip galvanized layer is formed, an alloying temperature is 600°C or less. When the alloying temperature is over 600°C, retained austenite is decomposed into ferrite and cementite, and therefore, the high ductility cannot be obtained.

[0051] The hot-dip galvanized layer or the alloyed hot-dip galvanized layer may contain Ni, Cu, Cr, Co, Al, Si, or Zn, or any combination thereof. When the galvanized cold-rolled steel sheet is manufactured, it is preferable that a base plating layer containing Ni, Cu, Co, or Fe, or any combination thereof is formed on the surface of the cold-rolled sheet between the cold-rolling and the continuous annealing. It is possible to improve adhesiveness of the hot-dip galvanized layer or the alloyed hot-dip galvanized layer by forming the base plating layer.

[0052] A plating layer may be formed by a electroplating method, but the hot-dip galvanizing method is preferable to form a thick plating layer.

[0053] Incidentally, the above-described embodiments are to be considered in all respects as illustrative and no restrictive. Namely, the present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof.

EXAMPLES

[0054] Next, examples of the present invention are described. Conditions in the examples are a conditional example which is applied to verify feasibility and effects of the present invention, and the present invention is not limited to the conditional example. The present invention is able to apply various conditions within the range of the present invention to the extent to achieve the objects thereof.

(First Experiment)

[0055] In a first experiment, slabs were casted using steels (steel types a to r and A to G) including chemical compositions listed in Table 1, then slab heating, hot-rolling, cooling, coiling, pickling, cold-rolling, and continuous annealing were performed. A thickness of the cold-rolled steel sheet was 0.65 mm. Blanks in Table 1 each indicate that a content of a corresponding element was less than a detection limit. For a part of the cold-rolled steel sheets, hot-dip galvanized treatment and alloying treatment were performed after the continuous annealing. The temperature of the slab heating, the finish-rolling temperature during the hot-rolling, the total reduction ratio at the last three stands in the finish-rolling, the coiling temperature, the reduction ratio in the cold-rolling, the annealing temperature in the continuous annealing, and the alloying temperature in the alloying treatment are listed in Table 2 and Table 3. The cooling was started within one second from the end of the finish-rolling in all of the conditions. Underlines in Table 1, Table 2, or Table 3 each indicate that a numerical value thereof was out of a range of the present invention.

[0056] A sample was taken from each of obtained steels, then mechanical tests and a structure observation were performed.

[0057] As for the tensile property, a tensile test piece conforming to JIS Z 2201 was taken, a tensile test was performed in conformity to JIS Z 2241, and a yield strength (YP), a tensile strength (TS), and an elongation (EL) were measured. As for the hole expandability, a test was performed by the method described in JIS Z 2256. Namely, a hole with a diameter of 10 mm (d_0) was punched, the hole was expanded using a 60-degree conical punch such that a burr extended outside, and a hole diameter (d) when cracks penetrated a steel sheet was measured. Then a hole expansion ratio λ ($= ((d - d_0)/d_0) \times 100$) was calculated.

[0058] In the structure observation, the area fraction of martensite (V_M), the area fraction of ferrite (V_F), the area fraction of retained austenite ($V_{\gamma R}$), and the area fraction of bainite (V_B) were measured. To measure these area fractions, a sample was taken which had a cross-section in parallel with the rolling direction and the thickness direction of the hot-stamped part as an observation surface, the observation surface was electropolished, a part where a depth from a surface is 1/8 to 3/8 of a thickness of the steel sheet was observed by the FESEM, and the area fraction was measured by the EBSD method. In the observation, area fractions of each structure were measured in 10 visual fields at a magnification of 5000 times, and an average value thereof was adopted as the area fraction of each structure. The "OIM-Analysis 5" made by TSL solutions Co., Ltd. was used for analysis. The crystal orientation analysis was performed by the FESEM-EBSD method, and the identification of the structure and the specification of the plane intensity ratio (the value of I(111)/{I(100) + I(110)}) at the sheet thickness 1/4t part were performed.

[0059] In the measurement of the carbon concentration ($C_{\gamma R}$) in retained austenite, the lattice constant was found from the midpoint of full width at half maximum of the plane intensity as for each of the (200) plane, the (220) plane, and the (311) plane of retained austenite by the X-ray diffraction whose target was Fe. An average value of these lattice constants was defined as the lattice constant of austenite (a_0), and the carbon concentration ($C_{\gamma R}$) was calculated from the above-stated expression 1.

[0060] Further, the sum (f_N) of the area fraction of retained austenite and the area fraction of martensite which were adjacent to bainite, a sum (f_s) of the area fraction of retained austenite and the area fraction of martensite which were not adjacent to bainite and existing at grain boundaries, and a sum (f_l) of the area fraction of retained austenite and the area fraction of martensite which were not adjacent to bainite and existing in grains were found. At this time, a sample was taken which had a cross-section in parallel with the rolling direction and the thickness direction of the hot-stamped part as an observation surface, the observation surface were corroded using the Nital reagent and the observation surface was observed with the SEM. A structure in which a block-like structure of bainite was observed was judged as bainite, and other island-shaped structures were judged as austenite and/or martensite.

[0061] These results are listed in Table 4 and Table 5. Here, it was judged to be good as for one whose yield strength (YP) was 400 MPa or less, tensile strength (TS) was 630 MPa or more, product (TS $\times$ EL) of the tensile strength (TS) and the elongation (EL) was 16500 MPa% or more, product ($TS^{1/3} \times \lambda$) of a cube root of the tensile strength (TS) and the hole expansion ratio (λ) was 810 $MPa^{1/3}$% or more. Underlines in Table 4 or Table 5 each indicate that a numerical value thereof was out of a desired range or the range of the present invention. When the yield strength (YP) is over 400 MP, a surface strain occurs and it is difficult to be processed. When the tensile strength (TS) is over 630 MPa, it is difficult to be processed. When the value of "TS $\times$ EL" is less than 16500 MPa%, fine press formability cannot be obtained. When the value of "$TS^{1/3} \times \lambda$" is less than 810 $MPa^{1/3}$%, fine press formability cannot be obtained. As listed in Table 4 and Table 5, in inventive examples, in which all of the conditions were within the range of the present invention, it was possible to obtain excellent ductility and hole expandability while securing the appropriate strength. On the other hand, in comparative examples, in which any one or more of the conditions were out of the range of the present invention, the desired strength, ductility and/or hole expandability could not be obtained.

[Table 1]

STEEL TYPE	CHEMICAL COMPONENT (MASS%)																		Ac3 (°C)	Ac1 (°C)	REMARKS
	C	Si	Al	Mn	Cr	B	P	S	N	O	Ti	Nb	V	Ni	Cu	Mo	Ca	REM	Mn+Cr			
a	0.034	0.05	0.878	1.01			0.004	0.0011	0.0026	0.0012						0.15			1.01	1203	714	INVENTIVE EXAMPLE
b	0.044	0.05	0.992	1.08			0.007	0.0014	0.0028	0.0011						0.21			1.08	1246	713	INVENTIVE EXAMPLE
c	0.047	0.04	1.532	1.28	0.19	0.0007	0.005	0.0015	0.0033	0.0009						0.14			1.47	1439	714	INVENTIVE EXAMPLE
d	0.057	0.02	1.476	1.25	0.11		0.012	0.0033	0.0045	0.0024						0.11			1.36	1417	712	INVENTIVE EXAMPLE
e	0.046	0.04	1.451	0.98	0.33		0.011	0.0023	0.0025	0.0008	0.029					0.15			1.31	1431	719	INVENTIVE EXAMPLE
f	0.044	0.05	1.223	1.39		0.0008	0.009	0.0038	0.0030	0.0012		0.049				0.14			1.39	1319	710	INVENTIVE EXAMPLE
g	0.042	0.05	1.487	1.04		0.0009	0.013	0.0027	0.0024	0.0018			0.045			0.23			1.04	1446	713	INVENTIVE EXAMPLE
h	0.048	0.07	1.387	0.88		0.0008	0.010	0.0024	0.0020	0.0010	0.019	0.011				0.30			0.88	1412	716	INVENTIVE EXAMPLE
i	0.046	0.05	1.085	1.29		0.0010	0.012	0.0029	0.0029	0.0013				0.28		0.25			1.29	1267	706	INVENTIVE EXAMPLE
j	0.047	0.08	1.523	1.35			0.009	0.0030	0.0025	0.0014					0.32	0.18			1.35	1435	711	INVENTIVE EXAMPLE
k	0.045	0.06	1.486	1.15	0.21		0.008	0.0022	0.0024	0.0009						0.42			1.36	1437	716	INVENTIVE EXAMPLE
l	0.048	0.08	1.521	1.06	0.18	0.0012	0.014	0.0027	0.0040	0.0010						0.18	0.0045		1.24	1450	717	INVENTIVE EXAMPLE
m	0.044	0.05	1.851	0.88	0.85		0.012	0.0038	0.0028	0.0013						0.23		0.0029	1.73	1581	728	REFERENCE EXAMPLE
n	0.057	0.02	0.884	1.11	0.25	0.0019	0.008	0.0015	0.0024	0.0019						0.17			1.36	1182	716	INVENTIVE EXAMPLE
o	0.058	0.05	0.967	0.67	0.22		0.009	0.0019	0.0016	0.0007	0.024	0.014				0.11			0.89	1238	721	INVENTIVE EXAMPLE
p	0.054	0.03	1.447	1.06			0.001	0.0022	0.0028	0.0014			0.024			0.22			1.06	1412	713	INVENTIVE EXAMPLE
q	0.056	0.08	1.257	0.85	0.18	0.0009	0.006	0.0011	0.0021	0.0009						0.33			1.03	1346	719	INVENTIVE EXAMPLE
r	0.058	0.02	1.553	0.97		0.0007	0.009	0.0018	0.0025	0.0011	0.058		0.029			0.31			0.97	1487	713	INVENTIVE EXAMPLE
A	0.028	0.07	1.458	1.13	0.19	0.0007	0.012	0.0038	0.0030	0.0024						0.15			1.32	1430	716	COMPARATIVE EXAMPLE
B	0.082	0.06	1.512	1.32	0.22	0.0004	0.008	0.0021	0.0024	0.0016						0.12			1.54	1417	714	COMPARATIVE EXAMPLE
C	0.042	0.72	1.448	1.22	0.32		0.010	0.0023	0.0032	0.0022						0.22			1.54	1445	736	COMPARATIVE EXAMPLE
D	0.038	0.33	2.027	1.29	0.55		0.008	0.0019	0.0024	0.0010						0.25			1.84	1656	728	COMPARATIVE EXAMPLE
E	0.044	0.48	1.448	0.45	0.12	0.0016	0.006	0.0024	0.0027	0.0008						0.15			0.57	1453	734	COMPARATIVE EXAMPLE
F	0.052	0.51	1.269	1.51	1.68	0.0008	0.014	0.0026	0.0026	0.0023						0.11			3.19	1335	750	COMPARATIVE EXAMPLE
G	0.047	0.42	1.863	1.36	0.20	0.0007	0.092	0.0020	0.0019	0.0024						0.34			1.56	1653	724	COMPARATIVE EXAMPLE

[Table 2]

CONDITION	STEEL TYPE	TYPE OF STEEL SHEET	SLAB HEATING TEMPERATURE (°C)	FINISH-ROLLING TEMPERATURE (°C)	TOTAL REDUCTION RATIO AT LAST THREE STANDS (%)	COILING TEMPERATURE (°C)	REDUCTION RATIO IN COLD-ROLLING (%)	ANNEALING TEMPERATURE (°C)	ALLOYING TEMPERATURE (°C)	REMARKS
a-1	a	COLD-ROLLED STEEL SHEET	1220	920	70	600	70	780	-	INVENTIVE EXAMPLE
a-2	a	COLD-ROLLED STEEL SHEET	1250	880	70	550	78	800	-	INVENTIVE EXAMPLE
a-3	a	COLD-ROLLED STEEL SHEET	1240	920	75	600	75	830	-	INVENTIVE EXAMPLE
a-4	a	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1230	860	80	620	80	800	500	INVENTIVE EXAMPLE
a-5	a	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1220	900	70	590	85	820	530	INVENTIVE EXAMPLE
a-6	a	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1220	930	75	600	70	850	560	INVENTIVE EXAMPLE
a-7	a	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1210	980	60	600	80	860	620	COMPARATIVE EXAMPLE
a-8	a	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1190	1020	60	620	85	800	520	COMPARATIVE EXAMPLE
a-9	a	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1200	860	70	700	75	820	500	COMPARATIVE EXAMPLE
a-10	a	COLD-ROLLED STEEL SHEET	1150	800	80	450	70	800	-	COMPARATIVE EXAMPLE
b-1	b	COLD-ROLLED STEEL SHEET	1210	940	60	520	75	790	-	INVENTIVE EXAMPLE
b-2	b	COLD-ROLLED STEEL SHEET	1200	890	70	580	80	800	-	INVENTIVE EXAMPLE
b-3	b	COLD-ROLLED STEEL SHEET	1200	830	80	600	70	820	-	INVENTIVE EXAMPLE
b-4	b	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1220	900	75	620	65	800	500	INVENTIVE EXAMPLE
b-5	b	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1230	910	75	580	70	850	530	INVENTIVE EXAMPLE
b-6	b	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1240	830	80	610	75	830	560	INVENTIVE EXAMPLE
b-7	b	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1200	880	80	600	80	860	610	COMPARATIVE EXAMPLE
b-8	b	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1200	1050	60	620	65	800	520	COMPARATIVE EXAMPLE
b-9	b	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1210	860	60	750	75	820	500	COMPARATIVE EXAMPLE
b-10	b	COLD-ROLLED STEEL SHEET	1150	800	80	450	70	800	-	COMPARATIVE EXAMPLE
c-1	c	COLD-ROLLED STEEL SHEET	1230	900	60	600	70	790	-	INVENTIVE EXAMPLE
c-2	c	COLD-ROLLED STEEL SHEET	1200	910	75	590	78	800	-	INVENTIVE EXAMPLE
c-3	c	COLD-ROLLED STEEL SHEET	1210	920	85	600	75	820	-	INVENTIVE EXAMPLE
c-4	c	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1200	900	65	610	80	800	500	INVENTIVE EXAMPLE
c-5	c	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1180	900	70	620	85	850	530	INVENTIVE EXAMPLE
c-6	c	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1230	930	70	600	70	830	560	INVENTIVE EXAMPLE
c-7	c	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1270	880	65	600	60	880	610	COMPARATIVE EXAMPLE
c-8	c	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1200	1050	65	620	65	800	520	COMPARATIVE EXAMPLE
c-9	c	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1230	860	70	750	75	820	500	COMPARATIVE EXAMPLE
c-10	c	COLD-ROLLED STEEL SHEET	1150	800	70	450	70	800	-	COMPARATIVE EXAMPLE
d-1	d	COLD-ROLLED STEEL SHEET	1220	870	85	620	75	800	-	INVENTIVE EXAMPLE
d-2	d	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1230	850	85	600	75	830	500	INVENTIVE EXAMPLE
e-1	e	COLD-ROLLED STEEL SHEET	1270	970	75	630	70	780	-	INVENTIVE EXAMPLE
f-1	f	COLD-ROLLED STEEL SHEET	1260	950	70	600	80	830	-	INVENTIVE EXAMPLE
g-1	g	COLD-ROLLED STEEL SHEET	1260	980	60	600	75	810	-	INVENTIVE EXAMPLE

[Table 3]

CONDITION	STEEL TYPE	TYPE OF STEEL SHEET	SLAB HEATING TEMPERATURE (°C)	FINISH-ROLLING TEMPERATURE (°C)	TOTAL REDUCTION RATIO AT LAST THREE STANDS (%)	COILING TEMPERATURE (°C)	REDUCTION RATIO IN COLD-ROLLING (%)	ANNEALING TEMPERATURE (°C)	ALLOYING TEMPERATURE (°C)	REMARKS
h-1	h	COLD-ROLLED STEEL SHEET	1280	850	75	590	85	810	-	INVENTIVE EXAMPLE
i-1	i	COLD-ROLLED STEEL SHEET	1230	910	75	610	70	810	-	INVENTIVE EXAMPLE
j-1	j	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1200	900	80	580	75	890	500	INVENTIVE EXAMPLE
k-1	k	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1200	930	90	600	75	830	520	INVENTIVE EXAMPLE
l-1	l	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1210	940	70	600	80	830	550	INVENTIVE EXAMPLE
m-1	m	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1230	920	80	590	80	830	550	REFERENCE EXAMPLE
n-1	n	COLD-ROLLED STEEL SHEET	1220	910	65	690	70	800	-	INVENTIVE EXAMPLE
n-2	n	COLD-ROLLED STEEL SHEET	1240	920	65	650	75	780	-	INVENTIVE EXAMPLE
n-3	n	COLD-ROLLED STEEL SHEET	1210	920	70	650	80	820	-	INVENTIVE EXAMPLE
n-4	n	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1200	890	75	630	75	830	500	INVENTIVE EXAMPLE
n-5	n	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1220	900	80	580	85	850	530	INVENTIVE EXAMPLE
n-6	n	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1230	920	80	570	80	880	560	INVENTIVE EXAMPLE
n-7	n	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1240	880	65	600	80	880	610	COMPARATIVE EXAMPLE
n-8	n	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1200	1050	70	620	85	800	520	COMPARATIVE EXAMPLE
n-9	n	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1210	860	80	750	75	820	500	COMPARATIVE EXAMPLE
n-10	n	COLD-ROLLED STEEL SHEET	1250	800	80	450	70	800	-	COMPARATIVE EXAMPLE
o-1	o	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1270	960	70	590	70	820	520	INVENTIVE EXAMPLE
p-1	p	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	940	65	650	80	890	540	INVENTIVE EXAMPLE
q-1	q	COLD-ROLLED STEEL SHEET	1180	880	70	600	75	820	-	INVENTIVE EXAMPLE
q-2	q	COLD-ROLLED STEEL SHEET	1210	900	70	580	75	800	-	INVENTIVE EXAMPLE
q-3	q	COLD-ROLLED STEEL SHEET	1230	920	80	590	80	780	-	INVENTIVE EXAMPLE
q-4	q	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1220	910	80	620	75	920	500	INVENTIVE EXAMPLE
q-5	q	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1220	910	80	630	80	850	520	INVENTIVE EXAMPLE
q-6	q	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1230	890	80	630	90	850	540	INVENTIVE EXAMPLE
q-7	q	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1230	980	60	600	85	880	610	COMPARATIVE EXAMPLE
q-8	q	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1210	1050	65	620	85	800	520	COMPARATIVE EXAMPLE
q-9	q	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1220	960	70	750	75	820	500	COMPARATIVE EXAMPLE
q-10	q	COLD-ROLLED STEEL SHEET	1200	800	75	450	70	800	-	COMPARATIVE EXAMPLE
r-1	r	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1280	920	70	620	75	820	520	INVENTIVE EXAMPLE
A-1	A	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1230	820	65	030	75	000	520	COMPARATIVE EXAMPLE
B-1	B	COLD-ROLLED STEEL SHEET	1210	930	65	620	70	810	-	COMPARATIVE EXAMPLE
C-1	C	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1210	910	75	580	70	820	530	COMPARATIVE EXAMPLE
D-1	D	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1230	900	85	600	80	850	550	COMPARATIVE EXAMPLE
E-1	E	COLD-ROLLED STEEL SHEET	1200	910	70	600	85	800	-	COMPARATIVE EXAMPLE
F-1	F	COLD-ROLLED STEEL SHEET	1210	920	60	620	80	810	-	COMPARATIVE EXAMPLE
G-1	G	COLD-ROLLED STEEL SHEET	1230	920	60	640	70	800	-	COMPARATIVE EXAMPLE

[Table 4]

CONDITION	V_M (%)	V_F (%)	V_{YR} (%)	$V_{YR} \times C_{YR}$	PLANE INTENSITY RATIO	YP (MPa)	TS (MPa)	EL (%)	λ (%)	V_M+V_{YR} (%)	V_B (%)	V_B/V_{YR}	TS×EL (MPa%)	$TS^{1/3}\times\lambda$ ($MPa^{1/3}$%)	f_N (%)	f_s (%)	f_I (%)	REMARKS
a-1	0.3	96.7	2.5	1.21	1.325	248	394	46	153	2.8	0.5	0.2	18124	1122	0.16	2.58	0.06	INVENTIVE EXAMPLE
a-2	0.2	97.1	2.2	1.18	1.732	243	386	47	142	2.4	0.5	0.2	18124	1034	0.14	2.16	0.10	INVENTIVE EXAMPLE
a-3	0.4	97.0	2.1	1.24	1.657	242	385	47	148	2.5	0.5	0.2	18124	1077	0.16	2.25	0.10	INVENTIVE EXAMPLE
a-4	0.2	97.5	1.8	1.19	1.742	246	391	46	166	2.1	0.4	0.2	18124	1214	0.12	1.88	0.09	INVENTIVE EXAMPLE
a-5	0.0	98.0	1.7	1.11	1.674	244	388	47	157	1.7	0.3	0.2	18124	1145	0.10	1.56	0.03	INVENTIVE EXAMPLE
a-6	0.0	98.2	1.5	1.07	1.714	247	393	46	162	1.5	0.3	0.2	18124	1167	0.09	1.34	0.08	INVENTIVE EXAMPLE
a-7	0.0	98.6	0.2	0.11	1.532	251	388	31	110	0.2	1.2	6.0	12028	802	0.20	0.00	0.00	COMPARATIVE EXAMPLE
a-8	0.0	98.5	1.2	0.86	1.258	244	395	38	152	1.2	0.3	0.2	15010	1115	0.07	1.10	0.03	COMPARATIVE EXAMPLE
a-9	0.0	95.0	4.2	0.87	1.493	251	385	37	115	4.2	0.8	0.2	14245	837	0.25	3.82	0.19	COMPARATIVE EXAMPLE
a-10	0.2	97.6	1.8	1.26	3.257	247	385	44	105	2.0	0.4	0.2	16940	764	0.12	1.80	0.08	COMPARATIVE EXAMPLE
b-1	0.2	96.6	2.7	1.41	1.287	290	448	42	156	2.9	0.5	0.2	18816	1194	0.17	2.64	0.10	INVENTIVE EXAMPLE
b-2	0.1	97.3	2.2	1.27	1.332	267	451	42	145	2.3	0.4	0.2	18942	1112	0.14	2.05	0.12	INVENTIVE EXAMPLE
b-3	0.1	97.2	2.3	1.33	1.524	274	460	41	150	2.4	0.4	0.2	18860	1158	0.14	2.21	0.05	INVENTIVE EXAMPLE
b-4	0.0	97.8	1.8	1.29	1.614	269	459	42	147	1.8	0.4	0.2	19278	1134	0.10	1.66	0.04	INVENTIVE EXAMPLE
b-5	0.0	97.6	2.0	1.24	1.712	274	462	41	152	2.0	0.4	0.2	18942	1175	0.12	1.82	0.06	INVENTIVE EXAMPLE
b-6	0.0	97.7	1.9	1.09	1.807	281	469	41	146	1.9	0.4	0.2	19229	1150	0.11	1.71	0.08	INVENTIVE EXAMPLE
b-7	0.0	98.1	0.2	0.11	1.532	285	462	31	108	0.2	1.7	8.5	14322	835	0.20	0.00	0.00	COMPARATIVE EXAMPLE
b-8	0.0	97.8	1.6	0.86	1.258	281	442	33	152	1.8	0.4	0.2	14586	1158	0.11	1.64	0.05	COMPARATIVE EXAMPLE
b-9	0.0	95.9	3.4	0.97	1.493	288	463	34	110	3.4	0.7	0.2	15742	851	0.21	3.13	0.06	COMPARATIVE EXAMPLE
b-10	0.2	97.0	2.3	1.26	3.257	278	461	42	98	2.5	0.5	0.2	19362	757	0.14	2.23	0.13	COMPARATIVE EXAMPLE
c-1	0.1	97.5	2.0	1.17	1.412	287	465	41	148	2.1	0.4	0.2	19065	1147	0.13	1.89	0.08	INVENTIVE EXAMPLE
c-2	0.2	96.8	2.5	1.20	1.387	279	461	41	152	2.7	0.5	0.2	18901	1174	0.16	2.48	0.06	INVENTIVE EXAMPLE
c-3	0.1	96.6	2.7	1.22	1.555	285	458	40	149	2.8	0.6	0.2	18320	1149	0.16	2.52	0.12	INVENTIVE EXAMPLE
c-4	0.0	97.8	1.8	1.17	1.238	277	462	40	138	1.8	0.4	0.2	18480	1067	0.11	1.62	0.07	INVENTIVE EXAMPLE
c-5	0.0	98.0	1.7	1.11	1.621	284	466	41	141	1.7	0.3	0.2	19106	1093	0.11	1.56	0.03	INVENTIVE EXAMPLE
c-6	0.0	98.2	1.5	1.08	1.523	277	458	40	145	1.5	0.3	0.2	18320	1116	0.09	1.37	0.05	INVENTIVE EXAMPLE
c-7	0.0	98.3	0.2	0.09	1.614	261	459	32	111	0.2	1.5	7.5	14688	856	0.20	0.00	0.00	COMPARATIVE EXAMPLE
c-8	0.0	98.2	1.5	0.94	1.332	277	462	34	141	1.5	0.3	0.2	15708	1080	0.09	1.38	0.03	COMPARATIVE EXAMPLE
c-9	0.0	96.2	3.1	0.88	1.421	281	471	33	101	3.1	0.7	0.2	15543	786	0.19	2.85	0.06	COMPARATIVE EXAMPLE
c-10	0.1	97.1	2.3	1.26	3.541	277	465	41	85	2.4	0.5	0.2	19065	736	0.14	2.21	0.05	COMPARATIVE EXAMPLE
d-1	0.2	97.2	2.1	1.15	1.562	384	611	32	138	2.3	0.5	0.2	19552	1171	0.14	2.05	0.12	INVENTIVE EXAMPLE
d-2	0.0	98.4	1.3	1.09	1.622	387	621	31	133	1.3	0.3	0.2	19251	1135	0.08	1.20	0.02	INVENTIVE EXAMPLE
e-1	0.2	97.4	1.9	1.21	1.632	288	456	42	145	2.1	0.5	0.2	19152	1116	0.12	1.93	0.05	INVENTIVE EXAMPLE
f-1	0.1	97.5	2.0	1.18	1.664	275	449	41	145	2.1	0.4	0.2	18409	1110	0.12	1.93	0.05	INVENTIVE EXAMPLE
g-1	0.2	97.2	2.1	1.15	1.486	269	442	42	151	2.3	0.5	0.2	18564	1150	0.14	2.05	0.12	INVENTIVE EXAMPLE

[Table 5]

CONDITION	V_M (%)	V_F (%)	$V_{\gamma R}$ (%)	$V_{\gamma R} \times C_{\gamma R}$	PLANE INTENSITY RATIO	YP (MPa)	TS (MPa)	EL (%)	λ (%)	$V_M+V_{\gamma R}$ (%)	V_B (%)	$V_B/V_{\gamma R}$	TS×EL (MPa%)	$TS^{1/3}\times\lambda$ ($MPa^{1/3}$%)	f_N (%)	f_s (%)	f_J (%)	REMARKS
h-1	0.3	97.5	1.8	1.32	1.388	279	452	41	148	2.1	0.4	0.2	18532	1136	0.12	1.88	0.09	INVENTIVE EXAMPLE
i-1	0.1	97.8	1.7	1.17	1.647	272	461	40	139	1.8	0.4	0.2	18440	1074	0.11	1.62	0.07	INVENTIVE EXAMPLE
j-1	0.0	98.4	1.3	1.11	1.721	269	452	41	148	1.3	0.3	0.2	18532	1136	0.08	1.17	0.05	INVENTIVE EXAMPLE
k-1	0.0	98.6	1.2	1.08	1.275	275	461	41	139	1.2	0.2	0.2	18901	1074	0.07	1.09	0.04	INVENTIVE EXAMPLE
l-1	0.0	98.3	1.4	1.11	1.346	272	458	41	152	1.4	0.3	0.2	18778	1172	0.08	1.25	0.07	INVENTIVE EXAMPLE
m-1	0.0	98.2	1.5	1.09	1.241	281	461	40	155	1.5	0.3	0.2	18440	1197	0.09	1.37	0.05	REFERENCE EXAMPLE
n-1	0.2	97.8	1.6	1.22	1.365	391	596	33	145	1.8	0.4	0.2	19668	1220	0.10	1.66	0.04	INVENTIVE EXAMPLE
n-2	0.1	97.8	1.7	1.36	1.654	387	608	32	140	1.8	0.4	0.2	19456	1186	0.11	1.60	0.09	INVENTIVE EXAMPLE
n-3	0.1	98.1	1.5	1.27	1.578	391	604	32	141	1.6	0.3	0.2	19328	1192	0.09	1.47	0.04	INVENTIVE EXAMPLE
n-4	0.0	98.6	1.2	1.12	1.458	388	612	31	135	1.2	0.2	0.2	18972	1146	0.07	1.07	0.06	INVENTIVE EXAMPLE
n-5	0.0	98.6	1.2	1.12	1.554	375	599	31	133	1.2	0.2	0.2	18569	1121	0.07	1.10	0.03	INVENTIVE EXAMPLE
n-6	0.0	98.7	1.1	1.08	1.397	383	610	31	138	1.1	0.2	0.2	18910	1170	0.06	0.98	0.06	INVENTIVE EXAMPLE
n-7	0.0	98.6	0.1	0.09	1.378	384	604	25	111	0.1	1.3	13.0	15100	938	0.10	0.00	0.00	COMPARATIVE EXAMPLE
n-8	0.0	98.6	1.2	0.94	1.354	394	611	22	141	1.2	0.2	0.2	13442	1198	0.07	1.07	0.06	COMPARATIVE EXAMPLE
n-9	0.0	96.2	3.2	0.88	1.441	381	609	23	101	3.2	0.6	0.2	14007	856	0.20	2.94	0.06	COMPARATIVE EXAMPLE
n-10	0.1	97.1	2.3	1.26	3.247	377	613	31	95	2.4	0.5	0.2	19003	807	0.14	2.16	0.10	COMPARATIVE EXAMPLE
o-1	0.0	98.5	1.3	1.19	1.297	381	602	32	142	1.3	0.2	0.2	19264	1199	0.08	1.17	0.05	INVENTIVE EXAMPLE
p-1	0.0	98.5	1.2	1.13	1.331	379	599	32	144	1.2	0.3	0.2	19168	1214	0.07	1.07	0.08	INVENTIVE EXAMPLE
q-1	0.2	98.0	1.5	1.24	1.351	381	610	31	151	1.7	0.3	0.2	18910	1281	0.11	1.56	0.03	INVENTIVE EXAMPLE
q-2	0.1	98.0	1.5	1.27	1.276	376	608	31	143	1.6	0.4	0.2	18848	1211	0.09	1.46	0.05	INVENTIVE EXAMPLE
q-3	0.1	98.2	1.4	1.18	1.314	384	611	31	138	1.5	0.3	0.2	18941	1171	0.09	1.38	0.03	INVENTIVE EXAMPLE
q-4	0.0	98.7	1.1	1.13	1.175	379	601	31	133	1.1	0.2	0.2	18631	1122	0.06	0.98	0.06	INVENTIVE EXAMPLE
q-5	0.0	98.8	1.0	1.14	1.156	374	597	32	144	1.0	0.2	0.2	19104	1213	0.06	0.80	0.04	INVENTIVE EXAMPLE
q-6	0.0	98.8	1.0	1.09	1.111	385	612	31	142	1.0	0.2	0.2	18972	1206	0.06	0.80	0.04	INVENTIVE EXAMPLE
q-7	0.0	98.8	0.2	0.09	1.287	388	614	23	98	0.2	1.0	5.0	14122	833	0.15	0.03	0.02	COMPARATIVE EXAMPLE
q-8	0.0	98.7	1.1	0.94	1.312	378	605	21	141	1.1	0.2	0.2	12705	1193	0.07	1.00	0.03	COMPARATIVE EXAMPLE
q-9	0.0	96.3	3.1	0.88	1.293	388	611	20	89	3.1	0.6	0.2	12220	755	0.18	2.82	0.10	COMPARATIVE EXAMPLE
q-10	0.2	97.0	2.3	1.26	3.541	385	607	31	95	2.5	0.5	0.2	18817	804	0.16	2.28	0.07	COMPARATIVE EXAMPLE
r-1	0.0	98.3	1.4	1.23	1.248	381	612	31	151	1.4	0.3	0.2	18972	1282	0.09	1.26	0.05	INVENTIVE EXAMPLE
A-1	0.2	98.9	0.7	0.65	1.245	201	345	48	145	0.9	0.2	0.2	16560	1017	0.05	0.81	0.04	COMPARATIVE EXAMPLE
B-1	0.9	94.8	4.0	1.52	1.341	405	782	28	102	4.3	0.9	0.2	21896	940	0.26	3.83	0.21	COMPARATIVE EXAMPLE
C-1	0.1	99.9	0.0	0.00	1.824	231	448	25	133	0.1	0.0	-	11200	1018	0.01	0.09	0.01	COMPARATIVE EXAMPLE
D-1	0.1	94.9	4.2	5.46	1.322	236	451	32	110	4.3	0.8	0.2	14432	844	0.25	3.86	0.09	COMPARATIVE EXAMPLE
E-1	0.2	99.4	0.2	0.02	1.884	244	395	27	142	0.4	0.2	0.5	10665	1042	0.20	-	-	COMPARATIVE EXAMPLE
F-1	0.5	97.3	1.8	1.15	1.594	275	463	31	115	2.3	0.4	0.2	14353	890	1.11	1.17	0.02	COMPARATIVE EXAMPLE
G-1	0.1	98.3	1.3	1.08	1.457	258	462	31	105	1.4	0.3	0.2	14322	812	0.09	1.05	0.26	COMPARATIVE EXAMPLE

(Second Experiment)

[0062] In a second experiment, slabs were casted using steels (steel types a2 to n2 and A2 to B2) including chemical compositions listed in Table 6, then slab heating, hot-rolling, cooling, coiling, pickling, cold-rolling, and continuous annealing were performed. A thickness of the cold-rolled steel sheet was 0.65 mm. As listed in Table 6, W, Mg, Zr, As, Co, Sn, Pb, Y or Hf was contained in these steels. Blanks in Table 6 each indicate that a content of a corresponding element was less than a detection limit. For a part of the cold-rolled steel sheets, hot-dip galvanized treatment and alloying treatment were performed after the continuous annealing. The temperature of the slab heating, the finish-rolling temperature during the hot-rolling, the total reduction ratio at the last three stands in the finish-rolling, the coiling temperature, the reduction ratio in the cold-rolling, the annealing temperature in the continuous annealing, and the alloying temperature in the alloying treatment are listed in Table 7. The cooling was started within one second from the end of the finish-rolling in all of the conditions. Underlines in Table 6 or Table 7 each indicate that a numerical value thereof was out of the range of the present invention.

[0063] A sample was taken from each of obtained steels, then mechanical tests and structure observation were performed as same as the first experiment. These results are listed in Table 8. Here, evaluations were performed with the same criteria as the first experiment. Underlines in Table 8 each indicate that a numerical value thereof was out of the desired range or the range of the present invention. As listed in Table 8, in inventive examples, in which all of the conditions were within the range of the present invention, it was possible to obtain excellent ductility and hole expandability while securing the appropriate strength. Under the conditions each using the steel types a2 to f2, whose Cr content was 0.3% or more, it was possible to suppress excessive increase of strength, although the C content was relatively high. This means that it is easy to suppress the increase of the strength when the Cr content is 0.3% or more. On the other hand, in comparative examples, in which any one or more of the conditions were out of the range of the present invention, the desired strength, ductility and/or hole expandability could not be obtained.

[Table 6]

STEEL TYPE	CHEMICAL COMPOUND (MASS%)																			Ac3 (°C)	Ac1 (°C)	REMARKS
	C	Si	Al	Mn	Cr	B	P	S	N	O	Ti	Nb	V	Ni	Cu	Mo	Ca	REM	OTHERS	Mn+Cr			
A2	0.028	0.01	1.645	0.60	0.60		0.006	0.0031	0.0030	0.0024				0.16	0.05	0.12				1.20	1505	724	COMPARATIVE EXAMPLE
a2	0.046	0.03	1.520	0.79	0.57		0.008	0.0025	0.0024	0.0019						0.14				1.36	1456	725	INVENTIVE EXAMPLE
b2	0.051	0.01	1.654	0.61	0.62		0.006	0.0031	0.0030	0.0024				0.16	0.05	0.16				1.23	1507	725	INVENTIVE EXAMPLE
c2	0.060	0.03	1.560	0.65	0.43		0.006	0.0035	0.0029	0.0024						0.15				1.08	1461	724	INVENTIVE EXAMPLE
d2	0.056	0.08	1.236	0.82	0.49		0.008	0.0020	0.0024	0.0018				0.16	0.05	0.15				1.31	1328	722	INVENTIVE EXAMPLE
e2	0.072	0.01	1.654	0.61	0.62		0.006	0.0031	0.0030	0.0024				0.16	0.05	0.12				1.23	1488	725	INVENTIVE EXAMPLE
B2	0.085	0.01	1.645	0.60	0.60		0.006	0.0031	0.0030	0.0024				0.16	0.05	0.12				1.20	1480	724	COMPARATIVE EXAMPLE
f2	0.051	0.01	1.654	0.70	0.40		0.006	0.0031	0.0030	0.0024						0.15			Sn:0.002	1.10	1501	723	INVENTIVE EXAMPLE
g2	0.051	0.01	1.654	1.00			0.006	0.0031	0.0030	0.0023						0.22			W:0.002	1.00	1498	713	INVENTIVE EXAMPLE
h2	0.050	0.01	1.654	1.02			0.006	0.0031	0.0030	0.0021						0.34			As:0.002	1.02	1502	712	INVENTIVE EXAMPLE
i2	0.050	0.02	1.654	1.03			0.006	0.0031	0.0030	0.0021						0.42			Mg:0.001	1.03	1505	713	INVENTIVE EXAMPLE
j2	0.049	0.01	1.598	0.97			0.006	0.0030	0.0030	0.0019						0.18			Zr:0.001	0.97	1476	713	INVENTIVE EXAMPLE
k2	0.051	0.01	1.644	0.80			0.006	0.0030	0.0030	0.0019						0.12			Hf:0.0033	0.80	1497	715	INVENTIVE EXAMPLE
l2	0.050	0.02	1.654	0.90			0.006	0.0030	0.0030	0.0019						0.15			Pb:0.003	0.90	1500	714	INVENTIVE EXAMPLE
m2	0.049	0.01	1.640	1.20			0.006	0.0030	0.0030	0.0019						0.11			Y:0.004	1.20	1484	710	INVENTIVE EXAMPLE
n2	0.049	0.01	1.620	1.10			0.006	0.0030	0.0030	0.0019						0.14			Co:0.003	1.10	1480	712	INVENTIVE EXAMPLE

[Table 7]

CONDITION	STEEL TYPE	TYPE OF STEEL SHEET	SLAB HEATING TEMPERATURE (°C)	FINISH-ROLLING TEMPERATURE (°C)	TOTAL REDUCTION RATIO AT LAST THREE STANDS (%)	COILING TEMPERATURE (°C)	REDUCTION RATIO IN COLD-ROLLING (%)	ANNEALING TEMPERATURE (°C)	ALLOYING TEMPERATURE (°C)	REMARKS
A2-1	A2	COLD-ROLLED STEEL SHEET	1250	930	70	600	70	780	-	COMPARATIVE EXAMPLE
a2-1	a2	COLD-ROLLED STEEL SHEET	1250	930	70	600	70	780	-	INVENTIVE EXAMPLE
a2-2	a2	COLD-ROLLED STEEL SHEET	1250	890	70	550	78	800	-	INVENTIVE EXAMPLE
a2-3	a2	COLD-ROLLED STEEL SHEET	1250	920	75	600	75	830	-	INVENTIVE EXAMPLE
a2-4	a2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	860	80	620	80	800	500	INVENTIVE EXAMPLE
a2-5	a2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	900	70	590	85	820	530	INVENTIVE EXAMPLE
a2-6	a2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	930	75	600	70	850	560	INVENTIVE EXAMPLE
a2-7	a2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	880	60	600	80	800	620	COMPARATIVE EXAMPLE
b2-1	b2	COLD-ROLLED STEEL SHEET	1250	840	60	550	75	780	-	INVENTIVE EXAMPLE
b2-2	b2	COLD-ROLLED STEEL SHEET	1250	880	70	600	60	800	-	INVENTIVE EXAMPLE
b2-3	b2	COLD-ROLLED STEEL SHEET	1250	930	80	600	70	820	-	INVENTIVE EXAMPLE
b2-4	b2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	900	75	600	85	800	500	INVENTIVE EXAMPLE
b2-5	b2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	910	75	600	70	850	530	INVENTIVE EXAMPLE
b2-6	b2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	930	80	600	75	830	560	INVENTIVE EXAMPLE
b2-7	b2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	880	80	600	80	800	610	COMPARATIVE EXAMPLE
c2-1	c2	COLD-ROLLED STEEL SHEET	1250	900	60	600	70	780	-	INVENTIVE EXAMPLE
c2-2	c2	COLD-ROLLED STEEL SHEET	1250	910	75	590	78	800	-	INVENTIVE EXAMPLE
c2-3	c2	COLD-ROLLED STEEL SHEET	1250	920	65	600	75	820	-	INVENTIVE EXAMPLE
c2-4	c2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	900	65	610	80	800	500	INVENTIVE EXAMPLE
c2-5	c2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	900	70	620	85	850	530	INVENTIVE EXAMPLE
c2-6	c2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	930	70	600	70	830	560	INVENTIVE EXAMPLE
c2-7	c2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	880	65	600	80	880	610	COMPARATIVE EXAMPLE
d2-1	d2	COLD-ROLLED STEEL SHEET	1250	870	65	620	75	790	-	INVENTIVE EXAMPLE
d2-2	d2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	950	65	600	75	820	500	INVENTIVE EXAMPLE
e2-1	e2	COLD-ROLLED STEEL SHEET	1250	870	75	630	70	780	-	INVENTIVE EXAMPLE
B2-1	B2	COLD-ROLLED STEEL SHEET	1250	850	70	600	80	780	-	COMPARATIVE EXAMPLE
f2-1	f2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	860	75	590	85	820	490	INVENTIVE EXAMPLE
g2-1	g2	COLD-ROLLED STEEL SHEET	1250	910	75	610	70	820	-	INVENTIVE EXAMPLE
h2-1	h2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	900	80	580	75	820	510	INVENTIVE EXAMPLE
i2-1	i2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	930	90	600	75	820	510	INVENTIVE EXAMPLE
j2-1	j2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	940	70	600	80	820	510	INVENTIVE EXAMPLE
k2-1	k2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	920	60	590	80	820	510	INVENTIVE EXAMPLE
l2-1	l2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	910	65	630	70	820	490	INVENTIVE EXAMPLE
m2-1	m2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	860	70	590	70	820	510	INVENTIVE EXAMPLE
n-1	n2	ALLOYED HOT-DIP GALVANIZED STEEL SHEET	1250	940	65	650	80	820	510	INVENTIVE EXAMPLE

[Table 8]

CONDITION	V_M (%)	V_F (%)	V_{YR} (%)	$V_{YR} \times C_{YR}$	PLANE INTENSITY RATIO	YP (MPa)	TS (MPa)	EL (%)	λ (%)	V_M+V_{YR} (%)	V_B (%)	V_B/V_{YR}	TS×EL (MPa%)	$TS^{1/3} \times \lambda$ ($MPa^{1/3}$%)	f_N (%)	f_s (%)	f_I (%)	REMARKS
A2-1	0.0	99.8	0.2	0.18	1.575	203	303	43	140	0.2	0.0	0.2	13029	940	0.01	0.18	0.01	COMPARATIVE EXAMPLE
a2-1	0.2	97.1	2.2	2.42	1.599	252	415	44	142	2.4	0.5	0.2	18260	1059	0.15	2.16	0.09	INVENTIVE EXAMPLE
a2-2	0.3	97.0	2.2	2.42	1.473	252	421	42	147	2.5	0.5	0.2	17682	1102	0.15	2.25	0.10	INVENTIVE EXAMPLE
a2-3	0.7	96.8	2.0	2.40	1.638	255	423	41	168	2.7	0.5	0.2	17343	1261	0.16	2.43	0.11	INVENTIVE EXAMPLE
a2-4	0.3	97.5	1.9	1.67	1.572	258	422	41	155	2.2	0.4	0.2	17302	1163	0.12	1.94	0.09	INVENTIVE EXAMPLE
a2-5	0.3	97.6	1.7	1.53	1.610	255	425	40	160	2.0	0.4	0.2	17000	1203	0.12	1.78	0.10	INVENTIVE EXAMPLE
a2-6	0.4	96.9	1.5	1.20	1.416	254	420	40	163	1.9	1.2	0.6	16800	1221	0.20	0.00	1.70	INVENTIVE EXAMPLE
a2-7	0.2	97.8	0.3	0.21	1.673	250	418	32	108	0.5	1.7	3.4	13376	808	0.45	0.03	0.02	COMPARATIVE EXAMPLE
b2-1	0.4	96.7	2.3	2.53	1.386	271	452	40	130	2.7	0.6	0.2	18080	988	0.17	2.46	0.08	INVENTIVE EXAMPLE
b2-2	0.5	96.6	2.3	2.53	1.416	272	456	39	135	2.8	0.6	0.2	17784	1039	0.17	2.58	0.05	INVENTIVE EXAMPLE
b2-3	0.6	96.8	2.1	2.52	1.581	274	460	38	150	2.7	0.5	0.2	17480	1158	0.15	2.41	0.08	INVENTIVE EXAMPLE
b2-4	0.5	97.1	1.9	1.71	1.662	275	459	38	142	2.4	0.5	0.2	17442	1095	0.14	2.16	0.10	INVENTIVE EXAMPLE
b2-5	0.4	97.4	1.8	1.62	1.719	273	461	38	150	2.2	0.4	0.2	17288	1159	0.13	2.02	0.04	INVENTIVE EXAMPLE
b2-6	0.4	97.6	1.6	1.28	1.387	270	455	38	148	2.0	0.4	0.2	17063	1138	0.12	1.78	0.10	INVENTIVE EXAMPLE
b2-7	0.4	97.5	0.4	0.28	1.358	267	455	30	98	0.8	1.7	2.1	13650	754	0.73	0.05	0.02	COMPARATIVE EXAMPLE
c2-1	0.3	96.6	2.5	3.00	1.713	304	500	38	120	2.8	0.6	0.2	19000	952	0.17	2.49	0.14	INVENTIVE EXAMPLE
c2-2	0.3	95.5	2.5	2.75	1.722	305	507	37	122	2.8	1.7	0.6	18759	973	0.20	0.00	2.60	INVENTIVE EXAMPLE
c2-3	0.3	97.0	2.2	2.86	1.380	307	513	36	133	2.5	0.6	0.2	18468	1065	0.15	2.25	0.10	INVENTIVE EXAMPLE
c2-4	0.3	97.1	2.1	2.00	1.502	309	510	35	133	2.4	0.5	0.2	17850	1063	0.14	2.14	0.12	INVENTIVE EXAMPLE
c2-5	0.3	97.3	2.0	1.80	1.389	306	512	35	140	2.3	0.4	0.2	18022	1120	0.13	2.07	0.10	INVENTIVE EXAMPLE
c2-6	0.3	97.3	1.9	1.52	1.360	304	509	35	135	2.2	0.5	0.2	17764	1078	0.13	1.96	0.11	INVENTIVE EXAMPLE
c2-7	0.3	98.9	0.6	0.36	1.540	300	507	29	80	0.9	0.2	0.2	14703	638	0.05	0.81	0.04	COMPARATIVE EXAMPLE
d2-1	0.3	96.9	2.3	2.76	1.541	309	502	39	119	2.6	0.5	0.2	19578	946	0.16	2.31	0.13	INVENTIVE EXAMPLE
d2-2	0.4	97.1	2.0	2.40	1.466	285	503	38	110	2.4	0.5	0.2	19114	875	0.14	2.14	0.12	INVENTIVE EXAMPLE
e2-1	0.3	96.4	2.7	3.24	1.570	357	588	35	104	3.0	0.6	0.2	20580	871	0.18	2.71	0.06	INVENTIVE EXAMPLE
B2-1	1.0	94.0	3.7	4.07	1.622	493	702	27	43	4.7	1.3	0.3	18954	382	0.29	4.18	0.23	COMPARATIVE EXAMPLE
f2-1	0.2	97.2	2.2	2.20	1.665	300	445	42	139	2.4	0.4	0.2	18468	1061	0.15	0.02	0.01	INVENTIVE EXAMPLE
g2-1	0.3	97.1	2.1	2.31	1.547	325	475	40	160	2.4	0.5	0.2	19143	1248	0.14	0.03	0.01	INVENTIVE EXAMPLE
h2-1	0.2	97.0	2.3	2.30	1.577	297	472	40	138	2.5	0.5	0.2	18880	1074	0.15	0.03	0.01	INVENTIVE EXAMPLE
i2-1	0.2	97.2	2.2	2.20	1.642	323	475	40	162	2.4	0.4	0.2	18858	1264	0.14	0.03	0.01	INVENTIVE EXAMPLE
j2-1	0.2	97.1	2.2	2.20	1.601	306	470	40	161	2.4	0.5	0.2	18800	1252	0.14	0.03	0.01	INVENTIVE EXAMPLE
k2-1	0.1	97.1	2.3	2.30	1.347	296	468	41	130	2.4	0.5	0.2	19188	1009	0.15	0.03	0.01	INVENTIVE EXAMPLE
l2-1	0.1	97.5	2.0	2.40	1.424	317	450	42	148	2.1	0.4	0.2	18900	1134	0.13	0.03	0.01	INVENTIVE EXAMPLE
m2-1	0.2	97.1	2.2	2.20	1.648	303	473	39	137	2.4	0.5	0.2	18447	1067	0.14	0.03	0.01	INVENTIVE EXAMPLE
n-1	0.0	97.3	2.3	2.99	1.696	296	435	43	148	2.3	0.4	0.2	18705	1121	0.14	0.03	0.01	INVENTIVE EXAMPLE

(Third Experiment)

[0064] In a third experiment, slabs were casted using steels (steel types a3 to d3 and A3 to H3) including chemical compositions listed in Table 9, then slab heating, hot-rolling, cooling, coiling, pickling, cold-rolling, and continuous annealing were performed. A thickness of the cold-rolled steel sheet was 0.65 mm. Blanks in Table 9 each indicate that a content of a corresponding element was less than a detection limit. The temperature of the slab heating, the finish-rolling temperature during the hot-rolling, the total reduction ratio at the last three stands in the finish-rolling, the coiling temperature, the reduction ratio in the cold-rolling, and the annealing temperature in the continuous annealing, and the alloying temperature in the alloying treatment are listed in Table 10. The cooling was started within one second from the end of the finish-rolling in all of the conditions. Underlines in Table 9 or Table 10 each indicate that a numerical value thereof was out of the range of the present invention.

[0065] A sample was taken from each of obtained steels, then mechanical tests and structure observation were performed as same as the first experiment. These results are listed in Table 11. Here, evaluations were performed with the same criteria as the first experiment. Underlines in Table 11 each indicate that a numerical value thereof was out of the desired range or the range of the present invention. As listed in Table 11, in inventive examples, in which all of the conditions were within the range of the present invention, it was possible to obtain the excellent ductility and hole expandability while securing the appropriate strength. On the other hand, in comparative examples, in which any one or more of the conditions were out of the range of the present invention, the desired strength, ductility and/or hole expandability could not be obtained.

[Table 9]

STEEL TYPE	CHEMICAL COMPONENT (MASS%) C	Si	Al	Mn	Cr	B	P	S	N	O	Ti	Nb	V	Ni	Cu	Mo	Ca	REM	OTHERS	Mn+Cr	Ac3 (°C)	Ac1 (°C)	REMARKS
a3	0.070	0.05	1.600	0.40	0.92		0.010	0.0025	0.0024	0.0019						0.09				1.32	1486	736	INVENTIVE EXAMPLE
b3	0.071	0.01	1.654	0.23	0.50		0.010	0.0025	0.0025	0.0019						0.09				0.73	1515	729	INVENTIVE EXAMPLE
c3	0.071	0.03	1.560		0.80		0.010	0.0010	0.0030	0.0019						0.09				0.80	1473	737	INVENTIVE EXAMPLE
d3	0.070	0.08	1.236		1.30		0.010	0.0010	0.0030	0.0019						0.09				1.30	1341	747	INVENTIVE EXAMPLE
A3	0.071	0.01	1.654	0.40	1.40		0.010	0.0024	0.0029	0.0019						0.08				1.80	1491	743	COMPARATIVE EXAMPLE
B3	0.069	0.01	1.654	0.10	0.58		0.010	0.0024	0.0029	0.0019						0.08				0.68	1510	732	COMPARATIVE EXAMPLE
C3	0.070	0.05	1.550	1.00	0.15		0.010	0.0020	0.0030	0.0003						0.10				1.15	1448	716	COMPARATIVE EXAMPLE
D3	0.048	0.53	0.030	1.20			0.010	0.0020	0.0030	0.0003						0.15				1.20	868	726	COMPARATIVE EXAMPLE
E3	0.048	0.05	0.770	1.20			0.010	0.0020	0.0030	0.0003						0.15				1.20	1142	712	COMPARATIVE EXAMPLE
F3	0.055	1.50	0.030	1.40			0.010	0.0024	0.0030	0.0019						0.10				1.40	901	752	COMPARATIVE EXAMPLE
G3	0.054	0.05	0.800	2.00			0.010	0.0024	0.0027	0.0019						0.10				2.00	1126	703	COMPARATIVE EXAMPLE
H3	0.120	0.01	0.820	1.40			0.010	0.0025	0.0028	0.0019						0.10				1.40	1127	708	COMPARATIVE EXAMPLE

[Table 10]

CONDITION	STEEL TYPE	TYPE OF STEEL SHEET	SLAB HEATING TEMPERATURE (°C)	FINISH-ROLLING TEMPERATURE (°C)	TOTAL REDUCTION RATIO AT LAST THREE STANDS (%)	COILING TEMPERATURE (°C)	REDUCTION RATIO IN COLD-ROLLING (%)	ANNEALING TEMPERATURE (°C)	REMARKS
a3-1	a3	COLD-ROLLED STEEL SHEET	1250	950	80	610	80	820	INVENTIVE EXAMPLE
b3-1	b3	COLD-ROLLED STEEL SHEET	1250	955	80	600	80	830	INVENTIVE EXAMPLE
c3-1	c3	COLD-ROLLED STEEL SHEET	1250	939	80	620	80	840	INVENTIVE EXAMPLE
d3-1	d3	COLD-ROLLED STEEL SHEET	1250	949	80	500	80	850	INVENTIVE EXAMPLE
A3-1	A3	COLD-ROLLED STEEL SHEET	1250	969	80	600	80	790	COMPARATIVE EXAMPLE
B3-1	B3	COLD-ROLLED STEEL SHEET	1250	949	80	610	80	790	COMPARATIVE EXAMPLE
C3-1	C3	COLD-ROLLED STEEL SHEET	1250	930	80	616	80	790	COMPARATIVE EXAMPLE

(continued)

CONDITION	STEEL TYPE	TYPE OF STEEL SHEET	SLAB HEATING TEMPERATURE (°C)	FINISH-ROLLING TEMPERATURE (°C)	TOTAL REDUCTION RATIO AT LAST THREE STANDS (%)	COILING TEMPERATURE (°C)	REDUCTION RATIO IN COLD-ROLLING (%)	ANNEALING TEMPERATURE (°C)	REMARKS
D3-1	D3	COLD-ROLLED STEEL SHEET	1250	939	80	610	80	790	COMPARATIVE EXAMPLE
E3-1	E3	COLD-ROLLED STEEL SHEET	1250	970	80	640	80	790	COMPARATIVE EXAMPLE
F3-1	F3	COLD-ROLLED STEEL SHEET	1250	930	80	600	80	850	COMPARATIVE EXAMPLE
G3-1	G3	COLD-ROLLED STEEL SHEET	1250	943	80	600	80	850	COMPARATIVE EXAMPLE
H3-1	H3	COLD-ROLLED STEEL SHEET	1250	948	80	600	80	850	COMPARATIVE EXAMPLE

[Table 11]

CONDITION	V_M (%)	V_F (%)	$V_{\gamma R}$ (%)	$V_{\gamma R} \times C_{\gamma R}$	PLANE INTENSITY RATIO	YP (MPa)	TS (MPa)	EL (%)	λ (%)	$V_M+V_{\gamma R}$ (%)	V_B (%)	$V_B/V_{\gamma R}$	$TS \times EL$ (MPa%)	$TS^{1/3} \times \lambda$ ($MPa^{1/3}$%)	f_N (%)	f_s (%)	f_l (%)	REMARKS
a3-1	0.6	97.2	2.1	2.31	1.698	298	463	36.7	133	2.7	0.1	0.05	16999	1029	0.15	2.46	0.09	INVENTIVE EXAMPLE
b3-1	0.8	96.5	1.9	2.09	1.687	299	446	38.2	135	2.7	0.8	0.42	17033	1031	0.17	2.49	0.11	INVENTIVE EXAMPLE
c3-1	0.4	96.0	2.4	2.64	1.700	297	472	37.1	155	2.8	1.2	0.50	17511	1207	0.17	2.55	0.08	INVENTIVE EXAMPLE
d3-1	0.3	95.6	2.6	2.86	1.720	287	478	37.4	131	2.9	1.5	0.58	17881	1024	0.17	2.58	0.15	INVENTIVE EXAMPLE
A3-1	2.8	94.2	2.8	2.49	1.759	238	498	30.1	95	5.6	0.2	0.07	14981	753	0.32	5.10	0.18	COMPARATIVE EXAMPLE
B3-1	0.0	97.0	0.2	0.21	1.347	299	420	30.1	118	0.2	2.8	14.00	12642	884	0.01	0.18	0.01	COMPARATIVE EXAMPLE
C3-1	0.9	95.7	3.4	3.57	1.657	396	660	27.8	101	4.3	0.0	0.00	18348	879	0.27	3.91	0.12	COMPARATIVE EXAMPLE
D3-1	0.9	94.4	2.8	3.08	2.312	341	510	40.2	88	3.7	1.9	0.68	20502	703	0.23	3.40	0.07	COMPARATIVE EXAMPLE
E3-1	0.3	96.2	1.2	1.32	1.865	279	456	32.1	100	1.5	2.3	1.92	14638	770	0.09	1.35	0.06	COMPARATIVE EXAMPLE
F3-1	0.8	95.6	2.1	2.14	2.311	305	510	34.6	90	2.9	1.5	0.71	17646	719	2.52	0.38	0.00	COMPARATIVE EXAMPLE
G3-1	1.9	95.4	0.8	0.69	1.976	245	488	32.9	99	2.7	1.9	2.37	16042	779	2.38	0.32	0.00	COMPARATIVE EXAMPLE
H3-1	1.0	89.4	5.2	5.33	1.991	350	663	30.2	90	6.2	4.4	0.85	20023	783	5.46	0.74	0.00	COMPARATIVE EXAMPLE

INDUSTRIAL APPLICABILITY

[0066] The present invention may be used for industries relating to a cold-rolled steel sheet and a galvanized cold-rolled steel sheet having, for example, strength of 380 MPa to 630 MPa and excellent in press formability.

Claims

1. A cold-rolled steel sheet, comprising:

    a chemical composition expressed by, in mass%:

        Si: 0.01% to 0.50%;
        Mn or Cr, or both thereof: 0.70% to 1.50% in total;
        C: 0.030% to 0.060% when Cr: "0" (zero)% or more and less than 0.30%, 0.030% to 0.080% when Cr: 0.30% or more and 1.50% or less;
        Al: 0.800% to 2.000%;
        P: 0.030% or less;
        S: 0.0100% or less;
        Mo: 0.10% to 0.50%;
        O: 0.0070% or less;
        N: 0.0070% or less;
        B: "0" (zero)% to 0.0020%;
        Ti: "0" (zero)% to 0.050%;
        Nb: "0" (zero)% to 0.050%;
        V: "0" (zero)% to 0.050%;
        Ni: "0" (zero)% to 1.00%;
        Cu: "0" (zero)% to 1.00%;
        Ca or REM, or both thereof: "0" (zero)% to 0.0300% in total;
        W: "0" (zero)% to 1.000%;
        Mg: "0" (zero)% to 0.010%;
        Zr: "0" (zero)% to 0.200%;
        As: "0" (zero)% to 0.500%;
        Co: "0" (zero)% to 1.000%;
        Sn: "0" (zero)% to 0.200%;
        Pb: "0" (zero)% to 0.200%;
        Y: "0" (zero)% to 0.200%;
        Hf: "0" (zero)% to 0.2000%; and
        the balance: Fe and impurities; and

    a structure expressed by:

        an area fraction of ferrite: 95% or more;
        an area fraction of retained austenite and an area fraction of martensite: 1% to 3% in total;
        a product of the area fraction of retained austenite and a carbon concentration in retained austenite: 1 or more;
        a value of I(111)/{I(100) + I(110)} at a region where a depth from a surface is 1/4 of a thickness of the cold-rolled steel sheet when intensity of a (hkl) plane is expressed by I(hkl): 2 or less;
        a quotient ($V_B/V_{\gamma R}$) where an area fraction of bainite (V_B) is divided by the area fraction of retained austenite ($V_{\gamma R}$): is 0.6 or less.

2. The cold-rolled steel sheet according to claim 1, wherein the chemical composition satisfies:

    Cr: 0.30% to 0.80%; or
    Mn: 0.40% to 1.00%; or

    both thereof.

3. The cold-rolled steel sheet according to claim 1 or 2, wherein the chemical composition satisfies:

B: 0.0003% to 0.0020%;
Ti: 0.005% to 0.050%;
Nb: 0.005% to 0.050%; or
V: 0.005% to 0.050%; or

any combination thereof.

4. The cold-rolled steel sheet according to any one of claims 1 to 3, wherein the chemical composition satisfies:

Ni: 0.01% to 1.00%; or
Cu: 0.01% to 1.00%; or

both thereof.

5. The cold-rolled steel sheet according to any one of claims 1 to 4, wherein the chemical composition satisfies Ca or REM, or both thereof: 0.0005% to 0.0300% in total.

6. The cold-rolled steel sheet according to any one of claims 1 to 5, wherein the chemical composition satisfies:

W: 0.001% to 1.000%;
Mg: 0.0001% to 0.010%;
Zr: 0.0001% to 0.200%;
As: 0.0001% to 0.500%;
Co: 0.0001% to 1.000%;
Sn: 0.0001% to 0.200%;
Pb: 0.0001% to 0.200%;
Y: 0.0001% to 0.200%; or
Hf: 0.0001% to 0.2000%; or

any combination thereof.

7. A galvanized cold-rolled steel sheet, comprising:

the cold-rolled steel sheet according to any one of claims 1 to 6; and
a hot-dip galvanized layer or an alloyed hot-dip galvanized layer on a surface of the cold-rolled steel sheet.

8. A method of manufacturing a cold-rolled steel sheet, comprising:

performing hot-rolling of a slab heated to a temperature of 1250°C or less to obtain a hot-rolled sheet;
coiling the hot-rolled sheet at a temperature of 650°C or less;
then, performing cold-rolling of the hot-rolled sheet with a reduction ratio of 70% or more to obtain a cold-rolled sheet; and
performing continuous annealing of the cold-rolled sheet at a temperature of 750°C to 900°C,
wherein
the performing the hot-rolling comprises performing finish-rolling at a temperature of 850°C to 1000°C under a state in which two phases of ferrite and austenite exist,
a total reduction ratio at last three stands is 60% or more in the finish-rolling,
cooling is started within one second from an end of the finish-rolling, and
the slab comprises a chemical composition expressed by, in mass%,

Si: 0.01% to 0.50%;
Mn or Cr, or both thereof: 0.70% to 1.50% in total;
C: 0.030% to 0.060% when Cr: "0" (zero)% or more and less than 0.30%,
0.030% to 0.080% when Cr: 0.30% or more and 1.50% or less;
Al: 0.800% to 2.000%;
P: 0.030% or less;

S: 0.0100% or less;
Mo: 0.10% to 0.50%;
O: 0.0070% or less;
N: 0.0070% or less;
B: "0" (zero)% to 0.0020%;
Ti: "0" (zero)% to 0.050%;
Nb: "0" (zero)% to 0.050%;
V: "0" (zero)% to 0.050%;
Ni: "0" (zero)% to 1.00%;
Cu: "0" (zero)% to 1.00%;
Ca or REM, or both of them: "0" (zero)% to 0.0300% in total;
W: "0" (zero)% to 1.000%;
Mg: "0" (zero)% to 0.010%;
Zr: "0" (zero)% to 0.200%;
As: "0" (zero)% to 0.500%;
Co: "0" (zero)% to 1.000%;
Sn: "0" (zero)% to 0.200%;
Pb: "0" (zero)% to 0.200%;
Y: "0" (zero)% to 0.200%;
Hf: "0" (zero)% to 0.2000%; and
the balance: Fe and impurities.

9. The method of manufacturing the cold-rolled steel sheet according to claim 8, wherein the chemical composition satisfies:

Cr: 0.30% to 0.80%; or
Mn: 0.40% to 1.00%; or

both thereof.

10. The method of manufacturing the cold-rolled steel sheet according to claim 8 or 9, wherein the chemical composition satisfies:

B: 0.0003% to 0.0020%;
Ti: 0.005% to 0.050%;
Nb: 0.005% to 0.050%; or
V: 0.005% to 0.050%; or

any combination thereof.

11. The method of manufacturing the cold-rolled steel sheet according to any one of claims 8 to 10, wherein the chemical composition satisfies:

Ni: 0.01% to 1.00%; or
Cu: 0.01% to 1.00%; or

both thereof.

12. The method of manufacturing the cold-rolled steel sheet according to any one of claims 8 to 11, wherein the chemical composition satisfies
Ca or REM, or both thereof: 0.0005% to 0.0300% in total.

13. The method of manufacturing the cold-rolled steel sheet according to any one of claims 8 to 12, wherein the chemical composition satisfies:

W: 0.001% to 1.000%;
Mg: 0.0001% to 0.010%;
Zr: 0.0001% to 0.200%;

As: 0.0001% to 0.500%;
Co: 0.0001% to 1.000%;
Sn: 0.0001% to 0.200%;
Pb: 0.0001% to 0.200%;
Y: 0.0001% to 0.200%; or
Hf: 0.0001% to 0.2000%; or

any combination thereof.

14. A method of manufacturing a galvanized cold-rolled steel sheet, comprising:

manufacturing a cold-rolled steel sheet by the method according to any one of claims 8 to 13; and
forming a hot-dip galvanized layer or an alloyed hot-dip galvanized layer on a surface of the cold-rolled steel sheet.

Patentansprüche

1. Ein kaltgewalztes Stahlblech, umfassend:
eine chemische Zusammensetzung, ausgedrückt in Massen-%:

Si: 0,01% bis 0,50%;
Mn oder Cr oder beide davon: insgesamt 0,70% bis 1,50%;
C: 0,030% bis 0,060%, wenn Cr: "0" (null)% oder mehr und weniger als 0,30% beträgt,
0,030% bis 0,080%, wenn Cr: 0,30% oder mehr und 1,50% oder weniger beträgt;
Al: 0,800% bis 2,000%;
P: 0,030% oder weniger;
S: 0,0100% oder weniger;
Mo: 0,10% bis 0,50%;
O: 0,0070% oder weniger;
N: 0,0070% oder weniger;
B: "0" (null)% bis 0,0020%;
Ti: "0" (null)% bis 0,050%;
Nb: "0" (null)% bis 0,050%;
V: "0" (null)% bis 0,050%;
Ni: "0" (null)% bis 1,00%;
Cu: "0" (null)% bis 1,00%;
Ca oder Seltenerdmetalle oder beide davon: insgesamt "0" (null)% bis 0,0300%;
W: "0" (null)% bis 1,000%;
Mg: "0" (null)% bis 0,010%;
Zr: "0" (null)% bis 0,200%;
As: "0" (null)% bis 0,500%;
Co: "0" (null)% bis 1,000%;
Sn: "0" (null)% bis 0,200%;
Pb: "0" (null)% bis 0,200%;
Y: "0" (null)% bis 0,200%;
Hf: "0" (null)% bis 0,2000%; und
den Rest: Fe und Verunreinigungen; und
einer Struktur ausgedrückt durch:

einen Flächenanteil von Ferrit: 95% oder mehr;
einen Flächenanteil aus Restaustenit und einen Flächenanteil aus Martensit: insgesamt 1% bis 3%;
ein Produkt des Flächenanteils aus Restaustenit und einer Kohlenstoffkonzentration in dem Restaustenit: 1 oder mehr;
einen Wert aus I(111)/{I(100) + I(110)} in einem Bereich, in welchem eine Tiefe von einer Oberfläche 1/4 einer Dicke des kaltgewalzten Stahlblechs beträgt, wobei die Intensität einer (hkl)-Fläche durch I(hkl): 2 oder weniger ausgedrückt wird;
einen Quotienten ($V_B/V_{\gamma R}$), wobei ein Flächenanteil von Bainit (V_B) durch den Flächenanteil des Restaustenits ($V_{\gamma R}$) geteilt wird: der 0,6 oder weniger ist.

2. Das kaltgewalzte Stahlblech gemäß Anspruch 1, wobei die chemische Zusammensetzung erfüllt:

Cr: 0,30% bis 0,80%; oder
Mn: 0,40% bis 1,00%; oder

beide davon.

3. Das kaltgewalzte Stahlblech gemäß Anspruch 1 oder 2, wobei die chemische Zusammensetzung erfüllt:

B: 0,0003% bis 0,0020%;
Ti: 0,005% bis 0,050%;
Nb: 0,005% bis 0,050%; oder
V: 0,005% bis 0,050%; oder

eine Kombination davon.

4. Das kaltgewalzte Stahlblech gemäß einem der Ansprüche 1 bis 3, wobei die chemische Zusammensetzung erfüllt:

Ni: 0,01% bis 1,00%; oder
Cu: 0,01% bis 1,00%; oder

beide davon.

5. Das kaltgewalzte Stahlblech gemäß einem der Ansprüche 1 bis 4, wobei die chemische Zusammensetzung erfüllt: Ca oder Seltenerdmetalle oder beide davon: insgesamt 0,0005% bis 0,0300%.

6. Das kaltgewalzte Stahlblech gemäß einem der Ansprüche 1 bis 5, wobei die chemische Zusammensetzung erfüllt:

W: 0,001% bis 1,000%;
Mg: 0,0001% bis 0,010%;
Zr: 0,0001% bis 0,200%;
As: 0,0001% bis 0,500%;
Co: 0,0001% bis 1,000%;
Sn: 0,0001% bis 0,200%;
Pb: 0,0001% bis 0,200%;
Y: 0,0001% bis 0,200%; oder
Hf: 0,0001% bis 0,2000%; oder

eine Kombination davon.

7. Ein galvanisiertes kaltgewalztes Stahlblech, umfassend:

das kaltgewalzte Stahlblech gemäß einem der Ansprüche 1 bis 6; und
eine heißtauchgalvanisierte Schicht oder eine legierte heißtauchgalvanisierte Schicht auf einer Oberfläche des kaltgewalzten Stahlblechs.

8. Ein Verfahren zur Herstellung eines kaltgewalzten Stahlblechs, umfassend:

Durchführen von Warmwalzen einer Bramme, welche auf eine Temperatur von 1250°C oder weniger erwärmt wurde, um ein warmgewalztes Blech zu erhalten;
Wickeln des warmgewalzten Blechs bei einer Temperatur von 650°C oder weniger;
dann Durchführen von Kaltwalzen des warmgewalzten Blechs mit einem Reduktionsverhältnis von 70% oder mehr, um ein kaltgewalztes Blech zu erhalten; und
Durchführen von kontinuierlichem Wärmebehandeln des kaltgewalzten Blechs bei einer Temperatur von 750°C bis 900°C,
wobei
das Durchführen des Warmwalzens das Durchführen von Endwalzen bei einer Temperatur von 850°C bis 1000°C in einem Zustand in welchem zwei Phasen von Ferrit und Austenit vorhanden sind, umfasst,

eine Gesamtreduktionsrate bei den letzten drei Walzgerüsten 60% oder mehr beim Endwalzen beträgt,
das Kühlen innerhalb einer Sekunde ab dem Ende des Endwalzens gestartet wird und
die Bramme eine chemische Zusammensetzung umfasst, ausgedrückt, in Massen-%, durch:

Si: 0,01% bis 0,50%;
Mn oder Cr oder beide davon: insgesamt 0,70% bis 1,50%;
C: 0,030% bis 0,060%, wenn Cr: "0" (null)% oder mehr und weniger als 0,30% beträgt,
0,030% bis 0,080%, wenn Cr: 0,30% oder mehr und 1,50% oder weniger beträgt;
Al: 0,800% bis 2,000%;
P: 0,030% oder weniger;
S: 0,0100% oder weniger;
Mo: 0,10% bis 0,50%;
O: 0,0070% oder weniger;
N: 0,0070% oder weniger;
B: "0" (null)% bis 0,0020%;
Ti: "0" (null)% bis 0,050%;
Nb: "0" (null)% bis 0,050%;
V: "0" (null)% bis 0,050%;
Ni: "0" (null)% bis 1,00%;
Cu: "0" (null)% bis 1,00%;
Ca oder Seltenerdmetalle oder beide davon: insgesamt "0" (null)% bis 0,0300%;
W: "0" (null)% bis 1,000%;
Mg: "0" (null)% bis 0,010%;
Zr: "0" (null)% bis 0,200%;
As: "0" (null)% bis 0,500%;
Co: "0" (null)% bis 1,000%;
Sn: "0" (null)% bis 0,200%;
Pb: "0" (null)% bis 0,200%;
Y: "0" (null)% bis 0,200%;
Hf: "0" (null)% bis 0,2000%; und
den Rest: Fe und Verunreinigungen.

9. Das Verfahren zur Herstellung des kaltgewalzten Stahlblechs gemäß Anspruch 8, wobei die chemische Zusammensetzung erfüllt:

Cr: 0,30% bis 0,80%; oder
Mn: 0,40% bis 1,00%; oder

beide davon.

10. Das Verfahren zur Herstellung des kaltgewalzten Stahlblechs gemäß Anspruch 8 oder 9, wobei die chemische Zusammensetzung erfüllt:

B: 0,0003% bis 0,0020%;
Ti: 0,005% bis 0,050%;
Nb: 0,005% bis 0,050%; oder
V: 0,005% bis 0,050%; oder

eine Kombination davon.

11. Das Verfahren zur Herstellung des kaltgewalzten Stahlblechs gemäß einem der Ansprüche 8 bis 10, wobei die chemische Zusammensetzung erfüllt:

Ni: 0,01% bis 1,00%; oder
Cu: 0,01% bis 1,00%; oder

beide davon.

12. Das Verfahren zur Herstellung des kaltgewalzten Stahlblechs gemäß einem der Ansprüche 8 bis 11, wobei die chemische Zusammensetzung erfüllt:
Ca oder Seltenerdmetalle oder beide davon: insgesamt 0,0005% bis 0,0300%.

13. Das Verfahren zur Herstellung des kaltgewalzten Stahlblechs gemäß einem der Ansprüche 8 bis 12, wobei die chemische Zusammensetzung erfüllt:

W: 0,001% bis 1,000%;
Mg: 0,0001% bis 0,010%;
Zr: 0,0001% bis 0,200%;
As: 0,0001% bis 0,500%;
Co: 0,0001% bis 1,000%;
Sn: 0,0001% bis 0,200%;
Pb: 0,0001% bis 0,200%;
Y: 0,0001% bis 0,200%; oder
Hf: 0,0001% bis 0,2000%; oder
eine Kombination davon.

14. Ein Verfahren zur Herstellung eines galvanisierten kaltgewalzten Stahlblechs, umfassend:

Herstellen eines kaltgewalzten Stahlblechs durch das Verfahren gemäß einem der Ansprüche 8 bis 13; und
Bilden einer heißtauchgalvanisierten Schicht oder einer legierten heißtauchgalvanisierten Schicht auf einer Oberfläche des kaltgewalzten Stahlblechs.

Revendications

1. Tôle d’acier laminée à froid comprenant :
une composition chimique représentée, en % en masse, par :

Si : 0,01 % à 0,50 % ;
Mn ou Cr ou les deux : 0,70 % à 1,50 % au total ;
C : 0,030 % à 0,060 % quand Cr : "0" (zéro) % ou plus et moins de 0,30 %,
0,030 % à 0,080 % quand Cr : 0,30 % ou plus et 1,50 % ou moins ;
Al : 0,800 % à 2,000 % ;
P : 0,030 % ou moins ;
S : 0,0100 % ou moins ;
Mo : 0,10 % à 0,50 % ;
O : 0,0070 % ou moins ;
N : 0,0070 % ou moins ;
B : "0" (zéro) % à 0,0020 % ;
Ti : "0" (zéro) % à 0,050 % ;
Nb : "0" (zéro) % à 0,050 % ;
V : "0" (zéro) % à 0,050 % ;
Ni : "0" (zéro) % à 1,00 % ;
Cu : "0" (zéro) % à 1,00 % ;
Ca ou REM ou les deux : "0" (zéro) % à 0,0300 % au total ;
W : "0" (zéro) % à 1,000 % ;
Mg : "0" (zéro) % à 0,010 % ;
Zr : "0" (zéro) % à 0,200 % ;
As : "0" (zéro) % à 0,500 % ;
Co : "0" (zéro) % à 1,000 % ;
Sn : "0" (zéro) % à 0,200 % ;
Pb : "0" (zéro) % à 0,200 % ;
Y : "0" (zéro) % à 0,200 % ;
Hf : "0" (zéro) % à 0,2000 % ; et
le reste : Fe et impuretés ; et
une structure représentée par :

une fraction surfacique de ferrite : 95 % ou plus ;
une fraction surfacique d'austénite résiduelle et une fraction surfacique de martensite : 1 % à 3 % au total ;
un produit de la fraction surfacique d'austénite résiduelle et de la concentration de carbone dans l'austénite résiduelle : 1 ou plus ;
une valeur I(111)/{I(100) + I(110)} au niveau d'une région où la profondeur par rapport à la surface est de 1/4 de l'épaisseur de la tôle d'acier laminée à froid quand l'intensité du plan (hkl) est représenté par I(hkl) : 2 ou moins ;
un quotient ($V_B/V_{\gamma R}$) où une fraction surfacique de bainite (V_B) est divisée par la fraction surfacique de l'austénite résiduelle ($V_{\gamma R}$) : 0,6 ou moins.

2. Tôle d'acier laminée à froid selon la revendication 1, dans laquelle la composition chimique satisfait à :

Cr : 0,30 % à 0,80 % ; ou
Mn : 0,40 % à 1,00 % ; ou

les deux.

3. Tôle d'acier laminée à froid selon la revendication 1 ou 2, dans laquelle la composition chimique satisfait à :

B : 0,0003 % à 0,0020 % ;
Ti : 0,005 % à 0,050 % ;
Nb : 0,005 % à 0,050 % ; ou
V : 0,005 % à 0,050 % ; ou

l'une quelconque de leurs combinaisons.

4. Tôle d'acier laminée à froid selon l'une quelconque des revendications 1 à 3, dans laquelle la composition chimique satisfait à :

Ni : 0,01 % à 1,00 % ; ou
Cu : 0,01 % à 1,00 % ; ou les deux.

5. Tôle d'acier laminée à froid selon l'une quelconque des revendications 1 à 4, dans laquelle la composition chimique satisfait à :
Ca ou REM ou les deux : 0,0005 % à 0,0300 % au total.

6. Tôle d'acier laminée à froid selon l'une quelconque des revendications 1 à 5, dans laquelle la composition chimique satisfait à :

W : 0,001 % à 1,000 % ;
Mg : 0,0001 % à 0,010 % ;
Zr : 0,0001 % à 0,200 % ;
As : 0,0001 % à 0,500 % ;
Co : 0,0001 % à 1,000 % ;
Sn : 0,0001 % à 0,200 % ;
Pb : 0,0001 % à 0,200 % ;
Y : 0,0001 % à 0,200 % ; ou
Hf : 0,0001 % à 0,2000 % ; ou

l'une quelconque de leurs combinaisons.

7. Tôle d'acier laminée à froid galvanisée, comprenant :

la tôle d'acier laminée à froid selon l'une quelconque des revendications 1 à 6 ; et
une couche galvanisée à chaud ou une couche galvanisée à chaud alliée sur une surface de la tôle d'acier laminée à froid.

8. Procédé de fabrication d'une tôle d'acier laminée à froid, comprenant :

la mise en oeuvre d'un laminage à chaud d'une brame chauffée à une température de 1250°C ou moins pour que soit obtenue une tôle laminée à chaud ;
le bobinage de la tôle laminée à chaud à une température de 650°C ou moins ;
puis la mise en oeuvre d'un laminage à froid de la tôle laminée à chaud avec un taux de réduction de 70 % ou plus pour que soit obtenue une tôle laminée à froid ; et
la mise en oeuvre d'un recuit continu de la tôle laminée à froid à une température de 750°C à 900°C,
dans lequel
la mise en oeuvre du laminage à chaud comprend la mise en oeuvre d'un laminage de finition à une température de 850°C à 1000°C dans un état dans lequel existent deux phases de ferrite et d'austénite,
le taux de réduction total des trois derniers passages est de 60 % ou plus dans le laminage de finition,
le refroidissement est commencé dans la seconde suivant la fin du laminage de finition, et
la brame comprend une composition chimique représentée, en % en masse, par :

Si : 0,01 % à 0,50 % ;
Mn ou Cr ou les deux : 0,70 % à 1,50 % au total ;
C : 0,030 % à 0,060 % quand Cr : "0" (zéro) % ou plus et moins de 0,30 %,
0,030 % à 0,080 % quand Cr : 0,30 % ou plus et 1,50 % ou moins ;
Al : 0,800 % à 2,000 % ;
P : 0,030 % ou moins ;
S : 0,0100 % ou moins ;
Mo : 0,10 % à 0,50 % ;
O : 0,0070 % ou moins ;
N : 0,0070 % ou moins ;
B : "0" (zéro) % à 0,0020 % ;
Ti : "0" (zéro) % à 0,050 % ;
Nb : "0" (zéro) % à 0,050 % ;
V : "0" (zéro) % à 0,050 % ;
Ni : "0" (zéro) % à 1,00 % ;
Cu : "0" (zéro) % à 1,00 % ;
Ca ou REM ou les deux : "0" (zéro) % à 0,0300 % au total ;
W : "0" (zéro) % à 1,000 % ;
Mg : "0" (zéro) % à 0,010 % ;
Zr : "0" (zéro) % à 0,200 % ;
As : "0" (zéro) % à 0,500 % ;
Co : "0" (zéro) % à 1,000 % ;
Sn : "0" (zéro) % à 0,200 % ;
Pb : "0" (zéro) % à 0,200 % ;
Y : "0" (zéro) % à 0,200 % ;
Hf : "0" (zéro) % à 0,2000 % ; et

le reste : Fe et impuretés.

9. Procédé de fabrication d'une tôle d'acier laminée à froid selon la revendication 8, dans lequel la composition chimique satisfait à :

Cr : 0,30 % à 0,80 % ; ou
Mn : 0,40 % à 1,00 % ; ou

les deux.

10. Procédé de fabrication d'une tôle d'acier laminée à froid selon la revendication 8 ou 9, dans lequel la composition chimique satisfait à :

B : 0,0003 % à 0,0020 % ;
Ti : 0,005 % à 0,050 % ;
Nb : 0,005 % à 0,050 % ; ou
V : 0,005 % à 0,050 % ; ou

l'une quelconque de leurs combinaisons.

11. Procédé de fabrication d'une tôle d'acier laminée à froid selon l'une quelconque des revendications 8 à 10, dans lequel la composition chimique satisfait à :

Ni : 0,01 % à 1,00 % ; ou
Cu : 0,01 % à 1,00 % ; ou

les deux.

12. Procédé de fabrication d'une tôle d'acier laminée à froid selon l'une quelconque des revendications 8 à 11, dans lequel la composition chimique satisfait à :
Ca ou REM ou les deux : 0,0005 % à 0,0300 % au total.

13. Procédé de fabrication d'une tôle d'acier laminée à froid selon l'une quelconque des revendications 8 à 12, dans lequel la composition chimique satisfait à :

W : 0,001 % à 1,000 % ;
Mg : 0,0001 % à 0,010 % ;
Zr : 0,0001 % à 0,200 % ;
As : 0,0001 % à 0,500 % ;
Co : 0,0001 % à 1,000 % ;
Sn : 0,0001 % à 0,200 % ;
Pb : 0,0001 % à 0,200 % ;
Y : 0,0001 % à 0,200 % ; ou
Hf : 0,0001 % à 0,2000 % ; ou

l'une quelconque de leurs combinaisons.

14. Procédé de fabrication d'une tôle d'acier laminée à froid galvanisée, comprenant :

la fabrication d'une tôle d'acier laminée à froid par le procédé selon l'une quelconque des revendications 8 à 13 ; et
la formation d'une couche galvanisée à chaud ou d'une couche galvanisée à chaud alliée sur une surface de la tôle d'acier laminée à froid.

REFERENCES CITED IN THE DESCRIPTION

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