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(54) PLATED STEEL SHEET HAVING EXCELLENT SURFACE QUALITY, STRENGTH AND DUCTILITY

(57) Disclosed are: a plated steel sheet having a plated film on the surface of a hot rolled steel sheet; and a method for manufacturing the same, wherein the hot rolled steel sheet comprises, by wt%, 0.15-0.25% of C, 0.5% or less of Si, 0.5-2.0% of Mn, 0.03% or less of P, 0.015% or less of S, 0.05% or less of Al, 0.01% or less of N, 0.05% or less of Ti (excluding 0%), 0.01% or less of B (excluding 0%) and the balance of Fe and inevitable impurities, satisfies the following relation 1, and comprises, as a microstructure, 10-30 area% of ferrite, 20-40 area% of pearlite and 35-55 area% of bainite.

[Relation 1]

$$0.235[C]+0.0158[Mn]+0.0625[Si]+0.0423[Mo]+0.317[Ti]+1.36[Nb]\leq 0.075$$

[Relation 1]

wherein [C], [Mn], [Si], [Mo], [Ti] and [Nb] respectively mean the amounts (wt%) of the corresponding elements included in a steel sheet.

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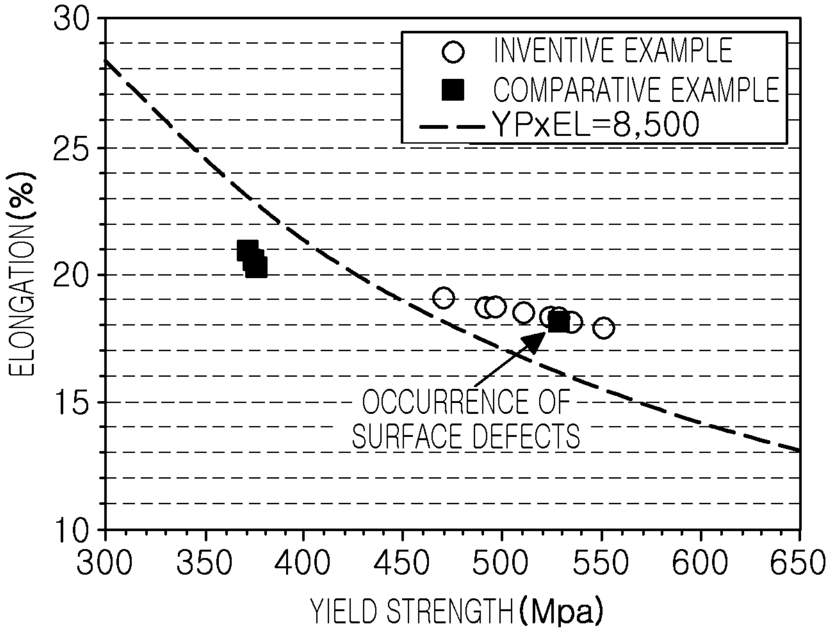
【FIG. 2】


INVENTIVE EXAMPLE
COMPARATIVE EXAMPLE
YPxEL=8,500
ELONGATION(%)
30
25
20
15
10
OCCURRENCE OF
SURFACE DEFECTS
300
350
400
450
500
550
600
650
YIELD STRENGTH(Mpa)

Description

[Technical Field]

[0001] The present disclosure relates to a plated steel sheet having excellent surface quality, strength, and ductility, and more particularly, to a plated steel sheet having excellent surface quality, strength, and ductility, which may be preferably used as a pre-engineered building (PEB) structure.

[Background Art]

[0002] The PEB method may be a method that minimizes the use of materials through optimal design, considering the supporting load, and may be a construction method capable of reducing construction costs and shortening a construction period. The PEB structure used in the PEB method may be required to have excellent strength in order to prevent buckling by load, and the like. Therefore, a steel sheet conventionally used as the PEB structure may be generally manufactured by adding C, Si, Mn, Ti, Nb, Mo, V, and the like to a high purity steel having minimized impurities therein.

[0003] Typically, a method of utilizing precipitation strengthening of the following elements by adding Ti, Nb, V, Mo, and the like (Patent Document 1, Patent Document 2), a method of securing strength by adding a relatively large amount of Cr, Mn, or the like (Patent Document 3, Patent document 4), and a method of increasing impact strength and tensile characteristics by temper annealing Mn and Cr-added steel (patent document 5), and the like have been known.

[0004] In addition, the construction industry in recent years has sought to process a thin material to a shape more due to the change of the design of the structure for reducing costs. Therefore, in order to cope with such a market situation, steel sheets having excellent ductility as well as strength are required. However, the conventional techniques presented above focus only on an increase in strength through solid solution strengthening by alloy components such as C, Si, Mn, Cr, Mo, W, and the like, and precipitation strengthening by alloy components such as Ti, Nb, Mo, and the like. Therefore, there is a limit to ductility improvement.

[0005] Meanwhile, since the PEB structure is required to have excellent corrosion resistance, a plating film may be generally formed on the surface of the steel sheet used as the PEB structure. Therefore, in the case of the steel sheet used as the PEB structure, the surface quality of the hot-rolled steel sheet before performing a plating process becomes a very important factor. In the case of the conventional techniques presented above, the alloy material may be relatively excessive, and the hot-rolling resistance may be relatively high. Therefore, in producing thin sheets having less than 2.0t thickness, there may be a problem that the plating quality is deteriorated due to occurrence of sand-type scales by a hot-rolling process.

[Related Prior Arts]

(Patent Documents)

[0006]

(Patent Document 1) Japanese Patent Publication No. 2011-102434

(Patent Document 2) Japanese Patent Publication No. 2004-359974

(Patent Document 3) European Patent Publication No. 1375694

(Patent Document 4) Korean Patent Publication No. 1997-7002384

(Patent Document 5) International Patent Publication No. 2011-154831

[Disclosure]

[Technical Problem]

[0007] An aspect of the present disclosure is to provide a plated steel sheet having excellent surface quality, strength, and ductility, and a method of manufacturing the same.

[Technical Solution]

[0008] According to an aspect of the present disclosure, a plated steel sheet having a plating film on a surface of a hot-rolled steel sheet, wherein the hot-rolled steel sheet comprises, by weight, 0.15 to 0.25% of C, 0.5% or less of Si, 0.5 to 2.0% of Mn, 0.03% or less of P, 0.015% or less of S, 0.05% or less of Al, 0.01% or less of N, 0.05% or less of Ti (excluding 0%), 0.01% or less of B (excluding 0%), a balance of Fe, and inevitable impurities, satisfies the following relationship 1, and comprises, by area, 10 to 30% of ferrite, 20 to 40% of pearlite, and 35 to 55% of bainite, as a microstructure:

[Relationship 1]

$$0.235[C]+0.0158[Mn]+0.0625[Si]+0.0423[Mo]+0.317[Ti]+1.36[Nb]\leq 0.075$$

[0009] Where [C], [Mn], [Si], [Mo], [Ti], and [Nb] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

[0010] According to another aspect of the present disclosure, a method for manufacturing a plated steel sheet, comprising: reheating a slab to 1100 to 1300°C; finish-rolling the reheated slab to a temperature of Ar3°C or higher to obtain a hot-rolled steel sheet; coiling the hot-rolled steel after cooling the hot-rolled steel sheet at a rate of Vc to (Vc+30)°C/s defined by the following equation 1; and hot-dip plating by dipping the coiled hot-rolled steel sheet in a hot-dip bath, wherein the slab comprises, by weight, 0.15 to 0.25% of C, 0.5% or less of Si, 0.5 to 2.0% of Mn, 0.03% or less of P, 0.015% or less of S, 0.05% or less of Al, 0.01% or less of N, 0.05% or less of Ti (excluding 0%), 0.01% or less of B (excluding 0%), a balance of Fe, and inevitable impurities, satisfies the following relationship 1:

[Relationship 1]

$$0.235[C]+0.0158[Mn]+0.0625[Si]+0.0423[Mo]+0.317[Ti]+1.36[Nb]\leq 0.075$$

[0011] Where [C], [Mn], [Si], [Mo], [Ti], and [Nb] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

[Equation 1]

$$Vc=158.0-156.6[C]+246.6[Si]-40.32[Mn]-25.74[Cr]-73.26[Ni]-8820[B]-1483.2[Ti]+1108.8[Nb]-291.6[Mo]-1092.6[V]$$

[0012] Where [C], [Si], [Mn], [Cr], [Ni], [B], [Ti], [Nb], [Mo], and [V] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

[Advantageous Effects]

[0013] As one of several effects of the present disclosure, the plated steel sheet according to the present disclosure may have the advantages not only of excellent surface quality, such as no surface defects, but also excellent balance of yield strength and elongation.

[0014] Various and advantageous advantages and effects of the present disclosure are not limited to the above description, it will be more readily understood in the course of describing specific embodiments of the present disclosure.

[Description of Drawings]

[0015] The above and other aspects, features, and advantages of the present disclosure will be more clearly understood from the following detailed description, taken in conjunction with the accompanying drawings, in which:

(a) of FIG. 1 is a photograph of a surface of a plated steel sheet of Comparative Example 2, and (b) of FIG. 1 is a photograph of a surface of a plated steel sheet of Inventive Example 1.
FIG. 2 is a graph illustrating elongation to yield strength of the Inventive and Comparative Examples.

[Best Mode for Invention]

[0016] Hereinafter, a plated steel sheet having excellent surface quality, strength, and ductility as an aspect of the present disclosure will be described in detail.
[0017] A plated steel sheet having excellent surface quality, strength, and ductility, which is one aspect of the present disclosure, may include a hot-rolled steel sheet, and a plating film formed on a surface of the hot-rolled steel sheet. The plating film may include, but is not necessarily limited to, Mg: 10% or less (excluding 0%), Al: 5% or less (excluding 0%), a balance of Zn, and inevitable impurities.
[0018] Hereinafter, alloying element and preferred content ranges of the hot-rolled steel sheet will be described in detail. It is to be noted that the content of each element described below may be based on weight unless otherwise specified.

Carbon (C) : 0.15 - 0.25%

[0019] C may be the most economical and effective element for securing strength. When the C content is too low, it may be difficult to secure the target strength. Therefore, it is preferable that the C content is 0.15% or more, and it is more preferable that the C content is 0.16% or more. When the content is overly excessive, ductility may be deteriorated due to an excessive increase in strength. Therefore, the C content is preferably 0.25% or less, and more preferably 0.22% or less.

Silicon (Si): 0.5% or less

[0020] Si may contribute to an increase in strength due to solid solution strengthening and deoxidation of molten steel, but may be not intentionally added in the present disclosure. Even when Si is not added, there may be no major problem in terms of securing physical properties. When the content is overly excessive, red scale due to Si may be formed on the surface of the hot-rolled steel sheet. Therefore, surface quality and plating quality may be deteriorated. In some cases, the Si content may exclude 0%.

Manganese (Mn) : 0.5 - 2.0%

[0021] Mn may be an effective element for solute strengthening of steel, and may need to be added 0.5% or more, preferably 0.6% or more to secure appropriate strength. When the content is excessively large, there may be a risk that a central segregation portion occurs in the continuous casting process. Therefore, it is preferable that the Mn content may be 2.0% or less, and it is more preferable that the Mn content may be 1.8% or less.

Phosphor (P): 0.03% or less

[0022] P may be an inevitable impurity contained in steel, and it is preferable to control its content as low as possible. In particular, when the content is excessive, the risk of weldability deterioration and brittleness of the steel may increase. Therefore, in the present disclosure, the P content may be managed to be 0.03% or less. In some cases, the P content may exclude 0%.

Silicon (S): 0.015% or less

[0023] S may be an impurity that may be inevitably included in steel, and it is preferable to control its content as low as possible. In particular, when the content is excessive, it may be combined with Mn to form a non-metallic inclusion, and the risk of brittleness of the steel may increase. Therefore, in the present disclosure, the content may be managed to be 0.015% or less. In some cases, the S content may exclude 0%.

Aluminum (Al): 0.05% or less

[0024] Al may contribute to deoxidation of molten steel, but may be not intentionally added in the present disclosure. Even when Al is not added, there may be no major problem in terms of securing physical properties. When the content is excessive, nozzle clogging, and the like may occur in the continuous casting process. In the present disclosure, the content may be managed to be 0.05% or less. In some cases, the Al content may exclude 0%.

Nitrogen (N): 0.01% or less

[0025] N may contribute to improvements in strength of steel, but in the present disclosure may be not added intentionally. Even when N is not added, there may be no major problem in terms of securing physical properties. When the content is excessive, the risk of brittleness of the steel may increase. Therefore, in the present disclosure, the content may be managed to be 0.01% or less. In some cases, the N content may exclude 0%.

Titanium (Ti): 0.05% or less (excluding 0%)

[0026] Ti may be present in steel as TiN, to suppress growth of crystal grains during a heating operation for hot-rolling. In addition, it may serve to remove N, such that B does not react with N. When the content is excessive, there may be a risk of clogging the nozzle during the continuous casting process due to excessive TiN precipitation. Therefore, the Ti content is preferably 0.05% or less, more preferably 0.04% or less, and even more preferably 0.03% or less. Further, since Ti needs to be added to steel to obtain the above-mentioned effect, the content of Ti content may exclude 0%. In addition, in the present disclosure, the lower limit of the Ti content is not particularly limited, but the lower limit thereof may be limited to 0.01% in terms of securing a sufficient crystal grain growth inhibiting effect.

Boron (B): 0.01% or less (excluding 0%)

[0027] B may be contained as an alternative element of Si, improve quenchability in very small amounts, and strengthen grain boundaries to improve strength. When the content is excessive, there may be a risk of surface quality deterioration due to excessive BN precipitation. Therefore, the B content is preferably 0.01% or less, more preferably 0.008% or less, and even more preferably 0.005% or less. Further, since B needs to be added to steel to obtain the above-mentioned effect, the B content may exclude 0%. In addition, in the present disclosure, the lower limit of the B content is not particularly limited, but the lower limit thereof may be limited to 0.0005%, more preferably 0.001% in terms of securing sufficient quenchability.

[0028] In addition to the above composition, the rest may be Fe. In the usual manufacturing process, since inevitable impurities that may be not intended from the raw materials or the surrounding environment may be inevitably mixed, these cannot be excluded. Since these impurities are known to those skilled in the art, not all of them may be specifically mentioned in the present specification. Addition of an effective element other than the above composition may be not excluded.

[0029] When designing alloy of steel having component ranges as described above, it is preferable to control to satisfy the following relationship 1. The relationship 1 below may be a factor of surface quality of the steel sheet. When the relationship 1 is satisfied, the finish temperature of hot-rolling may be secured to less than 900°C thanks to the reduction of the hot-rolling resistance. Therefore, since sand-type scale, which is generated by a high temperature during hot-rolling, is not generated, it is possible to secure a plated steel sheet having excellent surface quality after a final plating operation. When the relationship 1 is not satisfied, sand-type scale may be generated due to the high temperature during the hot-rolling operation, and plating quality may be degraded.

[Relationship 1]

$$0.235[C]+0.0158[Mn]+0.0625[Si]+0.0423[Mo]+0.317[Ti]+1.36[Nb]\leq 0.075$$

[0030] Where [C], [Mn], [Si], [Mo], [Ti], and [Nb] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

[0031] Hereinafter, a microstructure of the steel sheet will be described in detail.

[0032] The hot-rolled steel sheet, which may be the base of the plated steel sheet of the present disclosure, may comprise, by area, 10 to 30% of ferrite, 20 to 40% of pearlite, and 35 to 55% of bainite, and more preferably 15 to 25% of ferrite, 25 to 35% of pearlite, and 40 to 50% of bainite, as a microstructure. When phase fractions as described above are not secured, it may be difficult to secure a balance of target strength and ductility due to a decrease in strength or ductility. According to an embodiment of the present disclosure, the sum of the fractions of ferrite, pearlite, and bainite may be 90 area% or more.

[0033] According to an example, an average grain size of the ferrite may be 20 μm or less (excluding 0 μm), and more preferably 15 μm or less (excluding 0 μm). When the average grain size of the ferrite exceeds 20μm, it may be difficult to secure the desired strength. The smaller the average grain size of the ferrite, the more advantageous for securing strength. Therefore, the lower limit thereof is not particularly limited in the present disclosure. In this case, the grain size refers to an equivalent circular diameter of particles detected by observing one cross section of the steel.

[0034] According to an example, an average colony size of pearlite may be 30 μm or less (excluding 0 μm), and more preferably 20 μm or less (excluding 0 μm). When the colony size of pearlite exceeds 30μm, it may be difficult to secure a desired combination of strength x ductility due to inferior ductility, and in particular, cracking may occur due to deterioration of bendability during the manufacture of final product. The smaller the average colony size of pearlite, the more advantageous for securing strength. Therefore, the lower limit thereof is not particularly limited in the present disclosure. In this case, the colony size refers to an equivalent circular diameter of particles, divided by tilt boundaries having misorientation angle of 15 degrees or more detected by observing the inside of pearlite.

[0035] In the present disclosure, residual structure, other than the ferrite, pearlite, and bainite, is not particularly limited, and in some cases, may be further include at least one second phase of martensite, cementite, and residual austenite. All of these second phases may be hard phases. When the area ratio of these second phases is too high, the combination of strength x ductility may be deteriorated, because the strength is relatively high and the ductility is relatively low. The sum of these area ratios may be controlled to be preferably 10% or less, more preferably 5% or less.

[0036] Plated steel sheet of the present disclosure may have a relatively high yield strength, and, according to an example, may have a yield strength of 450 - 600MPa.

[0037] In addition, the plated steel sheet of the present disclosure may have the advantage of excellent balance of strength and ductility, and, according to an example, the product of yield strength and elongation may be 8,500MPa·% or more.

[0038] A plated steel sheet of the present disclosure described above may be manufactured by various methods, and a method for manufacturing the same is not particularly limited. As a preferred example, it may be prepared by the following method.

[0039] Hereinafter, a method of manufacturing a plated steel sheet having excellent strength and ductility which may be another aspect of the present disclosure will be described in detail.

[0040] First, a slab having the above-described composition system may be reheated at 1100 to 1300°C. When the reheating temperature is less than 1100°C, the rolling load may be too large in a subsequent hot-rolling process. When the reheating temperature is higher than 1300°C, austenite grains may be partially coarsened due to abnormal growth of some austenite grains, such that the grain size of the final microstructure may be not homogeneous. In addition, in the present disclosure, slab reheating time is not specifically limited, and is acceptable under normal conditions. In a non-limiting example, the slab reheating time may be 100 to 400 minutes.

[0041] Next, after rough-rolling the reheated slab, the rough-rolled slab may be finish-rolled at the austenite single phase temperature (temperature of Ar3°C or higher), to obtain a hot-rolled steel steel. In this case, rough-rolling refers to a series of intermediate rolling processes performed before finish-rolling. In addition, in the present disclosure, the rough-rolling is not specifically limited, and is acceptable under normal conditions. In a non-limiting example, a thickness of the rough-rolled slab relative to a thickness of the reheated slab may be 10 to 25%, and the rough-rolling temperature may be set to a sufficiently high temperature at which the finish-rolling temperature is ensured.

[0042] According to an example, the finish-rolling may be carried out in the range of (FDT-20)°C to (FDT+20)°C defined by the following equation 2. When the finish rolling temperature exceeds FDT+20°C, austenitic grains of the slab may be coarsened such that sizes of the final ferrite grains and pearlite colonies may be coarse, leading to a decrease in strength. Therefore, it may be difficult to secure desired excellent strength x ductility. When the finish-rolling temperature is less than FDT-20°C, mixed-grain structure may be generated due to two phase temperature rolling, to reduce the ductility, and rolling load may greatly increase during hot-rolling, to decrease productivity. In addition, the mixed-grain structure refers that crystal grains having different particle sizes are mixed. When finish-rolling in the above temperature range, the austenitic structure of the hot finish-rolled steel sheet has an average grain size of 10 - 40μm.

[Equation 2]

$$FDT(°C)=1002.1-353[C]+43.9[Si]-74.1[Mn]-20.4[Cu]-19.9[Cr]-45.6[Ni]-80[Mo]$$

[0043] Where [C], [Si], [Mn], [Cu], [Cr], [Ni], and [Mo] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

[0044] Next, the hot-rolled steel sheet may be cooled at a cooling rate of Vc°C/s or more and (Vc+30) °C/s or less, defined by the following equation 1, and may be then coiled. When the cooling rate is less than Vc°C/s, it may be difficult to secure the desired strength, because the fraction of ferrite and pearlite exceeds the range limited by the present disclosure. When the cooling rate exceeds (Vc+30)°C/s, the fraction of bainite or second phase may exceed the limit of the present disclosure, to deteriorate the ductility. Therefore, a combination of excellent (yield strength x ductility) may be not be obtained.

[Equation 1]

$$Vc=158.0-156.6[C]+246.6[Si]-40.32[Mn]-25.74[Cr]-73.26[Ni]-8820[B]-1483.2[Ti]+1108.8[Nb]-291.6[Mo]-1092.6[V]$$

[0045] Where [C], [Si], [Mn], [Cr], [Ni], [B], [Ti], [Nb], [Mo], and [V] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

[0046] According to an example, the coiling may be carried out in a range of (CT-20) °C to (CT+20) °C defined by the following equation 3. When the coiling temperature exceeds (CT+20)°C, coarse ferrite and pearlite may be formed to lower yield strength. Therefore, the desired (yield strength x elongation) value may be not be obtained. When the coiling temperature is less than CT-20°C, ductility may be deteriorated. More specifically, when the coiling temperature is less than CT-20°C, bainite may be excessively formed beyond the fraction of the present disclosure to cause the ductility deteriorated while making the yield strength increase. Therefore, the desired (yield strength x elongation) value may be not be obtained. Therefore, when controlling and cooling the coiling temperature in the above temperature range, it is possible to obtain a hot-rolled steel sheet having a preferred microstructure, proposed by the present disclosure.

[Equation 3]

$$CT=751.7-357.3[C]-85.3[Mn]-35[Si]-73[Cr]-36[Ni]-84.4[Mo]$$

[0047] Where [C], [Mn], [Si], [Cr], [Ni], and [Mo] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

[0048] Next, hot-dip plating process of the coiled hot-rolled steel sheet may be followed. The hot-dip plating process according to an embodiment of the present disclosure may be carried out by hot-dip plating a solution comprising, by weight, Mg: 10% or less (excluding 0), Al: 5% or less (excluding 0), a balance of Zn, and inevitable impurities.

[Mode for Invention]

[0049] Hereinafter, the present disclosure will be described in more detail with reference to examples. However, the description of these examples may be only for illustrating the practice of the present disclosure, and the present disclosure is not limited by the description of these examples. This may be because the scope of the present disclosure may be determined by the matters described in the claims and the matters reasonably inferred therefrom.

(Example)

[0050] A steel slab having a component system described in the following Table 1 (the contents of P and S as impurities in each steel were controlled at 0.03% by weight or less and 0.015% by weight or less, respectively, the Cu content was 0% by weight, and the N content was 0.005% by weight) was heated to 1200°C, and finish-rolling was performed at the hot finish-rolling temperature shown in the following Table 2, to obtain a hot-rolled steel sheet. Thereafter, the hot-rolled steel sheet was cooled to the coiling temperature described in the following Table 2 at a cooling rate (CR, °C/s), and then coiled up. Thereafter, the coiled hot-rolled steel sheet was subjected to hot-dip plating.

[0051] Then, a microstructure of the plated steel sheet thus-prepared was analyzed, mechanical properties were evaluated, and results therefrom were shown in the following Table 3. In the microstructure of the following Table 3, F refers to ferrite, P refers to pearlite, B refers to bainite, and among grain size, F refers to an average grain size of ferrite, P refers to an average colony size of pearlite, and among mechanical properties, YP refers to yield strength, TS refers to tensile strength, and El refers to elongation.

[0052] In addition, surface quality after plating was visually measured, and results therefrom were shown in the following Table 3. A case in which surface defects such as scales or tear marks were detected is evaluated to be "X", and a case in which surface defects were not detected is evaluated to be "O".

[Table 1]

Type of Steel	Alloy Composition (wt%)											R1***
	C	Si	Mn	s.Al	Cr	Ni	B	Ti	Nb	Mo	V	
IS1*	0.18	0.06	1.1	0.035	0	0	0.0015	0.025	0	0	0	0.071
IS2	0.17	0.06	1.1	0.035	0	0	0.0015	0.025	0	0	0	0.069
IS3	0.19	0.06	1.1	0.035	0	0	0.0015	0.025	0	0	0	0.074
IS4	0.18	0.06	1.05	0.035	0	0	0.0015	0.025	0	0	0	0.071
IS5	0.18	0.06	1.15	0.035	0	0	0.0015	0.025	0	0	0	0.072
IS6	0.18	0.06	1.1	0.035	0	0	0.001	0.025	0	0	0	0.071
IS7	0.18	0.06	1.1	0.035	0	0	0.0018	0.025	0	0	0	0.071
IS8	0.18	0.06	1.1	0.035	0	0	0.0015	0.022	0	0	0	0.070
IS9	0.18	0.06	1.1	0.035	0	0	0.0015	0.028	0	0	0	0.072
CS1**	0.22	0	0. 8	0.035	0	0	0.0015	0	0	0	0	0.064
CS2	0.22	0.06	1	0.035	0	0	0.0015	0.025	0	0	0	0.079
CS3	0.16	0.06	1.1	0.035	0	0	0.0015	0	0.02	0	0	0.086
CS4	0.16	0.06	1.3	0.035	0	0	0	0	0	0	0	0.062
CS5	0.18	0.06	1.1	0.035	0	0	0.0015	0.025	0	0	0	0.071
*IS: Inventive Steel, **CS: Comparative Steel, ***R: Relationship												

[Table 2]

Type of Steel	Ar3	FDT (°C)	Finish-Rolling Temp. (°C)	CT(°C)	Coiling Temp.(°C)	Vc (°C/sec)	CR (°C/sec)	Remark
IS1*	772	860	870	591	580	50	55	IE1***
IS2	775	863	870	595	580	52	57	IE2
IS3	769	856	860	588	580	48	53	IE3
IS4	776	863	870	596	580	52	57	IE4
IS5	768	856	865	587	580	48	53	IE5
IS6	772	860	870	591	580	54	59	IE6
IS7	772	860	870	591	580	47	52	IE7
IS8	772	860	870	591	580	54	59	IE8
IS9	772	860	870	591	580	45	50	IE9
CS1**	784	865	870	605	590	78	70	CE1****
CS2	768	853	900	586	580	48	53	CE2
CS3	778	867	900	599	580	112	70	CE3
CS4	762	852	860	582	580	95	70	CE4
CS5	772	860	870	591	520	50	55	CE5
IS1	772	860	750	591	580	50	55	CE6
IS1	772	860	870	591	580	50	30	CE7

(continued)

Type of Steel	Ar3	FDT (°C)	Finish-Rolling Temp. (°C)	CT(°C)	Coiling Temp.(°C)	Vc (°C/sec)	CR (°C/sec)	Remark
IS2	775	860	875	595	580	48	40	CE8
*IS: Inventive Steel, **CS: Comparative Steel, ***IE: Inventive Example, ****CE: Comparative Example								

[Table 3]

Remark	Surface Quality	Microstructure (area%)			Grain Size (μm)		Mechanical Properties			
		F	P	B	F	P	YP (MPa)	TS (MPa)	EL (%)	YP* EL
IE1*	○	20	30	45	9	12	510	615	18.5	9440
IE2	○	22	29	44	10	13	496	604	18.7	9281
IE3	○	18	31	46	9	11	525	626	18.3	9594
IE4	○	22	29	43	11	14	493	602	18.7	9216
IE5	○	18	31	47	9	9	528	629	18.3	9657
IE6	○	25	29	42	14	13	471	584	19.1	8982
IE7	○	17	31	47	8	7	534	634	18.1	9693
IE8	○	25	28	41	13	14	470	584	19.1	8977
IE9	○	15	32	49	8	6	551	647	17.9	9855
CE1**	○	37	25	33	15	15	376	511	20.2	7602
CE2	X	18	31	47	22	36	529	629	18.1	9592
CE3	X	37	25	33	21	32	374	510	20.5	7676
CE4	○	20	30	45	11	17	373	508	20.7	7730
CE5	○	20	15	60	12	13	615	698	11.2	6888
CE6	○	50	30	15	15	17	400	570	23.1	9240
CE7	○	40	45	10	12	16	420	590	21. 4	8988
CE8	○	45	33	17	13	17	380	550	24.2	9196
*IE: Inventive Example, **CE: Comparative Example										

[0053] As may be seen from Table 3, Inventive Examples 1 to 9 satisfying all of the alloy composition and manufacturing conditions proposed by the present disclosure had excellent surface quality due to no surface defects. In addition, the product of yield strength and elongation was 8,500 MPa·% or more. Therefore, balance between strength and ductility was excellent.

[0054] On the other hand, in the case of Comparative Examples 1 and 4, the cooling rate CR was lower than the limit of the present disclosure, and the ferrite fraction was high. Therefore, the yield strength was lowered, and the product of yield strength and elongation was deteriorated.

[0055] In the case of Comparative Example 2, the relationship 1 exceeded the defined ranges of the present disclosure and the hot finish-rolling temperature (FDT) exceeded the defined ranges of the present disclosure. Therefore, the plated surface was deteriorated by the occurrence of surface defects due to the scale.

[0056] In the case of Comparative Example 3, the relationship 1 and the cooling rate were both outside the defined ranges of the present disclosure. Therefore, the surface quality was also deteriorated, and the product of yield strength and elongation was also deteriorated.

[0057] In the case of Comparative Example 5, the coiling temperature was beyond the defined ranges of the present disclosure, the strength was excessively high. Therefore, the elongation was deteriorated, and as a result, the product of yield strength and elongation was deteriorated.

[0058] In the case of Comparative Example 6, the alloy composition satisfies the defined ranges of the present disclosure, but when the finish rolling temperature was lower than Ar3, the ferrite fraction was excessively produced during rolling. Therefore, sufficient yield strength could not be obtained.

[0059] Comparative Examples 7 and 8 may be cases in which the cooling rate did not satisfy the ranges defined by the present disclosure. As a result, the fractions of ferrite and pearlite were higher than the value to be controlled by the present disclosure, and the yield of bainite was low. Therefore, sufficient yield strength could not be obtained.

[0060] Portion (a) in FIG. 1 is a photograph of a surface of a plated steel sheet of Comparative Example 2, and portion (b) in FIG. 1 is a photograph of a surface of a plated steel sheet of Inventive Example 1. FIG. 2 is a graph illustrating elongation to yield strength of the Inventive and Comparative Examples.

[0061] While example embodiments have been shown and described above, it will be apparent to those skilled in the art that modifications and variations could be made without departing from the scope of the present disclosure as defined by the appended claims.

Claims

1. A plated steel sheet having a plating film on a surface of a hot-rolled steel sheet,
wherein the hot-rolled steel sheet comprises, by weight, 0.15 to 0.25% of C, 0.5% or less of Si, 0.5 to 2.0% of Mn, 0.03% or less of P, 0.015% or less of S, 0.05% or less of Al, 0.01% or less of N, 0.05% or less of Ti (excluding 0%), 0.01% or less of B (excluding 0%), a balance of Fe, and inevitable impurities, satisfies the following relationship 1, and comprises, by area, 10 to 30% of ferrite, 20 to 40% of pearlite, and 35 to 55% of bainite, as a microstructure:

[Relationship 1]

$$0.235[C]+0.0158[Mn]+0.0625[Si]+0.0423[Mo]+0.317[Ti]+1.36[Nb]\leq 0.075$$

Where [C], [Mn], [Si], [Mo], [Ti], and [Nb] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

2. The plated steel sheet according to claim 1, wherein a sum of the fractions of the ferrite, pearlite, and bainite is 90 area% or more.

3. The plated steel sheet according to claim 1, wherein an average grain size of the ferrite is 20μm or less (excluding 0μm).

4. The plated steel sheet according to claim 1, wherein an average colony size of the pearlite is 30μm or less (excluding 0μm).

5. The plated steel sheet according to claim 1, wherein the plating film comprises, by weight, 10% or less of Mg (excluding 0%), 5% or less of Al (excluding 0%), a balance of Zn, and inevitable impurities.

6. The plated steel sheet according to claim 1, having a yield strength of 450 to 600MPa.

7. The plated steel sheet according to claim 1, wherein a product of a yield strength and an elongation of the plated steel sheet is 8,500MPa ·% or more.

8. The plated steel sheet according to claim 1, wherein the hot-rolled steel sheet is a thin material of less than 2.0mm sheet thickness.

9. A method for manufacturing a plated steel sheet, comprising:

reheating a slab comprising, by weight, 0.15 to 0.25% of C, 0.5% or less of Si, 0.5 to 2.0% of Mn, 0.03% or less of P, 0.015% or less of S, 0.05% or less of Al, 0.01% or less of N, 0.05% or less of Ti (excluding 0%), 0.01% or less of B (excluding 0%), a balance of Fe, and inevitable impurities, and satisfying the following relationship 1, to 1100 to 1300°C;

finish-rolling the reheated slab to a temperature of Ar3°C or higher to obtain a hot-rolled steel sheet;
cooling the hot-rolled steel sheet at a rate of Vc to (Vc+30)°C/s defined by the following equation 1, and coiling the cooled hot-rolled steel sheet; and
hot-dip plating by dipping the coiled hot-rolled steel sheet in a hot-dip bath.

[Relationship 1]

$$0.235[C]+0.0158[Mn]+0.0625[Si]+0.0423[Mo]+0.317[Ti]+1.36[Nb]\leq 0.075$$

Where [C], [Mn], [Si], [Mo], [Ti], and [Nb] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

[Equation 1]

$$Vc=158.0-156.6[C]+246.6[Si]-40.32[Mn]-25.74[Cr]-73.26[Ni]-8820[B]-1483.2[Ti]+1108.8[Nb]-291.6[Mo]-1092.6[V]$$

Where [C], [Si], [Mn], [Cr], [Ni], [B], [Ti], [Nb], [Mo], and [V] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

10. The method according to claim 9, wherein the finish-rolling is carried out in a range of (FDT-20)°C to (FDT+20)°C defined by the following equation (2):

[Equation 2]

$$FDT(^{\circ}C)=1002.1-353[C]+43.9[Si]-74.1[Mn]-20.4[Cu]-19.9[Cr]-45.6[Ni]-80[Mo]$$

Where [C], [Si], [Mn], [Cu], [Cr], [Ni], and [Mo] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

11. The method according to claim 9, wherein the coiling is carried out in a range of (CT-20) °C to (CT+20) °C defined by the following equation 3:

[Equation 3]

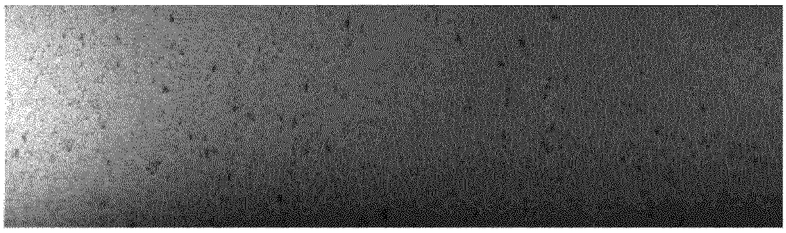
$$CT=751.7-357.3[C]-85.3[Mn]-35[Si]-73[Cr]-36[Ni]-84.4[Mo]$$

Where [C], [Mn], [Si], [Cr], [Ni], and [Mo] represent the content (by wt%) of the corresponding elements contained in the steel sheet, respectively.

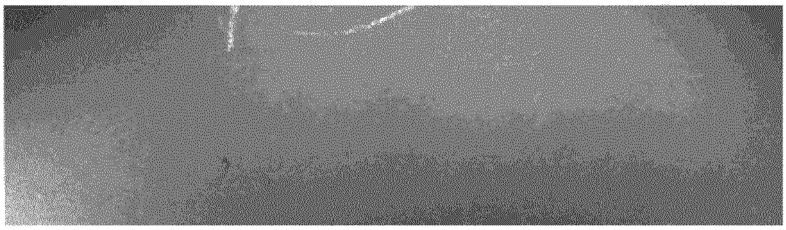
12. The method according to claim 9, wherein the hot-dip bath comprises, by weight, 10% or less of Mg (excluding 0%), 5% or less of Al (excluding 0%), a balance of Zn, and inevitable impurities.

【FIG. 1】

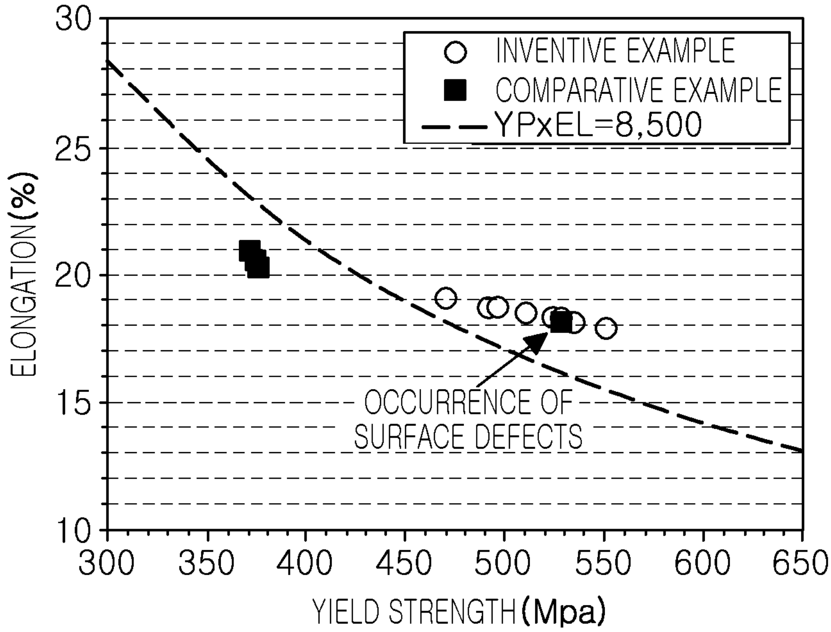
(a)



(b)



【FIG. 2】



30
25
20
15
10
ELONGATION(%)
300
350
400
450
500
550
600
650
YIELD STRENGTH(Mpa)
INVENTIVE EXAMPLE
COMPARATIVE EXAMPLE
YPxEL=8,500
OCCURRENCE OF
SURFACE DEFECTS

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2018/008848

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/14(2006.01)i, C22C 38/04(2006.01)i, C22C 38/06(2006.01)i, C22C 38/02(2006.01)i, C23C 2/06(2006.01)i, C21D 8/02(2006.01)i, C21D 9/46(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/14; C21D 1/18; C21D 8/02; C21D 8/06; C22C 38/00; C22C 38/04; C22C 38/06; C22C 38/02; C23C 2/06; C21D 9/46

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models: IPC as above
Japanese Utility models and applications for Utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS (KIPO internal) & Keywords: hot rolling, plating, titanium, boron, ferrite, perlite, bainite, cooling

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	KR 10-2015-0029742 A (HANWHA PETROCHEMICAL CO., LTD.) 18 March 2015 See paragraphs [0299], [0335], [0342] and claim 1.	1,2,5-8
A	JP 2010-144242 A (NIPPON STEEL CORP. et al.) 01 July 2010 See paragraphs [0018], [0024] and claims 1, 3, 4, 7.	1-12
A	KR 10-2014-0138854 A (JFE STEEL CORPORATION) 04 December 2014 See paragraphs [0085], [0101]-[0110] and claims 1-5.	1-12
A	KR 10-1033752 B1 (NIPPON STEEL CORPORATION) 09 May 2011 See paragraphs [0141]-[0148] and claims 1-4.	1-12

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

* Special categories of cited documents:
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 NOVEMBER 2018 (09.11.2018)	**09 NOVEMBER 2018 (09.11.2018)**
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex Daejeon Building 4, 189, Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2018/008848

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