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(54) Title: HIGH STRENGTH THIN STEEL SHEET HAVING EXCELLENT PLATING AND ELONGATION PROPERTY AND THE METHOD FOR MANUFACTURING THE SAME

(57) Abstract: Provided is a high-strength, thin steel sheet for deep-drawing which is largely used for automotive interior panels and has excellent plating and elongation properties, and a method for manufacturing the same. The thin steel sheet for deep-drawing having excellent plating and elongation properties comprises (i) less than 0.01 wt% of carbon, less than 0.3 wt% of silicon, 0.03-0.2 wt% of manganese, less than 0.15 wt% of phosphorus, 0.003-0.015 wt% of sulfur, 0.1-0.4 wt% of soluble aluminum (Sol.Al), less than 0.01 wt% of nitrogen, 0.003-0.01 wt% of titanium, 0.003-0.04 wt% of niobium, 0.0002-0.002 wt% of boron, less than 0.05 wt% of molybdenum, 0.005-0.2 wt% of copper, 0.05-0.5 wt% of chromium, 0.02-0.1 wt% of antimony, and the balance of Fe with inevitable impurities, and ii) more than 75% MnS, CuS and (Mn,Cu)S precipitates having a size of less than 20 nm. The present invention can provide a thin steel sheet for deep-drawing, having tensile strength of more than 440 MPa and excellent plating and elongation properties.

Description

HIGH STRENGTH THIN STEEL SHEET HAVING EXCELLENT PLATING AND ELONGATION PROPERTY AND THE METHOD FOR MANUFACTURING THE SAME

Technical Field

[1] The present invention relates to a thin steel sheet which is largely used for automotive interior panels. More specifically, the present invention relates to a thin steel sheet for deep-drawing which is capable of securing tensile strength of more than 440 MPa and has excellent plating and elongation properties, and a method for manufacturing the same.

[2]

Background Art

[3] Recently, there has been a rapid increase in applications and uses of high-strength steel sheets for deep-drawing which have been largely used as steel sheets for automotive interior panels, due to excellent formability thereof. This is because these high-strength, deep-drawing steel sheets exhibit significantly low probability of poor molding upon processing thereof, due to high strength as well as excellent elongation properties.

[4]

[5] These excellent properties of the deep-drawing steel sheets are very closely related to trends toward demands of steel sheets having higher strength and superior formability, in order to actively cope with customers' demands and diversification of preference in automotive industry. However, strengthening of automotive steel sheets leads to deterioration of the formability which makes it difficult to simultaneously meet both of strength and formability. Therefore, in order to overcome such disadvantages, there is a need for the development of a more advanced steel-making technology.

[6]

[7] Meanwhile, from an environmental point of view, the automotive steel sheets require to have a clean and attractive surface by surface plating of the steel sheet. However, it is already well-known that it is difficult to secure good surface finish of the steel sheets, due to the presence of the impurity elements added for strengthening of the steel sheets.

[8]

[9] Generally, in order to improve the strength and formability of the steel sheet, strength-improving elements (solid solution strengthening elements such as manganese

(Mn), phosphorus (P), silicon (Si) and the like) and workability-improving elements (carbonitride-forming elements such as titanium (Ti), niobium (Nb), and the like) are usually added to high-purity steel with minimized impurities. However, due to intrinsic properties of steel materials, it is not easy to simultaneously secure the strength and the formability.

[10] Further, strength-improving elements (such as Mn, Si and the like) added to increase the steel strength suffer from various difficulties to make plated steel sheets having an attractive surface, because manganese and silicon oxides are migrated on the plated surface during an annealing process, thereby resulting in deterioration of surface properties of the plated steel sheets. Consequently, alloying elements added to improve the strength of the steel materials usually serve as detrimental factors adversely affecting the workability and plating properties.

[11]

[12] Commonly, the thin steel sheets for deep-drawing is typically manufactured using ultra-low carbon interstitial free (ULC-IF) steel in which amounts of interstitial solid solution elements such as carbon (C) and nitrogen (N) are reduced to a level of less than 50 ppm and the carbonitride-forming elements such as Ti, Nb, and the like are added alone or in any combination thereof during a steel-making process, so as to secure good formability.

[13]

[14] As conventional arts for manufacturing such high-strength, deep-drawing steel sheets having excellent plating properties, there are methods for manufacturing the deep-drawable thin steel sheets developed and proposed by Japanese blast furnace steel makers. As parent patents concerning manufacturing methods of deep-drawable, thin steel sheets utilizing the IF steel, there are Nb-added steels developed by Armco Steel Corp. (US), improved Ti-added steels developed by NSC, and steels with combined addition of Ti-Nb developed by Kawasaki Steel Corp. (KSC), starting from Ti-added steels, which were the listed earliest first patent applications filed by Yawata Steel Corp. (present. Nippon Steel Corp.).

[15] In addition to the above-mentioned parent patents, it is already well-known that numerous steel-related patents were applied for patents, with slightly different limiting conditions and factors in components, composition methods and manufacturing conditions.

[16]

[17] Further, the common point between these patents is to typically add the carbonitride-forming element such as Ti or Nb in an amount of 0.01 to 0.07% to the ultra-low carbon steel, in order to secure the workability. However, this method suffers from problems associated with the occurrence of secondary work embrittlement due to the

absence of the interstitial solid solution elements serving as grain boundary-strengthening elements, in the steel, as well as insignificant improvement of the workability.

[18]

[19] On the other hand, the solid solution strengthening elements (such as P, Mn, Si and the like) added for improvement of the steel strength lead to further weakening of the grain boundary-strength. As conventional arts to alleviate such a disadvantage, mention may be made of Japanese Unexamined Patent Publication Nos. Hei 5-009587, Hei 5-279798, Hei 5-214487, Hei 6-057373 and Hei 7-179946. These conventional arts overcome the above-mentioned problems by addition of boron (B) in an amount of about 5 to 10 ppm. However, due to the addition of Mn, Si and B, migration of manganese oxides and silicon oxides to the steel sheet surface during the annealing process leads to the significant deterioration of characteristics of plated steel sheets, thereby making it difficult to make plated products having an attractive surface.

[20]

Disclosure of Invention

Technical Problem

[21] Therefore, the present invention has been made in view of the above problems, and it is an object of the present invention to provide a high-strength, thin steel sheet for deep-drawing having excellent plating and elongation properties in conjunction with high tensile strength of more than 440 MPa, by appropriate control of contents of alloying elements; and a method for manufacturing the same.

[22]

Technical Solution

[23] In accordance with an aspect of the present invention, the above and other objects can be accomplished by the provision of a high-strength, thin steel sheet having excellent plating and elongation properties, comprising (i) less than 0.01 wt% of carbon (C), less than 0.3 wt% of silicon (Si), 0.03-0.2 wt% of manganese (Mn), less than 0.15 wt% of phosphorus (P), 0.003-0.015 wt% of sulfur (S), 0.1-0.4 wt% of soluble aluminum (Sol.Al), less than 0.01 wt% of nitrogen (N), 0.003-0.01 wt% of titanium (Ti), 0.003-0.04 wt% of niobium (Nb), 0.0002-0.002 wt% of boron (B), less than 0.05 wt% of molybdenum (Mo), 0.005-0.2 wt% of copper (Cu), 0.05-0.5 wt% of chromium (Cr), 0.02-0.1 wt% of antimony (Sb), and the balance of iron (Fe) with inevitable impurities, and (ii) MnS, CuS and (Mn,Cu)S precipitates, wherein more than 75% of the precipitates is MnS, CuS and (Mn,Cu)S precipitates having a size of less than 20 nm.

[24]

[25] In accordance with another aspect of the present invention, there is provided a method for manufacturing a high-strength, thin steel sheet having excellent plating and elongation properties, comprising re-heating a steel slab composed of less than 0.01 wt% of carbon (C), less than 0.3 wt% of silicon (Si), 0.03-0.2 wt% of manganese (Mn), less than 0.15 wt% of phosphorus (P), 0.003-0.015 wt% of sulfur (S), 0.1-0.4 wt% of soluble aluminum (Sol.Al), less than 0.01 wt% of nitrogen (N), 0.003-0.01 wt% of titanium (Ti), 0.003-0.04 wt% of niobium (Nb), 0.0002-0.002 wt% of boron (B), less than 0.05 wt% of molybdenum (Mo), 0.005-0.2 wt% of copper (Cu), 0.05-0.5 wt% of chromium (Cr), 0.02-0.1 wt% of antimony (Sb), and the balance of iron (Fe) with inevitable impurities; subjecting the steel slab to hot finish rolling at the temperature of an austenite single-phase region above 880℃; winding the hot-rolled steel sheet at a temperature of less than 700℃; cold-rolling the hot-rolled steel sheet at a reduction ratio of less than 65%; and continuously annealing the cold-rolled steel sheet at a temperature range of 780℃ to 830℃.

[26]

Advantageous Effects

[27] According to the present invention, a thin steel sheet can secure high tensile strength of more than 440 MPa and excellent elongation properties. Further, a surface defect-free, high-strength thin steel sheet having excellent plating properties can be provided by inhibiting migration of oxides into the steel sheet surface.

[28]

Best Mode for Carrying Out the Invention

[29] Hereinafter, the present invention will be described in more detail.

[30] As a result of a variety of extensive and intensive studies and experiments to solve the problems associated with surface defects resulting from the addition of silicon (Si) and manganese (Mn), the inventors of the present invention discovered that it is possible to inhibit enriching and coarsening of oxides on a steel sheet surface by addition of an proper amount of antimony (Sb). That is, addition of antimony (Sb) interferes with migration of the oxides to grain boundaries, thereby resulting in significant reduction of the probability of surface defects due to Si and Mn. Therefore, it is possible to secure excellent plating properties even when Si and Mn are added.

[31]

[32] Further, the present invention can achieve stable deep drawability even at a relatively low annealing temperature, by appropriately controlling an amount of soluble aluminum (Sol.Al). That is, in the present invention, the Sol.Al affects the formation behavior of carbonitrides such as titanium and niobium precipitates, which consequently leads to coarsening of the precipitate size, causing the development of a

{111} texture. As a result, it is possible to secure better workability even with addition of a smaller amount of Ti and Nb, as compared to conventional IF steels.

[33] Therefore, the present invention can provide a steel sheet having excellent formability, due to improved deep drawability by appropriate addition of Sol.Al to the steel sheet.

[34] Hereinafter, the composition components of the steel according to the present invention will be described.

[35]

[36] Steel Composition

[37]

[38] Carbon (C): less than 0.01 wt%

[39] Carbon (C) is an interstitial solid solution element, and inhibits the formation of a {111} texture which is advantageous for the workability in a formation process of the texture of the steel sheet upon cold rolling and annealing. Further, where a large amount of carbon is contained, the contents of carbonitride-forming elements such as titanium (Ti) and niobium (Nb) should be increased. This is economically disadvantageous. Therefore, the carbon content is preferably limited to the range of less than 0.01 wt%.

[40]

[41] Silicon (Si): Less than 0.3 wt%

[42] Silicon (Si) is a solid solution strengthening element. Addition of Si is advantageous for improvement of the steel strength, but leads to migration of silicon oxides on the steel surface upon annealing, thereby resulting in degradation of a plating surface properties. Therefore, it is preferred to add a smaller amount of Si. However, in order to secure the steel strength which is desired by the present invention, the silicon content is preferably limited to the range of less than 0.3 wt%.

[43]

[44] Manganese (Mn): 0.03-0.2 wt%

[45] Manganese (Mn) is an element known to prevent hot shortness due to solid-solution sulfur (S) by precipitation of solid-solution sulfur in the steel as MnS. The present invention provides significant improvement of the strength and planar anisotropy by controlling the Mn content to a range of 0.03 to 0.2 wt%, such that very fine MnS can be precipitated via the elaborate control of Mn and S contents. Where the content of manganese is lower than 0.03 wt%, it is difficult to achieve the above-mentioned effects. On the other hand, where the content of manganese exceeds 0.2 wt%, this may result in the high possibility of poor aging resistance, due to formation of coarse MnS precipitates. Therefore, the content of Mn is preferably limited to the range of 0.03 to 0.2 wt%.

[46]

[47] Phosphorus (P): Less than 0.15 wt%

[48] Phosphorus (P) is a typical solid solution strengthening element which is added to enhance the strength, in conjunction with Mn. Ti-Nb based component system, corresponding to the subject steel of the present invention, exhibits an increase of the strength, as well as development of a {111} texture which is favorable for an r-value, due to grain refining and grain boundary segregation. The content of phosphorus (P) exceeding 0.15 wt% leads to a significant increase of embrittlement, in conjunction with a sharp decrease of an elongation ratio. Therefore, the content of P is preferably limited to the range of 0.15 wt%.

[49]

[50] Sulfur (S): 0.003-0.015 wt%

[51] Where a content of sulfur (S) is lower than 0.003 wt%, this leads to formation of small amounts of MnS, CuS, (Mn,Cu)S precipitates and excessive coarsening of the precipitates, which in turn are likely to deteriorate the strength and aging resistance. On the other hand, where a content of sulfur (S) is higher than 0.015 wt%, this leads to an increased content of solid-solution sulfur, which consequently results in significant deterioration of the ductility and formability and may cause the risk of hot shortness. Therefore, the content of S is preferably limited to the range of 0.003 to 0.015 wt%.

[52]

[53] Soluble aluminum (Sol.Al): 0.1-0.4 wt%

[54] Soluble aluminum (Sol.Al) serves to ensure stable securing of the deep drawability even at a relatively low annealing temperature, while maintaining an amount of dissolved oxygen in the steel at a sufficiently low level. That is, the Sol.Al in the present invention serves to coarsen (Ti,Nb)C precipitates and to interfere with recrystallization inhibitory action of phosphorus (P), thereby facilitating recrystallization and the development of a {111} texture. Further, the Sol.Al in the present invention affects the formation behavior of carbonitrides, e.g. Ti and Nb precipitates, which thereby leads to coarsening of the precipitates.

[55] As a result, it is possible to secure better workability even with addition of a smaller amount of Ti and Nb, as compared to a conventional IF steel. If the content of Sol.Al is lower than 0.1 wt%, it is difficult to achieve desired effects as mentioned above. On the other hand, if the content of Sol.Al exceeds 0.4 wt%, this may result in an increase of production costs and deterioration of continuous casting operability. Therefore, the content of Sol.Al is preferably limited to the range of 0.1-0.4 wt%.

[56]

[57] Nitrogen (N): less than 0.01 wt%

[58] Nitrogen (N) significantly decreases the workability of the steel, when it is present

in a solid solution state. If a content of N exceeds 0.01 wt%, it is necessary to increase addition amounts of Ti and Nb for fixation thereof as the precipitates. Therefore, the content of N is preferably limited to the range of less than 0.01 wt%.

[59]

[60] Titanium (Ti): 0.003-0.01 wt%

[61] Where a content of titanium (Ti) is lower than 0.003 wt%, it may be difficult to achieve effective precipitation of the residual nitrogen which is not precipitated in the form of AlN, and therefore the processed surface may be inferior due to the occurrence of the aging during steel processing. On the other hand, where a content of titanium (Ti) exceeds 0.01 wt%, titanium oxides are migrated on the steel surface during a plating process, thereby resulting in poor plating surface properties. Therefore, the content of Ti is preferably limited to the range of 0.003 to 0.01 wt%.

[62]

[63] Niobium (Nb): 0.003-0.04 wt%

[64] Where a content of niobium (Nb) is lower than 0.003 wt%, it may be difficult to achieve effective removal of solid solution elements (Mn, Si, etc.) present in the steel, thereby resulting in deterioration of the workability. On the other hand, where a content of niobium (Nb) is higher than 0.04 wt%, this may result in an increase of production costs, as well as deterioration of workability due to the unprecipitated solid-solution Nb. Therefore, the content of Nb is preferably limited to the range of 0.003 to 0.04 wt%.

[65]

[66] Boron (B): 0.0002-0.002 wt%

[67] Boron (B) is a grain boundary-strengthening element, and is a useful component which is capable of improving fatigue properties of spot welds and preventing phosphorus-induced grain boundary embrittlement. If a content of B is lower than 0.0002 wt%, it is difficult to achieve the above-mentioned effects. On the other hand, if a content of B is higher than 0.002 wt%, this leads to a sharp decrease of the workability and degradation of surface properties of the plated steel sheet. Therefore, the content of B is preferably limited to the range of 0.0002-0.002 wt%.

[68]

[69] Molybdenum (Mo): Less than 0.05 wt%

[70] Molybdenum (Mo) is an element of improving secondary work embrittlement resistance and platability. Where a content of Mo exceeds 0.05 wt%, this leads to significant decreases of the above-mentioned effects and is also economically disadvantageous. Therefore, the content of Mo is preferably limited to the range of less than 0.05 wt%.

[71]

[72] Copper (Cu): 0.005-0.2 wt%

[73] Copper (Cu) serves to increase the strength of the steel sheet. Where a content of Cu is lower than 0.005 wt%, it is difficult to achieve the steel strength which is desired by the present invention. On the other hand, where a content of Cu is higher than 0.2 wt%, this leads to no significant advantage in terms of improvement of the strength due to coarsening of copper precipitates, and increased production costs. Therefore, the content of Cu is preferably limited to the range of 0.005-0.2 wt%.

[74]

[75] Chromium (Cr): 0.05-0.5 wt%

[76] Chromium (Cr) serves as an element of improving elongation properties by precipitation of solid-solution carbon present in the steel, through the formation of chromium carbide (CrC) upon annealing of the steel. Where a content of Cr is lower than 0.05 wt%, insufficient precipitation of CrC leads to deterioration of the workability. On the other hand, where a content of Cr exceeds 0.5 wt%, this is economically disadvantageous. Therefore, the content of Cr is preferably limited to the range of 0.05 to 0.5 wt%.

[77]

[78] Antimony (Sb): 0.02-0.1 wt%

[79] Antimony (Sb) is a very important element in the present invention, and is an essential component added to secure excellent plating properties. Sb improves plating properties by blocking the migration of Si and Mn oxides on the steel sheet surface upon annealing.

[80] That is, after hot-rolling, Sb is primarily segregated at grain boundaries, blocks migration paths of Mn and Si oxides to thereby reduce surface defects, consequently obtaining excellent plating properties. If a content of Sb is lower than 0.02 wt%, there is substantially no blocking effect on migration paths of Mn and Si oxides. On the other hand, if a content of Sb is higher than 0.1 wt%, excessive amounts of Sb in the solid-solution state lead to deterioration of elongation properties of the steel. Therefore, the content of Sb is preferably limited to the range of 0.02 to 0.1 wt%.

[81]

[82] The steel sheet of the present invention comprises MnS, CuS and (Mn,Cu)S precipitates, wherein more than 75% of the precipitates is MnS, CuS and (Mn,Cu)S precipitates having a size of less than 20 nm. The size of the precipitates exceeding 20 nm does not make a great contribution to securing of the strength. Further, when an amount of the precipitates having a size of less than 20 nm is lower than 75%, it is also difficult to achieve the steel strength which is desired by the present invention. Therefore, the amount of the precipitates having a size of less than 20 nm is preferably limited to the range of more than 75%.

[83]

[84] In addition to the steel composition components as specified above, the following relational expressions may be preferably satisfied for Ti, Al and N; Nb, Cr and C; and Mn, Cu and S, respectively:

[85] $5.2 \le (Ti/3.42N)+(Al/1.92N) \le 21.1$;

[86] $1.2 \le (Nb/7.75C)+(Cr/4.3C) \le 12.1$; and

[87] $6.7 \le (Mn/1.7S)+(Cu/1.96S) \le 14.6$

[88]

[89] That is, in order to secure excellent aging resistance, drawability, elongation ratio and plating properties in the present invention, relational expressions of Ti and Nb are presented. Hereinafter, the relational expression of the present invention will be described.

[90] For Ti, Al and N, it is preferred to meet the relational expression: $5.2 \le (Ti/3.42N)+(Al/1.92N) \le 21.1$.

[91] N added to the steel is commonly precipitated in the form of TiN and AlN, thereby improving the workability of the steel. Therefore, if contents of Ti and Al are not sufficient, aging may take place due to solid-solution N, and the drawability may also be lowered. However, where solid-solution Ti in the steel exceeds a given content, the steel may be highly susceptible to deterioration of the stretchability, upon processing and lowering of the plating properties. That is, where the value of the above relational expression is smaller than 5.2, this may lead to high susceptibility to the occurrence of the aging and causes deterioration of the drawability. On the other hand, where the value of the above relational expression is larger than 21.1, this may result in deterioration of the stretchability and plating properties. Therefore, the value of the relational expression is preferably limited to the range of 5.2 to 21.1.

[92]

[93] For Nb, Cr and C, it is preferred to meet the relational expression: $1.2 \le (Nb/7.75C)+(Cr/4.3C) \le 12.1$.

[94] The above relational expression is an empirical formula for stable securing of the deep drawability and the stretchability. Where the value of the relational expression is lower than 1.2, this may lead to deterioration of the drawability due to incomplete scavenging of carbon in the steel. On the other hand, where the value of the relational expression exceeds 12.1, this may lead to increased production costs and significant deterioration of the stretchability due to increased contents of solid-solution Nb and Cr in the steel. Therefore, the value of the relational expression is preferably limited to the range of 1.2 to 12.1.

[95]

[96] Further, in order to control sizes of MnS, CuS, (Mn,Cu)S precipitates, a relational

expression between Mn, Cu and S is presented. Hereinafter, the relational expression of the present invention will be described.

[97] For Mn, Cu and S, it is preferred to meet the relational expression: $6.7 \le (Mn/1.7S)+(Cu/1.96S) \le 14.6$

[98] The steel sheet of the present invention, satisfying the above relational expression, contains more than 75% MnS, CuS and (Mn,Cu)S precipitates having a size of less than 20 nm and can therefore achieve the steel strength which is desired by the present invention. Where the value of the relational expression is smaller than 6.7, there are substantially no precipitation effects, making it difficult to secure the steel strength which is desired by the present invention. On the other hand, where the value of the relational expression exceeds 14.6, formation of large amounts of coarse precipitates deteriorates improvement of the steel strength. Therefore, the relational expression is preferably limited to the range of 6.7 to 14.6.

[99]

[100] Hereinafter, a method for manufacturing a thin steel sheet having the above-specified steel composition will be described in more detail.

[101] First, a steel slab, as composed above, is re-heated and then subjected to hot finish rolling at the temperature of an austenite single-phase region above 880℃.

[102] When the hot finish rolling temperature is less than 880℃, this may result in high probability of a two-phase region, instead of the austenite single-phase region. Therefore, the hot finish rolling temperature is preferably limited to the range of 880℃ or higher.

[103] Thereafter, the hot-rolled steel sheet is subjected to the winding at a temperature of less than 700℃ and cold-rolling at a cold-rolling reduction ratio of less than 65%. Where the winding temperature exceeds 700℃, there are substantially no effects on improvements of the strength due to excessive coarsening of the precipitates. Therefore, the winding temperature is preferably limited to the range of less than 700℃.

[104]

[105] Further, the cold-rolling at the above-specified reduction ratio can increase an r-value which is a workability evaluation index, whereas the cold-rolling at the reduction ratio exceeding 65% leads to frequent occurrence of work troubles due to high load on the roll upon field work. Therefore, the cold-rolling reduction ratio is preferably limited to the range of less than 65%.

[106] Thereafter, the cold-rolled steel sheet is subjected to continuous annealing in a temperature range of 780℃ to 830℃. Where the annealing temperature is lower than 780℃, this may probably result in deterioration of the elongation properties. On the other hand, where the annealing temperature exceeds 830℃, this may lead to very high

risk of problems associated with threading performance of steel strips due to high-temperature annealing during the operation, and deterioration of the plating properties due to increased feasibility in surface migration of silicon and manganese oxides. Therefore, the annealing temperature is preferably limited to the range of 780°C to 830°C.

[107] Further, the continuously annealed steel of the present invention may be subjected to alloying treatment by a conventional method.

[108]

Mode for the Invention

[109] Now, the present invention will be described in more detail with reference to the following examples. These examples are provided only for illustrating the present invention and should not be construed as limiting the scope and spirit of the present invention.

[110]

[111] EXAMPLES

[112] Steel slabs having a steel composition as set forth in Table 1 below were subjected to re-heating at 1200°C and hot finish rolling at 910°C which is above the Ar_3 transformation point. Next, the hot-rolled steel sheets were wound under manufacturing conditions as set forth in Table 2 below and then cold-rolled. At continuous annealing temperatures given in Table 2, the cold-rolled steel sheets were heated to a crack temperature at a rate of 10°C/sec and maintained at that temperature for 40 sec.

[113]

[114] For examination of mechanical properties, the annealed steel sheets thus obtained were processed into standard test specimens according to ASTM E-8 standard. Yield strength, tensile strength, elongation, plastic anisotropy factor (r_m value) and planar anisotropy factor (Δr value) of the test specimens were measured using a tensile testing machine (INSTRON Model 6025).

[115] Herein, the r_m value and the Δr value are calculated by the following equations:

[116] $r_m = (r_0+2r_{45}+r_{90})/4$;

[117] $\Delta r = (r_0-2r_{45}+r_{90})/2$.

[118]

[119] Evaluation of the secondary work embrittlement resistance (DBTT) was carried out by laying down the cup, molded under the conditions with a processing ratio of 1.9, and dropping a pendulum on the cup to measure a ductile-brittle transition temperature (DBTT).

[120] In addition, the plating properties were evaluated based on the scale of powdering after measuring a peeling width.

[121] Mechanical properties, secondary work embrittlement resistance and plating performance of Inventive steels and Comparative steels are given in Table 2 below.

[122] Table 1

	Chemical components (wt%)														Formula 1	Formula 2	Formula 3
	C	Si	Mn	P	S	Al	N	Ti	Nb	B	Mo	Cu	Cr	Sb			
Inventive composition	≤0.01	≤0.3	0.03~0.2	≤0.15	0.003~0.015	0.1~0.4	≤0.01	0.003~0.01	0.003~0.04	0.0002~0.002	≤0.05	0.005~0.2	0.05~0.5	0.02~0.1	5.29~21.1	1.2~12.1	6.7~14.6
Inventive steel 1	0.005	0.25	0.08	0.07	0.008	0.11	0.004	0.006	0.035	0.0011	0.04	0.11	0.08	0.03	14.7	4.62	12.9
Inventive steel 2	0.0045	0.23	0.15	0.09	0.012	0.12	0.005	0.007	0.025	0.0008	0.03	0.1	0.2	0.025	12.9	11.0	11.6
Inventive steel 3	0.0062	0.26	0.12	0.08	0.013	0.13	0.004	0.008	0.031	0.0009	0.04	0.12	0.07	0.04	17.5	3.27	10.1
Inventive steel 4	0.0056	0.15	0.11	0.11	0.011	0.12	0.0045	0.008	0.032	0.0012	0.035	0.11	0.15	0.06	14.4	6.96	10.9
Inventive	0.0048	0.28	0.08	0.09	0.007	0.11	0.003	0.007	0.028	0.0008	0.04	0.08	0.32	0.07	19.7	8.98	12.5

steel 5																
Comparative steel 1	0.0048	0.5	0.8	0.08	0.0013	0.05	0.004	0.05	-	0.0007	-	-	-	-	10.1		361.9
Comparative steel 2	0.0062	0.6	0.7	0.11	0.014	0.04	0.003	0.03	0.04	0.0015	-	-	-	-	9.8	0.83	29.4
Formula 1: 5.2≤ (Ti/3.42N)+(Al/1.92N) ≤ 21.1 Formula 2: 1.2≤ (Nb/7.75C)+(Cr/4.3C) ≤ 12.1Formula 3: 6.7≤ (Mn/1.7S)+(Cu/1.96S) ≤ 14.6																

[123] Table 2

	Operating conditions			Mechanical properties						Plating properties	Remarks
	Windingtemp.(℃)	Cold-rolling reduction ratio(%)	Annealing temp.(℃)	Yield strength(MPa)	Tensile Strength(MPa)	Elongation(%)	R-value	DBTT(℃)	Distributionof precipitates(≤20nm)	Peeling width(mm)	
Inventive material 1	685	62	795	283	445	35.2	1.92	-40	78%	4.8	Inventive steel1
Inventive material	681	61	796	285	448	35.3	1.88	-45	77%	4.1	Inventive steel1

2											
Inventive material 3	683	62	810	286	453	34.5	1.93	-50	81%	4.2	Inventive steel2
Inventive material 4	682	61	812	284	455	34.6	1.96	-40	80%	3.6	Inventive steel2
Inventive material 5	654	59	805	275	448	36.1	2.01	-40	82%	3.8	Inventive steel3
Inventive material 6	651	58	812	274	486	34.2	1.89	-50	79%	4.5	Inventive steel3
Inventive material 7	652	63	789	295	462	35.7	2.05	-50	77%	4.3	Inventive steel4
Inventive material 8	694	62	785	287	451	36.2	2.04	-50	81%	5.5	Inventive steel5
Inventive material 9	691	61	804	284	453	35.8	1.91	-40	80%	5.2	Inventive steel5
Comparative material 10	720	62	802	268	446	33.1	1.75	-30	56%	7.8	Comparative steel1
Comparative material	560	62	803	284	451	32.6	1.68	-30	45%	7.2	Comparative steel1

11											
Comparative material 12	722	59	796	285	456	32.9	1.67	-20	52%	8.8	Comparative steel2
Comparative material 13	558	58	795	278	458	33.1	1.62	-30	51%	7.2	Comparative steel2
Score of powdering: grade 1: peeling width≤4 mm; grade 2: peeling width≤6 mm; grade 3: peeling width≤7 mm; and grade 4: peeling width≤8 mm											

[124]

[125] As shown in Tables 1 and 2, Inventive materials (1 to 9) manufactured according to the method of the present invention, using Inventive steels (1 to 5) satisfying a steel composition range of the present invention, achieved high tensile strength of more than 440 MPa by the formation of more than 75% fine precipitates having a size of less than 20 nm, an elongation ratio of more than 34%, and a plastic anisotropy factor (r_m value) of more than 1.88, thus representing 2 to 3% improvements of elongation properties as compared to Comparative steels. Further, Inventive steel materials of the present invention secured secondary work embrittlement resistance (DBBT) of less than -40°C, and a peeling width of 4 to 5 mm, thus representing excellent plating performance as compared to Comparative steels.

[126]

[127] On the other hand, Comparative materials (10 to 13), manufactured using Comparative steels (1 and 2) that do not meet the composition range of the present invention, achieved the tensile strength which was desired in present invention, by adding large amounts of the solid solution strengthening elements Si and Mn, but exhibited inferior elongation properties due to the fact that they did not meet the composition range of the present invention. Further, Comparative steels are steels with no addition of Sb, and Comparative materials (10 to 13) exhibited inferior plating properties due to addition of large amounts of Si and Mn.

[128]

[129] Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

[130]

Claims

[1] A high-strength, thin steel sheet having excellent plating and elongation properties, comprising (i) less than 0.01 wt% of carbon (C), less than 0.3 wt% of silicon (Si), 0.03-0.2 wt% of manganese (Mn), less than 0.15 wt% of phosphorus (P), 0.003-0.015 wt% of sulfur (S), 0.1-0.4 wt% of soluble aluminum (Sol.Al), less than 0.01 wt% of nitrogen (N), 0.003-0.01 wt% of titanium (Ti), 0.003-0.04 wt% of niobium (Nb), 0.0002-0.002 wt% of boron (B), less than 0.05 wt% of molybdenum (Mo), 0.005-0.2 wt% of copper (Cu), 0.05-0.5 wt% of chromium (Cr), 0.02-0.1 wt% of antimony (Sb), and the balance of iron (Fe) with inevitable impurities, and (ii) MnS, CuS and (Mn,Cu)S precipitates, wherein more than 75% of the precipitates is MnS, CuS and (Mn,Cu)S precipitates having a size of less than 20 nm.

[2] The steel sheet according to claim 1, wherein Ti, Al and N satisfy a relational expression of $5.2 \leq (Ti/3.42N)+(Al/1.92N) \leq 21.1$ and Nb, Cr and C satisfy a relational expression of $1.2 \leq (Nb/7.75C)+(Cr/4.3C) \leq 12.1$.

[3] The steel sheet according to claim 1, wherein Mn, Cu and S satisfy a relational expression of $6.7 \leq (Mn/1.7S)+(Cu/1.96S) \leq 14.6$.

[4] A method for manufacturing a high-strength, thin steel sheet having excellent plating and elongation properties, comprising:
re-heating a steel slab composed of less than 0.01 wt% of carbon (C), less than 0.3 wt% of silicon (Si), 0.03-0.2 wt% of manganese (Mn), less than 0.15 wt% of phosphorus (P), 0.003-0.015 wt% of sulfur (S), 0.1-0.4 wt% of soluble aluminum (Sol.Al), less than 0.01 wt% of nitrogen (N), 0.003-0.01 wt% of titanium (Ti), 0.003-0.04 wt% of niobium (Nb), 0.0002-0.002 wt% of boron (B), less than 0.05 wt% of molybdenum (Mo), 0.005-0.2 wt% of copper (Cu), 0.05-0.5 wt% of chromium (Cr), 0.02-0.1 wt% of antimony (Sb), and the balance of iron (Fe) with inevitable impurities;
subjecting the steel slab to hot finish rolling at the temperature of an austenite single-phase region above 880°C;
winding the hot-rolled steel sheet at a temperature of less than 700°C;
cold-rolling the hot-rolled steel sheet at a reduction ratio of less than 65%; and
continuously annealing the cold-rolled steel sheet at a temperature range of 780°C to 830°C.

[5] The method according to claim 4, wherein Ti, Al and N satisfy a relational expression of $5.2 \leq (Ti/3.42N)+(Al/1.92N) \leq 21.1$ and Nb, Cr and C satisfy a relational expression of $1.2 \leq (Nb/7.75C)+(Cr/4.3C) \leq 12.1$.

[6] The method according to claim 4, wherein Mn, Cu and S satisfy a relational

expression of $6.7 \leq (Mn/1.7S)+(Cu/1.96S) \leq 14.6$.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2006/005208

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/04(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)

IPC8 C21D 9/46, C22C 38/06, C22C 38/12, C22C 38/58

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

Korean Patents and applications for inventions since 1975.
Korean Utility models and applications for Utility models since 1975.
Japanese Utility models and applications for Utility models since 1975.

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

eKIPASS (KIPO internal) & keywords: thin steel sheet, high strength, workability

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP2003166035A (NIPPON STEEL CORPORATION) 13 June 2003 See the abstract and claim 1.	1 - 6
A	EP1041167A (KAWASAKI STEEL CORPORATION) 04 October 2000 See the abstract and claim 1.	1 - 6
A	JP2005314792A (JFE STEEL KK.) 10 November 2005 See the abstract and claims 1-6.	1 - 6
A	JP2001131695A (NKK STEEL CORPORATION) 15 May 2001 See the abstract and claim 1.	1 - 6

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"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
27 FEBRUARY 2007 (27.02.2007)	**05 MARCH 2007 (05.03.2007)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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