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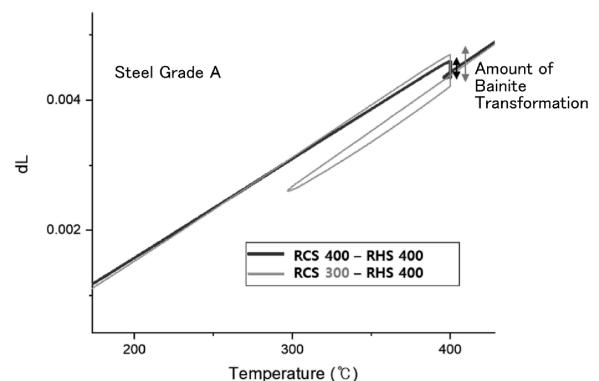
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(54) **COLD-ROLLED STEEL SHEET AND MANUFACTURING METHOD THEREFOR**

(57) The present invention relates to a cold-rolled steel sheet and a manufacturing method therefor and, more specifically, to a cold-rolled steel sheet applicable to a collision energy absorbing member requiring high formability among body-in-white (BIW) structural members, and a manufacturing method therefor.

[FIG. 1]



EP 4 826 034 A1

Description

Technical Field

[0001] The present disclosure relates to a cold-rolled steel sheet and a method for manufacturing the same, and more specifically, to a cold-rolled steel sheet applicable to collision energy absorbing members requiring high formability among Body-in-white (BIW) structural members, and a method for manufacturing the same.

Background Art

[0002] Recently, in the automotive industry, research to reduce vehicle body weight has been actively conducted, led by advanced countries in Europe, to improve fuel efficiency and performance. In the steel industry, efforts are being made to respond to these lightweighting demands from automakers by increasing the strength and further reducing the thickness of steel sheets compared to competing materials (Mg, Al, CFRP) of the same grade. In addition to this lightweighting, with strengthened CO₂ emission regulations and the rapid shift to the era of electric vehicles, the stability and high strength of vehicle body materials are also being required due to enhanced safety regulations for vehicle occupants and pedestrians. Furthermore, the demand for cold-rolled steel sheets is increasing to reduce processing costs, and much research is being conducted on forming multiple parts into a single part at once. To form parts with such complex shapes in a single step, better formability than conventional materials is required.

[0003] In addition to formability, such structural members need to have a high yield ratio to facilitate impact energy absorption. A representative manufacturing method for increasing the yield strength is to utilize water cooling during continuous annealing. A representative conventional technology for this method is disclosed in Patent Document 1. Patent Document 1 relates to a technology for manufacturing a steel material in which a steel with 0.18-0.3% carbon is water-cooled to room temperature after continuous annealing, and then subjected to an overaging treatment at a temperature of 120-300°C for 1-15 minutes, resulting in a martensite volume fraction of 80-97% with the remainder being ferrite. As such, an ultra-high-strength steel can be manufactured by quenching a cold-rolled steel sheet to room temperature after dual-phase or single-phase region annealing and then tempering it. However, according to this method, while the yield strength and hole expansion ratio are excellent, problems arise such as degradation of the coil's shape quality due to temperature deviations in the width and longitudinal directions, and issues like material defects and reduced workability in specific areas during the processing of roll-formed parts.

[0004] Furthermore, there is a problem in that as the strength of a steel sheet increases, its elongation generally decreases, leading to reduced formability, which limits its application as a material for cold stamping. To form a steel material into a complex shape, high elongation is fundamentally required. A representative method for increasing elongation, as disclosed in Patent Document 2, is widely used, which utilizes the Transformation Induced Plasticity (TRIP) phenomenon by introducing retained austenite. However, in conventional patents for developing 780 MPa grade steel types using the TRIP phenomenon, the product of elongation and tensile strength (elongation x TS) does not stably reach the 21800 MPa% level. Therefore, to solve the above-mentioned problems, there is a need to develop a high-strength, ultra-high-elongation cold-rolled steel sheet with excellent elongation and a tensile strength of 780 MPa or more.

[PRIOR ART DOCUMENT]

[Patent Document]

[0005]

(Patent Document 1) Japanese Unexamined Patent Publication No. 1992-289120

(Patent Document 2) Japanese Unexamined Patent Publication No. 2002-382250

Disclosure of Invention

Technical Problem

[0006] An aspect of the present disclosure is to provide a cold-rolled steel sheet and a method for manufacturing the same.

[0007] More specifically, an aspect of the present disclosure is to provide a cold-rolled steel sheet having a tensile strength of 780 MPa grade, high elongation, and an appropriate balance of strength and elongation, and a method for manufacturing the same.

[0008] The technical problems of the present disclosure are not limited to the above-mentioned content. A person having ordinary skill in the art to which the present disclosure pertains will have no difficulty in understanding additional technical problems of the present disclosure from the overall content of this specification.

Solution to Problem

[0009] A cold-rolled steel sheet according to an aspect of the present invention comprises, by weight%, C: 0.20 to 0.30%, Si: 1.45 to 2.0%, Mn: 1.2 to 1.85%, Al: 0.010 to 1.0%, P: 0.100% or less (excluding 0%), S: 0.0300% or less (excluding 0%), and N: 0.01000% or less (excluding 0%), with the balance being Fe and other unavoidable impurities, wherein the C, Si, and Mn simultaneously satisfy the following Relational Expressions 1, 2, and 3, the microstructure comprises, by area%, 8 to 20% of retained austenite, 5% to 60% of bainite, 20% or less of fresh martensite, and the balance of ferrite, and the product of total elongation and tensile strength ($T-EI \times TS$) may be 21800 MPa% or more.

[Relational Expression 1]

$$0.315 \leq C_{Mn} \leq 0.415$$

(In Relational Expression 1, C_{Mn} means the product of the C content and the Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[Relational Expression 2]

$$Si_{Parameter} = -2 \times C_{Mn} + 2.53$$

(In Relational Expression 2, C_{Mn} means the product of the C content and the Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[Relational Expression 3]

$$Si_{Parameter} - 0.175 \leq Si \leq Si_{Parameter} + 0.220$$

(In Relational Expression 3, $Si_{Parameter}$ means the value derived from Relational Expression 2, and Si means the Si content included in the cold-rolled steel sheet, and each unit is excluded.)

[0010] The above-described cold-rolled steel sheet may further include one or more of niobium (Nb), titanium (Ti), and vanadium (V) in a total content of 0.100% or less by weight%.

[0011] The area fraction of the ferrite described above may be 35 to 75 area%.

[0012] A galvanized steel sheet according to another aspect of the present invention may have one of a hot-dip galvanized layer, a galvanized layer, and an electrogalvanized layer formed on at least one surface of the above-described cold-rolled steel sheet.

[0013] The above-described cold-rolled steel sheet may have a yield strength (YS) of 400 MPa or more, a tensile strength (TS) of 780 MPa or more, and a total elongation (T-EI) of 28% or more.

[0014] A method for manufacturing a cold-rolled steel sheet according to another aspect of the present invention may include: a step of heating a slab comprising, by weight%, C: 0.20 to 0.30%, Si: 1.45 to 2.0%, Mn: 1.2 to 1.85%, Al: 0.010 to 1.0%, P: 0.100% or less (excluding 0%), S: 0.0300% or less (excluding 0%), and N: 0.01000% or less (excluding 0%), with the balance being Fe and other unavoidable impurities; a step of finish hot-rolling the slab to obtain a hot-rolled steel sheet; a step of coiling the hot-rolled steel sheet; a step of pickling and then cold-rolling the hot-rolled steel sheet to obtain a cold-rolled steel sheet; a step of continuously annealing the cold-rolled steel sheet for 30 seconds or more at a temperature of $Ae3-15^{\circ}\text{C}$ or less and a γ phase fraction of 50% or more; a first cooling step of cooling the cold-rolled steel sheet to a cooling stop temperature of 600°C to 750°C at an average cooling rate of 2°C/s or more; a second cooling step of cooling the cold-rolled steel sheet to $Ms^{\circ}\text{C}$ or higher and 500°C or lower at an average cooling rate of 10°C/s or more; and a step of reheating the cold-rolled steel sheet to a temperature range of

(B_{nose})±100°C and then maintaining it for 1 minute to 30 minutes for over-aging heat treatment or isothermal heat treatment; wherein C, Si, and Mn included in the slab may simultaneously satisfy the following Relational Expressions 1, 2, and 3.

[Relational Expression 1]

$$0.315 \leq C_{Mn} \leq 0.415$$

(In Relational Expression 1, C_{Mn} means the product of the C content and the Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[Relational Expression 2]

$$Si_{Parameter} = -2 \times C_{Mn} + 2.53$$

(In Relational Expression 2, C_{Mn} means the product of the C content and the Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[Relational Expression 3]

$$Si_{Parameter} - 0.175 \leq Si \leq Si_{Parameter} + 0.220$$

(In Relational Expression 3, Si_{Parameter} means the value derived from Relational Expression 2, and Si means the Si content included in the cold-rolled steel sheet, and each unit is excluded.)

[0015] The above-described slab may further include one or more of niobium (Nb), titanium (Ti), and vanadium (V) in a total content of 0.100% or less by weight%.

[0016] The cooling stop temperature RCS in the second cooling step described above may satisfy the following Relational Expression 4.

[Relational Expression 4]

$$B_{nose} \text{ temperature} - 100^{\circ}\text{C} \geq \text{RCS} > M_s$$

[0017] The heating step may be performed at 1100°C to 1300°C, the finish hot rolling may be performed at Ar3 or higher, the coiling step may be performed at 700°C or lower, and the cold reduction ratio during the cold rolling may be 30% to 80%.

[0018] Finally, a method for manufacturing a galvanized steel sheet according to another aspect of the present invention may further include a step of electro-galvanizing after the over-aging heat treatment or isothermal heat treatment, or a step of immersing in a hot-dip galvanizing bath at 440 to 480°C.

[0019] In addition, the method for manufacturing a galvanized steel sheet may include a step of performing an alloying heat treatment at 450 to 520°C after the immersion. Advantageous Effects of Invention

[0020] According to an aspect of the present disclosure, a cold-rolled steel sheet and a method for manufacturing the same can be provided.

[0021] More specifically, according to an aspect of the present disclosure, it is possible to provide a cold-rolled steel sheet having a tensile strength of 780 MPa grade, high elongation, and an appropriate balance of strength and elongation, and a method for manufacturing the same.

Brief Description of Drawings

[0022]

FIG. 1 is a photograph showing an example of a dilatometer experiment simulating the annealing process of steel grade A.

FIG. 2 is an SEM photograph showing the microstructure of a cold-rolled steel sheet according to an example of the present disclosure.

Best Mode for the Invention

[0023] Hereinafter, preferred embodiments of the present invention will be described. However, the embodiments of the present invention may be modified into various other forms, and the scope of the present invention is not limited to the embodiments described below.

[0024] In this specification, the term "comprising" is used to indicate that other components may be further included, rather than excluding other components, unless there is a specific statement to the contrary.

[0025] Hereinafter, a cold-rolled steel sheet according to an embodiment of the present invention will be described. First, the alloy composition of the present invention will be described. The content of the alloy composition described below is in weight% unless otherwise specified.

[0026] A cold-rolled steel sheet according to an embodiment of the present invention may comprise, by weight%, C: 0.20 to 0.30%, Si: 1.45 to 2.0%, Mn: 1.2 to 1.85%, Al: 0.010 to 1.0%, P: 0.100% or less (excluding 0%), S: 0.0300% or less (excluding 0%), and N: 0.01000% or less (excluding 0%), with the balance being Fe and other unavoidable impurities.

C: 0.20 to 0.30%

[0027] C is an interstitial solid solution element that is the most effective and important element for improving the strength of steel, and it is an element that must be added to secure the strength of bainite and martensite steel. In order to obtain an ultra-high-strength steel that satisfies the target elongation and tensile strength in the present invention, it is preferable that C is added at 0.20% or more. However, if the content exceeds 0.30%, martensite may be excessively formed during cooling due to an increase in hardenability, or the effect of solid solution strengthening may become excessive, causing a sharp increase in strength and deterioration of elongation. Therefore, it is preferable that the C content has a range of 0.20 to 0.30%. In another example, the C content may be from 0.23% to 0.25%, and in yet another example, it may be from 0.20% to 0.22%. In addition, the C content of the cold-rolled steel sheet according to an example of the present invention tends to depend on the Mn content, and as a result, it is necessary to satisfy Relational Expression 1, which will be described later.

Si: 1.45 to 2.0%

[0028] Si is a key element of TRIP (Transformation Induced Plasticity) steel, which increases the fraction of retained austenite and elongation by inhibiting the precipitation of cementite. If the content of Si is less than 1.45%, the control of cementite precipitation during the reheating and over-aging heat treatment step or the isothermal heat treatment step is insufficient, which may result in a small fraction or low stability of the finally formed retained austenite, so that the final elongation may not satisfy the target material properties. On the other hand, if the Si content exceeds 2.0%, the surface properties and plateability of the steel material deteriorate, and excessive solid solution strengthening can hinder elongation due to an increase in strength. Therefore, it is preferable that the Si content has a range of 1.45 to 2.0%. In another example, the Si content may be from 1.5% to 1.65%, and in yet another example, from 1.75% to 1.9%. The Si content of the cold-rolled steel sheet according to an example of the present invention tends to depend on the C and Mn contents, and as a result, it is necessary to satisfy Relational Expressions 2 and 3, which will be described later.

Mn: 1.2 to 1.85%

[0029] Mn is an element added to secure strength and retained austenite stability. If the Mn content is less than 1.2%, it is difficult to secure the level of strength desired in the present invention. On the other hand, if the content exceeds 1.85%, the transformation of ferrite and bainite is excessively delayed, so that the ferrite transformation introduced during cooling after annealing hardly proceeds, and the transformation of fresh martensite proceeds excessively, making it difficult to secure the high elongation targeted in the present invention. In addition, Mn segregates in the thickness direction, facilitating the formation of an Mn band in the slab, which increases the occurrence of defects during the rolling process, in addition to continuous casting cracks. Therefore, it is preferable that the Mn content has a range of 1.2 to 1.85%. In another example, the Mn content may be from 1.3% to 1.5%, and in yet another example, from 1.6% to 1.8%. In the cold-rolled steel sheet according to an example of the present invention,

the control of the Mn content is very important, and since the Mn content depends on the C content, it is necessary to satisfy Relational Expression 1, which will be described later.

Al: 0.010 to 1.0%

[0030] Al may be added to remove oxygen in molten steel, and if the content of Al is less than 0.010%, deoxidation of the steel is not sufficiently achieved, and the cleanliness of the steel is impaired. On the other hand, if the content of Al exceeds 1.0%, not only does the castability of the slab deteriorate, but also the temperature required for single-phase region heating during annealing increases, which can cause production and equipment problems. Therefore, it is preferable that the Al content has a range of 0.010 to 1.0%. The lower limit of the Al content is more preferably 0.020%. The upper limit of the Al content is more preferably 0.90%, and even more preferably 0.80%.

P: 0.100% or less (excluding 0%)

[0031] P is an impurity element contained in steel, and 0% is excluded in consideration of cases where it is unavoidably included during the manufacturing process. However, if the content of P exceeds 0.100%, weldability deteriorates and there is a risk of embrittlement of the steel, so its upper limit can be restricted to 0.100%. A more preferable upper limit for the P content may be 0.0300%.

S: 0.0300% or less (excluding 0%)

[0032] Like P, S is an impurity contained in steel, and 0% is excluded in consideration of cases where it is unavoidably included during the manufacturing process. Since S is an element that impairs the ductility and weldability of the steel sheet, it is desirable to manage its content as low as possible. Therefore, in the present invention, it is preferable to limit the S content to 0.0300% or less. A more preferable upper limit for the S content may be 0.00500%.

N: 0.01000% or less (excluding 0%)

[0033] Nitrogen (N) is an impurity unavoidably contained in steel, and if its content exceeds 0.01000%, there is a concern that it may impair the continuous casting quality by combining with Al in the steel to form AlN.

[0034] Therefore, N can be included at 0.01000% or less, more advantageously 0.007000% or less, and even more advantageously 0.005000% or less.

[0035] A cold-rolled steel sheet according to a non-limiting embodiment of the present invention may further include one or more of Nb, Ti, and V in a total content of 0.100% or less.

[0036] The Nb, Ti, and V can improve the yield strength of the steel even with a small amount of addition, but their effect on improving ductility is insignificant. Therefore, when added, the total content of Nb, Ti, and V can be included at 0.100% or less.

[0037] The remaining component is iron (Fe). However, in a conventional manufacturing process, unintended impurities may be unavoidably incorporated from raw materials or the surrounding environment, so these cannot be excluded. Since these impurities are known to any person skilled in the art of conventional manufacturing processes, all of their details are not specifically mentioned in this specification.

[0038] The cold-rolled steel sheet according to an example of the present invention may satisfy the following Relational Expression 1 regarding the relative content between C and Mn.

[Relational Expression 1]

$$0.315 \leq C_{Mn} \leq 0.415$$

(In Relational Expression 1, C_{Mn} means the product of the C content and the Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[0039] Relational Expression 1 is for securing both high strength and high elongation characteristics. To be specific, both C and Mn are austenite stabilizing elements, but in the case of C, partitioning, in which additional diffusion occurs into the austenite remaining in the temperature range of the Rapid Cooling Section (RCS) and Rapid Heating Section (RHS) during the annealing process, can actively occur. As a result, the addition of C can further increase the final retained austenite fraction and stability after the annealing process is completed. On the other hand, since the aforementioned partitioning phenomenon occurs very weakly for Mn, the effect of increasing elongation is small compared to the increase in strength when adding Mn content compared to C in TRIP steel. However, if Mn is not added or the amount of addition is significantly reduced, a pearlite phase may be induced by the high C content, making it difficult to

achieve the desired microstructure and material properties.

[0040] Therefore, the inventors of the present invention, recognizing the need to control the relative contents of C and Mn, derived Relational Expression 1. If the cold-rolled steel sheet does not satisfy the relationship between C and Mn of Relational Expression 1 within the above-mentioned ranges of C and Mn, the cold-rolled steel sheet may not be able to secure high strength and high elongation characteristics, or may not be able to obtain the target material properties of the steel sheet. In another example, the C_{Mn} may be from 0.315 to 0.330, and in yet another example, it may be from 0.364 to 0.380.

[0041] In addition, the cold-rolled steel sheet according to an example of the present invention may satisfy the following Relational Expressions 2 and 3.

[Relational Expression 2]

$$Si_{Parameter} = -2 \times C_{Mn} + 2.53$$

(In Relational Expression 2, C_{Mn} means the product of the C content and the Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[Relational Expression 3]

$$Si_{Parameter} - 0.175 \leq Si \leq Si_{Parameter} + 0.220$$

(In Relational Expression 3, $Si_{Parameter}$ means the value derived from Relational Expression 2, and Si means the Si content included in the cold-rolled steel sheet, and each unit is excluded.)

[0042] Relational Expression 2 and Relational Expression 3 are particularly for securing the high strength and high elongation desired in the present invention, while simultaneously securing excellent weldability by controlling the Si content. That is, the inventors of the present invention experimentally confirmed that it may be difficult to secure the target levels of strength, elongation, and weldability if Relational Expressions 2 and 3 are not satisfied, even if the above-mentioned range of Si is satisfied, and thus derived Relational Expressions 2 and 3.

[0043] That is, an embodiment of the present invention can not only increase the fraction and stability of retained austenite by setting the Si content to $Si_{Parameter} - 0.175$ or more through Relational Expression 3, but also simultaneously increase the elongation and strength in TRIP steel through solid solution strengthening. Therefore, when the above-mentioned Relational Expression 3 is satisfied, the cold-rolled steel sheet according to an embodiment of the present invention can achieve the target material properties. In another embodiment, the Si content may be $Si_{Parameter} - 1.70$ or more, and in yet another embodiment, $Si_{Parameter} - 0.100$ or more. However, if the Si content exceeds $Si_{Parameter} + 0.220$, it can lower the elongation due to an excessive solid solution strengthening effect and significantly reduce weldability. Therefore, in an embodiment of the present invention, the upper limit of the Si content can be set to $Si_{Parameter} + 0.210$ or $Si_{Parameter} + 0.190$.

[0044] Meanwhile, a cold-rolled steel sheet according to an embodiment of the present invention may include, as its microstructure, by area%, 8 to 20% of retained austenite, 5 to 60% of bainite, 20% or less of fresh martensite, and the balance of ferrite.

[0045] First, the cold-rolled steel sheet according to an example of the present invention may include 8 to 20 area% of retained austenite as its microstructure. The retained austenite is an essential structure, along with ferrite, for securing elongation. If the fraction of retained austenite is less than 8 area%, it may be difficult to secure the level of elongation targeted in the present invention. On the other hand, if the fraction of retained austenite exceeds 20 area%, the stability of the retained austenite may be insufficient, making it difficult to secure the target elongation. In another example, the area fraction of the retained austenite may be 8 to 10 area%, and 12 to 20 area%.

[0046] The cold-rolled steel sheet according to an example of the present invention may include 5 to 60 area% of bainite as its microstructure. Bainite is a necessary structure for securing strength and elongation, and when the phase transformation proceeds such that the bainite fraction becomes 5 to 60 area%, stable retained austenite can be included in the range of 8 to 20 area% at room temperature through the diffusion of C into untransformed austenite. If the bainite fraction is less than 5 area%, it may be difficult to secure the target retained austenite fraction in the present invention due to an insufficient total transformation amount, and fresh martensite may be excessively formed, making it difficult to simultaneously secure high strength and high elongation. On the other hand, if the bainite fraction exceeds 60 area%, it may be difficult to secure high elongation as the fractions of ferrite and retained austenite phases become

relatively low. In another example, the area fraction of bainite may be 10 to 20 area%, and 25 to 35 area%.

[0047] A cold-rolled steel sheet according to an embodiment of the present invention may include 20 area% or less of fresh martensite as its microstructure. If the area fraction of the fresh martensite exceeds 20 area%, it may be difficult to obtain a cold-rolled steel sheet with both excellent strength and elongation.

[0048] Finally, a cold-rolled steel sheet according to an embodiment of the present invention may include ferrite as the balance. At this time, the ferrite may include both annealed ferrite and ferrite formed during cooling. An example of the present invention can obtain a cold-rolled steel sheet with both excellent strength and elongation characteristics by including the ferrite, which is a structure advantageous for securing elongation, as the balance. The area fraction of the ferrite can be controlled to an appropriate level by defining the area fractions of the other microstructures, but as an example, the area fraction of the ferrite may be 35 to 75 area%.

[0049] The cold-rolled steel sheet of the present invention provided as described above may have a yield strength of 400 MPa or more, a tensile strength of 780 MPa or more, and a total elongation of 28% or more. Meanwhile, in the present invention, since higher yield strength, tensile strength, and elongation are more advantageous, their upper limits are not particularly limited, but as an example, they may be 650 MPa or less, 980 MPa or less, and 40% or less, respectively.

[0050] In addition, as described above, the present invention has characteristics in which both strength and elongation are excellent, and according to an embodiment of the present invention, the product of the total elongation and the tensile strength ($T-EI \times TS$) may be 21800 MPa% or more.

[0051] Meanwhile, the cold-rolled steel sheet of the present invention may have one of a hot-dip galvanized layer, a galvanized layer, and an electrogalvanized layer formed on at least one surface. The present invention does not particularly limit the hot-dip galvanized layer, the galvanized layer, and the electrogalvanized layer, and all types conventionally used in the art can be used.

[0052] Hereinafter, a method for manufacturing a cold-rolled steel sheet according to an embodiment of the present invention will be described.

[0053] A method for manufacturing a cold-rolled steel sheet according to an embodiment of the present invention may include: a step of heating a slab comprising, by weight%, C: 0.20 to 0.30%, Si: 1.45 to 2.0%, Mn: 1.2 to 1.85%, Al: 0.010 to 1.0%, P: 0.100% or less (excluding 0%), S: 0.0300% or less (excluding 0%), and N: 0.01000% or less (excluding 0%), with the balance being Fe and other unavoidable impurities; a step of finish hot-rolling the slab to obtain a hot-rolled steel sheet; a step of coiling the hot-rolled steel sheet; a step of pickling and then cold-rolling the hot-rolled steel sheet to obtain a cold-rolled steel sheet; a step of continuously annealing the cold-rolled steel sheet for 30 seconds or more at a temperature of $Ae3-15^{\circ}\text{C}$ or less and a γ phase fraction of 50% or more; a first cooling step of cooling the cold-rolled steel sheet to a cooling stop temperature of 600°C to 750°C at an average cooling rate of 2°C/s or more; a second cooling step of cooling the cold-rolled steel sheet to $M_s^{\circ}\text{C}$ or higher and 500°C or lower at an average cooling rate of 10°C/s or more; and a step of performing an over-aging heat treatment or an isothermal heat treatment on the cold-rolled steel sheet. Hereinafter, each step will be described in detail.

[0054] First, a method for manufacturing a cold-rolled steel sheet according to an embodiment of the present invention may include a step of heating a slab comprising, by weight%, C: 0.20 to 0.30%, Si: 1.45 to 2.0%, Mn: 1.2 to 1.85%, Al: 0.010 to 1.0%, P: 0.100% or less (excluding 0%), S: 0.0300% or less (excluding 0%), and N: 0.01000% or less (excluding 0%), with the balance being Fe and other unavoidable impurities, wherein C, Si, and Mn included in the slab may simultaneously satisfy the following Relational Expressions 1, 2, and 3.

[Relational Expression 1]

$$0.315 \leq C_{Mn} \leq 0.415$$

(In Relational Expression 1, C_{Mn} means the product of the C content and the Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[Relational Expression 2]

$$Si_{\text{Parameter}} = -2 \times C_{Mn} + 2.53$$

(In Relational Expression 2, C_{Mn} means the product of the C content and the Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[Relational Expression 3]

$$Si_{\text{Parameter}} - 0.175 \leq Si \leq Si_{\text{Parameter}} + 0.220$$

(In Relational Expression 3, $Si_{\text{Parameter}}$ means the value derived from Relational Expression 2, and Si means the Si content included in the cold-rolled steel sheet, and each unit is excluded.)

[0055] The alloy composition of the slab and Relational Expressions 1, 2, and 3 have been described above, so a description thereof will be omitted. The slab heating may be performed to smoothly carry out the subsequent hot rolling process and to obtain the target physical properties of the steel sheet.

[0056] Furthermore, according to a non-limiting example of the present invention, the temperature range in the heating step may be 1100°C to 1300°C. If the slab heating temperature is less than 1100°C, a problem may occur in which the hot rolling load increases sharply. On the other hand, if the slab heating temperature exceeds 1300°C, the amount of surface scale may increase, leading to a decrease in productivity.

[0057] As described above, after heating the slab, an example of the present invention may obtain a hot-rolled steel sheet by finish hot rolling. And, as a non-limiting example, the temperature during the finish hot rolling may be Ar3 or higher. If the finish hot rolling temperature is less than Ar3, rolling is performed in the two-phase region of ferrite + austenite or in the ferrite region, creating a mixed grain structure, and fluctuations in the hot rolling load may cause equipment malfunctions. Meanwhile, the Ar3 can be obtained through Equation 1 below.

$$Ar3(^{\circ}C) = 910 - 203\sqrt{C} + 44.7Si + 31.5Mo - 30Mn - 11Cr + 700P + 400Al + 400Ti \quad [\text{Equation 1}]$$

[0058] Next, according to an embodiment of the present invention, the hot-rolled steel sheet can be coiled. In addition, as a non-limiting example, the coiling may be performed at 700°C or lower. If the coiling temperature exceeds 700°C, an excessive oxide film may be formed on the surface of the steel sheet, causing defects. It is more preferable that the coiling temperature is 650°C or lower. Meanwhile, the lower the coiling temperature, the higher the strength of the hot-rolled steel sheet, which has the disadvantage of increasing the rolling load of the subsequent cold rolling process. However, since this is not a factor that makes actual production impossible, the present invention does not particularly limit its lower limit. However, as an example, the lower limit of the coiling temperature may be 300°C.

[0059] Thereafter, the coiled hot-rolled steel sheet can be pickled and then cold-rolled to obtain a cold-rolled steel sheet. The pickling is a process for removing the oxide layer formed on the surface of the coiled hot-rolled steel sheet. In addition, as a non-limiting example, the cold rolling may be performed with a cold reduction ratio of 30 to 80%. If the cold reduction ratio is less than 30%, it is not only difficult to secure the target thickness, but there is also a concern that the retention of crystal grains formed during hot rolling may affect austenite formation and physical property securement during annealing. If the cold reduction ratio exceeds 80%, material deviation may occur due to non-uniform reduction amounts rolled in the length and width directions due to work hardening that occurs during cold rolling, and it may be difficult to secure the target thickness due to the rolling load.

[0060] Subsequently, in an example of the present invention, the cold-rolled steel sheet may be continuously annealed for 30 seconds or more at a temperature of Ae3-15°C or less, where the γ phase fraction is 50% or more.

[0061] The inventors of the present invention have found that the annealing temperature during the continuous annealing is critical for securing the desired levels of strength and elongation. More specifically, through extensive research, the inventors have determined that when the process is controlled to satisfy the aforementioned alloy composition and Relational Expressions 1, 2, and 3, while simultaneously satisfying the said annealing temperature range, it is possible to produce a steel material having a tensile strength of 780 MPa or more and an elongation of 28% or more.

[0062] If the annealing temperature exceeds Ae3-15°C, the fraction of annealed ferrite becomes insufficient due to heating to the single-phase region level, and as a result, the elongation may be deteriorated. In another example, the upper limit of the annealing temperature may be Ae3-25°C.

[0063] On the other hand, if the annealing temperature is such that the high-temperature equilibrium austenite phase fraction is less than 50%, annealed ferrite is excessively formed, making it difficult to secure excellent strength and elongation. According to another example of the present invention, the annealing temperature may be such that the high-temperature equilibrium austenite phase fraction is 60% or more, and the annealing temperature may be such that the high-temperature equilibrium austenite phase fraction is 75% or more.

[0064] Furthermore, if the annealing time is less than 30 seconds, there is a disadvantage that a sufficient annealing effect cannot be obtained. Meanwhile, since a longer annealing time is more advantageous, the present invention does not particularly limit its upper limit. However, as an example, the upper limit of the annealing time may be 500 seconds. The aforementioned equilibrium phase fraction temperatures, including the Ae3 temperature, follow the

calculated values from commercial thermodynamic software, including Thermo-Calc and J-MatPro, for each component system.

[0065] Subsequently, the method for manufacturing a cold-rolled steel sheet according to an embodiment of the present invention may include a first cooling step of cooling the cold-rolled steel sheet to a cooling stop temperature of 600°C to 750°C at an average cooling rate of 2°C/s or more.

[0066] If the cooling stop temperature in the first cooling step is less than 600°C, there is a concern that phases such as ferrite or bainite may form, leading to a decrease in strength. If the cooling stop temperature exceeds 750°C, problems may occur in the actual production line. The lower limit of the cooling stop temperature is more preferably 610°C, and even more preferably 630°C. The upper limit of the cooling stop temperature is more preferably 740°C, and even more preferably 730°C.

[0067] If the average cooling rate is less than 2°C/s, an excessive amount of ferrite may be formed during cooling, which can affect the phase fractions of bainite and retained austenite, making its application undesirable. If the average cooling rate is fast, for example, if it exceeds 10°C/s, the fraction of cooled ferrite decreases. Therefore, if the annealing temperature is set within a range that can secure a ferrite fraction of 35% or more, the target microstructure can be obtained, making an upper limit on the cooling rate unnecessary. However, in a conventional annealing heat treatment process, a cooling rate of 10°C/s or less is advantageous for target temperature control, so the upper limit of the average cooling rate may preferably be 10°C/s. Furthermore, if the ferrite fraction proposed in this patent is sufficiently secured in the annealing process, applying the first cooling process at a fast cooling rate exceeding 10°C/s may result in the first cooling process and the second cooling process, which generally has a faster cooling rate, being cooled at almost the same rate. In such cases, the distinction between the first and second cooling processes may be unnecessary, and even in this scenario, the target material properties can be secured.

[0068] After the first cooling step, the method for manufacturing a cold-rolled steel sheet according to an embodiment of the present invention may include a second cooling step of cooling the cold-rolled steel sheet to the bainite transformation temperature region of Ms°C or higher and 500°C or lower at an average cooling rate of 10°C/s or more.

[0069] That is, in an embodiment of the present invention, to secure the target strength and elongation, bainite transformation can be induced by performing a second cooling to Ms°C or higher and 500°C or lower, reheating to $(B_{nose}) \pm 100^\circ\text{C}$, and then performing an over-aging heat treatment or isothermal heat treatment for 1 to 30 minutes in the same temperature range.

[0070] However, more preferably, in the method for manufacturing a cold-rolled steel sheet according to an embodiment of the present invention, the cooling stop temperature RCS in the second cooling step may satisfy the following Relational Expression 4.

[Relational Expression 4]

$$Ms < RCS \leq (B_{nose}) - 100^\circ\text{C}$$

[0071] The temperature range proposed in Relational Expression 4 is the formation temperature for lower bainite. Within this temperature range, full-scale bainite transformation is limited during the second cooling, but some nucleation sites for the lower bainite transformation are introduced, which can accelerate the bainite transformation during the subsequent over-aging or isothermal heat treatment.

[0072] That is, an example of the present invention can secure an additional fraction of bainite through Relational Expression 4, thereby sufficiently securing the area fraction of retained austenite and stabilizing said retained austenite. As a result, when an embodiment of the present invention satisfies Relational Expression 4, it can be advantageous for stably securing the target material properties and elongation.

[0073] Furthermore, since it is advantageous to perform the second cooling at or above a critical cooling rate that can minimize the formation of ferrite, pearlite, and the like, in an embodiment of the present invention, the lower limit of the average cooling rate during the second cooling can be set to 10°C/s. That is, if the average cooling rate is less than 10°C/s, high-temperature transformation structures such as ferrite and pearlite may form during cooling even if the target cooling temperature is reached, making it impossible to secure high-strength characteristics. The upper limit of the average cooling rate is not limited, but in a general process, if it exceeds 45°C/s, it becomes difficult to control the second cooling end temperature, which can lead to deterioration of the steel sheet's surface shape due to rapid martensite transformation. Even if the aforementioned problem does not occur, material deviation may arise due to non-uniform cooling in the width direction. Therefore, a non-limiting example of the present invention may set the upper limit of the average cooling rate to 45°C/s.

[0074] After the second cooling, an example of the present invention may include a step of over-aging heat treatment or isothermal heat treatment, which involves reheating the cold-rolled steel sheet to a temperature range of $(B_{nose}) \pm 100^\circ\text{C}$ and then holding it for 1 to 30 minutes. That is, in an embodiment of the present invention, the transformation is maximized at the B_{nose} temperature, located near 400°C, thereby stabilizing the retained austenite

that is ultimately obtained at room temperature by partitioning (enriching) C into the untransformed austenite that remained untransformed during the annealing process. Here, the B_{nose} temperature can be determined by conducting repetitive simulated annealing experiments using a dilatometer while varying the reheating temperature, to find the reheating temperature at which the most bainite transformation occurs. Generally, the B_{nose} temperature can be in the range of 400 to 450°C.

[0075] If the over-aging or isothermal heat treatment temperature is below $(B_{nose})-100^{\circ}\text{C}$, the fraction of fresh martensite, which adversely affects the material properties, may increase. In another example, the over-aging or isothermal heat treatment temperature may be $(B_{nose})-40^{\circ}\text{C}$ or higher, and in yet another example, $(B_{nose})-25^{\circ}\text{C}$ or higher.

[0076] On the other hand, if the over-aging or isothermal heat treatment is performed at a temperature exceeding $(B_{nose})+100^{\circ}\text{C}$, the final retained austenite may become unstable due to delayed bainite transformation. In another example, the over-aging or isothermal heat treatment temperature may be $(B_{nose})+40^{\circ}\text{C}$ or lower, and in yet another example, $(B_{nose})+25^{\circ}\text{C}$ or lower.

[0077] Furthermore, if the over-aging or isothermal heat treatment time is less than 1 minute, it may be difficult to obtain the desired partitioning effect because sufficient transformation cannot proceed. If the time exceeds 30 minutes, the over-aging or isothermal heat treatment section must be very long, and productivity decreases, making it difficult to apply to an actual production line.

[0078] Meanwhile, after the over-aging or isothermal heat treatment, a hot-dip galvanized layer can be formed by immersing the cold-rolled steel sheet in a hot-dip galvanizing bath at 440 to 480°C. If the temperature of the hot-dip galvanizing bath is below 440°C, managing the bath can be difficult, and if the temperature exceeds 480°C, the final elongation may decrease.

[0079] Furthermore, after the formation of the hot-dip galvanized layer, the cold-rolled steel sheet with the formed layer can be subjected to an alloying heat treatment at 450 to 520°C. If the alloying heat treatment temperature is below 450°C, it may be difficult to form a sufficient Fe-Zn galvanized layer. If the alloying heat treatment temperature exceeds 520°C, the final elongation may be deteriorated due to the decomposition of the retained austenite formed in the previous step. Although not particularly limited, the zinc-based coating layer may be a galvanized layer mainly containing zinc, or a zinc alloy coating layer containing aluminum and/or magnesium in addition to zinc.

[0080] On the other hand, an electrogalvanized layer can be formed after the over-aging or isothermal heat treatment.

[0081] Hereinafter, the present invention will be described in more detail through examples. However, it should be noted that the following examples are merely for illustrating the present invention in more detail and are not intended to limit the scope of rights of the present invention. This is because the scope of rights of the present invention is determined by the matters described in the claims and matters reasonably inferred therefrom.

Mode for the Invention

(Example)

[0082] Steel slabs having the alloy compositions shown in Table 1 below were heated in a temperature range of 1150-1200°C, then hot-rolled at a finish hot rolling temperature of 930°C or higher, and then subjected to a process of [coiling - cold rolling - continuous annealing - first cooling - second cooling - over-aging heat treatment or isothermal heat treatment] according to the conditions shown in Tables 2 and 3 below to produce respective cold-rolled steel sheets.

[0083] The microstructure, physical properties, etc., of the cold-rolled steel sheets produced as described above were measured, and the results are shown in Table 4 below.

[0084] At this time, the microstructure of each steel sheet was observed with a scanning electron microscope (SEM), and then measured by the point counting method. However, the fraction of the retained austenite phase was measured by XRD.

[0085] The tensile strength (TS), yield strength (YS), and elongation (EI) of each steel sheet were evaluated through a tensile test in the rolling direction, using a test piece specification with a gauge length of 50 mm and a tensile specimen width of 25 mm.

[0086] Here, the B_{nose} temperature was derived as the reheating temperature at which the most bainite transformation occurs, through repetitive simulated annealing experiments using a dilatometer while changing the reheating temperature, as described above. The M_s temperature is the value measured by quenching to room temperature at -50°C/s after implementing the conditions of Tables 2 and 3 up to each continuous annealing temperature and first cooling temperature with a dilatometer.

[Table 1]

Steel Grade	C	Si	Mn	Al	P	S	N	Ti	Nb	V	C _{Mn}	Relational Exp. 1	Si _{Parameter}	Relational Exp. 3
A	0.200	1.71	1.81	0.02	0.010	0.002	0.005	-	-	-	0.36	O	1.81	O
B	0.223	1.69	1.57	0.03	0.010	0.002	0.005	-	-	-	0.35	O	1.83	O
C	0.250	2.00	1.51	0.04	0.007	0.002	0.003	-	-	-	0.38	O	1.78	O
D	0.250	1.95	1.50	0.03	0.010	0.002	0.005	0.015	0.025	0.05	0.38	O	1.78	O
E	0.2	1.60	1.56	0.04	0.007	0.002	0.003	-	-	-	0.31	X	1.91	X
F	0.285	1.50	1.60	0.05	0.007	0.002	0.003	-	-	-	0.46	X	1.62	O
G	0.217	1.51	1.53	0.05	0.007	0.002	0.003	-	-	-	0.33	O	1.87	X

[Table 2]

Division	Steel Grade	Ae3-15 (°C, Thermo .)	γ 50% (°C, Thermo .)	Hot-rolling CT (°C)	Cold Reduction Ratio (%)	Continuous Annealing Step	
						Temp. (°C)	Time (sec)
Inventive Example 1	A	835	775	450	52	800	35
Inventive Example 2	A	835	775	450	52	800	65
Inventive Example 3	B	838	775	450	48	830	78
Inventive Example 4	B	838	775	450	48	830	100
Inventive Example 5	C	841	775	520	50	820	45
Inventive Example 6	C	841	775	520	50	820	42
Comparative Example 1	C	841	775	520	50	765	34
Inventive Example 7	D	852	770	450	50	825	45
Comparative Example 2	E	843	780	450	50	840	33
Comparative Example 3	F	812	745	520	50	805	70
Comparative Example 4	G	836	770	450	45	803	65

[Table 3]

Division	1st Cooling Step		2nd Cooling Step		Heat Treatment Step		Ms (°C)	B _{nose} -100 (°C)	Relational Exp. 4
	Cooling Stop Temp. (°C)	Cooling Rate (°C/s)	Cooling Stop Temp. (°C)	Cooling Rate (°C/s)	Temp. (°C)	Time (min)			
Inventive Ex-ample 1	700	4.5	400	13	440	128	128	320	X
Inventive Ex-ample 2	700	3	300	14	300	128	128	320	O
Inventive Ex-ample 3	680	4	440	28	440	135	135	340	X
Inventive Ex-ample 4	680	2.4	300	11	300	135	135	340	O
Inventive Ex-ample 5	650	2	400	10.5	400	119	119	300	X
Inventive Ex-ample 6	650	3.5	300	18	400	119	119	300	O
Comparative Example 1	620	5	400	10	400	108	108	300	X
Inventive Ex-ample 7	620	4.5	400	34	400	111	111	300	X
Comparative Example 2	640	5	400	11.5	400	142	142	310	X
Comparative Example 3	620	6	200	10.4	400	109	109	300	O
Comparative Example 4	650	4	400	16	400	107	107	310	X

[Table 4]

Division	Steel Grade	TS* EI	YS	TS	T-EI	U-EI	P-EI	Microstructure (fraction%)			
								F	B	RA	FM
Inventive Example 1	A	23026	455	794	29.0	22.1	8.6	56.4	17.0	14.0	12.6
Inventive Example 2	A	24339	442	798	30.5	23.5	7.6	56.4	19.5	17.8	6.3
Inventive Example 3	B	24812	426	785	31.6	24.3	7.3	43.7	25.4	16.0	14.9
Inventive Example 4	B	26256	440	786	33.4	23.3	10.1	43.7	26.7	18.4	11.2
Inventive Example 5	C	25646	467	822	31.2	23.2	5.2	66.5	7.4	13.2	12.9
Inventive Example 6	C	27440	471	829	33.1	26.1	7.0	66.5	13.2	17.0	3.3
Comparative Example 1	C	27648	428	768	36.0	29.4	6.6	78.4	4.2	14.5	2.9
Inventive Example 7	D	27588	480	856	32.2	25.4	6.8	52.4	18.3	14.8	14.5
Comparative Example 2	E	21234	386	755	28.1	20.8	7.4	48.2	25.0	14.5	12.3
Comparative Example 3	F	22988	540	961	24.3	20.4	3.9	52.3	24.0	11.0	12.7
Comparative Example 4	G	22796	418	820	26.8	23.0	4.8	61.5	11.4	7.7	19.5

[0087] In Comparative Example 1, although the alloy composition satisfied the range proposed in the present invention, the continuous annealing temperature was excessively low, leading to the excessive introduction of annealed ferrite, and thus high-strength characteristics could not be secured.

[0088] In Comparative Example 2, the C_{Mn} value was below the 0.315 proposed in Relational Expression 1, failing to achieve the target yield strength. Conversely, in Comparative Example 3, the C_{Mn} value exceeded the 0.415 proposed in Relational Expression 1, and the resulting excessive solid-solution strengthening led to an increase in strength and a corresponding decrease in elongation, thus failing to secure high-elongation characteristics.

[0089] Comparative Example 4 did not satisfy Relational Expression 3, and thus failed to meet the target elongation due to an insufficiency of retained austenite.

[0090] On the other hand, Inventive Examples 1 to 7 were able to secure high-strength and high-elongation characteristics by satisfying the conditions for the alloy composition and production method proposed in the present invention. In particular, looking at Inventive Examples 2, 4, and 6, when the cooling stop temperature during the second cooling is set to satisfy Relational Expression 4 proposed in the present invention, it can be confirmed that the final bainite fraction and retained austenite fraction were measured to be higher, despite performing continuous annealing and first cooling under the same conditions for the same steel grade. Thus, when Relational Expression 4 is satisfied, the cold-rolled steel sheet of the present invention can secure a higher TS x T-EI value.

[0091] FIG. 1 is a photograph showing an example of a dilatometer experiment simulating the annealing process of steel grade A. In FIG. 1, the y-axis represents the value of the changed sample length after expansion or contraction due to temperature change, from which the transformation amount of steel grade A in Table 1 can be inferred, expressed as a fraction relative to the initial sample length, and the x-axis represents the temperature (°C). As shown in (b) of FIG. 1, it can be confirmed that even when the same heat treatment temperature (RHS) of 400°C is maintained, an additional bainite transformation occurs under the condition of a second cooling temperature (RCS) of 300°C, which satisfies Relational Expression 4. From this, a higher fraction of retained austenite can be expected in the specimen that satisfies Relational Expression 4.

Claims

1. A cold-rolled steel sheet, comprising: by weight%, C: 0.20 to 0.30%, Si: 1.45 to 2.0%, Mn: 1.2 to 1.85%, Al: 0.010 to 1.0%, P: 0.100% or less (excluding 0%), S: 0.0300% or less (excluding 0%), and N: 0.01000% or less (excluding 0%), with a balance of Fe and other unavoidable impurities,

wherein the C, Si, and Mn simultaneously satisfy the following Relational Expressions 1, 2, and 3,
 wherein a microstructure comprises, by area%, 8 to 20% of retained austenite, 5% to 60% of bainite, 20% or less of fresh martensite, and a balance of ferrite, and
 wherein a product of total elongation and tensile strength ($T-EI \times TS$) is 21800 MPa% or more.

[Relational Expression 1]

$$0.315 \leq C_{Mn} \leq 0.415$$

(In Relational Expression 1, C_{Mn} denotes a product of a C content and an Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[Relational Expression 2]

$$Si_{Parameter} = -2 \times C_{Mn} + 2.53$$

(In Relational Expression 2, C_{Mn} denotes a product of a C content and an Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[Relational Expression 3]

$$Si_{Parameter} - 0.175 \leq Si \leq Si_{Parameter} + 0.220$$

(In Relational Expression 3, $Si_{Parameter}$ denotes a value derived from Relational Expression 2, and Si denotes an Si content included in the cold-rolled steel sheet, and each unit is excluded.)

2. The cold-rolled steel sheet of claim 1, further comprising: by weight%, one or more of niobium (Nb), titanium (Ti), and vanadium (V) in a total content of 0.100% or less.
3. The cold-rolled steel sheet of claim 1, wherein an area fraction of the ferrite is 35 to 75 area%.
4. The cold-rolled steel sheet of any one of claims 1 to 3, wherein a yield strength (YS) is 400 MPa or more, a tensile strength (TS) is 780 MPa or more, and a total elongation (T-EI) is 28% or more.
5. A galvanized steel sheet, wherein one of a hot-dip galvanized layer, a galvanized layer, and an electrogalvanized layer is formed on at least one surface of the cold-rolled steel sheet of any one of claims 1 to 3.
6. A method for manufacturing a cold-rolled steel sheet, the method comprising:

heating a slab comprising, by weight%, C: 0.20 to 0.30%, Si: 1.45 to 2.0%, Mn: 1.2 to 1.85%, Al: 0.010 to 1.0%, P: 0.100% or less (excluding 0%), S: 0.0300% or less (excluding 0%), and N: 0.01000% or less (excluding 0%), with a balance of Fe and other unavoidable impurities;

finish hot-rolling the slab to obtain a hot-rolled steel sheet;

coiling the hot-rolled steel sheet;

pickling and then cold-rolling the hot-rolled steel sheet to obtain a cold-rolled steel sheet;

continuously annealing the cold-rolled steel sheet for 30 seconds or more at a temperature of $Ae_3-15^\circ\text{C}$ or less and a γ phase fraction of 50% or more;

a first cooling step of cooling the cold-rolled steel sheet to a cooling stop temperature of 600°C to 750°C at an average cooling rate of 2°C/s or more;

a second cooling step of cooling the cold-rolled steel sheet to a temperature of $M_s^\circ\text{C}$ or higher and 500°C or lower at an average cooling rate of 10°C/s or more;

and performing an over-aging heat treatment or an isothermal heat treatment by reheating the cold-rolled steel sheet to a temperature range of $(B_{nose}) \pm 100^\circ\text{C}$ and then maintaining it for 1 minute to 30 minutes, wherein C, Si, and Mn included in the slab simultaneously satisfy the following Relational Expressions 1, 2, and 3:

[Relational Expression 1]

$$0.315 \leq C_{Mn} \leq 0.415$$

(In Relational Expression 1, C_{Mn} denotes a product of a C content and an Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[Relational Expression 2]

$$Si_{Parameter} = -2 \times C_{Mn} + 2.53$$

(In Relational Expression 2, C_{Mn} denotes a product of a C content and an Mn content included in the cold-rolled steel sheet, and each unit is excluded.)

[Relational Expression 3]

$$Si_{Parameter} - 0.175 \leq Si \leq Si_{Parameter} + 0.220$$

(In Relational Expression 3, $Si_{Parameter}$ denotes a value derived from Relational Expression 2, and Si denotes an Si content included in the cold-rolled steel sheet, and each unit is excluded.)

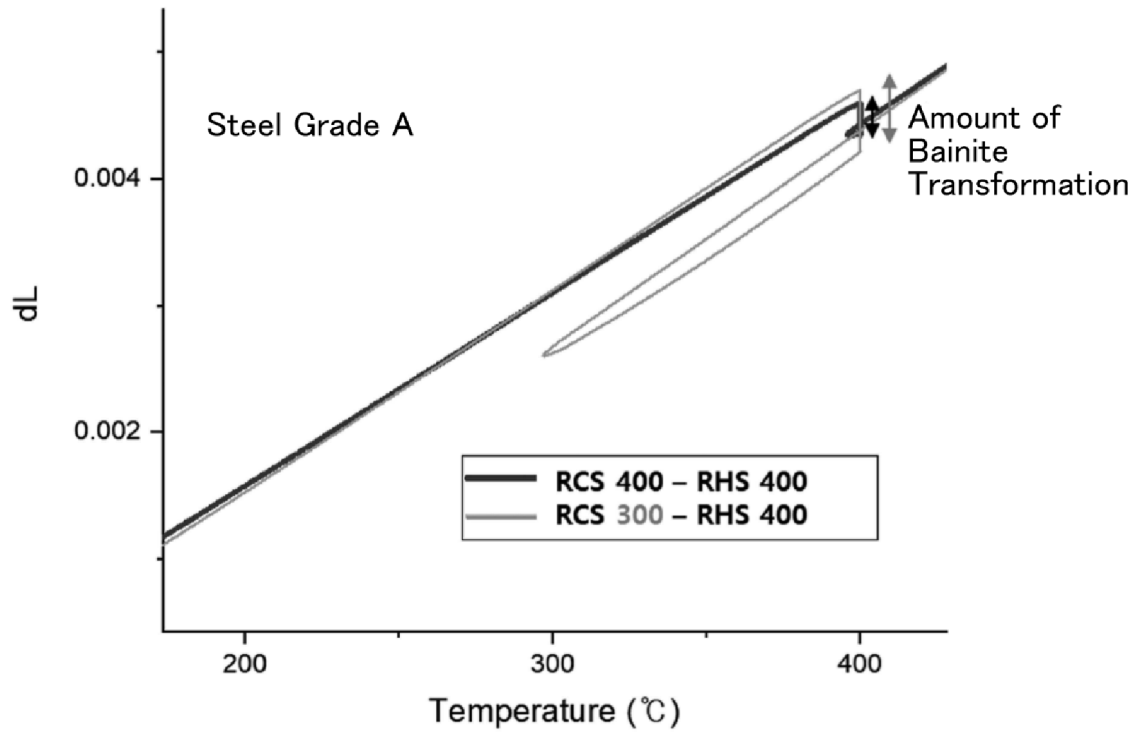
7. The method for manufacturing a cold-rolled steel sheet of claim 6, wherein the slab further comprises, by weight%, one or more of niobium (Nb), titanium (Ti), and vanadium (V) in a total content of 0.100% or less.
8. The method for manufacturing a cold-rolled steel sheet of claim 6, wherein a cooling stop temperature RCS in the second cooling step satisfies the following Relational Expression 4:

[Relational Expression 4]

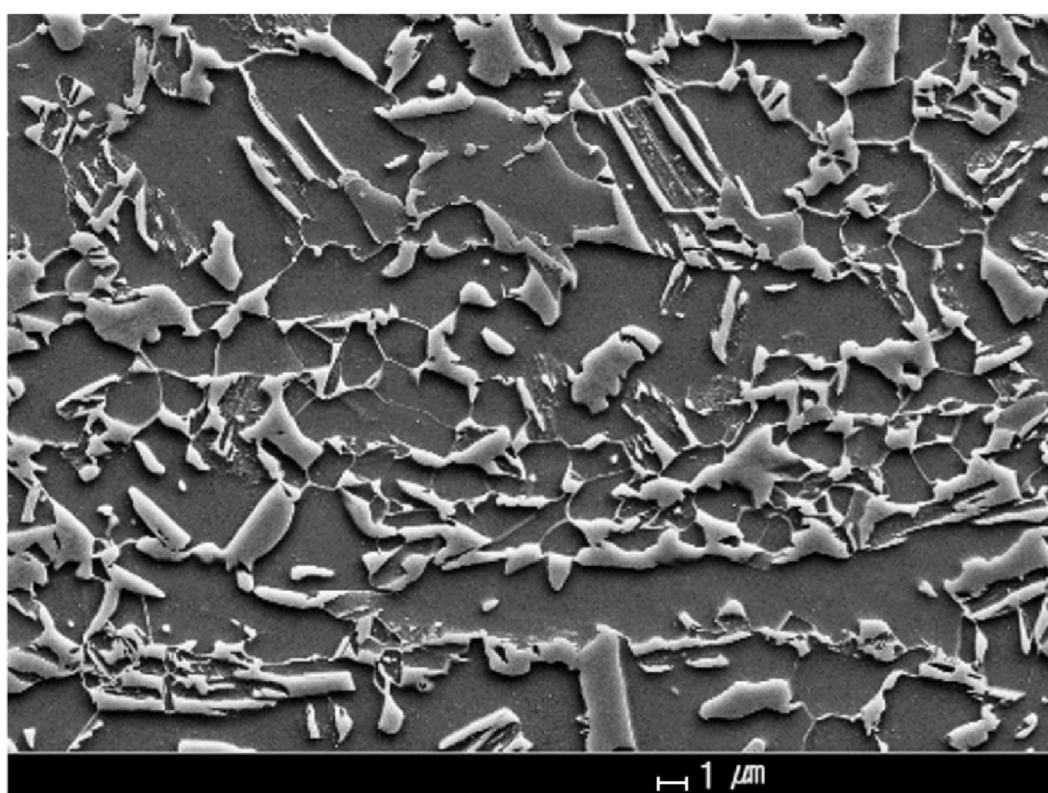
$$B_{nose} \text{ temperature} - 100^\circ\text{C} \geq RCS > Ms$$

9. The method for manufacturing a cold-rolled steel sheet of claim 6, wherein the heating step is performed at 1100°C to 1300°C , the finish hot rolling is performed at Ar3 or higher, the coiling step is performed at 700°C or lower, and a cold reduction ratio during the cold rolling is 30% to 80%.
10. The method for manufacturing a galvanized steel sheet of claim 6, further comprising: a step of electro-galvanizing after the over-aging heat treatment or the isothermal heat treatment.
11. The method for manufacturing a galvanized steel sheet of claim 6, further comprising: a step of immersing in a hot-dip galvanizing bath at 440 to 480°C after the over-aging heat treatment or the isothermal heat treatment.
12. The method for manufacturing a galvanized steel sheet of claim 11, further comprising: a step of performing an alloying heat treatment at 450 to 520°C after the immersion.

[FIG. 1]



[FIG. 2]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/096955

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/02(2006.01)i; **C22C 38/04**(2006.01)i; **C22C 38/06**(2006.01)i; **C22C 38/00**(2006.01)i; **C22C 38/12**(2006.01)i;
C22C 38/14(2006.01)i; **C21D 8/02**(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 38/02(2006.01); B21C 47/02(2006.01); C21D 8/02(2006.01); C22C 38/00(2006.01); C22C 38/04(2006.01);
C22C 38/06(2006.01)

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: 연속소둔(continuous annealing), 과시효(overaging), 항온열처리(isothermal heat treatment), 냉각(cooling), 용융아연도금(hot-dip galvanizing), 탄소(C), 망간(Mn), 규소(Si)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2023-0043352 A (POSCO) 31 March 2023 (2023-03-31) See paragraphs [0115]-[0120] and claims 1-10.	1-12
Y	KR 10-2022-0019395 A (POSCO) 17 February 2022 (2022-02-17) See paragraphs [0084]-[0088] and claims 1-19.	1-12
A	KR 10-2023-0110340 A (JFE STEEL CORPORATION) 21 July 2023 (2023-07-21) See paragraph [0096] and claims 1-7.	1-12
A	CN 114763595 B (BAOSHAN IRON & STEEL CO., LTD.) 07 July 2023 (2023-07-07) See claims 1-5.	1-12
A	JP 6680421 B1 (JFE STEEL CORP.) 15 April 2020 (2020-04-15) See paragraphs [0098]-[0109] and claims 1-10.	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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Information on patent family members

International application No.

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