



(11)

EP 4 403 663 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
24.07.2024 Bulletin 2024/30

(21) Application number: **22887483.0**

(22) Date of filing: **20.10.2022**

(51) International Patent Classification (IPC):
C22C 38/40 (2006.01) **C22C 38/00** (2006.01)
C21D 8/02 (2006.01) **C21D 9/46** (2006.01)
B21C 47/02 (2006.01) **C23G 1/02** (2006.01)

(52) Cooperative Patent Classification (CPC):
B21C 47/02; C21D 8/02; C21D 9/46; C22C 38/00;
C22C 38/40; C23G 1/02

(86) International application number:
PCT/KR2022/015994

(87) International publication number:
WO 2023/075287 (04.05.2023 Gazette 2023/18)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **26.10.2021 KR 20210143706**

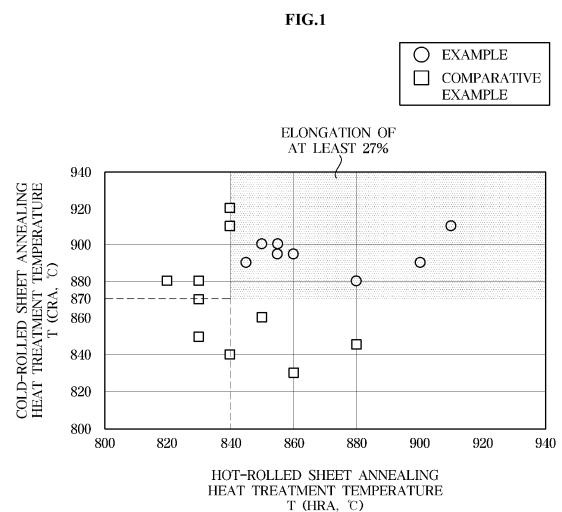
(71) Applicant: **POSCO Co., Ltd**
Pohang-si, Gyeongsangbuk-do 37859 (KR)

(72) Inventors:
• **PARK, Sooho**
Pohang-si Gyeongsangbuk-do 37680 (KR)
• **JUN, Jiwoong**
Pohang-si Gyeongsangbuk-do 37583 (KR)
• **YU, Jeehyun**
Pohang-si Gyeongsangbuk-do 37834 (KR)
• **KIM, Hoihun**
Pohang-si Gyeongsangbuk-do 37650 (KR)

(74) Representative: **Nederlandsch Octrooibureau**
P.O. Box 29720
2502 LS The Hague (NL)

(54) **FERRITIC STAINLESS STEEL AND MANUFACTURING METHOD THEREFOR**

(57) Disclosed in the present specification are: a ferritic stainless steel having improved elongation even if batch annealing is omitted; and a manufacturing method therefor. A ferritic stainless steel according to one embodiment of the present invention may comprise, by wt%, 0.01-0.1% of C, 0.01-1.0% of Si, 0.01-1.5% of Mn, P in an amount greater than 0% and less than or equal to 0.05%, S in an amount greater than 0% and less than or equal to 0.005%, 13.0-18.0% of Cr, 0.005-0.1% of N, 0.005-0.2% of Al, 0.05-0.25% of Ni, and the balance of Fe (iron) and other inevitable impurities.



EP 4 403 663 A1

Description

[Technical Field]

5 **[0001]** The disclosure relates to a ferritic stainless steel and method of manufacturing the same, and more particularly, to a ferritic stainless steel and method of manufacturing the same, by which elongation is improved while omitting box annealing.

[Background Art]

10 **[0002]** Ferritic stainless steel has less costly alloy elements added thereto, and is thus highly competitive in price as compared to austenitic stainless steel. The ferritic stainless steel has good corrosion resistance, so is widely used for construction materials, vehicles, home appliances, kitchen tools, etc.

15 **[0003]** In general, 430 series hot-rolled steel material undergoes a box annealing process, and the box annealing process is performed at a temperature of 800 to 850 °C, at which an austenite phase is transformed to a ferrite phase, for 35 to 50 hours. A purpose of the box annealing is to recrystallize the deformed structure formed in hot rolling and decompose the austenite phase into the ferrite phase and carbides. However, the box annealing not only consumes a lot of energy but also reduces productivity due to the long-term heat treatment. Hence, the development of a continuous annealing manufacturing technology that may facilitate reduction of manufacturing costs by reducing energy and improving productivity has been proceeded.

20 **[0004]** Patent document 1 discloses that hot rolling is performed on 430 steel alloy-designed to enable continuous annealing at least 1 pass with a reduction rate of at least 20% per rough rolling pass, and patent document 2 discloses that when work is done with a starting temperature of finishing rolling being at least 950 °C and a coiling temperature being 650 °C or less, quality characteristics are good without occurrence of sticking defects.

25 **[0005]** In the meantime, when the box annealing is omitted but continuous annealing is performed and then heat treatment is performed under a normal annealing condition for the 430 series stainless steel, there is a risk of having low elongation due to formation of fine Cr carbides precipitated during cooling after hot rolling.

30 **[0006]** There have been almost no attempts to improve the elongation by controlling the annealing heat treatment temperature of the hot-rolled steel material and cold-rolled steel material associated with Ac1, which is the phase transformation temperature calculated by an alloy composition to solve the problem.

(Prior Art Literature)

[0007]

35 Patent Document 1: JP Patent Publication No. 57- 70230 (published on February 10, 1997)

Patent Document 2: JP Patent Publication No. 57- 155326 (published on December 22, 1989)

40 [Disclosure]

[Technical Problem]

45 **[0008]** To solve the aforementioned problem, the disclosure aims to provide a ferritic stainless steel and method of manufacturing the same, by which elongation is improved while omitting box annealing but performing continuous annealing.

[Technical Solution]

50 **[0009]** According to an embodiment of the disclosure, a ferritic stainless steel includes, in percent by weight (wt%), 0.01 to 0.1% of C, 0.01 to 1.0% of Si, 0.01 to 1.5% of Mn, more than 0 to 0.05% of P, more than 0 to 0.005% of S, 13.0 to 18.0% of Cr, 0.005 to 0.1% of N, 0.005 to 0.2% of Al, 0.05 to 0.25% of Ni, the remaindered Fe (iron) and other unavoidable impurities, wherein an Ac1 value defined in the following equation 1 may be at least 920 and less than 990.

55
$$\text{Ac1} = 36 \cdot [\text{Cr}] + 90 \cdot [\text{Si}] + 760 \cdot [\text{Al}] + 350 - (800 \cdot [\text{C}] + 1300 \cdot [\text{N}] + 150 \cdot [\text{Ni}] + 50 \cdot [\text{Mn}])$$
 Equation 1:

[0010] In equation 1, [Cr], [Si], [Al], [C], [N], [Ni], and [Mn] refer to contents (wt%) of the respective elements.

[0011] In an embodiment of the disclosure, the ferritic stainless steel has 27% or more of elongation.

[0012] In an embodiment of the disclosure, a method of manufacturing a ferritic stainless steel includes manufacturing a slab including, in percent by weight (wt%), 0.01 to 0.1% of C, 0.01 to 1.0% of Si, 0.01 to 1.5% of Mn, more than 0 to 0.05% of P, more than 0 to 0.005% of S, 13.0 to 18.0% of Cr, 0.005 to 0.1% of N, 0.005 to 0.2% of Al, 0.05 to 0.25% of Ni, the remaindered Fe (iron) and other unavoidable impurities, wherein an Ac1 value defined in the following equation 1 is at least 920 and less than 990; reheating the slab; manufacturing a hot-rolled steel material by hot-rolling and coiling the reheated slab; obtaining a hot-rolled and wound hot-rolled sheet by hot-rolled-sheet-annealing the hot-rolled steel material at a hot-rolled sheet annealing heat treatment temperature T (HRA, °C) which satisfies equation (2) below, followed by cooling and winding; manufacturing a cold-rolled sheet by cold-rolling the hot-rolled and wound hot-rolled sheet; and cold-rolled-sheet-annealing the cold-rolled sheet at a cold-rolled sheet annealing heat treatment temperature T (CRA, °C) which satisfies equation (3) below, followed by cooling and winding.

$$Ac1 = 36*[Cr] + 90*[Si] + 760*[Al] + 350 - (800*[C] + 1300*[N] + 150*[Ni] + 50*[Mn]) \quad \text{Equation 1:}$$

[0013] In equation 1, [Cr], [Si], [Al], [C], [N], [Ni], and [Mn] refer to contents (wt%) of the respective elements.

$$\text{Equation 2: } 840 \leq T \text{ (HRA, } ^\circ\text{C)} \leq Ac1 - 20$$

$$\text{Equation 3: } 870 \leq T \text{ (CRA, } ^\circ\text{C)} \leq Ac1 - 20$$

[0014] In an embodiment of the disclosure, in the method of manufacturing the ferritic stainless steel, the reheating may be performed at 1100 to 1250 °C.

[0015] In an embodiment of the disclosure, in the method of manufacturing the ferritic stainless steel, the hot-rolling may be performed at a finish rolling completion temperature of 800 to 950 °C.

[0016] In an embodiment of the disclosure, in the method of manufacturing the ferritic stainless steel, the coiling may be performed at 750 to 850 °C.

[0017] In an embodiment of the disclosure, in the method of manufacturing the ferritic stainless steel, the hot-rolled sheet annealing and winding and the cold-rolled sheet annealing and winding may be performed for 30 seconds to 10 minutes.

[0018] In an embodiment of the disclosure, in the method of manufacturing the ferritic stainless steel, the cooling after the hot-rolled sheet annealing and the cooling after the cold-rolled sheet annealing may be performed at a cooling rate of 10 to 50 °C/s.

[0019] In an embodiment of the disclosure, in the method of manufacturing the ferritic stainless steel, the cold-rolling may be performed at a reduction rate of 60 to 90%.

[Advantageous Effects]

[0020] According to an embodiment of the disclosure, a ferritic stainless steel and method of manufacturing the same, by which elongation is improved by controlling an annealing heat treatment temperature while omitting box annealing and performing continuous annealing, may be provided.

[0021] Furthermore, according to an embodiment of the disclosure, manufacturing costs may be saved by omitting the box annealing process that requires long time.

Brief Description of Drawings

[0022] FIG. 1 is a graph representing an annealing heat treatment temperature range that may secure 27% or more of elongation.

Best Mode

[0023] According to an embodiment of the disclosure, a ferritic stainless steel includes, in percent by weight (wt%), 0.01 to 0.1% of C, 0.01 to 1.0% of Si, 0.01 to 1.5% of Mn, more than 0 to 0.05% of P, more than 0 to 0.005% of S, 13.0 to 18.0% of Cr, 0.005 to 0.1% of N, 0.005 to 0.2% of Al, 0.05 to 0.25% of Ni, the remaindered Fe (iron) and other unavoidable impurities, wherein an Ac1 value defined in the following equation 1 may be at least 920 and less than 990.

$$Ac1 = 36*[Cr] + 90*[Si] + 760*[Al] + 350 - (800*[C] + 1300*[N] + 150*[Ni] + 50*[Mn])$$

Equation 1:

[0024] In equation 1, [Cr], [Si], [Al], [C], [N], [Ni], and [Mn] refer to contents (wt%) of the respective elements

Modes

[0025] Reference will now be made in detail to embodiments, which are illustrated in the accompanying drawings. The following embodiments are provided as examples to convey the full spirit of the disclosure to those of ordinary skill in the art to which the embodiments of the disclosure belong. The disclosure is not limited to the embodiments suggested herein but may be specified in other forms. In the drawings, unrelated part of the description is not shown to clarify the disclosure, and the size of an element may be a little exaggerated to help understanding.

[0026] Throughout the specification, the term "include (or including)" or "comprise (or comprising)" is inclusive or open-ended and does not exclude additional, unrecited components, elements or method steps, unless otherwise stated.

[0027] It is to be understood that the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise.

[0028] A reason for numerical limitation of the content of an alloy composition in an embodiment of the disclosure will now be described. A unit of weight(wt)% will now be used unless otherwise mentioned.

[0029] In an embodiment of the disclosure, a ferritic stainless steel includes, in percent by weight (wt%), 0.01 to 0.1% of C, 0.01 to 1.0% of Si, 0.01 to 1.5% of Mn, more than 0 to 0.05% of P, more than 0 to 0.005% of S, 13.0 to 18.0% of Cr, 0.005 to 0.1% of N, 0.005 to 0.2% of Al, 0.05 to 0.25% of Ni, the remaindered Fe (iron) and other unavoidable impurities.

[0030] The content of C (carbon) may be 0.01 to 0.1%.

[0031] C is a powerful austenite phase stabilizing element, which is effective to increase strength of the material through solid solution strengthening. Considering this, at least 0.01% of C may be added. However, when the content of C is excessive, the strength overly increases, causing deterioration of elongation, toughness, etc., of the steel material. Considering this, the upper limit of the content of C is limited to 0.1%.

[0032] The content of Si (silicon) may be 0.01% to 1.0%.

[0033] Si is an element added as a deoxidizer in a steelmaking step, which is effective in increasing yield strength and corrosion resistance. Also, Si is an element that may increase stability of the ferrite phase. Considering this, 0.01% or more of Si may be added. However, when the content of Si is excessive, it may cause hardening of the material, thereby deteriorating elongation and toughness. Considering this, the upper limit of the content of Si may be limited to 1.0%.

[0034] The content of Mn (manganese) may be 0.01 to 1.5%.

[0035] Mn is an element effective in increasing corrosion resistance. Considering this, Mn may be added in at least 0.01% and preferably, at least 0.2%. However, when the content of Mn is excessive, it forms inclusions (MnS), which deteriorates hot workability, ductility and toughness of the steel material. Considering this, the upper limit of the Mn content may be limited to 1.5%, more preferably, 1.0%.

[0036] The content of P (phosphorus) may be more than 0 to 0.05%.

[0037] P is an impurity unavoidably contained in steel, and is a source element to cause intergranular corrosion in winding or hinder hot workability. Hence, it is desirable to control the P content as low as possible. Considering this, the upper limit of the P content may be limited to 0.05%.

[0038] The content of S (sulfur) may be more than 0 to 0.005%.

[0039] S is an impurity unavoidably contained in steel, and is a source element that is precipitated on grain boundaries and hinders hot workability. Hence, it is desirable to control the S content as low as possible. Considering this, the upper limit of the S content may be limited to 0.005%.

[0040] The content of Cr (chrome) may be 13.0 to 18.0%.

[0041] Cr is an element that improves corrosion resistance by forming a passive state film in an oxidizing environment. Considering this, Cr may be added in at least 13.0%. However, when the content of Cr is excessive, it promotes delta (δ) ferrite formation in the slab, reducing the elongation rate and impact toughness, and increases manufacturing costs. Considering this, the upper limit of the content of Cr may be limited to 18.0%.

[0042] The content of N (nitrogen) may be 0.005 to 0.1%.

[0043] Like C, N is an interstitial element, which is effective in increasing yield strength of the steel material according to the solid solution strengthening effect. Considering this, N may be added in at least 0.005%. However, when the content of N is excessive, impact toughness and formability may deteriorate. Considering this, the upper limit of the content of N may be limited to 0.1%.

[0044] The content of Al (aluminum) may be 0.005 to 0.2%.

[0045] Al is a powerful deoxidizer, an element that plays a role to reduce the content of oxygen in melted steel.

Considering this, Al may be added in at least 0.005%. However, when the content of Al is excessive, non-metal inclusions increase, so that Sliver defects in the cold-rolled strip may occur and at the same time, weldability may deteriorate. Considering this, the upper limit of the Al content may be limited to 0.2%, and more preferably, 0.15% or less.

[0046] The content of Ni (nickel) may be 0.05 to 0.25%.

[0047] Ni is effective in softening the steel material. Considering this, 0.05% or more of Ni may be added. However, when the content of Ni is excessive, it may increase costs. Considering this, the upper limit of the content of Ni may be limited to 0.25%.

[0048] The remaining component is iron (Fe) in the disclosure. However, unintended impurities may be inevitably mixed in from raw materials or surroundings in the normal manufacturing process, so they may not be excluded. These impurities may be known to anyone skilled in the ordinary manufacturing process, so not all of them are specifically mentioned in this specification.

[0049] In an embodiment of the disclosure, the ferritic stainless steel may have an Ac1 value defined in the following equation 1, which may be at least 920 and less than 990.

$$Ac1 = 36*[Cr] + 90*[Si] + 760*[Al] + 350 - (800*[C] + 1300*[N] + 150*[Ni] + 50*[Mn]) \quad \text{Equation 1:}$$

[0050] In equation 1, [Cr], [Si], [Al], [C], [N], [Ni], and [Mn] refer to contents (wt%) of the respective elements.

[0051] Ac1 refers to a temperature at which an austenite phase is transformed to a ferrite phase. The disclosure is characterized by improvement of the elongation rate by controlling an annealing heat treatment temperature based on an Ac1 value calculated by designing an alloy composition and ingredient ranges.

[0052] When the calculated value of Ac1 is low, heat treatment is performed at low temperature so that sufficient recrystallization does not occur during continuous annealing of the hot-rolled sheet. Considering this, the alloy composition and ingredient ranges may be designed such that the calculated value of Ac1 is at least 920. However, when the calculated value of Ac1 is overly high, contents of austenite forming elements such as C, N, etc., are reduced, leading to insufficient formation of carbides and nitrides, which deteriorates strength. Considering this, the alloy composition and ingredient ranges may be designed such that the calculated value of Ac1 is less than 990.

[0053] In an embodiment of the disclosure, the ferritic stainless steel may have at least 27% of elongation rate by controlling the annealing heat treatment temperature based on the calculated value of Ac1.

[0054] Next, a method of manufacturing a ferritic stainless steel according to another aspect of the disclosure will now be described.

[0055] In an embodiment of the disclosure, a method of manufacturing a ferritic stainless steel includes manufacturing a slab including, in percent by weight (wt%), 0.01 to 0.1% of C, 0.01 to 1.0% of Si, 0.01 to 1.5% of Mn, more than 0 to 0.05% of P, more than 0 to 0.005% of S, 13.0 to 18.0% of Cr, 0.005 to 0.1% of N, 0.005 to 0.2% of Al, 0.05 to 0.25% of Ni, the remaindered Fe (iron) and other unavoidable impurities, wherein an Ac1 value defined in equation 1 below is at least 920 and less than 990; reheating the slab; manufacturing a hot-rolled steel material by hot-rolling and coiling the reheated slab; obtaining a hot-rolled and wound hot-rolled sheet by hot-rolled-sheet-annealing the hot-rolled steel material at a hot-rolled sheet annealing heat treatment temperature T (HRA, °C) which satisfies equation (2) below, followed by cooling and winding; manufacturing a cold-rolled sheet by cold-rolling the hot-rolled and wound hot-rolled sheet; and cold-rolled-sheet-annealing the cold-rolled sheet at a cold-rolled sheet annealing heat treatment temperature T (CRA, °C) which satisfies equation (3) below, followed by cooling and winding.

$$Ac1 = 36*[Cr] + 90*[Si] + 760*[Al] + 350 - (800*[C] + 1300*[N] + 150*[Ni] + 50*[Mn]) \quad \text{Equation 1:}$$

[0056] In equation 1, [Cr], [Si], [Al], [C], [N], [Ni], and [Mn] refer to contents (wt%) of the respective elements.

$$\text{Equation 2: } 840 \leq T \text{ (HRA, } ^\circ\text{C)} \leq Ac1 - 20$$

$$\text{Equation 3: } 870 \leq T \text{ (CRA, } ^\circ\text{C)} \leq Ac1 - 20$$

[0057] The reason of numerical limitation of equation 1 and the ingredient range of each alloy composition is as described above, and each manufacturing step will now be described in more detail.

[0058] First, a slab that satisfies the alloy composition and equation 1 may be manufactured, and may then undergo a series of hot rolling, hot-rolled sheet annealing and winding, cold rolling, cold-rolled sheet annealing and winding processes.

[0059] The slab may be hot-rolled at a reheating temperature of 1100 to 1250 °C.

[0060] When the reheating temperature of the slab is too low, the load of the rolling roll may increase. Considering this, the reheating temperature of the slab may be at least 1100 °C. However, when the reheating temperature is too high, the grain diameter of the slab may be coarsened, which may deteriorate the strength. Considering this, the upper limit of the reheating temperature of the slab may be limited to 1250 °C.

[0061] Next, the hot rolling may be performed at a finish rolling completion temperature of 800 to 950 °C.

[0062] When the finish rolling completion temperature is low, the rolling load may increase, leading to a reduction in productivity. Considering this, the finish rolling completion temperature may be at least 800 °C. However, when the finish rolling completion temperature is too high, the crystal grain size may increase to reduce strength. Considering this, the finish rolling completion temperature may be controlled to be 950 °C or less.

[0063] Furthermore, the coiling may be performed at 750 to 850 °C.

[0064] When the coiling temperature is low, it may be difficult to control the shape of the coil, and when the coiling temperature is too high, it is likely to cause defects in the post-process due to continuous phase transformation after the coiling. Considering this, the coiling temperature may be set to 750 to 850 °C.

[0065] After this, the hot-rolled steel material may be hot-rolled-sheet-annealed at the hot-rolled sheet annealing heat treatment temperature T (HRA, °C) that satisfies the following equation (2):

$$\text{Equation 2: } 840 \leq T(\text{HRA}, ^\circ\text{C}) \leq \text{Ac1} - 20$$

[0066] When the hot-rolled sheet annealing heat treatment temperature T (HRA, °C) is low, sufficient recrystallization is not performed. However, as cold-rolled sheet annealing is performed as the post-process, it may proceed at a relatively low temperature. Considering this, the hot-rolled sheet annealing heat treatment temperature T (HRA, °C) may be at least 840 °C. However, when the hot-rolled sheet annealing heat treatment temperature T (HRA, °C) is at least Ac1 temperature, an austenite phase may be formed, and a martensite phase may be formed during quenching after the heat treatment. Considering this, the upper limit of the hot-rolled sheet annealing heat treatment temperature T (HRA, °C) may be limited to (Ac1 - 20).

[0067] The hot-rolled sheet annealing may be performed for 30 seconds to 10 minutes.

[0068] When the hot-rolled sheet annealing time is short, the elongation may deteriorate due to the high fraction of residual martensite. Considering this, the hot-rolled sheet annealing may be performed for at least 30 seconds. However, when the hot-rolled sheet annealing time is too long, the strength may be reduced due to coarsening of crystal grains, and thickness of a surface oxide layer may increase so that winding hours to remove the oxide layer may be prolonged or the oxide layer may not sufficiently removed. Considering this, the hot-rolled sheet annealing may be controlled to 10 minutes or less.

[0069] The cooling after the hot-rolled sheet annealing may be performed at a cooling rate of 10 to 50 °C/s.

[0070] When the cooling rate is low, elongation and formability may deteriorate because of non-uniformity of the structure due to softening. On the other hand, when the cooling rate is too high, the elongation is affected adversely due to excessive hardening. Considering this, the cooling rate may be controlled to 10 to 50 °C/s.

[0071] The cold rolling may be performed at a reduction rate of 60 to 90%.

[0072] When the reduction rate is low, it is difficult to obtain a recrystallized structure because accumulated energy from cold working is not sufficient. However, when the reduction rate is too high, cracks may occur due to rolling. Considering this, the reduction rate may be controlled to 60 to 90%.

[0073] After this, the cold-rolled sheet may be cold-rolled-sheet-annealed at a cold-rolled sheet annealing heat treatment temperature T (CRA, °C) which satisfies the following equation (3).

$$\text{Equation 3: } 870 \leq T(\text{CRA}, ^\circ\text{C}) \leq \text{Ac1} - 20$$

[0074] Like the hot-rolled sheet annealing heat treatment temperature T (HRA, °C), when the cold-rolled sheet annealing heat treatment temperature T (CRA, °C) is low, recrystallization is not sufficiently done. Considering this, the cold-rolled sheet annealing heat treatment temperature T (CRA, °C) may be at least 870 °C. However, when the cold-rolled sheet annealing heat treatment temperature T (CRA, °C) is at least Ac1 temperature, an austenite phase is formed and a martensite phase may be formed during quenching after the heat treatment, so the upper limit of the cold-rolled sheet annealing heat treatment temperature T (CRA, °C) may be limited to (Ac1 - 20).

[0075] The cold-rolled sheet annealing may be performed for 30 seconds to 10 minutes, and cooling after the cold-rolled sheet annealing may be performed at a cooling rate of 10 to 50 °C/s.

[0076] The reason for limiting the numerical values of the cold-rolled sheet annealing time and cooling rate is as described above.

[0077] Embodiments of the disclosure will now be described in more detail. The embodiments may be merely for

illustration, and the disclosure is not limited thereto. The scope of the disclosure is defined by the claims and their equivalents.

{Embodiment}

[0078] A slab was manufactured with various alloy ingredient ranges shown in table 1 below. The manufactured slab was reheated at 1200 °C, hot-rolled at a finish rolling completion temperature of 800 °C, and then coiled at 750 °C to produce hot rolled steel material.

[0079] Ac1 refers to a value defined in the following equation 1:

$$\text{Ac1} = 36 * [\text{Cr}] + 90 * [\text{Si}] + 760 * [\text{Al}] + 350 - (800 * [\text{C}] + 1300 * [\text{N}] + 150 * [\text{Ni}] + 50 * [\text{Mn}]) \quad \text{Equation 1:}$$

[0080] In equation 1, [Cr], [Si], [Al], [C], [N], [Ni], and [Mn] refer to contents (wt%) of the respective elements.

[Table 1]

	alloy ingredients									
	C	Si	M n	Cr	Ni	N	Al	P	S	
A	0.0 44	0.3 4	0.1 7	16. 18	0.1 4	0.01 29	0.1 22	0.0 26	0.00 05	97 4.3
B	0.0 31	0.2 7	0.8 0	16. 25	0.0 9	0.01 98	0.1 07	0.0 23	0.00 06	93 6.6
C	0.0 41	0.1 9	0.8 1	16. 39	0.1 1	0.02 13	0.0 93	0.0 25	0.00 07	91 0.3

[0081] The manufactured hot-rolled steel material was hot-rolled-sheet annealed at a hot-rolled sheet annealing heat treatment temperature T (HRA, °C) for 10 minutes, cooled at a cooling rate of 30 °C/s and wound to obtain a hot-rolled wound hot-rolled sheet. Next, it is cold rolled at a reduction rate of 60%, cold-rolled-sheet annealed at the cold-rolled sheet annealing heat treatment temperature T (CRA, °C) for 10 minutes, cooled at a cooling rate of 30 °C/s and then wound to produce steel. Table 2 below shows the hot-rolled sheet annealing heat treatment temperature T (HRA, °C), the cold-rolled sheet annealing heat treatment temperature T (CRA, °C), thickness and elongation of the manufactured steel.

[0082] The elongation (rate) was measured with a tensile tester from Zwick Roell.

[Table 2]

section		Hot-rolled sheet annealing heat treatment temperature T (HRA, °C)	Cold-rolled sheet annealing heat treatment temperature T (CRA, °C)	Thickness (mm)	Elongation (rate) (%)
example	A1	855	900	0.6	30
	B1	910	910	0.6	33
	B2	900	890	0.6	31
	B3	880	880	0.5	28
	B4	845	890	0.6	29
	B5	860	895	0.6	30
	B6	850	900	0.6	31
	B7	855	895	0.6	30

(continued)

section		Hot-rolled sheet annealing heat treatment temperature T (HRA, °C)	Cold-rolled sheet annealing heat treatment temperature T (CRA, °C)	Thickness (mm)	Elongation (rate) (%)
Comparative example	A1	880	845	0.8	24
	A2	850	860	0.5	26
	A3	830	870	0.5	25
	A4	840	840	1.0	23
	A5	830	850	1.2	23
	A6	860	810	1.5	22
	B1	840	920	0.5	25
	B2	830	880	0.5	26
	C1	820	880	0.6	25
	C2	840	910	0.4	25

[0083] Referring to table 2, the examples performed annealing at an annealing heat treatment temperature that satisfies both equations 2 and 3 below. Accordingly, all the examples had elongation rates that satisfied at least 27%. Equation 2: $840 \leq T \text{ (HRA, } ^\circ\text{C)} \leq \text{Ac1} - 20$

$$\text{Equation 3: } 870 \leq T \text{ (CRA, } ^\circ\text{C)} \leq \text{Ac1} - 20$$

[0084] Comparative examples A3, A5, B2 and C1 failed to satisfy equation 2.

[0085] In comparative examples A3, A5, B2 and C1, recrystallization was not done sufficiently because the hot-rolled sheet annealing heat treatment temperature T (HRA, °C) did not satisfy at least 840 °C, so the elongation rate did not satisfy at least 27%.

[0086] Comparative examples A1, A2, A4, A6, B1 and C2 did not satisfy equation 3.

[0087] In comparative examples A1, A2, A4 and A6, recrystallization was not done sufficiently because the cold-rolled sheet annealing heat treatment temperature T (CRA, °C) did not satisfy at least 870 °C, so the elongation rate did not satisfy at least 27%.

[0088] In comparative examples B1 and C2, the cold-rolled sheet annealing heat treatment temperature T (CRA, °C) did not satisfy $(\text{Ac1} - 20 \text{ } ^\circ\text{C})$ or less, leading to formation of an austenite phase, so a martensite phase was formed during quenching after heat treatment. Hence, the elongation rate did not satisfy at least 27%.

[0089] FIG. 1 is a graph representing an annealing heat treatment temperature range that may secure at least 27% of elongation.

[0090] Referring to FIG. 1, it can be seen that when annealing is performed at an annealing heat treatment temperature that satisfies equations (2) and (3) below, an elongation of at least 27% may be secured.

$$\text{Equation 2: } 840 \leq T \text{ (HRA, } ^\circ\text{C)} \leq \text{Ac1} - 20$$

$$\text{Equation 3: } 870 \leq T \text{ (CRA, } ^\circ\text{C)} \leq \text{Ac1} - 20$$

[Industrial Applicability]

[0091] According to an embodiment of the disclosure, a ferritic stainless steel and method of manufacturing the same, by which elongation is improved by controlling annealing heat treatment temperature while omitting box annealing and performing continuous annealing, may be provided, so that manufacturing costs may be saved by omitting the box annealing that requires long time, so the industrial applicability is acknowledged.

Claims

1. A ferritic stainless steel comprising:

in percent by weight (wt%), 0.01 to 0.1% of C, 0.01 to 1.0% of Si, 0.01 to 1.5% of Mn, more than 0 to 0.05% of P, more than 0 to 0.005% of S, 13.0 to 18.0% of Cr, 0.005 to 0.1% of N, 0.005 to 0.2% of Al, 0.05 to 0.25% of Ni, the remaindered Fe (iron) and other unavoidable impurities, wherein an Ac1 value defined in equation 1 below is at least 920 and less than 990:

$$Ac1 = 36*[Cr] + 90*[Si] + 760*[Al] + 350 - (800*[C] + 1300*[N] + 150*[Ni] + 50*[Mn]) \quad \text{Equation 1:}$$

(wherein in equation 1, [Cr], [Si], [Al], [C], [N], [Ni], and [Mn] refer to contents (wt%) of the respective elements).

2. The ferritic stainless steel of claim 1, wherein an elongation rate is at least 27%.

3. A method of manufacturing a ferritic stainless steel comprising:

manufacturing a slab including, in percent by weight (wt%), 0.01 to 0.1% of C, 0.01 to 1.0% of Si, 0.01 to 1.5% of Mn, more than 0 to 0.05% of P, more than 0 to 0.005% of S, 13.0 to 18.0% of Cr, 0.005 to 0.1% of N, 0.005 to 0.2% of Al, 0.05 to 0.25% of Ni, the remaindered Fe (iron) and other unavoidable impurities, wherein an Ac1 value defined in equation 1 below is at least 920 and less than 990;

reheating the slab;

manufacturing a hot-rolled steel material by hot-rolling and coiling the reheated slab;

obtaining a hot-rolled and wound hot-rolled sheet by hot-rolled-sheet-annealing the hot-rolled steel material at a hot-rolled sheet annealing heat treatment temperature T (HRA, °C) which satisfies equation (2) below, followed by cooling and winding;

manufacturing a cold-rolled sheet by cold-rolling the hot-rolled and wound hot-rolled sheet; and

cold-rolled-sheet-annealing the cold-rolled sheet at a cold-rolled sheet annealing heat treatment temperature T (CRA, °C) which satisfies equation (3) below, followed by cooling and winding:

$$Ac1 = 36*[Cr] + 90*[Si] + 760*[Al] + 350 - (800*[C] + 1300*[N] + 150*[Ni] + 50*[Mn]) \quad \text{Equation 1:}$$

(wherein in equation 1, [Cr], [Si], [Al], [C], [N], [Ni], and [Mn] refer to contents (wt%) of the respective elements).

$$\text{Equation 2: } 840 \leq T \text{ (HRA, } ^\circ\text{C)} \leq Ac1 - 20$$

$$\text{Equation 3: } 870 \leq T \text{ (CRA, } ^\circ\text{C)} \leq Ac1 - 20.$$

4. The method of claim 3, wherein the reheating is performed at 1100 to 1250 °C.

5. The method of claim 3, wherein the hot-rolling is performed at a finish rolling completion temperature of 800 to 950 °C.

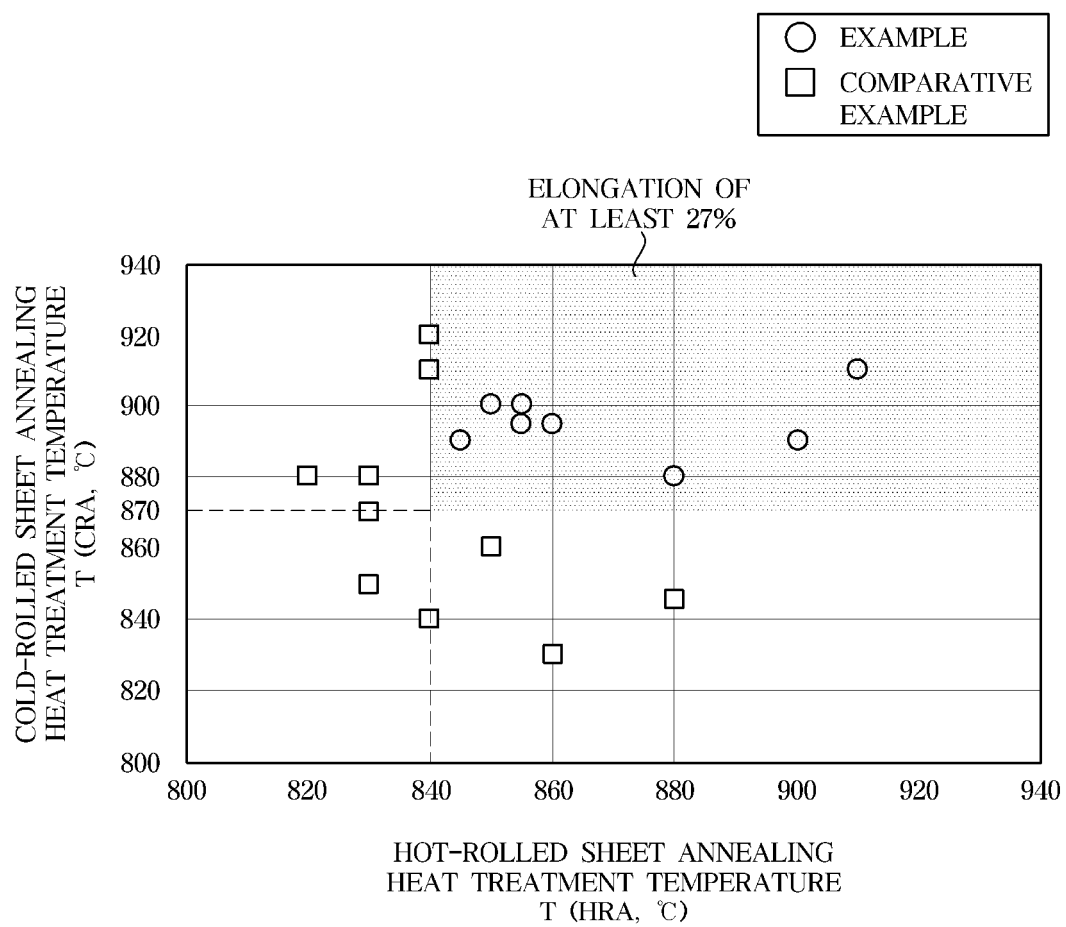
6. The method of claim 3, wherein the coiling is performed at 750 to 850 °C.

7. The method of claim 3, wherein the hot-rolled sheet annealing and the cold-rolled sheet annealing are performed for 30 seconds to 10 minutes.

8. The method of claim 3, wherein the cooling after the hot-rolled sheet annealing and the cooling after the cold-rolled sheet annealing are performed at a cooling rate of 50 °C/s.

9. The method of claim 3, wherein the cold rolling is performed with a reduction rate of 60 to 90%.

FIG.1



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2022/015994

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/40(2006.01)i; C22C 38/00(2006.01)i; C21D 8/02(2006.01)i; C21D 9/46(2006.01)i; B21C 47/02(2006.01)i; C23G 1/02(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 38/40(2006.01); B21B 37/74(2006.01); C21D 8/02(2006.01); C22C 38/00(2006.01); C22C 38/38(2006.01); C22C 38/50(2006.01); C22C 38/60(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: 스테인리스(stainless), 페라이트(ferrite), 열간압연(hot-rolled), 냉간압연(cold-rolled), 소둔(annealing), 냉각(cooling), 크롬(Cr), 니켈(Ni)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2021-0019519 A (JFE STEEL CORPORATION) 22 February 2021 (2021-02-22) See paragraphs [0123], [0125], [0128]-[0129], [0135], [0147], [0159]-[0160] and [0164] and claims 1-2.	1-9
A	JP 2017-048417 A (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORP.) 09 March 2017 (2017-03-09) See paragraph [0048] and claim 1.	1-9
A	CN 102234740 A (BAOSHAN IRON & STEEL CO., LTD.) 09 November 2011 (2011-11-09) See claims 1 and 6.	1-9
A	JP 2006-328524 A (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORP.) 07 December 2006 (2006-12-07) See paragraph [0029] and claims 1-2 and 8.	1-9

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"D" document cited by the applicant in the international application	"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
"E" earlier application or patent but published on or after the international filing date	"&" document member of the same patent family
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 13 February 2023	Date of mailing of the international search report 14 February 2023
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2022/015994

5

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2019-044215 A (JFE STEEL CORP.) 22 March 2019 (2019-03-22) See paragraph [0076] and claims 1 and 5.	1-9

10

15

20

25

30

35

40

45

50

55

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2022/015994

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
KR 10-2021-0019519 A	22 February 2021	JP 2021-080015 A1	15 February 2021
		JP 6881666 B2	02 June 2021
		TW 202022127 A	16 June 2020
		TW I727451 B	11 May 2021
		WO 2020-080015 A1	23 April 2020
JP 2017-048417 A	09 March 2017	JP 6602112 B2	06 November 2019
CN 102234740 A	09 November 2011	CN 102234740 B	17 July 2013
JP 2006-328524 A	07 December 2006	JP 2006-328525 A	07 December 2006
		JP 4721916 B2	13 July 2011
		JP 4721917 B2	13 July 2011
JP 2019-044215 A	22 March 2019	JP 6680279 B2	15 April 2020

Form PCT/ISA/210 (patent family annex) (July 2022)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 57070230 A [0007]
- JP 57155326 A [0007]