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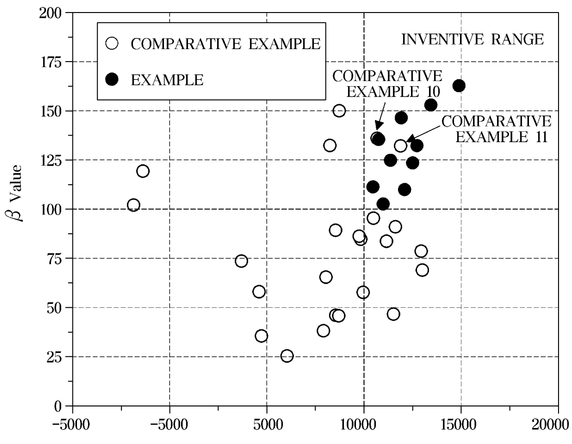
(54) AUSTENITIC STAINLESS STEEL AND MANUFACTURING METHOD THEREFOR

(57) The present disclosure relates to an austenitic stainless steel and a manufacturing method therefor, and specifically, to an austenitic stainless steel and a manufacturing method therefor, wherein the austenitic stainless steel can secure both excellent strength and ductility even after undergoing low-temperature annealing and have excellent competitiveness and corrosion resistance.

Fig1.



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Description

[Technical Field]

[0001] The present disclosure relates to an austenitic stainless steel and a manufacturing method therefor, and more particularly, to an austenitic stainless steel having both high strength and ductility even after undergoing low-temperature annealing and having excellent price-competitiveness and corrosion resistance and a manufacturing method therefor.

[Background Art]

[0002] Stainless steels with excellent corrosion resistance, which do not require additional investment for separate facilities to improve corrosion resistance, are suitable not only for transportation and construction parts but also mass production in small variety that is a recent market trend. Particularly, due to excellent formability and elongation, austenitic stainless steels are easy to form complex shapes to meet various needs of customers and have aesthetically appealing appearance.

[0003] However, due to lower yield strength of 200 to 350 MPa of frequently used austenitic stainless steels than that of carbon steels, there are limits to apply the austenitic stainless steels to structures. In order to obtain higher yield strength in such general-purpose 300 series stainless steels, an additional skin pass rolling process, which causes problems of increasing costs and rapidly deteriorating elongation and formability, is performed. In addition, because common stainless steels contain high-priced alloying elements, a problem of low price-competitiveness may occur. Particularly, Ni contained in austenitic stainless steels has low price competitiveness because the supply of raw materials is unstable due to extreme fluctuation in price, it is difficult to secure stable supply price, and the price thereof itself is high.

[0004] For example, Korean Patent Application Publication No. 10-2016-0138277 discloses an austenitic stainless steel and a manufacturing method therefor, wherein the austenitic stainless steel includes 0.10% or less of C, 1.0% or less of Si, 2.1 to 6.0% of Mn, 0.045% or less of P, 0.1% or less of S, 8.0 to 16.0% of Ni, 15.0 to 30.0% of Cr, 1.0 to 5.0% of Mo, 0.05 to 0.45% of N, 0 to 0.50% of Nb, 0 to 0.50% of V, and the balance of Fe and impurities, has a chemical composition satisfying a specific Equation (1), a grain size number of less than 8.0, and a tensile strength of 690 MPa or more. However, a large amount of nickel is required.

[0005] Meanwhile, the technology of realizing ultra-fine grains in an austenitic stainless steel may generally be conducted by transforming an austenite phase into a martensite phase by cold rolling, and annealing at a low temperature. However, although ultra-fine grains are formed, it is difficult to prepare a material having both excellent yield strength and elongation. This is because the contents of Ni, Cr, Mn, and the like may vary within a range capable of obtaining price-competitiveness, the amount of martensitic transformation may vary according to the austenitic stability parameter (ASP) value, and elongation may vary in accordance with transformation induced plasticity (TRIP) transformation behavior during a tensile test.

[0006] Therefore, there is a need to develop a material having excellent yield strength, elongation, and corrosion resistance with minimum amounts of high-priced alloying elements such as Ni and a manufacturing method therefor.

(Related Art Document(s))

[0007] Patent Document 1: Korean Patent Application Publication No. 10-2016-0138277 (Published on December 2, 2016)

[Disclosure]

[Technical Problem]

[0008] Embodiments of the present disclosure provide an austenitic stainless steel having excellent yield strength and elongation, and high price-competitiveness, and excellent corrosion resistance so as to be applicable to industrial materials.

[0009] Specifically, the present disclosure provides a high strength-high ductility austenitic stainless steel sheet having applicable to outer panels of automobiles and construction parts by using the technology of manufacturing ultrafine grains and a manufacturing method therefor.

[0010] However, the technical problems to be solved by the present disclosure are not limited to the aforementioned problems, and any other technical problems not mentioned herein will be clearly understood from the following description by those skilled in the art to which the present disclosure pertains.

[Technical Solution]

[0011] In accordance with an aspect of the present disclosure to achieve the above-described objects, an austenitic stainless steel includes, in percent by weight (wt%), 0.005 to 0.060% of carbon (C), 0.1 to 1.5% of silicon (Si), 5.0 to 10.0% of manganese (Mn), more than 0% but not more than 3% of nickel (Ni), 14.0 to 18.0% of chromium (Cr), more than 0% but not more than 2.0% of copper (Cu), 0.01 to 0.25% of nitrogen (N), and the balance of iron (Fe) and inevitable impurities, wherein an α value defined in Equation (1) below satisfies 10,000 or more, and a β value defined in Equation (2) below satisfies 100 or more.

$$\text{Equation (1): } \alpha = YS \times EL - 200(8[Ni]+[Cr]+3[Mn])$$

$$\text{Equation (2): } \beta = ASP + [150/\sqrt{d}]$$

[0012] In Equation (1) and Equation (2), [Ni], [Cr], and [Mn] represent amounts (wt%) of respective elements, YS refers to yield stress (MPa), EL refers to elongation (%), austenitic stability parameter (ASP) is a value calculated by using Equation (2-1) below, and d refers to an average grain size (μm) of a thickness central region.

ASP = 551-462([C]+[N])-9.2[Si]-8.1[Mn]-13.7[Cr]- 29([Ni]+[Cu])

[0013] In Equation (2-1), [C], [N], [Si], [Mn], [Cr], [Ni], and [Cu] represent amounts (wt%) of respective elements.

[0014] In addition, the average grain size (d) of the thickness central region may be 5.0 μm or less.

[0015] In addition, the ASP value of Equation (2) may satisfy a range of 15 to 70.

[0016] In addition, the austenitic stainless steel may have a pitting potential of 100 mV or more.

[0017] In addition, the austenitic stainless steel may have a yield strength of 540.0 MPa or more an elongation of 30.0% or more.

[0018] In accordance with another aspect of the present disclosure to achieve the above-described objects, a method for manufacturing an austenitic stainless steel includes: providing a material including, in percent by weight (wt%), 0.005 to 0.060% of carbon (C), 0.1 to 1.5% of silicon (Si), 5.0 to 10.0% of manganese (Mn), more than 0% but not more than 3% of nickel (Ni), 14.0 to 18.0% of chromium (Cr), more than 0% but not more than 2.0% of copper (Cu), 0.01 to 0.25% of nitrogen (N), and the balance of iron (Fe) and inevitable impurities; hot rolling the material to prepare a hot-rolled steel sheet; cold rolling the hot-rolled steel sheet to prepare a cold-rolled steel sheet; and finally annealing the cold-rolled steel sheet, wherein the finally-annealed steel sheet satisfies an α value defined in Equation (1) below of 10,000 or more, a β value defined in Equation (2) below of 100 or more, and a γ defined in Equation (3) below of 0 or more.

$$\text{Equation (1): } \alpha = YS \times EL - 200(8[Ni]+[Cr]+3[Mn])$$

$$\text{Equation (2): } \beta = ASP + [150/\sqrt{d}]$$

$$\text{Equation (3): } \gamma = [Cr]+16[N]-0.5[Mn]-[390/\sqrt{Temp}]$$

[0019] In Equation (1) to Equation (3), [Ni], [Cr], [Mn], and [N] represent amounts (wt%) of respective elements, YS refers to yield stress (MPa), EL refers to elongation (%), austenitic stability parameter (ASP) is a value calculated by using Equation (2-1) below, d refers to an average grain size (μm) of a thickness central region, and Temp refers to a final annealing temperature (°C).

ASP = 551-462([C]+[N])-9.2[Si]-8.1[Mn]-13.7[Cr]- 29([Ni]+[Cu])

[0020] In Equation (2-1), [C], [N], [Si], [Mn], [Cr], [Ni], and [Cu] represent amounts (wt%) of respective elements.

[0021] In addition, the final annealing process may be performed in a temperature range of 750 to 850°C.

[0022] In addition, the method may further include primarily annealing the hot-rolled steel sheet at 1000 to 1150°C before the cold rolling.

[0023] In addition, in the cold rolling process, the hot-rolled steel sheet may be rolled with a thickness reduction ratio of 50% or more in a room temperature range to form the cold-rolled steel sheet.
[0024] In addition, the austenitic stainless steel may satisfy an ASP value range of 15 to 70.
[0025] In addition, in the finally annealed steel sheet, an average grain size (d) of the thickness central region may be 5.0 μm or less.

[Advantageous Effects]

[0026] According to an embodiment of the present disclosure, an austenitic stainless steel having excellent yield strength and elongation and manufactured with low costs by minimizing the Ni content.
[0027] The present disclosure may provide an austenitic stainless steel having excellent ultra-fine grain characteristics with excellent strength, ductility, and corrosion resistance as well as high price-competitiveness, and a manufacturing method therefor.

[Description of Drawings]

[0028]

FIG. 1 shows ranges of α value calculated by Equation (1) and β value calculated by Equation (2) according to examples and comparative examples.
FIG. 2 shows average grain sizes of thickness central regions of austenitic stainless steels according to examples and comparative examples.

[Best Mode]

[0029] An embodiment of the present disclosure provides an austenitic stainless steel including, in percent by weight (wt%), 0.005 to 0.060% of carbon (C), 0.1 to 1.5% of silicon (Si), 5.0 to 10.0% of manganese (Mn), more than 0% but not more than 3% of nickel (Ni), 14.0 to 18.0% of chromium (Cr), more than 0% but not more than 2.0% of copper (Cu), 0.01 to 0.25% of nitrogen (N), and the balance of iron (Fe) and inevitable impurities, wherein an α value defined by Equation (1) below satisfies 10,000 or more and a β value defined by Equation (2) below satisfies 100 or more.

$$\text{Equation (1)}: \alpha = YS \times EL - 200(8[Ni]+[Cr]+3[Mn])$$

$$\text{Equation (2)}: \beta = ASP + [150/\sqrt{d}]$$

[0030] In Equation (1) and Equation (2),

[Ni], [Cr], and [Mn] represent amounts (wt%) of respective elements,
YS refers to yield stress (MPa),
EL refers to elongation (%),
austenitic stability parameter (ASP) is a value calculated by using Equation (2-1) below, and
d is an average grain size (μm) of a thickness central region.

ASP = 551-462([C]+[N])-9.2[Si]-8.1[Mn]-13.7[Cr]- 29([Ni]+[Cu])

[0031] In Equation (2-1), [C], [N], [Si], [Mn], [Cr], [Ni], and [Cu] represent amounts (wt%) of respective elements.

[Modes of the Invention]

[0032] The terms used herein are merely used to describe the present disclosure and not intended to the scope of the present disclosure. Thus, an expression used in the singular encompasses the expression of the plural, unless it has a clearly different meaning in the context.
[0033] Hereinafter, the unit is wt% unless otherwise stated. In addition, it is to be understood that the terms such as

"including" or "having" are intended to indicate the existence of components disclosed in the specification, and are not intended to preclude the possibility that one or more other components may exist or may be added.

[0034] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which present disclosure belongs. Terms defined in the dictionary are interpreted to have meanings consistent with related technical documents and content disclosed herein.

[0035] In addition, the terms "about", "substantially", etc. used throughout the specification mean that when a natural manufacturing and substance allowable error are suggested, such an allowable error corresponds a value or is similar to the value, and such values are intended for the sake of clear understanding of the present invention or to prevent an unconscious infringer from illegally using the disclosure of the present invention.

[0036] Ultra-fine grain (UFG) materials have properties such as excellent strength-elongation balance, fatigue resistance, and etching processibility. The present disclosure provides an austenitic stainless steel including ultra-fine grains realizing high strength-high ductility, and a manufacturing method therefor. Furthermore, provided is an austenitic stainless steel sheet having yield strength and elongation suitable for structural members such as outer panels of automobiles and construction parts.

[0037] In addition, in the present disclosure, in order to increase price-competitiveness of the austenitic stainless steel, manganese and nitrogen have been used to maintain excellent performance while reducing high-priced elements such as nickel.

[0038] Hereinafter, an austenitic stainless steel according to an embodiment of the present disclosure will be described in more detail.

[Austenitic Stainless Steel]

[0039] An austenitic stainless steel according to an embodiment of the present disclosure may include, in percent by weight (wt%), 0.005 to 0.060% of carbon (C), 0.1 to 1.5% of silicon (Si), 5.0 to 10.0% of manganese (Mn), more than 0% but not more than 2.0% of copper (Cu), more than 0% but not more than 3.0% of nickel (Ni), 14.0 to 18.0% of chromium (Cr), 0.01 to 0.25% of nitrogen (N), and the balance of iron (Fe) and inevitable impurities.

[Range of Components]

Carbon (C): 0.005% to 0.060%

[0040] Carbon, as an element effective on stabilizing an austenite phase, may be added in an amount of 0.005% or more to obtain yield strength of an austenitic stainless steel. However, an excess of C may not only deteriorate cold workability due to solid strengthening effect, but also induce grain boundary precipitation of a Cr carbide during low-temperature annealing adversely affecting ductility, toughness, corrosion resistance, and the like. Thus, an upper limit thereof may be controlled to 0.060%.

Silicon (Si): 0.1% to 1.5%

[0041] Silicon, serving as a deoxidizer during a steelmaking process, is effective on enhancing corrosion resistance and may be added in an amount of 0.01% or more. However, Si is also an element effective on stabilizing a ferrite phase, and an excess of Si may promote formation of delta (δ) ferrite in a cast slab, thereby not only deteriorating hot workability but also adversely affecting ductility and impact properties. Thus, an upper limit thereof may be controlled to 1.5%.

Manganese (Mn): 5.0% to 10.0%

[0042] Manganese (Mn), as an element stabilizing an austenite phase added as a Ni substitute, may be added in an amount of 5.0% or more to improve stability of an austenite. However, an excess of Mn may cause excessive formation of S-based inclusions (MnS), resulting in deterioration of ductility, toughness, and corrosion resistance of an austenitic stainless steel, and may also cause formation of Mn fumes during a steelmaking process, resulting in increases in risks in the manufacture. Thus, an upper limit thereof may be controlled to 10.0%.

Nickel (Ni): more than 0% but not more than 3.0%

[0043] Nickel (Ni), as a strong austenite phase-stabilizing element, is essential to obtain excellent hot workability and cold workability. However, Ni that is a high-priced element may increase costs of raw materials in the case of adding a large amount. Thus, an upper limit thereof may be controlled to 3.0% in consideration of both costs and efficiency of steel materials.

Chromium (Cr): 14.0% to 18.0%

[0044] Chromium (Cr) is an element stabilizing a ferrite phase but effective on suppressing formation of a martensite phase. As a basic element for obtaining corrosion resistance required in stainless steels, Cr may be added in an amount of 14% or more. However, an excess of Cr may increase manufacturing costs and promote formation of a large amount of delta (δ) ferrite in a steel material, resulting in deterioration of hot workability and adverse effects on properties. Thus, an upper limit thereof may be controlled to 18.0%.

Copper (Cu): more than 0% but not more than 2.0%

[0045] Copper (Cu), as an austenite phase-stabilizing element, is added instead of nickel (Ni) in the present disclosure. Cu may be added as an element for enhancing corrosion resistance under a reducing environment. However, an excess of Cu not only increases costs of raw materials but also causes liquefaction and embrittlement at a low temperature. Thus, an upper limit thereof may be controlled to 2.0% in consideration of cost efficiency and properties of steel materials.

Nitrogen (N): 0.01% to 0.25%

[0046] Nitrogen, as a strong austenite-stabilizing element effective on enhancing corrosion resistance and yield strength of an austenitic stainless steel, may be added in an amount of 0.01% or more. However, an excess of N may cause hardening of a material and deterioration of hot workability due to solid strengthening effect. Thus, an upper limit thereof may be controlled to 0.25%.

Other Components

[0047] In addition, the austenitic stainless steel according to an embodiment of the present disclosure may further include at least one of phosphorous (P) and sulfur (S) as inevitable impurities.

[0048] A content of phosphorus (P) is 0.035% or less. Phosphorus (P), as an impurity inevitably contained in steels, is a major element causing grain boundary corrosion or deterioration of hot workability, and therefore, it is preferable to control the P content as low as possible. In the present disclosure, an upper limit of the P content is controlled to 0.035% or less.

[0049] A content of sulfur (S) is 0.01% or less. Sulfur (S), as an impurity that is inevitably contained in steels, is a major element causing deterioration of hot workability as being segregated in grain boundaries, and therefore, it is preferable to control the S content as low as possible. In the present disclosure, an upper limit of the S content is controlled to 0.01% or less.

[0050] The remaining component of the composition of the present disclosure is iron (Fe). However, the composition may include unintended impurities inevitably incorporated from raw materials or surrounding environments, and thus addition of other alloy components is not excluded. These impurities are known to any person skilled in the art of manufacturing and details thereof are not specifically mentioned in the present disclosure.

[Parameters and Physical Properties]

[0051] In addition, the austenitic stainless steel is characterized to have an α value defined by Equation (1) below satisfying 10,000 or more. If the α value is 10,000 or more, not only price-competitiveness, but also high strength and high ductility may be obtained.

$$\text{Equation (1): } \alpha = YS \times EL - 200(8[Ni]+[Cr]+3[Mn])$$

[0052] In Equation (1), [Ni], [Cr], and [Mn] represent amounts (wt%) of respective elements, YS refers to yield stress (MPa), and EL refers to elongation (%).

[0053] In addition, the austenitic stainless steel is characterized to have a β value defined by Equation (2) below satisfying 100 or more. If the β value is 100 or more, ultra-fine grains are formed to obtain both high strength and high ductility.

$$\text{Equation (2): } \beta = ASP + [150/\sqrt{d}]$$

[0054] In Equation (2), austenitic stability parameter (ASP) is a value calculated by using Equation (2-1) below, and d refers to an average grain size (μm) of a thickness central region.

$$ASP = 551-462([C]+[N])-9.2[Si]-8.1[Mn]-13.7[Cr]- 29([Ni]+[Cu])$$

[0055] In Equation (2-1), [C], [N], [Si], [Mn], [Cr], [Ni], and [Cu] represent amounts (wt%) of respective elements.

[0056] The average grain size (d) of the thickness central region may be 5.0 μm or less indicating ultra-fine grains, and the ASP value of Equation (2) may satisfy the range of 15 to 70.

[0057] The austenitic stainless steel according to an embodiment may have a pitting potential of 100 mV or more indicating excellent corrosion resistance when the potting potential is measured using a 3.5% NaCl solution at 30°C.

[0058] The austenitic stainless steel according to an embodiment has a yield strength of 540.0 MPa or more indicating excellent strength and an elongation of 30.0% or more indicating excellent ductility.

[0059] In the case where a material produced in a casting process according to an embodiment of the present disclosure is hot rolled and finally cold rolled with a total thickness reduction ratio of 50% or more at room temperature without performing annealing, and then finally cold annealed in an annealing temperature range of 750 to 850°C, or in the case where a material produced in the casting process is hot rolled, annealed in an annealing temperature range of 1000 to 1150°C, and finally cold rolled with a total thickness reduction ratio of 50% or more at room temperature, and then finally annealed in a temperature range of 750 to 850°C, the average grain size (d) of the thickness central region is 5 μm or less, and the pitting potential, when measured using a 3.5% NaCl solution (30°C), satisfies 100 mV or more.

[Method for Manufacturing Austenitic Stainless Steel]

[0060] Therefore, hereinafter, a method for manufacturing an austenitic stainless steel according to an embodiment of the present disclosure will be described.

[0061] The method for manufacturing an austenitic stainless steel according to an embodiment of the present disclosure may include: providing a material; hot rolling the material to prepare a hot-rolled steel sheet; cold-rolling the hot-rolled steel sheet to prepare a cold-rolled steel sheet; and finally annealing the cold-rolled steel sheet, wherein the method may further include primarily annealing the hot-rolled steel sheet before the cold rolling.

[0062] In the providing of the material, a material (ingot or slab) including, in percent by weight (wt%) 0.005 to 0.060% of carbon (C), 0.1 to 1.5% of silicon (Si), 5.0 to 10.0% of manganese (Mn), more than 0% but not more than 3.0% of nickel (Ni), 14.0 to 18.0% of chromium (Cr), more than 0% but not more than 2.0% of copper (Cu), 0.01 to 0.25% of nitrogen (N), and the balance of iron (Fe) and inevitable impurities may be provided.

[0063] The composition of the material may be controlled such that the ASP value defined by Equation (2-1) below satisfies a range of 15 to 70.

$$ASP = 551-462([C]+[N])-9.2[Si]-8.1[Mn]-13.7[Cr]- 29([Ni]+[Cu])$$

[0064] In the equation, [C], [N], [Si], [Mn], [Cr], [Ni], and [Cu] represent amounts (wt%) of respective elements.

[0065] In addition, the method for manufacturing an austenitic stainless steel according to an embodiment of the present disclosure includes controlling the α value defined by Equation (1) below to satisfy 10,000 or more. If the α value is controlled to 10,000 or more, not only high price-competitiveness but also high strength and high ductility may be obtained.

$$\text{Equation (1): } \alpha = YS \times EL - 200(8[Ni]+[Cr]+3[Mn])$$

[0066] In Equation (1), Ni, Cr, and Mn represent amounts (wt%) of respective elements, YS refers to yield stress (MPa), and EL refers to elongation (%).

[0067] In addition, the method for manufacturing an austenitic stainless steel according to an embodiment of the present disclosure includes controlling the β value defined by Equation (2) below to satisfy 100 or more. If the β value is controlled to 100 or more, ultra-fine grains having an average grain size (d) of the thickness central region of 5.0 μm or less are formed, thereby obtaining both high strength and high ductility.

$$\text{Equation (2): } \beta = ASP + [150/\sqrt{d}]$$

[0068] In Equation (2), austenitic stability parameter (ASP) is a value calculated by Equation (2-1) described above and may preferably satisfy a range of 15 to 70.

[0069] D refers to an average grain size (μm) of a thickness central region and may preferably be 5.0 μm or less.

[0070] After the hot rolling process, cold rolling may be performed without conducting annealing, or cold rolling may be performed after primary annealing. In the case of performing primary annealing, the primary annealing may be performed in a temperature range of 1000 to 1150°C.

[0071] The cold rolling process may be performed such that a thickness reduction ratio of the hot-rolled steel sheet is 50% or more in a room temperature range.

[0072] The final annealing process may be performed in a temperature range of 750 to 850°C, and furthermore, a final annealing temperature may be controlled such that the γ value defined by Equation (3) below is 0 or more. If the γ value is controlled to 0 or more, the components such as manganese, chromium, and nitrogen may be balanced so as to obtain sufficient corrosion resistance although low-temperature annealing is performed.

$$\text{Equation (3): } \gamma = [Cr]+16[N]-0.5[Mn]-[390/\sqrt{Temp}]$$

[0073] In Equation (3), [Cr], [N], and [Mn] represent amounts (wt%) of respective elements, and Temp refers to a final annealing temperature (°C).

[0074] Specifically, if the γ value is controlled to 0 or more, a pitting potential, which is measured using a 3.5% NaCl solution at 30°C, is 100 mV or more, thereby achieving excellent corrosion resistance.

[Examples]

[0075] Hereinafter, the present disclosure will be described in more detail with reference to the following examples.

[0076] Alloying elements and composition ranges of steel types used in examples and comparative examples of the austenitic stainless steel, and austenite stability parameter (ASP) values, as parameters of major components, are listed in Table 1 below.

ASP = 551-462([C]+[N])-9.2[Si]-8.1[Mn]-13.7[Cr]- 29([Ni]+[Cu])

[Table 1]

Category	Alloying element (wt%)							ASP
	C	Si	Mn	Ni	Cr	Cu	N	
Steel Type 1	0.030	0.5	8.5	2.5	15.5	1.2	0.20	51.64
Steel Type 2	0.040	0.5	8.5	2.0	16.0	2.5	0.20	16.97
Steel Type 3	0.040	0.5	9.2	1.2	15.5	1.8	0.20	61.65
Steel Type 4	0.030	0.4	9.5	1.9	15.2	1.5	0.20	57.27
Steel Type 5	0.030	0.4	9.5	2.5	16.2	1.0	0.22	31.43
Steel Type 6	0.030	1.0	9.5	1.9	15.2	1.0	0.23	52.39
Steel Type 7	0.120	0.6	0.9	6.8	17.1	0.0	0.05	28.18
Steel Type 8	0.055	0.4	1.1	8.1	18.2	0.1	0.04	7.38
Steel Type 9	0.030	1.0	8.8	2.5	16.2	0.5	0.20	55.32
Steel Type 10	0.030	0.4	10.0	3.5	16.5	1.0	0.23	-10.35
Steel Type 11	0.030	1.5	10.0	1.8	15.8	1.9	0.23	12.32

[0077] Some of the steel types of Table 1 were manufactured as ingots by Lab. vacuum melting, and some were manufactured as slabs via an electric furnace-casting process. Coils of Examples 1 to 10 and Comparative Examples 1 to 24 were prepared at final annealing temperatures (Temp; °C) shown in Table 2 below. The average grain size (d) was measured at the thickness central region of the prepared materials, and the yield strength (YS; MPa) and the elongation (EL; %) were measured by using JIS13B tensile test pieces by a tensile test at room temperature in a crosshead range of 10 mm/min to 20 mm/min, and the pitting potential was measured by using a 3.5% NaCl solution (30°C), and the results are shown in Table 2 below.

[0078] In addition, based on the compositions and measurement values of Table 1, α, β, and γ values defined by Equation (1) to Equation (3) below were calculated and shown in Table 2 below. FIG. 1 shows α values and β values of the examples and comparative examples.

$$\text{Equation (1): } \alpha = \text{YS(MPa)} \times \text{EL(\%)} - 200(8[\text{Ni}]+[\text{Cr}]+3[\text{Mn}])$$

$$\text{Equation (2): } \beta = \text{ASP} + [150/\sqrt{d}]$$

$$\text{Equation (3): } \gamma = [\text{Cr}]+16[\text{N}]-0.5[\text{Mn}]-[390/\sqrt{Temp}]$$

[Table 2]

Category	Steel Type	Temp. (°C)	d (μm)	YS (MPa)	EL (%)	Pitting potential (mV)	α	β	γ
Example 1	Steel Type 1	800	2.5	636.4	37.9	110.7	11919.56	146.51	0.66
Example 2	Steel Type 1	850	3.2	543.8	42.2	106.1	10748.36	135.49	1.07
Example 3	Steel Type 2	850	2.6	653.3	36.1	142.2	12084.13	110.00	1.57
Example 4	Steel Type 3	800	2.2	658.6	38.6	107.6	14881.96	162.78	0.31
Example 5	Steel Type 3	850	2.7	584.2	41.0	112.5	13412.20	152.94	0.72
Example 6	Steel Type 4	850	4.9	599.7	38.6	103.5	11368.42	125.03	0.27
Example 7	Steel Type 5	750	3.5	760.0	30.8	115.5	10468.00	111.61	0.73
Example 8	Steel Type 5	800	4.4	666.1	35.9	109.0	10972.99	102.94	1.18
Example 9	Steel Type 6	800	3.5	710.5	34.5	116.9	12732.25	132.57	0.34
Example 10	Steel Type 6	850	4.4	650.5	37.3	107.5	12483.65	123.90	0.75
Comparative Example 1	Steel Type 7	800	2.7	620.7	21.7	262.7	-1370.81	119.47	3.66
Comparative Example 2	Steel Type 7	850	4.1	569.3	22.8	311.7	-1859.96	102.26	4.07
Comparative Example 3	Steel Type 7	1050	25.5	494.7	50.1	388.3	9944.47	57.88	5.41
Comparative Example 4	Steel Type 8	800	5.1	594.9	35.2	288.4	3680.48	73.80	4.50
Comparative Example 5	Steel Type 8	850	8.7	593.5	36.8	284.0	4580.80	58.23	4.91
Comparative Example 6	Steel Type 8	1050	27.7	465.8	47.2	332.4	4725.76	35.88	6.25
Comparative Example 7	Steel Type 1	1050	20.9	402.9	54.7	109.3	9838.63	84.45	2.41
Comparative Example 8	Steel Type 2	1050	26.3	420.0	47.7	192.8	8534.00	46.22	2.91
Comparative Example 9	Steel Type 3	1050	25.9	413.3	53.6	152.4	11612.88	91.11	2.06
Comparative Example 10	Steel Type 4	750	3.6	762.9	29.4	6.3	10649.26	136.33	-0.59
Comparative Example 11	Steel Type 4	800	4.0	655.0	36.1	26.8	11865.50	132.27	-0.14
Comparative Example 12	Steel Type 4	1050	26.8	430.2	50.0	142.2	9730.00	86.25	1.61
Comparative Example 13	Steel Type 5	850	5.5	618.1	37.9	127.4	10485.99	95.39	1.59

(continued)

Category	Steel Type	Temp. (°C)	d (μm)	YS (MPa)	EL (%)	Pitting potential (mV)	α	β	γ
Comparative Example 14	Steel Type 5	1050	19.3	453.0	46.3	113.8	8033.90	65.57	2.93
Comparative Example 15	Steel Type 6	1050	22.8	457.8	50.1	132.2	11155.78	83.80	2.09
Comparative Example 16	Steel Type 9	800	2.5	730.4	29.1	74.1	8734.64	150.19	1.21
Comparative Example 17	Steel Type 9	850	3.8	689.4	30.1	145.9	8230.94	132.27	1.62
Comparative Example 18	Steel Type 9	1050	19.5	494.3	42.6	169.0	8537.18	89.29	2.96
Comparative Example 19	Steel Type 10	800	7.1	661.7	35.6	81.1	8656.52	45.94	1.39
Comparative Example 20	Steel Type 10	850	9.5	612.5	37.2	171.9	7885.00	38.32	1.80
Comparative Example 21	Steel Type 10	1050	17.3	449.2	46.6	196.3	6032.72	25.71	3.14
Comparative Example 22	Steel Type 11	800	5.1	742.9	33.6	51.2	12921.44	78.74	0.69
Comparative Example 23	Steel Type 11	850	6.9	686.1	36.5	54.3	13002.65	69.42	1.10
Comparative Example 24	Steel Type 11	1050	19.0	482.1	48.8	60.7	11486.48	46.73	2.44

[0079] Referring to Tables 1 and 2, Examples 1 to 10 had ASP values of 15 to 70 and average grain sizes (d) of the thickness central region satisfying 5 μm or less. On the contrary, it was confirmed that Comparative Examples 1 to 9 and 12 to 24 had ASP values out of the range of 10 to 70 or average grain sizes (d) of the thickness central region of not less than 5.1 μm. Examples 1 to 10 exhibit austenitic stainless steel having excellent corrosion resistance with high strength and high ductility with low manufacturing costs. All of Examples 1 to 10 satisfy the α value of 10,000 or more, the β value of 100 or more, the γ value of 0 or more, and the pitting potential value of 100 mV or more.

[0080] Comparative Examples 1 to 6, which are commercially produced standard austenitic stainless steels, have low price-competitiveness because steel types not satisfying the composition range of the present disclosure were used and do not satisfy the α value conditions because the α values were less than 10,000, thereby failing to realize high strength and high ductility with high price-competitiveness.

[0081] Comparative Examples 7 and 8, 12, 14, and 16 to 21 have problems of failing to realize high strength and high ductility with high price-competitiveness because the α values, less than 10,000 in common, do not satisfy the α value conditions.

[0082] Comparative Examples 7 to 9, 12 to 15, and 18 to 24 had problems that the average grain size (d) of the thickness central region could not satisfy 5 μm or less, and the β value was less than 100. FIG. 2 shows grain sizes of Example 1 and Comparative Example 9. In the comparative examples not satisfying 5 μm or less, coarse grains are formed as shown in the right image (Comparative Example 9), and thus ultra-fine grains, as shown in the left image (Example 1) could not be realized. Accordingly, high strength and high ductility could not be obtained simultaneously.

[0083] Comparative Examples 10 and 11 exhibits a problem that the γ value is less than 0. This is because the components consisting of a large amount of Mn and small amounts of Cr and N are not balanced. Since it is difficult to obtain sufficient corrosion resistance of the material while undergoing low-temperature annealing, problems of failing to obtain both high strength and high ductility with excellent corrosion resistance may be caused.

[0084] While the present disclosure has been particularly described with reference to exemplary embodiments, it should be understood by those of skilled in the art that various changes and modifications in form and details may be made without departing from the spirit and scope of the present disclosure.

[Industrial Applicability]

[0085] Because the austenitic stainless steel according to the present disclosure has excellent strength, ductility, and corrosion resistance as well as excellent price-competitiveness, the present disclosure has industrial applicability.

Claims

1. An austenitic stainless steel comprising, in percent by weight (wt%), 0.005 to 0.060% of carbon (C), 0.1 to 1.5% of silicon (Si), 5.0 to 10.0% of manganese (Mn), more than 0% but not more than 3% of nickel (Ni), 14.0 to 18.0% of chromium (Cr), more than 0% but not more than 2.0% of copper (Cu), 0.01 to 0.25% of nitrogen (N), and the balance of iron (Fe) and inevitable impurities,

wherein an α value defined by Equation (1) below satisfies 10,000 or more,
a β value defined by Equation (2) below satisfies 100 or more,

$$\text{Equation (1): } \alpha = YS \times EL - 200(8[Ni]+[Cr]+3[Mn])$$

$$\text{Equation (2): } \beta = ASP + [150/\sqrt{d}]$$

in Equation (1) and Equation (2),
[Ni], [Cr], and [Mn] represent amounts (wt%) of respective elements,
YS refers to yield stress (MPa),
EL refers to elongation (%),
austenitic stability parameter (ASP) is a value calculated by using Equation (2-1) below,
d is an average grain size (μm) of a thickness central region; and

ASP = 551-462([C]+[N])-9.2[Si]-8.1[Mn]-13.7[Cr]- 29([Ni]+[Cu])

in Equation (2-1), [C], [N], [Si], [Mn], [Cr], [Ni], and [Cu] represent amounts (wt%) of respective elements.

2. The austenitic stainless steel according to claim 1, wherein the average grain size (d) of the thickness central region is 5.0 μm or less.

3. The austenitic stainless steel according to claim 1, wherein the ASP value of Equation (2) satisfies a range of 15 to 70.

4. The austenitic stainless steel according to claim 1, wherein the austenitic stainless steel has a pitting potential value of 100 mV or more.

5. The austenitic stainless steel according to claim 1, wherein the austenitic stainless steel has a yield strength of 540.0 MPa or more and an elongation of 30.0% or more.

6. A method for manufacturing an austenitic stainless steel, the method comprising:

providing a material comprising, in percent by weight (wt%), 0.005 to 0.060% of carbon (C), 0.1 to 1.5% of silicon (Si), 5.0 to 10.0% of manganese (Mn), more than 0% but not more than 3.0% of nickel (Ni), 14.0 to 18.0% of chromium (Cr), more than 0% but not more than 2.0% of copper (Cu), 0.01 to 0.25% of nitrogen (N), and the balance of iron (Fe) and inevitable impurities;
hot rolling the material to obtain a hot-rolled steel sheet;
cold rolling the hot-rolled steel sheet to prepare a cold-rolled steel sheet; and
finally annealing the cold-rolled steel sheet,
wherein the finally annealed steel sheet has an α value defined by Equation (1) below satisfying 10,000 or more,
a β value defined by Equation (2) below satisfying 100 or more, and
a γ defined by Equation (3) below satisfying 0 or more,

$$\text{Equation (1): } \alpha = YS \times EL - 200(8[Ni]+[Cr]+3[Mn])$$

$$\text{Equation (2): } \beta = ASP + [150/\sqrt{d}]$$

$$\text{Equation (3): } \gamma = [Cr]+16[N]-0.5[Mn]-[390/\sqrt{Temp}]$$

in Equation (1) to Equation (3),
[Ni], [Cr], [Mn], and [N] represent amounts (wt%) of respective elements,
YS refers to yield stress (MPa),
EL refers to elongation (%),
austenitic stability parameter (ASP) is a value calculated by using Equation (2-1) below,
d is an average grain size (μm) of a thickness central region,
Temp refers to a final annealing temperature (°C); and

ASP = 551-462([C]+[N])-9.2[Si]-8.1[Mn]-13.7[Cr]- 29([Ni]+[Cu])

in Equation (2-1), [C], [N], [Si], [Mn], [Cr], [Ni], and [Cu] represent amounts (wt%) of respective elements.

7. The method according to Claim 6, wherein the finally annealing is performed in a temperature range of 750 to 850°C.

8. The method according to Claim 6, further comprising primarily annealing the hot-rolled steel sheet at 1000 to 1150°C before the cold rolling.

9. The method according to Claim 6, wherein the cold-rolled steel sheet is prepared by rolling the hot-rolled steel sheet with a thickness reduction ratio of 50% in a room temperature range.

10. The method according to Claim 6, wherein the ASP value of the austenitic stainless steel satisfies a range of 15 to 70.

11. The method according to Claim 6, wherein the finally annealed steel sheet has an average grain size (d) of the thickness central region of 5.0 μm or less.

Fig1.

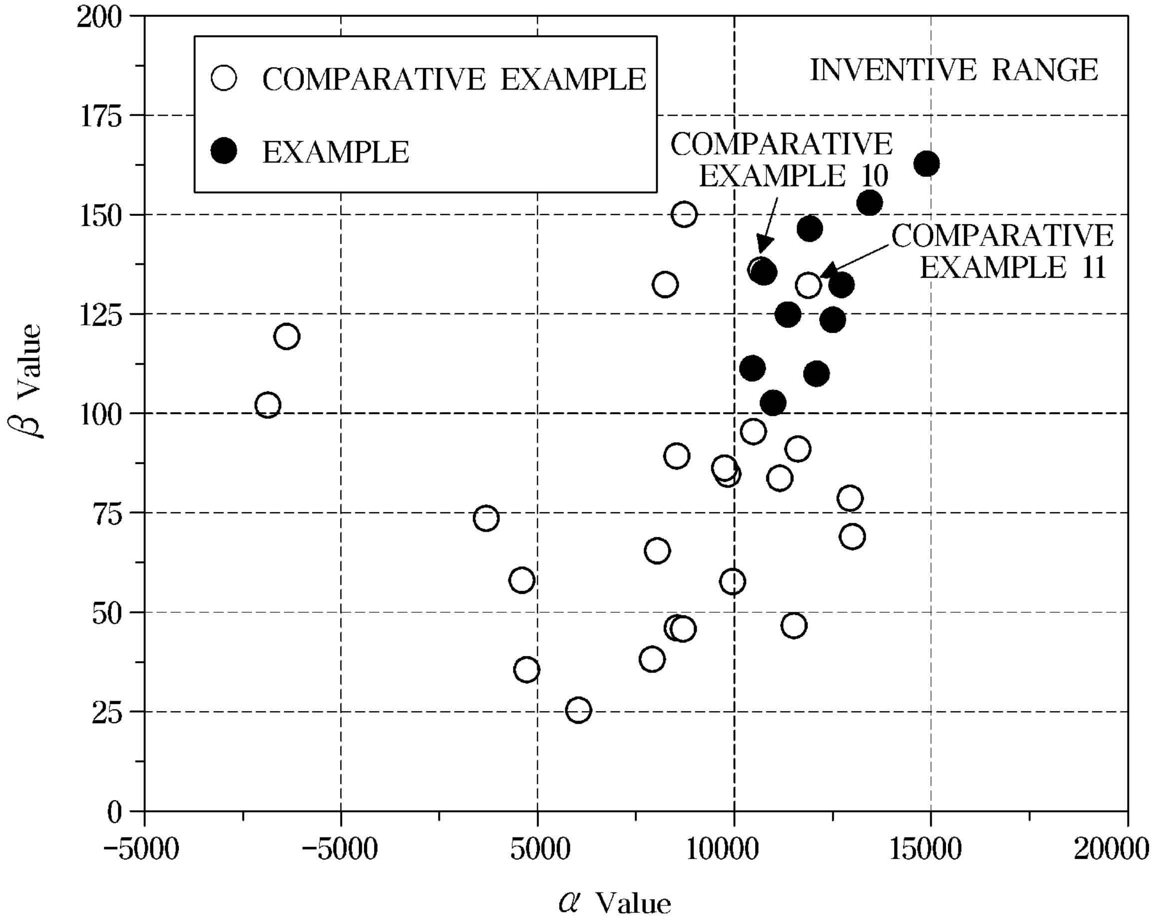
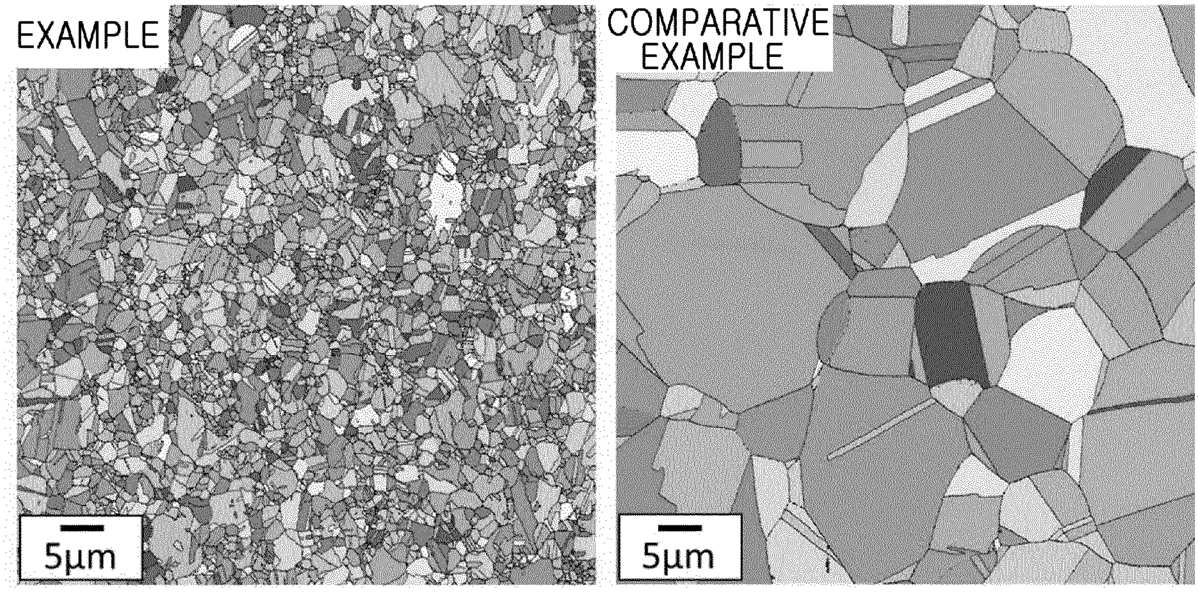

COMPARATIVE EXAMPLE
EXAMPLE
INVENTIVE RANGE
COMPARATIVE EXAMPLE 10
COMPARATIVE EXAMPLE 11
β Value
α Value
200
175
150
125
100
75
50
25
0
−5000
−5000
5000
10000
15000
20000

Fig2.



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2022/016305

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/58(2006.01)i; **C22C 38/42**(2006.01)i; **C22C 38/00**(2006.01)i; **C21D 9/46**(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 38/58(2006.01); C21D 1/26(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01); C22C 38/18(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: 저원가(low cost), 오스테나이트계 스테인리스강(austenitic stainless steel), 저온 소둔(low temperature annealing), 항복강도(yield strength), 초미세립(ultra fine grain)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2021-0009606 A (POSCO) 27 January 2021 (2021-01-27) See paragraphs [0078], [0081], [0083] and [0088], claim 7 and tables 1 and 2.	1-11
A	KR 10-2017-0029631 A (OUTOKUMPU OYJ) 15 March 2017 (2017-03-15) See paragraphs [0013] and [0021] and claims 1-2 and 7-9.	1-11
A	JP 2014-001422 A (NIPPON STEEL & SUMITOMO METAL) 09 January 2014 (2014-01-09) See paragraphs [0030] and [0032]-[0033], claim 1 and table 2.	1-11
A	KR 10-2006-0075725 A (POSCO) 04 July 2006 (2006-07-04) See claim 1 and tables 1 and 2.	1-11
A	WO 2014-157146 A1 (NISSHIN STEEL CO., LTD.) 02 October 2014 (2014-10-02) See paragraph [0034], claim 1 and table 3.	1-11

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
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"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)
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"P" document published prior to the international filing date but later than the priority date claimed
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

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

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2022/016305

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WO 2014-157146 A1	02 October 2014	JP WO2014-157146 A1	16 February 2017

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

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