(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 822 384 A1**

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

(43) Date of publication:
19.05.2021 Bulletin 2021/20

(21) Application number: **19849274.6**

(22) Date of filing: **08.08.2019**

(51) Int Cl.:
C22C 38/58 $^{(2006.01)}$ ***C22C 38/42*** $^{(2006.01)}$
C22C 38/44 $^{(2006.01)}$ ***C22C 38/02*** $^{(2006.01)}$
C22C 38/00 $^{(2006.01)}$

(86) International application number:
PCT/KR2019/009977

(87) International publication number:
WO 2020/036370 (20.02.2020 Gazette 2020/08)

(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 MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
KH MA MD TN

(30) Priority: **13.08.2018 KR 20180094523**

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(54) AUSTENITIC STAINLESS STEEL HAVING IMPROVED STRENGTH

(57) An austenitic stainless steel with improved strength is disclosed. The austenitic stainless steel includes, in percent (%) by weight of the entire composition, C: 0.02 to 0.14%, Si: 0.2 to 0.6%, S: less than 0.01%, Mn: 2.0 to 4.5%, Ni: 2.5 to 5.0%, Cr: 19.0 to 22.0%, Cu: 1.0 to 3.0%, Mo: less than 1.0%, N: 0.25 to 0.40%, the remainder of iron (Fe) and other inevitable impurities, and the Solubility of Nitrogen in Liquid (SNL) value represented by the following equation (1) is equal to or greater than the content of N.

$$SNL = -0.188 - 0.0423\times C - 0.0517\times Si + 0.012\times Mn + 0.0048\times Ni + 0.0252\times Cr - 0.00906\times Cu + 0.00021\times Mo$$

Equation (1):

Here, C, Si, Mn, Ni, Cr, Cu, and Mo mean the content (% by weight) of each element.

Printed by Jouve, 75001 PARIS (FR)

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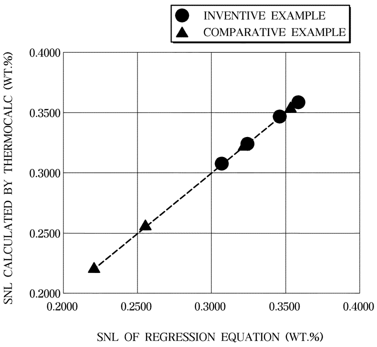
【FIG. 1】


● INVENTIVE EXAMPLE
▲ COMPARATIVE EXAMPLE
SNL CALCULATED BY THERMOCALC (WT.%)
0.4000
0.3500
0.3000
0.2500
0.2000
0.2000
0.2500
0.3000
0.3500
0.4000
SNL OF REGRESSION EQUATION (WT.%)

Description

[Technical Field]

[0001] The present disclosure relates to austenitic stainless steel, in particular, to austenitic stainless steel with improved strength while securing elongation and corrosion resistance.

[Background Art]

[0002] Stainless steel refers to steel that has strong corrosion resistance by suppressing corrosion, a weak point of carbon steel. In general, stainless steel is classified according to its chemical composition or metal structure. According to the metal structure, stainless steel can be classified into austenite, ferrite, martensite and dual phase.

[0003] Among them, austenitic stainless steel is a steel containing a large amount of chromium (Cr) and nickel (Ni), and is most commonly used. For example, 316L stainless steel has a component based on 16~18% Cr, 10~14% Ni, and 2~3% molybdenum (Mo), is applied in various industrial fields by securing corrosion resistance and molding properties.

[0004] However, in the case of Ni and Mo, there is a problem in terms of price competitiveness due to high material prices, and raw material supply and demand are unstable due to extreme fluctuations in material prices, and it is difficult to secure supply price stability.

[0005] Therefore, research has been conducted to reduce the content of Ni and Mo while securing corrosion resistance and formability of the conventional 316L stainless steel level. As a substitute for such 316L stainless steel, 200 series stainless steel, for example, 216 steel, which reduced Ni and increased the content of Mn was developed.

[0006] 216 stainless steel is basically a steel containing a large amount of Mn of 7% or more in order to reduce the material price by reducing the Ni content to a certain amount or less, and to secure the stability of the austenite phase according to the amount of Ni reduction. It contains 17.5~22% Cr, 5~7% Ni, 7.5~9% Mn and 2~3% Mo in percent (%) by weight.

[0007] By this component-based design, 216 stainless steel can secure a level of corrosion resistance similar to that of 316L stainless steel, but due to the generation of a large amount of Mn fume during the steel making process due to the addition of a large amount of Mn, not only environmental improvement is required, but also the production of steel making inclusions (MnS) results in a decrease in productivity in the manufacturing process and a decrease in the surface quality of the final material.

[0008] Meanwhile, the duplex stainless steel is a substitute for 316L stainless steel.

[0009] Duplex stainless steel is a stainless steel having a microstructure in which austenite phase and ferrite phase are mixed. Specifically, the austenite phase and the ferrite phase each exist in a volume fraction of about 35 to 65%, showing the characteristics of both austenitic stainless steel and ferritic stainless steel.

[0010] Duplex stainless steel secures corrosion resistance equivalent to 316L stainless steel, and has low Ni content, making it economical and easy to secure high strength. Therefore, it is in the spotlight as a steel for industrial facilities such as desalination facilities, pulp, paper, and chemical facilities that require corrosion resistance.

[0011] In particular, among duplex stainless steels, research on Lean Duplex stainless steel limited to 19~23% Cr, 1.8~3.5% Ni, 0~2% Mn and 0.5-1.0% Mo by reducing expensive alloying elements such as Ni and Mo and, which further highlights the advantages of low alloy cost through the addition of 0.16~0.3% high nitrogen, is being actively conducted.

[0012] However, in the case of lean duplex stainless steel, there is a problem in that the formability and elongation are inferior due to the formation of an phase interface between austenite and ferrite. Therefore, it is required to develop austenitic stainless steel with improved strength while securing elongation and corrosion resistance while reducing Ni and Mo.

[Disclosure]

[Technical Problem]

[0013] Embodiments of the present disclosure are intended to provide an austenitic stainless steel with improved strength while securing elongation and corrosion resistance of the existing 316L stainless steel level.

[Technical Solution]

[0014] In accordance with an aspect of the present disclosure, an austenitic stainless steel with improved strength includes, in percent (%) by weight of the entire composition, C: 0.02 to 0.14%, Si: 0.2 to 0.6%, S: less than 0.01%, Mn: 2.0 to 4.5%, Ni: 2.5 to 5.0%, Cr: 19.0 to 22.0%, Cu: 1.0 to 3.0%, Mo: less than 1.0%, N: 0.25 to 0.40%, the remainder of iron (Fe) and other inevitable impurities, and the Solubility of Nitrogen in Liquid (SNL) value represented by the following equation (1) is equal to or greater than the content of N.

$$\text{Equation (1): } SNL= -0.188- 0.0423\times C -0.0517\times Si+ 0.012\times Mn +0.0048\times Ni + 0.0252\times Cr -0.00906\times Cu +0.00021\times Mo$$

[0015] (Here, C, Si, Mn, Ni, Cr, Cu, and Mo mean the content (% by weight) of each element.)

[0016] The C+N is 0.5% or less (excluding 0).

[0017] The austenitic stainless steel may further include: one or more of B: 0.001 to 0.005% and Ca: 0.001 to 0.003%.

[0018] The Md_{30} value represented by the following equation (2) may satisfy -50 or less.

$$\text{Equation (2): } Md_{30} = 551 -462\times(C +N) -9.2\times Si -8.1\times Mn -13.7\times Cr -29\times(Ni +Cu)-8.5\times Mo$$

[0019] (Here, C, N, Si, Mn, Cr, Ni, Cu, and Mo mean the content (% by weight) of each element.)

[0020] The austenitic stainless steel may satisfy the following equation (3).

$$\text{Equation (3): } Creq/Nieq \leq 1.8$$

[0021] (Here, Creq = Cr +Mo +1.5 × Si, Nieq = Ni +0.5 × Mn +30 × (C +N) +0.5 × Cu.)

[0022] The Pitting Resistance Equivalent Number (PREN) represented by the following equation (4) may satisfy 22 or more.

$$\text{Equation (4): } PREN = 16 +3.3Mo +16N -0.5Mn$$

[0023] (Here, Mo, N, and Mn mean the content (% by weight) of each element.)

[0024] The yield strength (0.2 off-set) may be 400 to 450 MPa and the tensile strength may be 700 to 850 MPa.

[0025] The elongation may be 35% or more.

[Advantageous Effects]

[0026] According to an embodiment of the present disclosure, it is possible to provide austenitic stainless steel with improved strength while securing elongation and corrosion resistance of the existing 316L stainless steel level.

[Description of Drawings]

[0027] FIG. 1 is a graph for illustrating a correlation between Thermocalc. calculation result and a regression equation applied value for deriving Solubility of Nitrogen in Liquid (SNL) value of austenitic stainless steel according to an embodiment of the present disclosure.

[Modes of the Invention]

[0028] Hereinafter, the embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. The following embodiments are provided to transfer the technical concepts of the present disclosure to one of ordinary skill in the art. However, the present disclosure is not limited to these embodiments, and may be embodied in another form. In the drawings, parts that are irrelevant to the descriptions may be not shown in order to clarify the present disclosure, and also, for easy understanding, the sizes of components are more or less exaggeratedly shown.

[0029] Throughout the specification, when a part "includes" a certain component, it means that other components may be further included rather than excluding other components unless specifically stated to the contrary.

[0030] Expressions in the singular number include expressions in the plural unless the context clearly has exceptions.

[0031] Hereinafter, embodiments according to the present disclosure will be described in detail with reference to the accompanying drawings.

[0032] An austenitic stainless steel according to an aspect of present disclosure includes, in percent (%) by weight of the entire composition, C: 0.02 to 0.14%, Si: 0.2 to 0.6%, P: less than 0.1%, S: less than 0.01%, Mn: 2.0 to 4.5%, Ni: 2.5 to 5.0%, Cr: 19.0 to 22.0%, Cu: 1.0 To 3.0%, Mo: less than 1.0%, N: 0.25 to 0.40%, the remainder of iron (Fe) and other inevitable impurities.

[0033] Hereinafter, the reason for limiting the numerical value of the content of the alloying component in the embodiment of the present disclosure will be described. Hereinafter, unless otherwise specified, the unit is % by weight.

[0034] The content of C is 0.02 to 0.14%.

[0035] Carbon (C) is an element effective in stabilizing the austenite phase, but when the content is low, 0.02% or more may be added as additional austenite stabilizing elements are required. However, if the content is excessive, workability may be lowered due to the solid solution strengthening effect. In addition, if the content is excessive, it may adversely affect the ductility, toughness, corrosion resistance, etc. by inducing grain boundary precipitation of Cr carbide due to latent heat after hot-rolled coiling and the heat-affected zone of the weld, so the upper limit may be limited to 0.14%.

[0036] The content of Si is 0.2 to 0.6%.

[0037] Silicon (Si) serves as a deoxidizing agent during the steelmaking process and is an effective element to improve corrosion resistance and can be added by 0.2% or more. However, Si is an element that is effective in stabilizing the ferrite phase, and when excessively added, it promotes the formation of delta ferrite in the casting slab, thereby reducing hot workability. In addition, when excessively added, the ductility/toughness of the steel material due to the solid solution strengthening effect may be lowered, and thus the upper limit thereof may be limited to 0.6%.

[0038] The content of Mn is 2.0 to 4.5%.

[0039] Manganese (Mn) is an austenite phase stabilizing element that is added instead of nickel (Ni) in the present disclosure. It is effective in improving cold rolling properties by suppressing the generation of strain-induced martensite, and is an element that increases the solubility of nitrogen (N) during a steelmaking process to be described later, and may be added by 2.0% or more. However, if the content is excessive, Mn may reduce the ductility, toughness, and corrosion resistance of steel materials as it causes an increase in S-based inclusions (MnS), and thus the upper limit thereof may be limited to 4.5%.

[0040] The content of Ni is 2.5 to 5.0%.

[0041] Nickel (Ni) is a strong austenite phase stabilizing element and is essential to secure good hot workability and cold workability. In particular, even when a certain amount of Mn is added, it is essential to add 2.5% or more. However, since Ni is an expensive element, it causes an increase in raw material cost when a large amount is added. Accordingly, the upper limit can be limited to 5.0% in consideration of both cost and efficiency of the steel.

[0042] The content of Cr is 19 to 22%.

[0043] Although chromium (Cr) is a ferrite stabilizing element, it is effective in suppressing the formation of martensite phase, and is a basic element that secures corrosion resistance required for stainless steel. In addition, 19% or more may be added as an element that increases the solubility of nitrogen (N) during a steelmaking process to be described later. However, if the content is excessive, the manufacturing cost increases, and the formation of delta (δ) ferrite in the slab leads to a decrease in hot workability. Accordingly, there is a problem that additional addition of austenite stabilizing elements such as Ni and Mn is required, and the upper limit thereof can be limited to 22%.

[0044] The content of P is less than 0.1%.

[0045] As phosphorus (P) lowers corrosion resistance or hot workability, its upper limit may be limited to 0.1%.

[0046] The content of S is less than 0.01 %.

[0047] As sulfur (S) lowers corrosion resistance or hot workability, its upper limit may be limited to 0.01%.

[0048] The content of Cu is 1.0 to 3.0%.

[0049] Copper (Cu) is an austenite phase stabilizing element added instead of nickel (Ni) in the present disclosure, and improves formability by improving corrosion resistance in a reducing environment and reducing Stacking Fault Energy (SFE). 1.0% or more may be added to sufficiently express such an effect. However, if the content is excessive, the upper limit may be limited to 3.0% because it may increase the material cost as well as lower the hot workability.

[0050] The content of Mo is less than 1.0%.

[0051] Molybdenum (Mo) is an effective element in improving the corrosion resistance of stainless steel by modifying the passive film. However, since Mo is an expensive element, when a large amount of Mo is added, it causes an increase in raw material cost and has a problem of deteriorating hot workability. Accordingly, in consideration of the cost-efficiency and hot workability of the steel, the upper limit can be limited to 1.0%.

[0052] The content of N is 0.25 to 0.40%.

[0053] Nitrogen (N) is an element that is effective in improving corrosion resistance and is a strong austenite stabilizing element. Therefore, nitrogen alloying can reduce material cost by enabling lower use of Ni, Cu, and Mn. 0.25% or more may be added to sufficiently express this effect. However, if the content is excessive, since workability and moldability may be deteriorated due to the solid solution strengthening effect, the upper limit may be limited to 0.40%.

[0054] The content of C+N is 0.5% or less.

[0055] C and N are elements that are effective for improving strength, but when the content is excessive, there is a problem of lowering the workability, and the upper limit of the total may be limited to 0.5%.

[0056] In addition, the austenitic stainless steel with improved strength according to an embodiment of the present disclosure may further include one or more of B: 0.001 to 0.005 and Ca: 0.001 to 0.003%.

[0057] The content of B is 0.001 to 0.005%.

[0058] Boron (B) is an element effective in securing good surface quality by suppressing the occurrence of cracks during casting, and can be added by 0.001% or more. However, if the content is excessive, nitride (BN) may be formed on the product surface during the annealing/pickling process, thereby reducing the surface quality. Therefore, the upper limit can be limited to 0.005%.

[0059] The content of Ca is 0.001 to 0.003%.

[0060] Calcium (Ca) is an element that improves product cleanliness by suppressing the formation of MnS steelmaking inclusions generated at grain boundaries when high Mn is contained, and can be added by 0.001 % or more. However, if the content is excessive, it may cause a decrease in hot workability and a decrease in product surface quality due to formation of Ca-based inclusions, and the upper limit may be limited to 0.003%.

[0061] The remaining component of the present disclosure is iron (Fe). However, since unintended impurities from the raw material or the surrounding environment may inevitably be mixed in the normal manufacturing process, this cannot be excluded. Since these impurities are known to anyone of ordinary skill in the manufacturing process, all the contents are not specifically mentioned in the present specification.

[0062] In order to secure price competitiveness of austenite stainless steel, it is necessary to reduce the content of expensive austenite stabilizing elements such as Ni and Mn, and it is required to predict the amount of N added that can compensate for this. To this end, it is necessary to set the optimal N content through calculation of the solubility limit of N in consideration of each alloy component.

[0063] Thus, using the state diagram prediction program Thermocalc., the content of N that can be dissolved in the molten metal temperature at 1150°C is derived according to the amount of each alloy element (C, Si, Mn, Ni, Cr, Cu, Mo) added.

[0064] FIG. 1 is a graph for illustrating a correlation between Thermocalc. calculation result and a regression equation applied value for deriving Solubility of Nitrogen in Liquid (SNL) value of austenitic stainless steel according to an embodiment of the present disclosure.

[0065] Referring to FIG. 1, the limit value at which nitrogen is dissolved in the molten metal is calculated and expressed as "N solubility limit (The.)".

[0066] The SNL (Solubility of Nitrogen in Liquid) regression equation of Equation (1) was derived based on the calculated value of Thermocalc. according to the component change.

$$\text{Equation (1): } SNL = -0.188 - 0.0423\times C - 0.0517\times Si + 0.012\times Mn + 0.0048\times Ni + 0.0252\times Cr - 0.00906\times Cu + 0.00021\times Mo$$

[0067] When applying the derived regression equation, it was confirmed that the R(sq) value corresponds to a high correlation of 100%. In addition, it was confirmed that it is possible to secure suitability in the relationship between the calculation result of the thermocalc for each component to derive SNL, which is N melting limit value, and the regression equation.

[0068] In the austenitic stainless steel with improved strength according to an embodiment of the present disclosure, the SNL value is greater than or equal to N content. In this way, when the SNL value was set higher than the N content to increase the nitrogen solubility limit, it was confirmed that the steelmaking operation of the target alloy component was performed satisfactorily.

[0069] In the case of austenitic stainless steel, it is applied to products that require a beautiful surface. For products that require a beautiful surface, it is common to perform a bright annealing on cold-rolled materials. This bright annealing is a heat treatment technology that keeps the surface bright and beautiful without changing the color and properties of the surface by preventing reoxidation occurring during the heat treatment process of the stainless steel cold rolled material by performing heat treatment on the stainless steel cold rolled material in a reducing atmosphere (Dew point -40 ~ -60°C) using nitrogen (N_2), hydrogen (H_2), etc. Bright annealing using hydrogen as the atmosphere gas used for bright annealing is the most common, because it is most widely used for suppressing discoloration of the surface as well as high heat capacity.

[0070] Compared to general austenitic stainless steel, in stainless steel that has reduced austenite stabilizing elements such as Ni and Mn as in the present disclosure, there is a point to be considered when applying bright annealing in a hydrogen atmosphere.

[0071] During bright annealing, there is a high possibility of inferior workability due to hydrogen embrittlement defects in the final material due to the penetration of hydrogen. In the case of stainless steel with reduced austenite stabilizing elements such as Ni and Mn, during cold rolling before final bright annealing, stress-induced martensite or strain-induced martensite is formed around the surface layer. The martensite phase formed on the surface layer is in contact with hydrogen atoms, which are inert gases, before being transformed into an austenite phase by heat treatment during bright annealing. Some of these hydrogen atoms penetrate into the martensite phase. As the existing stress-induced martensite or strain-induced martensite is phase-transformed into the austenite phase by bright annealing, hydrogen atoms that have penetrated inside cannot be discharged to the outside and are trapped in the atomic state at the surface.

[0072] The hydrogen atoms penetrating into the surface layer are naturally bake-out after a certain period of time at room temperature for ferrite or martensite phase, which are general BCC and BCT structures, and do not significantly affect the physical properties.

[0073] On the other hand, when the martensite phase of the surface layer is transformed into an austenite phase by bright annealing, that is, when hydrogen atoms are present in the lattice structure of FCC, even after a considerable amount of time has passed at room temperature, the natural bakeout of hydrogen atoms is not smooth and remains in the material for a long time.

[0074] This hydrogen atom is known as a factor causing hydrogen embrittlement. Hydrogen atoms trapped in the material due to some processing or deformation change to the state of hydrogen molecules (gas), and when a certain pressure is reached, it acts as a starting point of cracks under a certain load, causing a decrease in elongation.

[0075] Therefore, for austenitic stainless steel with relatively low Ni and Mn, the beautiful surface quality and workability can be secured through bright annealing only by controlling the amount of martensite phase formed on the surface by work hardening together with the alloy component.

[0076] Accordingly, for the austenitic stainless steel with improved strength according to an embodiment of the present disclosure, the Md30 value expressed by the following equation (2) satisfies the range of -50°C or less.

$$\text{Equation (2): } Md_{30} = 551 - 462\times(C + N) - 9.2\times Si - 8.1\times Mn - 13.7\times Cr - 29\times(Ni + Cu) - 8.5\times Mo$$

[0077] In austenitic stainless steel, martensitic transformation occurs by plastic working at a temperature of the martensitic transformation initiation temperature (Ms) or more. The upper limit temperature that causes phase transformation by such processing is represented by the Md value, and is a criterion of the degree to which phase transformation occurs by processing.

[0078] In particular, the temperature (°C) at which 50% phase transformation to martensite occurs when 30% strain is applied is defined as Md_{30}. When the Md_{30} value is high, it is easy to form the strain-induced martensite phase, whereas when the Md_{30} value is low, the strain-induced martensite phase is relatively difficult to form. In general, the Md30 value is used as an index to determine the austenite stability of austenitic stainless steel, and can be calculated through the Nohara regression equation expressed by the equation (2).

[0079] The reason why various kinds of phases are formed by the difference in alloy component content is because the effect of each added alloy component on the phase balance is different.

[0080] The degree to which each alloy component affects the phase balance can be calculated through Creq and Nieq, and the phase generated at room temperature can be predicted through the Creq/Nieq ratio expressed as in the equation (3) below.

$$\text{Equation (3): } Creq/Nieq$$

[0081] Here, Creq = Cr +Mo +1.5xSi, Nieq = Ni +0.5×Mn +30x(C +N) +0.5×Cu.

[0082] That is, when the Creq/Nieq ratio is low, austenite single phase can be formed at room temperature due to relatively high austenite stability. When the Creq/Nieq ratio is high, the austenite stability is low and the ferrite phase is likely to be formed locally.

[0083] As a result of reviewing by applying the Creq/Nieq ratio to various alloy components, present inventor confirmed that the formation of austenite single-phase matrix structure was possible when the Creq/Nieq ratio was 1.8 or less.

[0084] Various methods are used as a criterion for evaluating the corrosion resistance of stainless steel, but the use of the Pitting Resistance Equivalent Number (PREN) is a simple method of examining the discrimination power of alloy components.

[0085] PREN is generally used to influence Cr, Mo, and N, but for steel grades with relatively high Mn content, since it is necessary to consider the influence of Mn as well, the following equation (4) was derived from the present disclosure.

[0086] When the generally used high corrosion resistance 316L stainless steel alloy composition is applied to the following equation, it shows a value of about 22. Therefore, in the present disclosure, the PREN value was set to 22 or higher in order to secure corrosion resistance equal to or higher than that of 316L stainless steel.

$$\text{Equation (4): } PREN = 16 + 3.3Mo + 16N - 0.5Mn$$

[0087] Hereinafter, the present disclosure will be described in more detail through examples.

[0088] For various alloy component ranges shown in Table 1 below, a slab having a thickness of 200 mm was prepared by melting an ingot, heated at 1,240°C for 2 hours, and then hot-rolled to prepare a hot-rolled steel sheet having a thickness of 3 mm.

[Table 1]

	C	Si	Mn	S	Ni	Cr	Cu	Mo	N	C+N
inventive example 1	0.104	0.48	2.91	0.005	3.53	20.8	2.1	0.52	0.3	0.404
inventive example 2	0.103	0.49	3.4	0.005	3.35	19.6	1.16	0.39	0.27	0.373
inventive example 3	0.088	0.31	3.41	0.004	3.7	21.7	2.51	0.10	0.34	0.428
inventive example 4	0.035	0.31	3.8	0.006	4.2	21	2.48	0.20	0.33	0.365
comparative example 1	0.02	0.52	1.4	0.004	10.4	16.6	0.39	2.00	0.018	0.038
comparative example 2	0.014	0.55	2.4	0.006	2.4	20.3	0.1	1.30	0.2	0.166
comparative example 3	0.1	0.38	3.8	0.006	3.4	17.2	1.45	0.10	0.21	0.310
comparative example 4	0.15	0.46	3.8	0.004	3.6	21.6	2.04	0.32	0.35	0.500

[0089] After performing a solution treatment at 1,150°C for 1 minute, microstructure observation and evaluation of various mechanical properties were performed.

[0090] Mechanical properties were measured using a No. 5 test piece specified in Japanese Industrial Standard JIS Z 2201. Specifically, a tensile test was conducted using JIS Z 2201, and the measured yield strength, tensile strength, and elongation were described in Table 2 below.

[0091] In addition, SNL calculation results, Md_{30} calculation results, Creq/Nieq ratio calculation results, and PREN calculation results for 4 inventive examples and 4 comparative examples in Table 1 are shown in Table 2 below.

[Table 2]

Steel grade	N solubility limit (The.)	N solubility limit (Reg.)	Md_{30} (°C)	Creq/ Nieq	PREN	Phase analysis	Mechanical properties		
							YS (MPa)	TS (MPa)	El (%)
inventive example 1	0.3238	0.3244	-121	1.2140	25.861	Austenite	490	780	44%
inventive example 2	0.3067	0.3080	-60	1.2322	23.507	Austenite	460	760	50%
inventive example 3	0.3582	0.3590	-170	1.0914	25.765	Austenite	510	800	44%
inventive example 4	0.3472	0.3488	-136	1.1845	25.04	Austenite	470	750	42%
comparative example 1	0.2205	0.2204	-60	1.5585	22.788	Austenite	220	540	58%
comparative example 2	0.3230	0.3233	76	2.6076	25.822	Duplex	480	700	45%
comparative example 3	0.2552	0.2556	-5	1.1661	18.99	Austenite	380	720	54%

(continued)

Steel grade	N solubility limit (The.)	N solubility limit (Reg.)	Md_{30} (°C)	Creq/ Nieq	PREN	Phase analysis	Mechanical properties		
							YS (MPa)	TS (MPa)	El (%)
comparative example 4	0.3544	0.3550	-180	1.0507	26.356	Austenite	530	830	32%

[0092] In the case of comparative example 1, which corresponds to the composition of general 316L stainless steel, it represents the tissue composed of the austenite phase, and it can be seen that the PREN value is 22 or higher. However, less than 0.25% of nitrogen was added, and the mechanical property evaluation result showed a yield strength of 220 MPa and a tensile strength of 540 MPa. This corresponds to the physical properties of generally widely used soft austenitic stainless steel, and thus has a problem that is difficult to apply to materials requiring high strength.

[0093] In the case of comparative example 2 in which the Creq/Nieq ratio exceeds 1.8, as Mo is added above a certain level, the PREN value is about 26, indicating excellent pitting resistance. In addition, it can be seen that the mechanical property evaluation results showed a yield strength of 480 MPa, a tensile strength of 700 MPa, and an elongation of 45%.

[0094] However, as an alloy component in which both Ni and N are relatively low, when observing the microstructure at room temperature, it was confirmed that the austenite phase and the ferrite phase formed a duplex structure with about 5:5. This is because the stabilization of ferrite in the phase balance is relatively higher than that of 316L stainless steel. In the duplex structure, cracks may occur at the interface between the austenite phase and the ferrite phase, so there is a problem that it is difficult to apply to materials requiring molding such as bending.

[0095] In the case of comparative example 3, in which the content of Ni and Mn was slightly increased compared to comparative example 2 and the Creq/Nieq ratio was set to 1.8 or less, when the microstructure was observed, a structure composed of austenite phase was formed, and the mechanical properties were harder than 316L of comparative example 1, and softer than the duplex stainless steel of comparative example 2.

[0096] However, the Md_{30} value is -5°C, and hydrogen embrittlement is likely to occur when producing bright annealing materials with beautiful surfaces in the future. In addition, since the N solubility limit, which is greatly affected by the Cr content, is low, the amount of N added is 0.21%, and the nitrogen factor of the PREN value cannot be maximized, making it difficult to secure pitting resistance of 316L level.

[0097] In the case of comparative example 4, in which the contents of N, C, and Cr were increased compared to comparative example 3, it is suitable for manufacturing bright annealing materials as it shows the Md_{30} value at the level of -180°C, and by setting the Creq/Nieq ratio to 1.8 or less, it can be seen that austenite single-phase structure can be secured.

[0098] However, it can be seen that the C+N content is 0.5%, exceeding 0.5%, which is the upper limit of the present disclosure, indicating hard mechanical properties and elongation of less than 35%.

[0099] Referring to Table 2, in the case of inventive examples 1 to 4 of the present disclosure, it is possible to secure Md_{30} value below -50°C, so the possibility of hydrogen embrittlement is low during bright annealing. In addition, the ratio of the nickel equivalent (Nieq) and the chromium equivalent (Creq) (Creq/Nieq) satisfies the range of 1.8 or less, so that the austenite single-phase structure can be formed at room temperature.

[0100] In addition, it was confirmed that the content of Ni and Mo is relatively low, and while securing price competitiveness, it has a PREN value of 22 or more. As a result of mechanical property evaluation, it was confirmed that it was possible to realize high-strength characteristics compared to 316L and secure good elongation of 35% or more.

[0101] From the above results, for austenitic stainless steel including, in percent (%) by weight of the entire composition, C: 0.02 to 0.14%, Si: 0.2 to 0.6%, P: less than 0.1%, S: less than 0.01%, Mn: 2.0 to 4.5%, Ni: 2.5 to 5.0%, Cr: 19.0 to 22.0%, Cu: 1.0 to 3.0%, Mo: less than 1.0%, N: 0.25 to 0.40%, the remainder of iron (Fe) and other inevitable impurities, it can secure the processability and corrosion resistance of the existing 316L stainless steel level through SNL value control for securing price competitiveness and ease of steel making newly proposed by the present disclosure, Md30 value control for securing austenite phase stability, Creq/Nieq ratio control for forming austenite phase in microstructure, and PREN control for securing corrosion resistance. In addition, it can be seen that stainless steel that can improve price competitiveness and strength can be manufactured.

[0102] In the foregoing, exemplary inventive examples of the present disclosure have been described, but the present disclosure is not limited thereto, and a person with ordinary knowledge in the relevant technical field does not depart from the concept and scope of the following claims. It will be appreciated that various changes and modifications are possible in.

Claims

1. An austenitic stainless steel with improved strength comprising, in percent (%) by weight of the entire composition, C: 0.02 to 0.14%, Si: 0.2 to 0.6%, S: less than 0.01%, Mn: 2.0 to 4.5%, Ni: 2.5 to 5.0%, Cr: 19.0 to 22.0%, Cu: 1.0 to 3.0%, Mo: less than 1.0%, N: 0.25 to 0.40%, the remainder of iron (Fe) and other inevitable impurities, and wherein the Solubility of Nitrogen in Liquid (SNL) value represented by the following equation (1) is equal to or greater than the content of N.

$$\text{Equation (1): } SNL= -0.188- 0.0423\times C -0.0517\times Si+ 0.012\times Mn +0.0048\times Ni + 0.0252\times Cr -0.00906\times Cu +0.00021\times Mo$$

(Here, C, Si, Mn, Ni, Cr, Cu, and Mo mean the content (% by weight) of each element.)

2. The austenitic stainless steel of claim 1, wherein the C+N is 0.5% or less (excluding 0).

3. The austenitic stainless steel of claim 1, further comprising: one or more of B: 0.001 to 0.005% and Ca: 0.001 to 0.003%.

4. The austenitic stainless steel of claim 1, wherein the Md_{30} value represented by the following equation (2) satisfies -50 or less.

$$\text{Equation (2): } Md_{30} = 551 -462\times(C +N) -9.2\times Si -8.1\times Mn -13.7\times Cr -29\times(Ni +Cu)-8.5\times Mo$$

(Here, C, N, Si, Mn, Cr, Ni, Cu, and Mo mean the content (% by weight) of each element.)

5. The austenitic stainless steel of claim 1, wherein the austenitic stainless steel satisfies the following equation (3).

$$\text{Equation (3): } Creq/Nieq \leq 1.8$$

(Here, Creq = Cr +Mo +1.5 × Si, Nieq = Ni +0.5 × Mn +30 × (C +N) +0.5 × Cu.)

6. The austenitic stainless steel of claim 1, wherein the Pitting Resistance Equivalent Number (PREN) represented by the following equation (4) satisfies 22 or more.

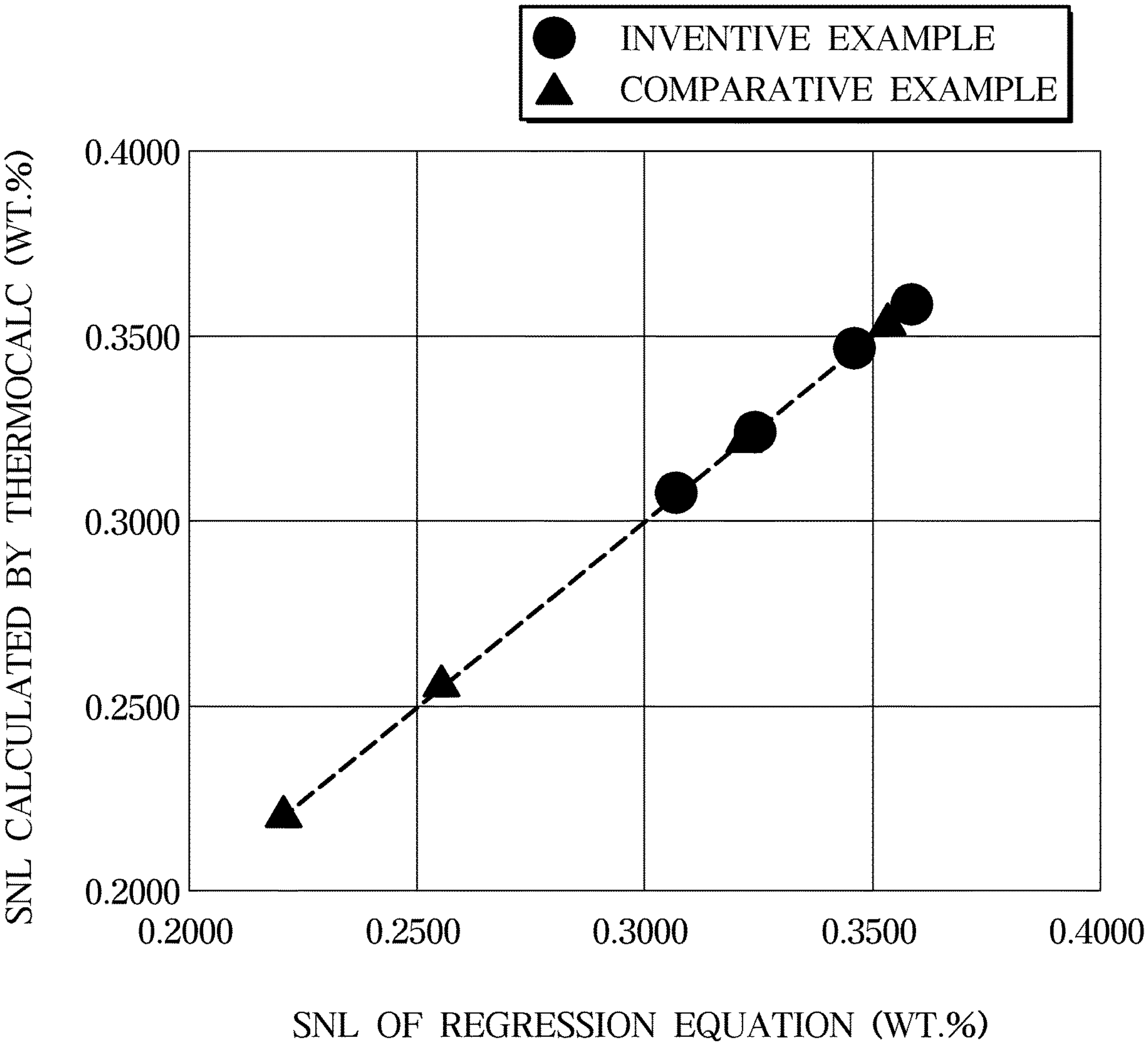
$$\text{Equation (4): } PREN = 16 +3.3Mo +16N -0.5Mn$$

(Here, Mo, N, and Mn mean the content (% by weight) of each element.)

7. The austenitic stainless steel of claim 1, wherein the yield strength (0.2 off-set) is 400 to 450 MPa and the tensile strength is 700 to 850 MPa.

8. The austenitic stainless steel of claim 1, wherein the elongation is 35% or more.

【FIG. 1】


● INVENTIVE EXAMPLE
▲ COMPARATIVE EXAMPLE
SNL CALCULATED BY THERMOCALC (WT.%)
0.4000
0.3500
0.3000
0.2500
0.2000
0.2000
0.2500
0.3000
0.3500
0.4000
SNL OF REGRESSION EQUATION (WT.%)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2019/009977

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/58(2006.01)i, C22C 38/42(2006.01)i, C22C 38/44(2006.01)i, C22C 38/02(2006.01)i, C22C 38/00(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; C21D 6/00; C21D 8/02; C22C 38/00; C22C 38/18; C22C 38/44; C22C 38/46; C23C 8/22; C22C 38/42; C22C 38/02

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: stainless steel, austenite, corrosion resistance, high strength, elongation

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2016-065296 A (AIR WATER NV. INC. et al.) 28 April 2016 See paragraph [0033] and claim 2.	1-8
X	KR 10-2012-0091075 A (ATI PROPERTIES, INC.) 17 August 2012 See paragraphs [0003], [0015]-[0017] and claim 1.	1-8
A	JP 2014-001422 A (NIPPON STEEL & SUMITOMO METAL) 09 January 2014 See paragraphs [0009]-[0012] and claims 1-2.	1-8
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A	WO 2012-143610 A1 (OUTOKUMPU OYJ. et al.) 26 October 2012 See page 4, line 13-page 5, line 8 and claim 1.	1-8

☐ 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
"E" earlier application or patent but published on or after the international filing date
"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
"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 04 DECEMBER 2019 (04.12.2019)	Date of mailing of the international search report **04 DECEMBER 2019 (04.12.2019)**
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex Daejeon Building 4, 189, Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

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