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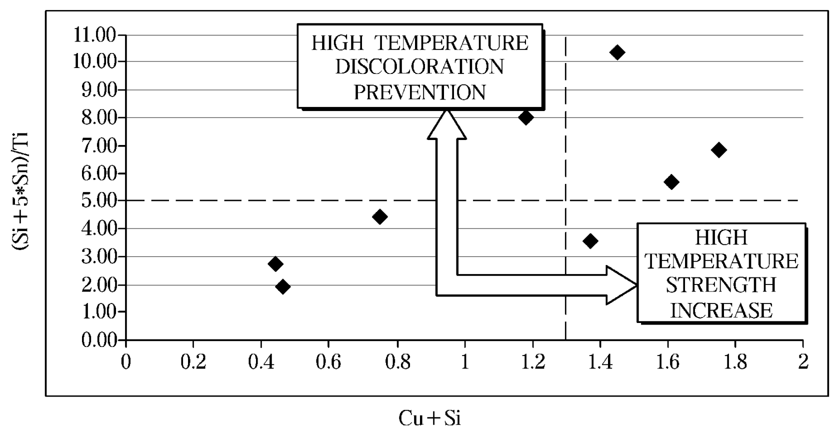
(54) **LOW-CR FERRITIC STAINLESS STEEL WITH EXCELLENT FORMABILITY AND HIGH TEMPERATURE PROPERTIES, AND MANUFACTURING METHOD THEREFOR**

(57) Disclosed is a low-Cr ferritic stainless steel with excellent formability and high temperature properties and a manufacturing method thereof.

The embodiments of the present disclosure provide a low-Cr ferritic stainless steel with excellent formability and excellent high-temperature strength and high-temperature oxidation resistance corresponding to high-Cr ferritic stainless steel without increasing Cr content or adding Nb by optimizing the content of Ci, Si, Sn and utilizing solid solution strengthening and precipitation strengthening, and a manufacturing method thereof.

【FIG. 1】



EP 3 875 627 A1

Description

[Technical Field]

[0001] The present disclosure relates to a low-Cr ferritic stainless steel, and more particularly, to a low-Cr ferritic stainless steel capable of securing formability while having excellent high-temperature strength and high-temperature oxidation resistance, and a manufacturing method thereof.

[Background Art]

[0002] A ferritic stainless steel has excellent corrosion resistance while adding less expensive alloying elements, and has high price competitiveness compared to austenitic stainless steels. In particular, 9~14% of low-Cr ferritic stainless steel has superior cost competitiveness, and is used in exhaust system parts (Muffler, Ex-manifold, Collector cone, etc.) corresponding to the exhaust gas temperature range of room temperature to 800°C.

[0003] However, the high-temperature strength and high-temperature oxidation resistance were inferior to those of high-Cr and Nb-added steels, so there was a limit to the expansion of use. Increasing the Cr content or adding Nb to improve the high-temperature strength and high-temperature oxidation resistance causes the manufacturing cost to rise. Therefore, there is a need for development that can improve high temperature properties without adding Nb to low-Cr ferritic stainless steel.

[Disclosure]

[Technical Problem]

[0004] The embodiments of the present disclosure provide a low-Cr ferritic stainless steel with excellent formability and excellent high-temperature strength and high-temperature oxidation resistance corresponding to high-Cr ferritic stainless steel without increasing Cr content or adding Nb by optimizing the content of Ci, Si, Sn and utilizing solid solution strengthening and precipitation strengthening, and a manufacturing method thereof.

[Technical Solution]

[0005] In accordance with an aspect of the present disclosure, a low-Cr ferritic stainless steel with excellent formability and high temperature properties includes, in percent (%) by weight of the entire composition, C: 0.005 to 0.015%, N: 0.005 to 0.015%, Si: 0.5 to 1.5%, Mn: 0.1 to 0.5%, Cr: 9 to 14%, Ti: 0.1 to 0.3%, Cu: 0.3 to 0.8%, Al: 0.01 to 0.05%, Sn: 0.005 to 0.15%, the remainder of iron (Fe) and other inevitable impurities, and satisfies following Formulas (1) and (2).

$$(1)\ Cu + Si \geq 1.3$$

$$(2)\ Si + Cu + 10*Sn \leq 3.0$$

[0006] Here, Si, Cu, Sn means the content (% by weight) of each element.

[0007] The low-Cr ferritic stainless steel may further include: Ni: 0.3% or less, P: 0.04% or less, and S: 0.002% or less.

[0008] The ferritic stainless steel may include a Cu precipitated phase of 0.03% or more having a size of 1 to 500 nm in the matrix.

[0009] The 900°C high-temperature strength may be 12 MPa or more.

[0010] The elongation may be 30% or more.

[0011] The low-Cr ferritic stainless steel may satisfy a following Formula (3).

$$(3)\ (Si + 5*Sn)/Ti \geq 5.0$$

[0012] Here, Si, Sn, and Ti mean the content (% by weight) of each element.

[0013] In accordance with an aspect of the present disclosure, a manufacturing method of a low-Cr ferritic stainless steel with excellent formability and high temperature properties includes: performing a cold rolled annealing heat treatment on a ferritic stainless steel cold rolled steel sheet including, in percent (%) by weight of the entire composition, C: 0.005 to 0.015%, N: 0.005 to 0.015%, Si: 0.5 to 1.5%, Mn: 0.1 to 0.5%, Cr: 9 to 14%, Ti: 0.1 to 0.3%, Cu: 0.3 to 0.8%, Al : 0.01

to 0.05%, Sn: 0.005 to 0.15%, the remainder of iron (Fe) and other inevitable impurities, and satisfying following Formulas (1) and (2); and rapid cooling to a temperature range of 450 to 550°C and maintaining for 5 minutes or more.

$$(1)\ Cu + Si \geq 1.3$$

$$(2)\ Si + Cu + 10*Sn \leq 3.0$$

[0014] Here, Si, Cu, Sn means the content (% by weight) of each element.

[0015] The cold-rolled annealed steel sheet may include a Cu precipitated phase of 0.09% or more having a size of 1 to 500 nm in a matrix.

[0016] The 900°C high-temperature strength of the cold-rolled annealed steel sheet may be 14.5 MPa or more.

[0017] The cold rolled steel sheet may satisfy a following Formula (3).

$$(3)\ (Si + 5*Sn)/Ti \geq 5.0$$

[0018] Here, Si, Sn, and Ti mean the content (% by weight) of each element.

[Advantageous Effects]

[0019] The low-Cr ferritic stainless steel according to the embodiment of the present disclosure can increase the high-temperature strength by 30% or more compared to the existing by distributing the fine Cu precipitated phase at the same time as the solid solution strengthening effect of Si and Cu and can also improve high-temperature oxidation resistance by the surface concentration of Si and Sn.

[0020] In addition, it is possible to prevent poor formability due to an increase in the content of alloying elements, and when the manufacturing method according to the present disclosure is applied, high-temperature strength properties may be more excellent.

[Description of Drawings]

[0021] FIG. 1 is a graph showing the correlation between high temperature properties according to Formula (1) and Formula (3) of a present disclosure.

[Best Mode]

[0022] A low-Cr ferritic stainless steel with excellent formability and high temperature properties according to an embodiment of the present disclosure includes, in percent (%) by weight of the entire composition, C: 0.005 to 0.015%, N: 0.005 to 0.015%, Si: 0.5 to 1.5%, Mn: 0.1 to 0.5%, Cr: 9 to 14%, Ti: 0.1 to 0.3%, Cu: 0.3 to 0.8%, Al : 0.01 to 0.05%, Sn: 0.005 to 0.15%, the remainder of iron (Fe) and other inevitable impurities, and satisfies following Formulas (1) and (2).

$$(1)\ Cu + Si \geq 1.3$$

$$(2)\ Si + Cu + 10*Sn \leq 3.0$$

[0023] Here, Si, Cu, Sn means the content (% by weight) of each element.

[Modes of the Invention]

[0024] 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.

[0025] Also, when a part "includes" or "comprises" an element, unless there is a particular description contrary thereto, the part may further include other elements, not excluding the other elements.

[0026] An expression used in the singular encompasses the expression of the plural, unless it has a clearly different meaning in the context.

[0027] As a result of conducting various studies to improve the high-temperature strength and high-temperature oxidation resistance of low-cost low-Cr ferritic stainless steel, the inventors were able to obtain the following knowledge.

[0028] In general, Nb is added to ferritic stainless steel for exhaust systems for high-temperature strength. Since Nb is relatively expensive in raw material costs and causes an increase in manufacturing cost, the addition of niobium is not a desirable development direction. It is widely known that substitutional solid solution strengthening elements are effective to increase high-temperature strength. In particular, when a substitutional solid solution strengthening element is added, the greater the difference in weight and atomic radius compared to Fe and Cr, the greater the solid solution strengthening effect. In the periodic table of the elements, alloying elements such as Si, Cu, Sn, etc. are far from Fe and Cr, and there are differences in weight and atomic radius. Therefore, it was determined that it could replace the existing Nb, and component optimization was performed to increase the high-temperature strength.

[0029] Meanwhile, the Cr content is generally increased for high-temperature oxidation resistance. However, since Cr also has a high raw material cost and causes an increase in manufacturing cost, increasing the content of chromium is not a desirable development direction. For high-temperature oxidation resistance, when exposed to high temperatures for a long time, certain elements are densely concentrated on the surface to suppress the formation of the Fe-oxide film. In the present disclosure, Si, Cu, and Sn were selected as candidates as elements that can be concentrated on the surface, and component optimization was performed for high-temperature oxidation resistance.

[0030] Including the above, the present disclosure must satisfy the component system conditions and formulas as follows.

[0031] A low-Cr ferritic stainless steel with excellent formability and high temperature properties according to an embodiment of the present disclosure includes, in percent (%) by weight of the entire composition, C: 0.005 to 0.015%, N: 0.005 to 0.015%, Si: 0.5 to 1.5%, Mn: 0.1 to 0.5%, Cr: 9 to 14%, Ti: 0.1 to 0.3%, Cu: 0.3 to 0.8%, Al : 0.01 to 0.05%, Sn: 0.005 to 0.15%, the remainder of iron (Fe) and other inevitable impurities.

[0032] Hereinafter, the reason for the numerical limitation of the content of the alloy component element in the embodiment of the present disclosure will be described. Hereinafter, unless otherwise specified, the unit is % by weight.

[0033] The content of C is 0.005 to 0.015%.

[0034] When the C content exceeds 0.015%, it combines with Cr to form $Cr_{23}C_6$ precipitates, which decreases high-temperature oxidation resistance due to local Cr depletion in the matrix. In addition, in order to control the C content to less than 0.005%, the VOD process cost for steelmaking increases, which is not preferable. Therefore, the content of C is limited to the range of 0.005 to 0.015%.

[0035] The content of N is 0.005 to 0.015%.

[0036] When N in the steel exceeds 0.015%, the concentration of solid solution N reaches its limit, and it combines with Cr, and Cr_2N precipitates are formed, resulting in a decrease in high-temperature oxidation resistance due to local Cr depletion in the matrix. In addition, in order to control the N content to less than 0.005%, the VOD process cost for steelmaking increases, which is not preferable. Therefore, the content of N is limited to the range of 0.005 to 0.015%.

[0037] The content of Si is 0.5 to 1.5%.

[0038] Si is a solid solution strengthening element for increasing high-temperature strength, and also increases high-temperature oxidation resistance by forming a Si-enriched oxide film on the surface layer. For the above two effects, a minimum Si content of 0.5% or more is required, and if it exceeds 1.5%, the workability of the material is greatly deteriorated, so the Si content is limited as above.

[0039] The content of Mn is 0.1 to 0.5%.

[0040] Mn is an impurity that is inevitably included in steel and plays a role in stabilizing austenite. If the Mn content exceeds 0.5% in low-Cr ferritic stainless steel, reverse austenite transformation occurs during annealing heat treatment after hot rolling or cold rolling, which adversely affects elongation. Therefore, the content of Mn is limited as above.

[0041] The content of Cr is 9 to 14%.

[0042] Cr is an essential element added to form a passivation film that inhibits oxidation in stainless steel. In order to form a stable passivation film, Cr of 9% or more should be added. However, since the present disclosure aims to develop low-cost steel with reduced Cr, the upper limit is limited to 14%. More preferably, it may be in the range of 10.5 to 12.5%.

[0043] The content of Ti is 0.1 to 0.3%.

[0044] Ti should be added at least 0.1% in order to increase the corrosion resistance of the weld. Ti combines with C and N to form Ti(C,N) precipitates, thereby lowering the amount of solid solution C and N, and suppressing the formation of a Cr depletion layer. However, when the Ti content exceeds 0.3%, the Ti component of the surface layer reacts with oxygen, causing yellow discoloration. Therefore, the Ti content is limited as above.

[0045] The content of Cu is 0.3 to 0.8%.

[0046] Cu is an element that contributes to high-temperature strength by replacing Nb as a solid solution strengthening element. In addition, when Cu generates fine precipitates through appropriate heat treatment, additional high-temperature strength can be expected due to the precipitation strengthening effect. Therefore, it is added at least 0.5%. However, if too much Cu is added, the high-temperature hot workability may be impaired, so the amount is limited to 0.8% or less.

[0047] The content of Al is 0.01 to 0.05%.

[0048] Al is an element added for deoxidation during steel making. When the Al content exceeds 0.05%, Al in the surface layer reacts with oxygen to form a nonuniform oxide layer, which adversely affects high-temperature oxidation resistance. Therefore, the Al content is limited as above.

[0049] The content of Sn is 0.005 to 0.15%.

[0050] Sn is a solid solution strengthening element for increasing high-temperature strength, and at the same time, it increases high-temperature oxidation resistance by forming a Sn-enriched oxide film on the surface layer. For the above two effects, at least Sn of 0.005% or more should be added. However, if it exceeds 0.15%, Sn segregates at the grain interface during hot rolling, weakening the bonding force between grains, causing microcracks in the surface layer. Therefore, the upper limit of the Sn content is limited to 0.15% or less.

[0051] In addition, according to an embodiment of the present disclosure, Ni: 0.3% or less, P: 0.04% or less, and S: 0.002% or less may be further included.

[0052] The content of Ni is 0.3% or less. Ni is an impurity that is inevitably included in steel, and may be contained in an amount of 0.01% or more, and plays a role in stabilizing austenite. When the Ni content exceeds 0.3% in low-Cr ferritic stainless steel, reverse austenite transformation occurs during annealing heat treatment after hot rolling or cold rolling, which adversely affects elongation. Therefore, the content of Ni is limited as above.

[0053] The content of P is 0.04% or less. P is an inevitable impurity contained in steel, and since it causes intergranular corrosion during pickling or impairs hot workability, its content is adjusted to 0.04% or less.

[0054] The content of S is 0.002% or less. S is an unavoidable impurity contained in steel, and its content is limited to 0.002% or less because it segregates at grain boundaries and impairs hot workability.

[0055] The remainder of the ferritic stainless steel except for the above alloying elements is made of Fe and other inevitable impurities.

[0056] Meanwhile, the low-Cr ferritic stainless steel with excellent formability and high temperature properties according to an embodiment of the present disclosure may satisfy the following Formulas (1) to (3).

$$(1) \qquad Cu + Si \geq 1.3$$

[0057] The high-temperature strength is usually affected by solid solution strengthening and precipitation strengthening. Since Cu and Si are representative solid solution strengthening elements, they are preferably added to increase high-temperature strength. When Cu is precipitated in the Cu precipitated phase, the high-temperature strength increases more effectively due to the precipitation strengthening effect. In addition, when the Si content is increased, since the limit of the solubility of Cu is lowered, the precipitation of the Cu precipitated phase becomes easier. Accordingly, a Cu precipitated phase of 0.03wt% or more having a size of 1 to 500 nm in the matrix may be precipitated. Therefore, the Cu+Si content is controlled in the range of 1.3% or more.

[0058] Through the above solid solution strengthening and precipitation strengthening effect, the low-Cr ferritic stainless steel according to the present disclosure can exhibit a high-temperature strength of 12 MPa or more at 900°C.

$$(2) \qquad Si + Cu + 10*Sn \leq 3.0$$

[0059] The Si, Cu, and Sn alloy elements have a positive effect on the high-temperature strength or high-temperature oxidation resistance, respectively, but the material is too hard, resulting in poor elongation and poor formability. In the present disclosure, when Si and Cu improve high-temperature strength and satisfy Formula (3) at the same time, an elongation of 30% or more can be secured to prevent poor formability. Therefore, in order to secure material workability, the relationship between Si, Cu, and Sn content is controlled within the above range.

$$(3) \qquad (Si + 5*Sn)/Ti \geq 5.0$$

[0060] In high temperature oxidation, when Si and Sn are added to low-Cr ferritic stainless steel, a uniform oxide film of Si and Sn is first formed to suppress abnormal oxidation. However, when Ti is added, the Ti oxide film is formed unevenly, and since the Ti oxide film itself exhibits yellow color, high temperature discoloration occurs. Therefore, it is possible to improve the high-temperature oxidation resistance by controlling the Si, Sn, and Ti content in the above range.

[0061] Next, a manufacturing method of a low-Cr ferritic stainless steel with excellent formability and high temperature properties according to an embodiment of the present disclosure will be described.

[0062] The manufacturing method of low-Cr ferritic stainless steel with excellent formability and high temperature properties of the present disclosure can manufacture cold rolled steel sheet through a conventional manufacturing process, and includes performing a cold rolled annealing heat treatment on a ferritic stainless steel cold rolled steel sheet containing the above-described alloy composition and satisfying Formulas (1) to (3); and rapid cooling to a temperature range of 450 to 550°C and maintaining for 5 minutes or more.

[0063] For example, the cold rolled steel sheets may be manufactured by hot-rolling the slab containing the above-described alloy component composition, annealing the hot-rolled steel sheet, and cold-rolling

[0064] The cold rolled steel sheet can be rapidly cooled to a temperature range of 450 to 550°C and maintained for 5 minutes or more after the usual recrystallization heat treatment in the cold rolling annealing process. Through the cooling and maintenance, it is possible to increase the precipitation of the Cu precipitated phase in the same component system, and to further improve the high-temperature strength.

[0065] Accordingly, the cold-rolled annealed steel sheet may contain a Cu precipitated phase of 0.09 wt% or more having a size of 1 to 500 nm in the matrix, and a high-temperature strength of 900°C may be 14.5 MPa or more.

[0066] Hereinafter, it will be described in more detail through a preferred embodiment of the present disclosure.

Example

[0067] Using the stainless steel lab scale melting and ingot production facilities, a 20mm bar sample was prepared with the alloy component system shown in Table 1 below. After reheating at 1,200°C and hot rolling to 6mm, hot rolling annealing was performed at 1,100°C. And after cold rolling to 2.0 mm, annealing heat treatment was performed at 1,100°C. For some Inventive Examples only, cold-rolled annealed steel sheet was manufactured by rapid cooling to 500°C after heat treatment, maintaining for 7 minutes, and air cooling. The remaining Inventive Examples and Comparative Examples were air-cooled after annealing heat treatment.

<Table 1 >

	C	N	Si	Mn	Cr	Ti	Cu	Al	Sn
Comparative Example1	0.005	0.010	0.41	0.21	11.4	0.21	0.05	0.02	0
Comparative Example2	0.006	0.008	0.6	0.21	12.1	0.19	0.15	0.02	0.05
Comparative Example3	0.007	0.007	0.2	0.21	11.1	0.18	0.24	0.03	0.06
Comparative Example4	0.006	0.008	1.1	0.20	11.7	0.20	0.08	0.02	0.1
Comparative Example5	0.006	0.007	1.31	0.20	11.9	0.21	0.41	0.02	0.18
Comparative Example6	0.005	0.009	0.6	0.19	11.3	0.15	0.76	0.02	0.21
Inventive Example1	0.006	0.009	0.64	0.21	11.5	0.22	0.73	0.02	0.03
Inventive Example2	0.006	0.008	1.1	0.16	11.8	0.24	0.65	0.02	0.11
Inventive Example3	0.005	0.010	0.86	0.21	12.2	0.22	0.75	0.02	0.08
Inventive Example4	0.007	0.008	0.96	0.21	12.0	0.16	0.49	0.03	0.14
Inventive Example5	0.006	0.008	1.1	0.21	11.8	0.24	0.65	0.02	0.11
Inventive Example6	0.005	0.009	0.86	0.23	12.2	0.22	0.75	0.02	0.08
Inventive Example7	0.007	0.008	0.96	0.20	12.0	0.16	0.49	0.02	0.14

[0068] For each cold-rolled annealed steel sheet, the fraction of the Cu precipitated phase was measured, and it was checked whether discoloration occurred after 1 hour at 500°C. In addition, high-temperature strength at 900°C and elongation at room temperature were measured and shown in Table 2.

<Table 2>

	Formul a (1)	Formul a (2)	Formul a (3)	Rapid cooling and maintenanc e after heat treatment	Cu precipitate d phase (wt%)	Whether high temperatur e discoloratio n occurs	High temperatur e strength (MPa)	elongatio n (%)
Comparativ e Example1	0.46	0.46	1.95	×	0.01	Occurrence	9.5	35.5
Comparativ e Example2	0.75	1.25	4.47	×	0.03	Occurrence	9.7	33.6
Comparativ e Example3	0.44	1.04	2.78	×	0.02	Occurrence	9.6	34.1
Comparativ e Example4	1.18	2.18	8.00	×	0.04	Not Occurrence	11.9	33.1
Comparativ e Example5	1.72	3.52	10.52	×	0.06	Not Occurrence	14.3	27.5
Comparativ e Example6	1.36	3.46	11.00	×	0.05	Not Occurrence	13.3	26.5
Inventive Example1	1.37	1.67	3.59	×	0.05	Occurrence	12.4	33.3
Inventive Example2	1.75	2.85	6.88	×	0.07	Not Occurrence	14.7	31.5
Inventive Example3	1.61	2.41	5.73	×	0.06	Not Occurrence	14.1	32.7
Inventive Example4	1.45	2.85	10.38	×	0.06	Not Occurrence	13.5	30.8
Inventive Example5	1.75	2.85	6.88	○	0.11	Not Occurrence	15.8	31.2
Inventive Example6	1.61	2.41	5.73	○	0.10	Not Occurrence	15.2	31.2
Inventive Example7	1.45	2.85	10.38	○	0.09	Not Occurrence	14.6	30.3

[0069] In the Comparative Examples and Inventive Examples listed in Table 1, the contents of Cu, Si, and Sn were varied, and alloying elements such as C, N, Cr, and Ti were controlled within the range of the content of the present disclosure.

[0070] In Comparative Examples 1 to 4, the content of Cu was less than 0.3%, and the value of Formula (1) was less than 1.3, and accordingly, the amount of fine Cu precipitated phase was low. It was confirmed that the high-temperature strength was lower than 12 MPa due to the lack of solid solution strengthening and precipitation strengthening effect.

[0071] Comparative Examples 1 to 3 showed dissatisfaction with Formula (3) because the content of Si and Sn was less than that of Ti, and high temperature discoloration occurred because the Si and Sn-enriched oxide film on the surface was not sufficiently formed. Comparative Example 4 satisfies Formula (3) due to its low Cu content but high Si content, so no discoloration occurred, and it was confirmed that high-temperature oxidation resistance was secured according to Formula (3).

[0072] In Comparative Examples 5 and 6, the value of Formula (2) exceeded 3.0 due to the high Sn content, and as a result, it was confirmed that elongation decreased by 5.0% compared to other Comparative Examples.

[0073] Inventive Example 1 satisfies the composition of the present disclosure and Formulas (1) and (2). Discoloration occurred at high temperature, but Cu precipitate of 0.05 wt% was precipitated by satisfying Formula (1), and high-temperature strength was 12 MPa or more. In addition, it was confirmed that the high-temperature strength was secured by satisfying Formula (2), and the elongation was measured as 33.3%, indicating excellent formability.

[0074] Inventive Examples 2 to 4 satisfy all of Formulas (1) to (3) by optimizing the Si, Cu, and Sn content. As a result, high-temperature strength of 13.5 MPa or more and elongation of 30.8% or more were exhibited, and high-temperature discoloration did not occur.

[0075] Inventive Examples 5 to 7 show that all of Formulas (1) to (3) were satisfied by optimizing the Si, Cu, and Sn contents, and the cooling schedule after heat treatment according to the present disclosure was applied. The elongation was secured to 30.3% or more, and as a result of meeting the rapid cooling and maintainig time after heat treatment, the fine Cu precipitated phase of 0.09wt% or more was precipitated, and the high-temperature strength was 14.6 MPa or more. In particular, Inventive Examples 5 and 6 showed high-temperature strength of 15 MPa or more.

[0076] FIG. 1 is a graph showing values of Formula (1) and Formula (3) of embodiments according to the present disclosure. The correlation between Formulas (1) and (3) regarding high-temperature strength and high-temperature oxidation resistance can be confirmed through FIG. 1.

[0077] As described above, although exemplary embodiments of the present disclosure have been described, the present disclosure is not limited thereto, and a person with ordinary knowledge in the relevant technical field may not depart from the concept and scope of the following claims. It will be appreciated that various changes and modifications are possible.

[Industrial Applicability]

[0078] The ferritic stainless steel according to the present disclosure can increase the high temperature properties of the existing steel by 30% or more without increasing the Cr content and adding Nb. Therefore, it is possible to reduce the cost of raw materials.

Claims

1. A low-Cr ferritic stainless steel with excellent formability and high temperature properties, the ferritic stainless steel comprising, in percent (%) by weight of the entire composition, C: 0.005 to 0.015%, N: 0.005 to 0.015%, Si: 0.5 to 1.5%, Mn: 0.1 to 0.5%, Cr: 9 to 14%, Ti: 0.1 to 0.3%, Cu: 0.3 to 0.8%, Al: 0.01 to 0.05%, Sn: 0.005 to 0.15%, the remainder of iron (Fe) and other inevitable impurities, and
satisfying following Formulas (1) and (2).

$$(1)\ Cu + Si \geq 1.3$$

$$(2)\ Si + Cu + 10*Sn \leq 3.0$$

(Here, Si, Cu, Sn means the content (% by weight) of each element)

2. The low-Cr ferritic stainless steel of claim 1, further comprising: Ni: 0.3% or less, P: 0.04% or less, and S: 0.002% or less.

3. The low-Cr ferritic stainless steel of claim 1, wherein the ferritic stainless steel comprises a Cu precipitated phase of 0.03% or more having a size of 1 to 500 nm in the matrix.

4. The low-Cr ferritic stainless steel of claim 1, wherein a 900°C high-temperature strength is 12 MPa or more.

5. The low-Cr ferritic stainless steel of claim 1, wherein an elongation is 30% or more.

6. The low-Cr ferritic stainless steel of claim 1, wherein the low-Cr ferritic stainless steel satisfies a following Formula (3).

$$(3)\ (Si + 5*Sn)/Ti \geq 5.0$$

(Here, Si, Sn, and Ti mean the content (% by weight) of each element)

7. A manufacturing method of a low-Cr ferritic stainless steel with excellent formability and high temperature properties, the manufacturing method comprising:

performing a cold rolled annealing heat treatment on a ferritic stainless steel cold rolled steel sheet comprising, in percent (%) by weight of the entire composition, C: 0.005 to 0.015%, N: 0.005 to 0.015%, Si: 0.5 to 1.5%, Mn: 0.1 to 0.5%, Cr: 9 to 14%, Ti: 0.1 to 0.3%, Cu: 0.3 to 0.8%, Al : 0.01 to 0.05%, Sn: 0.005 to 0.15%, the remainder of iron (Fe) and other inevitable impurities, and satisfying following Formulas (1) and (2); and
rapid cooling to a temperature range of 450 to 550°C and maintaining for 5 minutes or more.

$$(1)\ Cu + Si \geq 1.3$$

$$(2)\ Si + Cu + 10*Sn \leq 3.0$$

(Here, Si, Cu, Sn means the content (% by weight) of each element)

8. The manufacturing method of claim 7, wherein the cold-rolled annealed steel sheet comprises a Cu precipitated phase of 0.09% or more having a size of 1 to 500 nm in a matrix.

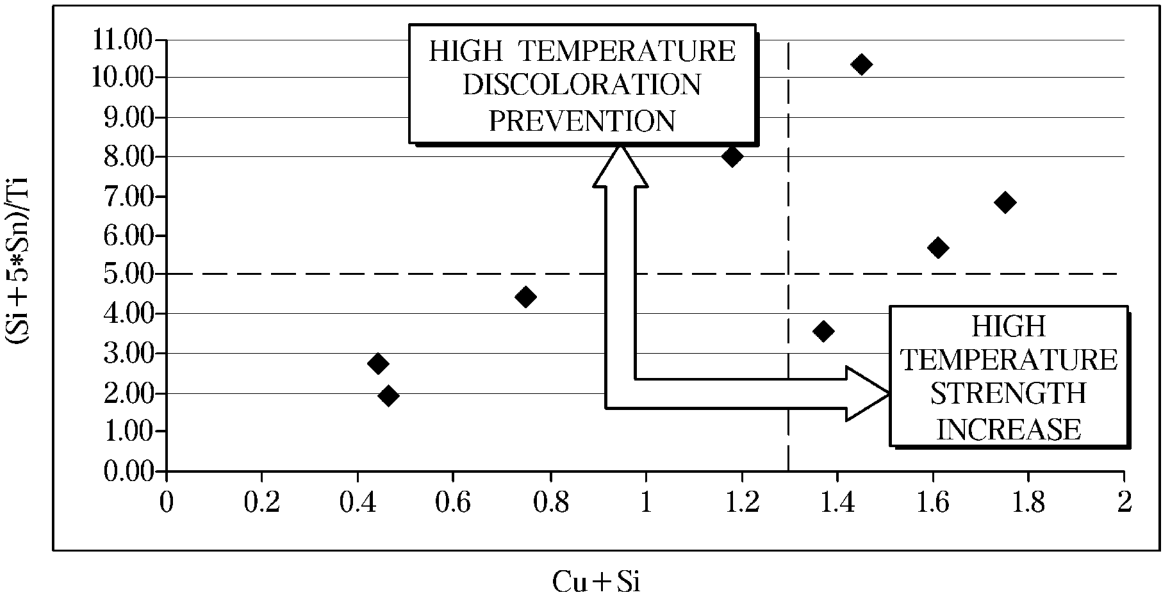
9. The manufacturing method of claim 7, wherein a 900°C high-temperature strength of the cold-rolled annealed steel sheet is 14.5 MPa or more.

10. The manufacturing method of claim 7, wherein the cold rolled steel sheet satisfies a following Formula (3).

$$(3)\ (Si + 5*Sn)/Ti \geq 5.0$$

(Here, Si, Sn, and Ti mean the content (% by weight) of each element)

【FIG. 1】


HIGH TEMPERATURE DISCOLORATION PREVENTION
HIGH TEMPERATURE STRENGTH INCREASE
(Si+5*Sn)/Ti
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Cu+Si

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2019/002017

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/20(2006.01)i, C22C 38/28(2006.01)i, C22C 38/06(2006.01)i, C22C 38/02(2006.01)i, C22C 38/04(2006.01)i, C22C 38/00(2006.01)i, C21D 9/46(2006.01)i, C21D 6/00(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 38/20; C21D 8/00; C21D 9/46; C22C 38/00; C22C 38/18; C22C 38/50; C22C 38/60; C22C 38/28; C22C 38/06; C22C 38/02; C22C 38/04; C21D 6/00

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, ferrite, chrome(Cr), silicon(Si), copper(Cu), titanium(Ti), tin(Sn), cooling, cold rolled

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2010-159487 A (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORP.) 22 July 2010 See paragraphs [0053], [0059], [0064]-[0065] and claims 1-2, 4.	1-10
X	KR 10-2017-0101262 A (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORPORATION) 05 September 2017 See paragraphs [0121]-[0122] and claims 1, 3, 10.	1-2,6
A	CN 102277538 A (SHANXI TAIGANG STAINLESS STEEL CO., LTD.) 14 December 2011 See claims 1, 3.	1-10
A	KR 10-2014-0083726 A (POSCO) 04 July 2014 See paragraph [0064] and claims 1, 4.	1-10
A	JP 2017-048417 A (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORP.) 09 March 2017 See paragraph [0058] and claims 1-2.	1-10

☐ 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	Date of mailing of the international search report
20 AUGUST 2019 (20.08.2019)	**21 AUGUST 2019 (21.08.2019)**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2019/002017

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