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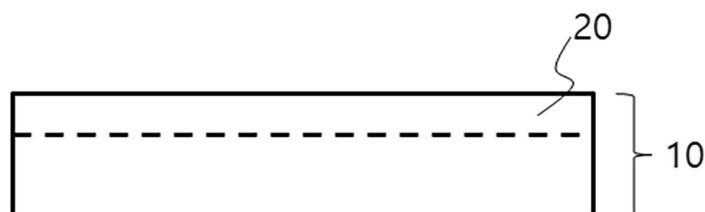
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(54) **ACID-RESISTANT STEEL PLATE AND METHOD FOR MANUFACTURING SAME**

(57) An acid-resistant steel sheet according to an embodiment of the present invention comprises, in wt%, C: 0.10% or less (excluding 0%), Cu: 0.20 to

0.35%, Ni: 0.23 to 0.40%, Sb: 0.05 to 0.15%, and Sn: 0.07 to 0.22%, with the balance being iron (Fe) and other unavoidable impurities.

FIG. 1



Description**[Technical Field]**

5 **[0001]** The present invention relates to an acid-resistant steel sheet and a method for manufacturing the same. Specifically, it relates to a steel sheet having excellent corrosion resistance against corrosion caused by various acids and excellent surface properties, and a method for manufacturing the same.

[Background Art]

10 **[0002]** Fossil fuels contain various impurity elements such as S and Cl. Since combustion is performed using these fossil fuels, there is always a problem of degradation due to corrosion in piping and equipment, which serve as passages through which combustion gas passes. This corrosion phenomenon is referred to as condensate corrosion, and typical applications where piping and equipment are exposed to these corrosive environments include exhaust
15 gas piping and environmental equipment of thermal power plants, automobile exhaust systems, and the like. Types of condensate corrosion include sulfuric acid condensate corrosion, in which S contained in exhaust gas is burned to form SO_x, and in particular, SO₃ reacts with moisture in the exhaust gas to form sulfuric acid; corrosion by hydrochloric acid condensate, which is generated through various reactions of chlorine contained in the exhaust gas or industrial water; and sulfuric acid/hydrochloric acid combined condensate corrosion occurring when sulfuric acid and
20 hydrochloric acid are mixed together. The starting temperature of such acid condensation is related to the temperature of the exhaust gas itself, the content of SO_x and Cl in the exhaust gas, and the water vapor content.

[0003] Recently, there has been a continuous demand for lowering the exhaust gas temperature itself for the purpose of improving power generation efficiency or utilizing waste heat discharged to the outside in applications such as power plants. Generally, when the exhaust gas temperature drops to a temperature at which sulfuric acid starts to
25 condense, not only does the amount of sulfuric acid gas formed in the exhaust gas liquefying and condensing on the surface of the steel material increase, causing corrosion, but also when the exhaust gas temperature drops to a lower temperature at which hydrochloric acid may condense, a complex corrosion phenomenon in which sulfuric acid and hydrochloric acid condense in combination occurs.

[Disclosure]**[Technical Problem]**

35 **[0004]** The present invention provides an acid-resistant steel sheet and a method for manufacturing the same. Specifically, the present invention provides a steel sheet having excellent corrosion resistance against corrosion caused by various acids and excellent formability, and a method for manufacturing the same.

[Technical Solution]

40 **[0005]** An acid-resistant steel sheet according to an embodiment of the present invention comprises, in wt%, C: 0.10% or less (excluding 0%), Cu: 0.20 to 0.35%, Ni: 0.23 to 0.40%, Sb: 0.05 to 0.15%, and Sn: 0.07 to 0.22%, with the balance being iron (Fe) and other unavoidable impurities.

[0006] The acid-resistant steel sheet according to an embodiment of the present invention may further include at least one of Mn: 0.5 wt% or less, Al: 0.1 wt% or less, P: 0.01 wt% or less, S: 0.01 wt% or less, and N: 0.01 wt% or less.

45 **[0007]** The acid-resistant steel sheet according to an embodiment of the present invention may further include at least one of Cr: 0.1 wt% or less, Nb: 0.1 wt% or less, and Mo: 0.1 wt% or less.

[0008] The acid-resistant steel sheet according to an embodiment of the present invention comprises an enrichment layer positioned from the surface of the steel sheet in an inward direction of the steel sheet, wherein the maximum Sn content in the enrichment layer is 5.0 wt% or less, and the maximum Ni content is 2.0 to 5.0 wt%.

50 **[0009]** A sum of the maximum Sn content and the maximum Ni content in the enrichment layer may be 7 wt% or less.

[0010] The acid-resistant steel sheet according to an embodiment of the present invention may have an average corrosion rate of 30 mg/(cm²·hr) or less when immersed in a 50 wt% sulfuric acid aqueous solution at 70°C for 6 hours.

55 **[0011]** The acid-resistant steel sheet according to an embodiment of the present invention may have an average corrosion rate of 2.0 mg/(cm²·hr) or less when immersed in an aqueous solution containing 28.5 wt% sulfuric acid and 0.5 wt% hydrochloric acid at 60°C for 6 hours.

[0012] The acid-resistant steel sheet according to an embodiment of the present invention may have a crack length

at the side portion of 5 mm or less.

[0013] A method for manufacturing an acid-resistant steel sheet according to an embodiment of the present invention comprises: heating a slab, wherein the slab comprises, in wt%, C: 0.10% or less (excluding 0%), Cu: 0.20 to 0.35%, Ni: 0.23 to 0.40%, Sb: 0.05 to 0.15%, and Sn: 0.07 to 0.22%, with the balance being iron (Fe) and other unavoidable impurities; and hot rolling the slab to manufacture a hot-rolled steel sheet.

[0014] In the heating of a slab, the heating temperature may be 1230°C or less.

[0015] The method of manufacturing a hot-rolled steel sheet comprises a rough rolling step and a finish rolling step, wherein a rough rolling finish temperature is 960°C or higher, and a finish rolling finish temperature may be 910°C or higher.

[0016] The manufacturing of a hot-rolled steel sheet further comprises a coiling step, and the coiling step may comprise coiling at a temperature ranging from 450 to 750°C.

[0017] After manufacturing the hot-rolled steel sheet, the method may further comprise a cold rolling step for the hot-rolled steel sheet.

[0018] After manufacturing the hot-rolled steel sheet, the method may further comprise an annealing heat treatment step at 750 to 880°C.

[Advantageous Effects]

[0019] The acid-resistant steel sheet according to an embodiment of the present invention has excellent acid resistance and surface properties.

[0020] The acid-resistant steel sheet according to an embodiment of the present invention may achieve excellent acid resistance and surface properties without the addition of expensive alloying elements such as Cr.

[0021] The acid-resistant steel sheet according to an embodiment of the present invention has an enrichment layer formed therein, and thus may effectively extend the lifespan of the material by having excellent corrosion resistance in a corrosive environment caused by acids.

[0022] The acid-resistant steel sheet according to an embodiment of the present invention may be effectively utilized as a raw material for piping through which exhaust gas passes after combustion of fossil fuels, and for hot-rolled products and cold-rolled products for fossil fuel combustion facilities.

[0023] In addition, by preventing surface and side sawtooth edges generated during the steel manufacturing process, safety during the manufacturing process, transport, and processing may be ensured.

[Brief Description of the Drawings]

[0024]

FIG. 1 is a schematic cross-section of an acid-resistant steel sheet according to an embodiment of the present invention.

FIG. 2 is a photograph of the surface of the acid-resistant steel sheet manufactured in Inventive Example 1.

FIG. 3 is a photograph of the surface of the acid-resistant steel sheet manufactured in Comparative Example 1.

FIG. 4 is a photograph of the surface of the acid-resistant steel sheet manufactured in Comparative Example 4.

[Mode for Invention]

[0025] Terms such as first, second, and third are used to describe various parts, components, regions, layers, and/or sections, but are not limited thereto. These terms are used only to distinguish one part, component, region, layer, or section from another part, component, region, layer, or section. Therefore, a first part, component, region, layer, or section described below may be referred to as a second part, component, region, layer, or section without departing from the technical spirit of the present invention.

[0026] The terminology used herein is for the purpose of referring to particular embodiments only and is not intended to limit the present invention. The singular forms used herein include the plural forms as well, unless the phrases clearly indicate the opposite meaning. The meaning of "comprising" as used in the specification specifies a particular characteristic, region, integer, step, operation, element, and/or component, and does not exclude the presence or addition of other characteristics, regions, integers, steps, operations, elements, and/or components.

[0027] In addition, unless otherwise stated, % means wt%, and 1 ppm is 0.0001 wt%.

[0028] In an embodiment of the present invention, further including additional elements means that the balance iron (Fe) is replaced by the additional amount of the additional elements.

[0029] Although not defined otherwise, all terms including technical and scientific terms used herein have the same meaning as commonly understood by a person having ordinary skill in the art in the technical field to which the present

invention belongs. Terms defined in commonly used dictionaries are additionally interpreted to have meanings consistent with relevant technical literature and the presently disclosed content, and are not interpreted in an ideal or very formal sense unless defined.

[0030] Hereinafter, embodiments of the present invention will be described in detail so that a person having ordinary skill in the art to which the present invention pertains may easily implement them. However, the present invention may be implemented in various different forms and is not limited to the embodiments described herein.

[0031] An acid-resistant steel sheet according to an embodiment of the present invention relates to a steel sheet for use in an environment where corrosion by acid occurs. A material for such use must have corrosion resistance in an acid environment to extend its lifespan, and at the same time, must suppress the formation of sawtooth-shaped cracks on a surface of the steel and a side portion of the steel material.

[0032] In an embodiment of the present invention, by the combined addition of Cu, Sb, Sn, and the like to the steel composition, corrosion resistance in a high concentration of sulfuric acid and a sulfuric acid/hydrochloric acid combined condensation environment may be significantly improved at the same time, and accordingly, the equipment corrosion resistance performance in a condensate corrosion environment may be dramatically increased. At the same time, by appropriately controlling the steel composition and manufacturing conditions, corrosion resistance performance may be improved while significantly reducing the formation of sawtooth-shaped cracks (commonly referred to as 'sawtooth edge') on the surface of the steel and the side portion of the steel material.

[0033] An acid-resistant steel sheet according to an embodiment of the present invention comprises, in wt%, 0.10% or less of C (excluding 0%), 0.20 to 0.35% of Cu, 0.23 to 0.40% of Ni, 0.05 to 0.15% of Sb, and 0.07 to 0.22% of Sn, with the balance being iron (Fe) and other unavoidable impurities.

[0034] Hereinafter, each component will be described in detail.

Carbon (C): 0.10 wt% or less

[0035] The carbon content of the acid-resistant steel sheet according to an embodiment of the present invention is 0.10 wt% or less. When the content of carbon in the steel is too high, degradation of corrosion resistance due to excessive carbide formation, particularly a decrease in corrosion resistance to sulfuric acid/hydrochloric acid combined condensates, may occur. More specifically, 0.001 to 0.100 wt% of C may be included. More specifically, 0.01 to 0.09 wt% of C may be included.

Copper (Cu): 0.20 to 0.35 wt%

[0036] Cu is a representative element that, when corroded in an acid immersion environment, is enriched between the surface of the steel material and the corrosion product to prevent additional corrosion. In order to exhibit the effect, an appropriate amount of Cu may be added. However, when added in an excessive amount, since it may cause cracks during manufacturing due to the low melting point of Cu, the content thereof is limited to 0.35 wt% or less. More specifically, the steel material may include 0.25 to 0.33 wt% of Cu.

Nickel (Ni): 0.23 to 0.40 wt%

[0037] When only Cu is added to the steel without Ni, liquid Cu may penetrate into the grain boundaries due to the low melting point of Cu, causing cracks. Ni is added for the purpose of suppressing crack formation by increasing the melting point. In addition, Ni plays a role in suppressing the surface enrichment of Sn, Sb, Cu, and the like, generated during the steel manufacturing process, by undergoing enrichment itself. This plays an important role in preventing sawtooth edges generated during the manufacturing process. However, if an excessive amount of Ni is added, Ni may become enriched on the surface of the steel, potentially causing surface cracks and defects; therefore, the upper limit is restricted to 0.4 wt%. More specifically, 0.25 to 0.37 wt% of Ni may be included. Even more specifically, 0.27 to 0.35 wt% of Ni may be included.

Antimony (Sb): 0.05 to 0.15 wt%

[0038] Sb is added to form a stable enrichment layer on the surface like Cu. When the content of Sb is too small, a sufficient enrichment layer may not be formed. Conversely, when it is too high, surface cracks due to surface enrichment may be caused in the manufacturing process. More specifically, 0.07 to 0.13 wt% of Sb may be included.

Tin (Sn): 0.07 to 0.22 wt%

[0039] Sn is added to form a stable enrichment layer on the surface, similar to Cu and Sb. In particular, Sn is

preferentially dissolved in an acid immersion environment, such as sulfuric acid, thereby significantly improving the corrosion resistance of the steel. When a steel sheet is placed in an immersion environment of sulfuric acid or a mixed acid, Sn and Cu are dissolved, and Sn is dissolved preferentially over Cu. As Sn is dissolved preferentially over Cu, Sn is dissociated into the solution. The dissociated Sn lowers the corrosion potential of the solution, thereby partially delaying the corrosion of the steel sheet. Herein, the 'corrosion potential' refers to the potential of a metal undergoing corrosion with respect to a reference electrode. In addition, a corrosion retardation layer may be formed during the process in which Sn that has been dissolved on the surface of the steel sheet is re-deposited, and this corrosion retardation layer may delay the corrosion of the steel sheet. If the Sn content is too low, a sufficient corrosion retardation layer may not be formed. If the Sn content is too high, serious surface cracks may be caused during the production process. More specifically, the Sn content may be 0.073 to 0.220 wt%.

[0040] The acid-resistant steel sheet according to an embodiment of the present invention may further include at least one of Mn: 0.1 to 0.5 wt%, Al: 0.1 wt% or less, P: 0.01 wt% or less, S: 0.01 wt% or less, and N: 0.01 wt% or less.

Manganese (Mn): 0.5 wt% or less

[0041] Manganese (Mn) is an element that prevents hot shortness due to solute S by combining with solute S in steel and precipitating as MnS. In order to produce such an effect, Mn may be further included. However, when Mn exceeds 0.5 wt%, the material is hardened and ductility may be lowered. More specifically, 0.10 to 0.50 wt% of Mn may be included. More specifically, 0.15 to 0.35 wt% of Mn may be included.

Aluminum (Al): 0.1 wt% or less

[0042] Al is an element having a very large deoxidation effect and prevents deterioration of formability due to solid solution N by reacting with N in steel to precipitate AlN, so it may be further included. However, when added in a large amount, since ductility is sharply lowered, the content is limited to 0.1 wt% or less. More specifically, 0.01 to 0.05 wt% of Al may be further included.

Phosphorus (P): 0.01 wt% or less

[0043] The addition of P in a certain amount or less is an element that may increase the strength of the steel without significantly reducing its ductility; however, if added in excess of 0.01 wt%, it segregates at the grain boundary to harden the steel, so the content of P may be limited to 0.01 wt% or less. More specifically, P may be further included in an amount of 0.001 to 0.01 wt%.

Sulfur (S): 0.01 wt% or less

[0044] Since S is an element that causes hot shortness during solid solution, precipitation of MnS must be induced through the addition of Mn. However, excessive precipitation of MnS is not desirable because it hardens the steel. Accordingly, the upper limit of S is limited to 0.01 wt%. More specifically, 0.001 to 0.01 wt% of S may be further included.

Nitrogen (N): 0.01 wt% or less

[0045] N is often contained as an inevitable element in steel, and N existing in a solid solution state without being precipitated not only lowers ductility and worsens aging resistance but also reduces formability. Accordingly, the upper limit is set to 0.01 wt%. More specifically, N may be further included in an amount of 0.001 to 0.005 wt%.

[0046] In addition to the above-described alloy composition, the balance consists of Fe and inevitable impurities. However, an embodiment of the present invention does not exclude the addition of other compositions. The inevitable impurities may be unintentionally mixed from raw materials or the surrounding environment during a typical steel manufacturing process, and thus may not be excluded. The inevitable impurities may be understood by a person skilled in the art of steel manufacturing. For example, the alloy composition may further include at least one selected from the group comprising of Cr: 0.1 wt% or less, Nb: 0.1 wt% or less, and Mo: 0.1 wt% or less.

[0047] FIG. 1 shows a schematic cross-section of an acid-resistant steel sheet according to an embodiment of the present invention. As shown in FIG. 1, an enriched layer (20) exists in an inward direction from the surface of the acid-resistant steel sheet (10). In FIG. 1, the enriched layer (20) is shown as being located on one side, but it may also be located on both sides.

[0048] The maximum Sn content in the enrichment layer (20) may be 5.0 wt% or less, and the maximum Ni content may be 2.0 to 5.0 wt%.

[0049] In this context, the enrichment layer (20) refers to a surface portion in which Cu, Sb, Sn, and Ni are enriched, and from another perspective, it is similar to the point where oxidation generally begins. In an embodiment of the present invention, the enrichment layer (20) is defined as a region extending from the surface of the steel sheet in the inward direction up to a position where the total content of Cu, Sb, Ni, and Sn is up to 4 times the total content of Cu, Sb, Ni, and Sn at the center of the steel sheet (position at 1/2 of the thickness). In this regard, the maximum content refers to the content in a portion where the concentration of the corresponding element is highest within the enrichment layer, and in most cases, the outermost surface portion has the highest concentration. It was confirmed that the enrichment layer, which consists of Ni, Sb, Sn, and Cu, exists on the surfaces of the steel material and corrosion products at a total content of 10 to 20 wt%. Meanwhile, the thickness of the enrichment layer (20) may be 20 μm to 30 μm . In an embodiment of the present invention, the enrichment layer (20) and the content of elements in the enrichment layer (20) may be measured by determining the element distribution from the surface to the interior of a steel sheet specimen through glow discharge spectrometer (GDS) measurement. Proper formation of the enrichment layer (20) may be achieved through control of conditions during hot rolling together with control of the steel composition described above.

[0050] The maximum Sn content in the enrichment layer (20) may be 5.0 wt% or less. As described above, while Sn is an element that delays corrosion, inclusion of a large amount of Sn in the enrichment layer (20) causes a sawtooth edge. Accordingly, the maximum Sn content in the enrichment layer (20) may be limited. More specifically, the maximum Sn content in the enrichment layer may be from 1.0 to 4.7 wt%.

[0051] The maximum Ni content in the enriched layer (20) may be 2.0 to 5.0 wt%. When a large amount of Sn is contained in the steel, enrichment of Sn is unavoidable, and in an embodiment of the present invention, Ni is enriched instead of Sn to reduce the Sn concentration in the enriched layer. However, since Ni may also cause a sawtooth edge to occur when excessively enriched, the maximum Ni content in the enriched layer (20) is limited as described above. More specifically, the maximum Ni content in the enriched layer (20) may be 2.0 to 4.8 wt%.

[0052] The sum of the maximum Sn content and the maximum Ni content in the enriched layer (20) may be 7 wt% or less. As described above, Ni is added to suppress the enrichment of Sn; however, if Ni is added in an excessive amount, Ni may rather cause the generation of a sawtooth edge. Therefore, the upper limit of the sum of the maximum Sn content and the maximum Ni content in the enriched layer (20) may be restricted. More specifically, the sum of the maximum Sn content and the maximum Ni content in the enriched layer (20) may be 3.5 to 6.7 wt%.

[0053] The maximum Sb content in the enrichment layer (20) may be 10 wt% or less. Similar to Sn, when Sb is heavily enriched on the surface, it may cause the generation of a sawtooth edge. In an embodiment of the present invention, Ni is enriched to reduce the Sb concentration in the enrichment layer. More specifically, the maximum Sb content in the enrichment layer (20) may be 3.0 to 8.5 wt%.

[0054] The maximum Cu content in the enrichment layer (20) may be 13 wt% or less. Similar to Sn, when Cu is heavily enriched on the surface, it may cause the generation of a sawtooth edge. In an embodiment of the present invention, Ni is enriched to reduce the Cu concentration in the enrichment layer. More specifically, the maximum Cu content in the enrichment layer (20) may be 3.0 to 8.5 wt%.

[0055] The acid-resistant steel sheet according to an embodiment of the present invention may have a crack length at the side portion of 5 mm or less. As described above, in an embodiment of the present invention, the crack length may be reduced by enriching Ni instead of Sn, Sb, and Cu.

[0056] A crack refers to a groove formed with a depth of 5 mm or more from the surface of the steel sheet, and the crack length refers to the length in a direction perpendicular to the end of the surface of the steel sheet.

[0057] In an embodiment of the present invention, the corrosion resistance to sulfuric acid and the corrosion resistance to a mixed acid of sulfuric acid and hydrochloric acid are simultaneously excellent.

[0058] Specifically, the acid-resistant steel sheet according to an embodiment of the present invention may have an average corrosion rate of 30 $\text{mg}/(\text{cm}^2 \cdot \text{hr})$ or less when immersed in a 50 wt% sulfuric acid aqueous solution at 70°C for 6 hours. More specifically, it may be 10 to 28 $\text{mg}/(\text{cm}^2 \cdot \text{hr})$.

[0059] The acid-resistant steel sheet according to an embodiment of the present invention may have an average corrosion rate of 2.0 $\text{mg}/(\text{cm}^2 \cdot \text{hr})$ or less when immersed in an aqueous solution containing 28.5 wt% sulfuric acid and 0.5 wt% hydrochloric acid at 60°C for 6 hours. More specifically, it may be 0.30 to 2.00 $\text{mg}/(\text{cm}^2 \cdot \text{hr})$.

[0060] A method for manufacturing an acid-resistant steel sheet according to an embodiment of the present invention comprises: heating a slab; and hot rolling the slab to manufacture a hot-rolled steel sheet.

[0061] Hereinafter, each step will be described in detail.

[0062] First, the slab is heated.

[0063] As the alloy composition of the slab has been described in the aforementioned acid-resistant steel sheet, redundant description is omitted. Since alloying elements do not substantially change during the manufacturing process of the acid-resistant steel sheet, the alloy composition of the acid-resistant steel sheet and the alloy composition of the slab are substantially the same.

[0064] The heating temperature of the slab may be 1230°C or less. If the slab heating temperature is too high, star

cracks originating from the Cu element may occur at a temperature similar to the melting point of Cu, and thus sawtooth edges of the hot-rolled sheet may occur from slab cracks. Meanwhile, since most of the precipitates present in the steel must be re-dissolved, a temperature of 1150°C or higher may be required.

[0065] Next, a hot-rolled steel sheet is manufactured by hot rolling the slab.

[0066] The method of manufacturing a hot-rolled steel sheet includes a rough rolling step and a finish rolling step, wherein a rough rolling finish temperature may be 960°C or higher, and a finish rolling finish temperature may be 910°C or higher. Enrichment of Ni instead of Sn may be promoted at the above-described rough rolling finish temperature and finish rolling finish temperature. More specifically, the rough rolling finish temperature may be 960 to 1050°C, and the finish rolling finish temperature may be 910 to 1000°C.

[0067] The method for manufacturing a hot-rolled steel sheet further comprises a coiling step for the hot-rolled steel sheet, and the coiling step may be performed at a temperature of 450 to 750°C. If the coiling temperature is too low, final cold rolling may become difficult due to an increase in the initial strength of the hot-rolled material; whereas, if the coiling temperature is too high, there may be problems of buckling and strength decrease due to phase transformation in the coiling section.

[0068] The thickness of the hot-rolled sheet may be 2.5 to 5.5 mm.

[0069] Thereafter, the method may comprise a step of pickling the coiled hot-rolled steel sheet.

[0070] After manufacturing the hot-rolled steel sheet, the method may further comprise a cold rolling step for the hot-rolled steel sheet. In this case, the reduction ratio may be 54 to 70%. If the reduction ratio is too low, it may be difficult to ensure complete recrystallization during cold rolling, which may result in a decrease in the elongation of the material and may cause cracks or the like during subsequent processing by customers. On the other hand, if the reduction ratio is too high, a problem in which rolling cannot be performed due to a motor load during the rolling process may occur.

[0071] In addition, after manufacturing the hot-rolled steel sheet, the method may further comprise an annealing step. In this case, the annealing temperature may be 750 to 880°C. If the annealing heat treatment temperature is too low, it may be difficult to ensure complete recrystallization, which may lead to a decrease in the elongation of the material and may cause cracks or the like during subsequent processing by the customer. On the other hand, if the annealing heat treatment temperature is too high, there is a problem that it is difficult to ensure the strength of the steel sheet.

[0072] Even if cold rolling and an annealing heat treatment are performed, the enriched layer (20) present in the hot-rolled steel sheet remains substantially the same.

[0073] Hereinafter, the present invention will be described in more detail through embodiments. However, these embodiments are only for illustrating the present invention, and the present invention is not limited thereto.

Example 1

[0074] First, a steel slab including alloying elements summarized in Table 1 below was manufactured. After heating the slab at 1200°C (SRT) for 200 minutes, hot rolling was performed to a thickness of 3.5 mm to manufacture a hot-rolled sheet. The rough rolling delivery temperature (RDT) was 1000°C, the finish rolling delivery temperature (FDT) was 950°C, and coiling was performed at 650°C.

[0075] The element distribution from the surface to the interior of the hot-rolled specimen was measured by GDS analysis and is summarized in Table 2.

[0076] After manufacturing the steel sheet, an immersion test was performed according to the method described in the ASTM G31 standard. The immersion test was performed by preparing a 50 wt% sulfuric acid aqueous solution and immersing the steel sheet therein at 70°C for 6 hours. After immersion, the specimen was cleaned using the specimen surface cleaning method of ASTM G1, and the weight loss was measured to determine the weight loss per unit time and unit surface area.

[0077] In addition, in order to simulate sulfuric acid/hydrochloric acid combined condensation encountered during low-temperature condensation in a Korean-type thermal power plant, a mixed aqueous solution containing 28.5 wt% sulfuric acid and 0.5 wt% hydrochloric acid was prepared, and an immersion test was performed at 60°C for 6 hours. After the immersion, the specimen was cleaned using the specimen surface cleaning method according to ASTM G1 in the same manner as described above, and weight loss per unit time and unit surface area was measured.

[0078] The edge crack length was measured by determining the longest crack extending from the edge toward the interior of the steel sheet, using a steel sheet magnifier.

[0079] The results are shown in Table 3 below.

[Table 1]

(wt%)	C	Cu	Ni	Sb	Sn
Inventive Example 1	0.07	0.30	0.30	0.10	0.15

(continued)

(wt%)	C	Cu	Ni	Sb	Sn
Inventive Example 2	0.07	0.30	0.23	0.10	0.15
Inventive Example 3	0.07	0.30	0.25	0.10	0.15
Inventive Example 4	0.07	0.30	0.35	0.10	0.15
Inventive Example 5	0.07	0.30	0.40	0.10	0.15
Inventive Example 6	0.07	0.30	0.30	0.10	0.07
Inventive Example 7	0.07	0.30	0.30	0.10	0.22
Inventive Example 8	0.07	0.20	0.30	0.10	0.10
Inventive Example 9	0.07	0.35	0.30	0.10	0.10
Inventive Example 10	0.10	0.30	0.30	0.10	0.15
Inventive Example 11	0.07	0.30	0.30	0.05	0.15
Inventive Example 12	0.07	0.30	0.30	0.15	0.15
Comparative Example 1	0.07	0.30	0.20	0.10	0.15
Comparative Example 2	0.07	0.30	0.50	0.10	0.15
Comparative Example 3	0.07	0.30	0.30	0.10	0.05
Comparative Example 4	0.07	0.30	0.30	0.10	0.30
Comparative Example 5	0.07	0.15	0.30	0.10	0.15
Comparative Example 6	0.07	0.40	0.30	0.10	0.15
Comparative Example 7	0.15	0.30	0.30	0.10	0.15
Comparative Example 8	0.07	0.30	0.30	0.02	0.15
Comparative Example 9	0.07	0.30	0.30	0.18	0.15

[Table 2]

(wt%)	Sn	Ni	Sb	Cu	Ni+Sn	Total
Inventive Example 1	2.5	3.5	5.5	6.5	6.0	18.0
Inventive Example 2	4.5	2.1	5.4	6.5	6.6	18.5
Inventive Example 3	2.5	2.3	5.4	6.5	4.8	16.7
Inventive Example 4	2.5	3.8	5.4	6.5	6.3	18.2
Inventive Example 5	1.5	4.8	5.3	4.0	6.3	15.6
Inventive Example 6	1.3	2.5	3.5	5.5	3.8	12.8
Inventive Example 7	3.9	3.0	4.3	5.5	6.9	16.7
Inventive Example 8	2.5	2.5	4.5	4.0	5.0	13.5
Inventive Example 9	1.5	3.5	4.3	8.5	5.0	17.8
Inventive Example 10	2.5	3.5	5.5	4.5	6.0	16.0
Inventive Example 11	2.5	2.5	3.5	4.5	5.0	13.0
Inventive Example 12	1.5	3.0	8.0	5.0	4.5	17.5
Comparative Example 1	6.5	1.0	4.5	8.0	7.5	20.0
Comparative Example 2	1.0	5.5	4.5	5.5	6.5	16.5
Comparative Example 3	0.8	5.0	4.3	4.5	5.8	14.6
Comparative Example 4	8.0	1.0	3.5	4.5	9.0	17.0

(continued)

(wt%)	Sn	Ni	Sb	Cu	Ni+Sn	Total
Comparative Example 5	2.5	2.0	5.5	2.0	4.5	12.0
Comparative Example 6	1.5	1.5	3.5	15.0	3.0	21.5
Comparative Example 7	2.5	3.5	4.5	2.5	6.0	13.0
Comparative Example 8	1.5	2.5	2.5	3.5	4.0	10.0
Comparative Example 9	1.5	3.5	10.2	5.5	5.0	20.7

[Table 3]

	Corrosion Weight Loss Ratio (mg/cm ² /hr.)		Edge Crack Occurrence Length (mm)
	Sulfuric acid alone	Combination	
Inventive Example 1	18.5	0.45	0.0
Inventive Example 2	18.0	0.52	2.0
Inventive Example 3	18.1	0.63	2.0
Inventive Example 4	22.0	1.20	1.0
Inventive Example 5	23.5	1.50	3.5
Inventive Example 6	22.5	2.00	0.0
Inventive Example 7	17.5	0.80	3.0
Inventive Example 8	26.5	1.20	0.0
Inventive Example 9	17.8	0.75	4.5
Inventive Example 10	28.0	1.89	0.0
Inventive Example 11	22.5	1.95	0.0
Inventive Example 12	17.5	0.38	3.5
Comparative Example 1	19.0	0.55	7.5
Comparative Example 2	35.0	1.85	5.5
Comparative Example 3	22.0	3.20	1.0
Comparative Example 4	21.0	0.35	9.5
Comparative Example 5	35.0	2.10	0.0
Comparative Example 6	18.5	0.65	7.5
Comparative Example 7	36.5	2.30	0.0
Comparative Example 8	32.0	5.50	0.0
Comparative Example 9	18.5	0.53	6.5

[0080] As shown in Tables 1 to 3, it may be confirmed that the steel composition in which Cu, Ni, Sn, and Sb are appropriately included has excellent corrosion resistance, and also, the generation of sawtooth edges is suppressed.

[0081] On the other hand, it may be confirmed that Comparative Example 3, Comparative Example 5, and Comparative Example 8, which contain small amounts of Sn, Sb, and Cu, exhibit poor corrosion resistance.

[0082] In addition, in the case of Comparative Example 4, Comparative Example 6, and Comparative Example 9, which included excessive amounts of Sn, Sb, and Cu, it may be confirmed that these elements were excessively enriched on the surface, and a large number of sawtooth edges occurred.

[0083] Meanwhile, it may be confirmed that Comparative Example 7, in which a large amount of C was added, exhibits poor corrosion resistance due to excessive carbide formation.

[0084] In Comparative Example 1, in which Ni was included in an insufficient amount, Sn was heavily enriched, resulting in the generation of a large number of sawtooth edges; similarly, in Comparative Example 2, in which Ni was included in an excessive amount, Ni was heavily enriched, which also resulted in the generation of a large number of

sawtooth edges.

[0085] FIGS. 2 to 4 show photographs of the surface of the steel sheet in Inventive Example 1, Comparative Example 1, and Comparative Example 4, respectively. In the case of Comparative Example 1 and Comparative Example 4, it may be confirmed that a large number of cracks occurred compared to Inventive Example 1.

Example 2

[0086] The process was performed in the same manner as in Inventive Example 1 of Embodiment 1, except that the hot rolling conditions were changed as shown in Table 4 below.

[0087] Corrosion weight loss ratio and edge crack length were measured in the same manner as in Example 1 and are summarized in Table 4. The maximum content of each element of the surface enriched layer is summarized in Table 5 below.

[Table 4]

	Hot rolling conditions (°C)			corrosion weight loss ratio (mg/cm ² /hr.)		Edge crack(mm)
	SRT	RDT	FDT	sulfuric acid alone	Combination	
Inventive Example 1	1200	1000	950	18.5	0.45	0.0
Comparative Example 10	1250	1000	950	17.5	0.55	7.5
Comparative Example 11	1200	950	950	18.5	0.55	5.5
Comparative Example 12	1200	1000	900	19.5	0.4	8.5

[Table 5]

(wt%)	Sn	Ni	Sb	Cu	Ni+Sn	Total
Inventive Example 1	2.5	3.5	5.5	6.5	6	21.5
Comparative Example 10	2.5	3.5	4.5	18.5	6	32.5
Comparative Example 11	6.5	3.5	5.5	4.5	10	23.5
Comparative Example 12	8.5	2.5	6.5	5.5	11	25.5

[0088] In Comparative Example 10, it may be confirmed that the slab heating temperature was too high, resulting in excessive enrichment of Cu and the occurrence of a large amount of sawtooth edges. In Comparative Example 11 and Comparative Example 12, it may be confirmed that the rough rolling finish temperature and the finish rolling finish temperature were low, respectively, resulting in excessive enrichment of Sn and the occurrence of a large amount of sawtooth edges.

[0089] The present invention is not limited to the embodiments, but may be manufactured in various different forms, and a person having ordinary skill in the art in the technical field to which the present invention belongs will understand that the present invention may be practiced in other specific forms without changing the technical spirit or essential features of the present invention. Therefore, it should be understood that the embodiments described above are illustrative in all respects and not restrictive.

[Explanation of symbols]

[0090]

10: acid-resistant steel sheet,
20: enrichment layer

Claims

1. An acid-resistant steel sheet comprising, in wt%, C: 0.10% or less (excluding 0%), Cu: 0.20 to 0.35%, Ni: 0.23 to

0.40%, Sb: 0.05 to 0.15%, and Sn: 0.07 to 0.22%, with the balance being iron (Fe) and other unavoidable impurities.

2. The acid-resistant steel sheet according to claim 1,
further comprising at least one selected from the group consisting of Mn: 0.5 wt% or less, Al: 0.1 wt% or less, P: 0.01 wt% or less, S: 0.01 wt% or less, and N: 0.01 wt% or less.

3. The acid-resistant steel sheet according to claim 1,
further comprising at least one selected from the group consisting of Cr: 0.1 wt% or less, Nb: 0.1 wt% or less, and Mo: 0.1 wt% or less.

4. The acid-resistant steel sheet according to claim 1,
comprising an enrichment layer positioned from the surface of the steel sheet in an inward direction of the steel sheet,
wherein a maximum Sn content in the enrichment layer is 5.0 wt% or less, and a maximum Ni content in the enrichment layer is 2.0 to 5.0 wt%.

5. The acid-resistant steel sheet according to claim 4,
wherein a sum of the maximum Sn content and the maximum Ni content in the enrichment layer is 7 wt% or less.

6. The acid-resistant steel sheet according to claim 1,
wherein an average corrosion rate is 30 mg/(cm²·hr) or less when immersed in a 50 wt% sulfuric acid aqueous solution at 70°C for 6 hours.

7. The acid-resistant steel sheet according to claim 1,
wherein an average corrosion rate is 2.0 mg/(cm²·hr) or less when subjected to immersion for 6 hours at 60°C in an aqueous solution comprising 28.5 wt% sulfuric acid and 0.5 wt% hydrochloric acid.

8. The acid-resistant steel sheet according to claim 1,
wherein a crack length at a side portion is 5 mm or less.

9. A method for manufacturing an acid-resistant steel sheet, comprising:

heating a slab containing, in wt%, C: 0.10% or less (excluding 0%), Cu: 0.20 to 0.35%, Ni: 0.23 to 0.40%, Sb: 0.05 to 0.15%, and Sn: 0.07 to 0.22%, with the balance being iron (Fe) and other unavoidable impurities; and hot-rolling the slab to manufacture a hot-rolled steel sheet.

10. The method for manufacturing an acid-resistant steel sheet of claim 9, wherein, in the heating step, the slab is heated to 1230°C or lower.

11. The method for manufacturing an acid-resistant steel sheet of claim 9,
wherein the hot-rolled steel sheet manufacturing step comprises a rough rolling step and a finish rolling step, and
wherein the rough rolling finish temperature is 960°C or higher, and the finish rolling finish temperature is 910°C or higher.

12. The method for manufacturing an acid-resistant steel sheet of claim 9,
wherein the hot-rolled steel sheet manufacturing step further comprises a coiling step for the hot-rolled steel sheet, and
wherein the coiling step is performed at a temperature of 450 to 750 °C.

13. The method for manufacturing an acid-resistant steel sheet of claim 9,
wherein, after manufacturing the hot-rolled steel sheet, the method further comprises a cold rolling step for the hot-rolled steel sheet.

- 14.** The method for manufacturing an acid-resistant steel sheet of claim 9, wherein, after manufacturing the hot-rolled steel sheet, the method further comprises an annealing heat treatment step at 750 to 880°C.

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FIG. 1

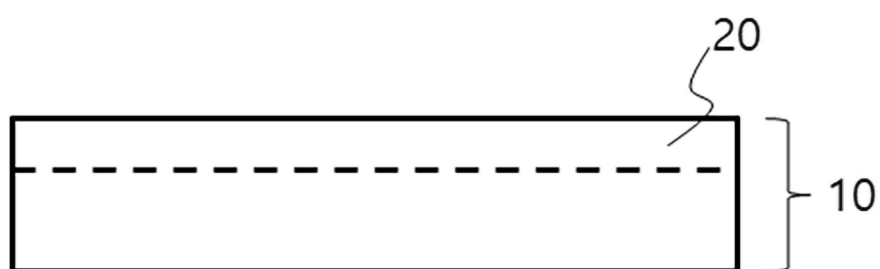


FIG. 2



FIG. 3

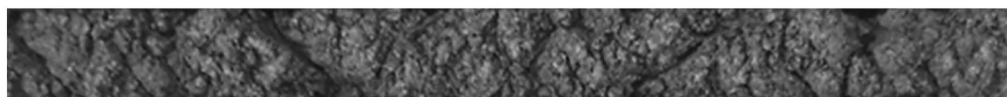


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2024/063300

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/08(2006.01)i; **C22C 38/16**(2006.01)i; **C22C 38/00**(2006.01)i; **C22C 38/04**(2006.01)i; **C22C 38/06**(2006.01)i;
C22C 38/44(2006.01)i; **C22C 38/48**(2006.01)i; **C23G 1/08**(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 38/08(2006.01); C21D 8/02(2006.01); C22C 38/00(2006.01); C22C 38/02(2006.01); C22C 38/16(2006.01);
C22C 38/42(2006.01); C22C 38/44(2006.01); C22C 38/60(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models: IPC as above

Japanese utility models and applications for utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS (KIPO internal) & keywords: 내산(acid resistance), 내식(corrosion resistance), 농화층(concentrated layer), 황산(sulfuric acid), 염산(hydrochloric acid)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	KR 10-2020-0096899 A (POSCO) 14 August 2020 (2020-08-14) See claims 1-2, 9-10 and 12-15.	1-3,8-14 4-7
X	JP 2006-241476 A (NIPPON STEEL CORP.) 14 September 2006 (2006-09-14) See claims 1 and 4-6.	1-3
A	KR 10-2016-0138185 A (NISSHIN STEEL CO., LTD.) 02 December 2016 (2016-12-02) See claims 1-2 and 4-8.	1-14
A	KR 10-1787283 B1 (HYUNDAI STEEL COMPANY) 15 November 2017 (2017-11-15) See claims 1-2 and 5-6.	1-14
A	US 2013-0011294 A1 (MATSUHASHI et al.) 10 January 2013 (2013-01-10) See claims 4-5.	1-14

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

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“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 14 April 2025	Date of mailing of the international search report 14 April 2025
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/IB2024/063300

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