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(54) **STEEL SHEET AND ENAMELED PRODUCT**

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(57) **ABSTRACT**

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A steel sheet includes, as a chemical composition, by mass %: C: 0.0050% or less; Si: 0.050% or less; Mn: 0.007% to 1.00%; P: 0.020% to 0.200%; S: 0.005% to 0.050%; Al: 0.010% or less; O: 0.0100% to 0.1000%; Cu: 0.010% to 0.060%; N: 0.0050% or less; Cr: 0.010% to 1.00%; one or two of Sn: 0.010% to 1.00% and Sb: 0.010% to 1.00%: 0.11% or more in total; one or more selected from the group consisting of B, Ni, Nb, As, Ti, Mo, Se, Ta, W, La, Ce, Ca, and Mg: 0% to 0.100% in total; and a remainder: Fe and impurities, in which, in a case where a Sn content in mass % is denoted by [Sn], a Sb content in mass % is denoted by [Sb], and a P content in mass % is denoted by [P], Expression (1) is satisfied, and a tensile strength obtained in a tensile test performed in accordance with JIS Z2241:2011 is 340 MPa or more.

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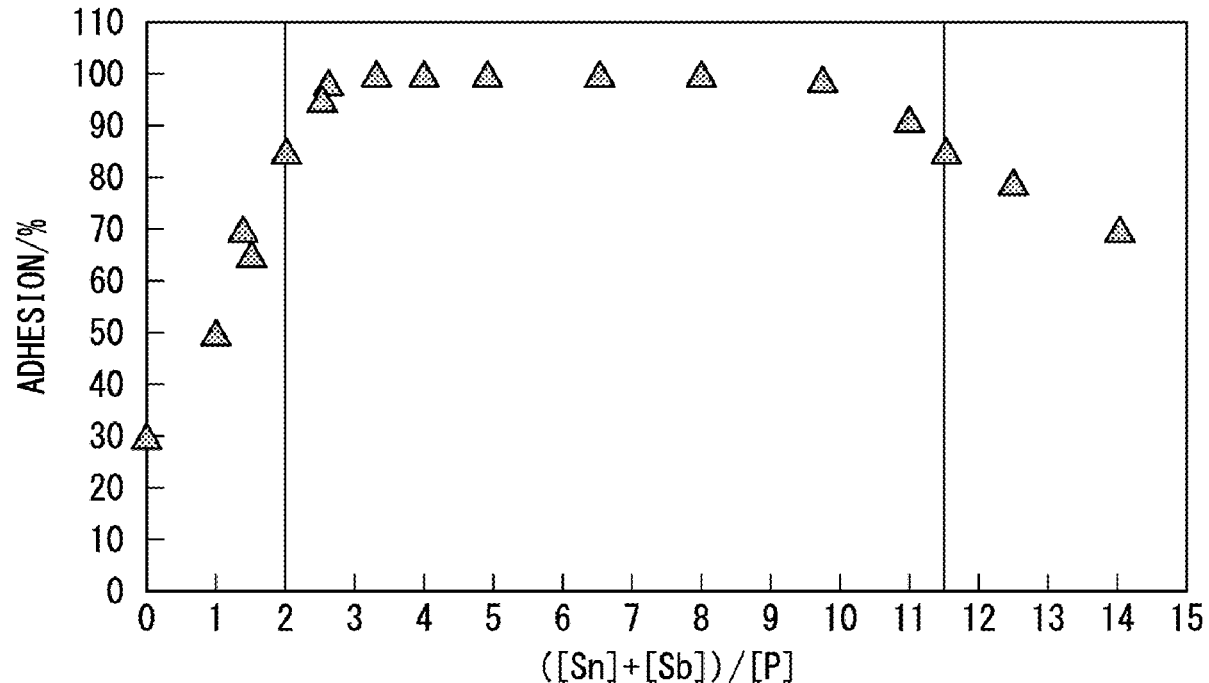
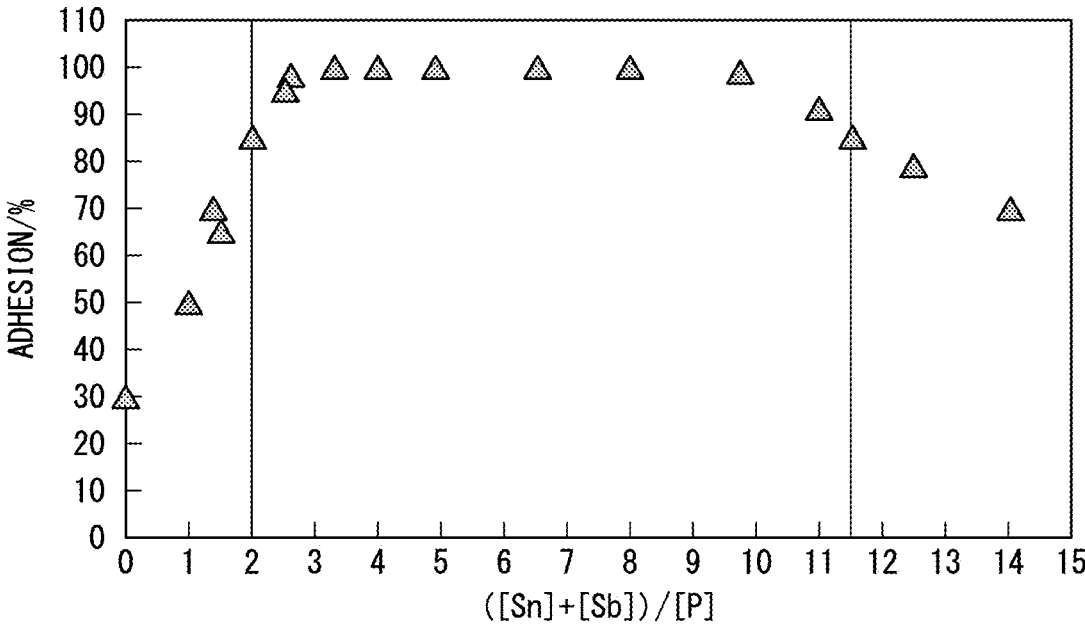


FIG. 1



**STEEL SHEET AND ENAMELED PRODUCT**

## TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to a steel sheet and an enameled product.

[0002] Priority is claimed on Japanese Patent Application No. 2022-064917, filed Apr. 11, 2022, the content of which is incorporated herein by reference.

## RELATED ART

[0003] Enameled products have a glassy substance glazed on a surface of a steel sheet. Enameled products have functions of heat resistance, weather resistance, chemical resistance, and water resistance and thus have been broadly used as materials for kitchen appliances such as pots and sinks, building materials, and the like in the related art. Such enameled products are usually manufactured by working steel sheets into predetermined shapes, assembling the steel sheets into a product shape by welding or the like, and then carrying out an enameling treatment (baking treatment) thereon.

[0004] Steel sheets that are used as materials for enameled products (steel sheets for vitreous enameling) are required to have properties such as baking strain resistance, fish scaling resistance after an enameling treatment, enamel adhesion, bubble resistance and black spot defect resistance after an enameling treatment, and the like.

[0005] Fish scaling is a phenomenon in which an enamel layer is damaged and crescent fragments are peeled off for approximately one week after baking. A reason for the occurrence of fish scaling is considered to be because hydrogen that has intruded into a steel sheet and formed a solid solution in the process of enamel baking or the like turns into a gas after cooling and gathers at the interface between the steel sheet and a glaze, and an enamel layer is fractured due to pressure attributed to the hydrogen gas.

[0006] In addition, for enameled products, there is a demand for high-strengthening of steel sheets to be used for the purpose of a reduction in the weight of components in some applications. The reason for this is that a burden on an operator can be reduced or the number of operators can be reduced in a case where the weight of components is reduced, which leads to a reduction in cost.

[0007] With regard to the high-strengthening of an enameled product, for example, Patent Document 1 discloses a technique for achieving high-strengthening by adding Ti to steel and finely precipitating TiC in a steel sheet during enamel baking (a baking step in an enameling treatment). Further, Patent Document 2 discloses a technique for refining grain sizes before and after enamel baking by optimizing the contents of C, Mn, P, and Nb to achieve high-strengthening and high-fatigue-strengthening.

[0008] However, in the technique disclosed in Patent Document 1, surface defects called bubbles or black spots are likely to occur in a case where the steel sheet is subjected to an enameling treatment. Further, since TiC is hardly generated sufficiently in a short-time heat treatment during the baking, fish scaling defects are likely to occur.

[0009] Furthermore, the technique disclosed in Patent Document 2 is premised on dry enameling in which a pretreatment, such as pickling or a Ni treatment, is not

performed. In wet enameling requiring a pretreatment, fish scaling defects are likely to occur due to a deterioration of enamel adhesion.

## PRIOR ART DOCUMENT

Patent Document

[0010] Patent Document 1: Japanese Unexamined Patent Application, First Publication No. S61-117246

[0011] Patent Document 2: Japanese Unexamined Patent Application, First Publication No. S58-31063

## DISCLOSURE OF THE INVENTION

## Problems to be Solved by the Invention

[0012] As described above, an enameled product having high strength and excellent enamel properties (fish scaling resistance, adhesion, and external appearance) and a steel sheet for vitreous enameling that is a material of the enameled product have not been disclosed in the related art.

[0013] Accordingly, an object of the present invention is to provide a steel sheet in which high strength and excellent enamel properties (fish scaling resistance, adhesion, and external appearance) are obtained after an enameling treatment. Further, another object of the present invention is to provide an enameled product that includes the steel sheet and has excellent enamel properties.

## Means for Solving the Problem

[0014] The present inventors investigated a method of improving the tensile strength of a steel sheet subjected to an enameling treatment while making the steel sheet have enamel properties (fish scaling resistance, adhesion (enamel adhesion), and external appearance after the enameling treatment) equivalent to or higher than those of a steel sheet for vitreous enameling in the related art. As a result, the following findings were obtained regarding the influence of a chemical composition and manufacturing conditions.

[0015] 1) The utilization of solid solution strengthening caused by P is effective for improving the strength of the steel sheet.

[0016] 2) On the other hand, in a case where P is contained, pickling weight loss is significantly increased, and the surface of a steel sheet is covered with smut in a pickling step of an enameling pretreatment, so that adhesion and fish scaling resistance after the enameling treatment deteriorate.

[0017] 3) In contrast, Sn and Sb adhere to the surface of the steel sheet in the pickling step and have an effect of delaying the melting of the surface of the steel sheet.

[0018] 4) For that reason, in a case where the Sn content and/or the Sb content is controlled in a predetermined range with respect to the P content, it is possible to suppress an increase in pickling weight loss while obtaining an effect of solid solution strengthening caused by P.

[0019] The present invention has been made on the basis of the above findings. The gist of the present invention is as follows.

[0020] [1] A steel sheet according to an aspect of the present invention includes, as a chemical composition, by mass %: C: 0.0050% or less; Si: 0.050% or less; Mn: 0.007% to 1.00%; P: 0.020% to 0.200%; S: 0.005% to 0.050%; Al:

0.010% or less; O: 0.0100% to 0.1000%; Cu: 0.010% to 0.060%; N: 0.0050% or less; Cr: 0.010% to 1.00%; one or two of Sn: 0.010% to 1.00% and Sb: 0.010% to 1.00%: 0.11% or more in total; one or more selected from the group consisting of B, Ni, Nb, As, Ti, Mo, Se, Ta, W, La, Ce, Ca, and Mg: 0% to 0.100% in total; and a remainder: Fe and impurities, in which, in a case where a Sn content in mass % is denoted by [Sn], a Sb content in mass % is denoted by [Sb], and a P content in mass % is denoted by [P], Expression (1) is satisfied, and a tensile strength obtained in a tensile test performed in accordance with JIS Z2241:2011 is 340 MPa or more.

$$2.0 \leq ([\text{Sn}] + [\text{Sb}])/[\text{P}] \leq 11.5. \quad (1)$$

**[0021]** [2] In the steel sheet according to [1], the [Sn], the [Sb], and the [P] may satisfy Expression (2).

$$2.3 \leq ([\text{Sn}] + [\text{Sb}])/[\text{P}] \leq 11.0. \quad (2)$$

**[0022]** [3] In the steel sheet according to [1], a yield stress or a 0.2% proof stress obtained in the tensile test may be 240 MPa or more.

**[0023]** [4] In the steel sheet according to [2], a yield stress or a 0.2% proof stress obtained in the tensile test may be 240 MPa or more.

**[0024]** [5] The steel sheet according to any one of [1] to [4] may be a cold-rolled steel sheet.

**[0025]** [6] The steel sheet according to any one of [1] to [4] may be a steel sheet for vitreous enameling.

**[0026]** [7] The steel sheet according to [5] may be a steel sheet for vitreous enameling.

**[0027]** [8] An enameled product according to another aspect of the present invention has the chemical composition according to [1] or [2].

**[0028]** [9] In the enameled product according to [8], a tensile strength obtained in a tensile test performed in accordance with JIS Z2241:2011 may be 310 MPa or more.

#### Effects of the Invention

**[0029]** According to the aspect of the present invention, it is possible to provide a steel sheet in which high strength and excellent enamel properties (fish scaling resistance, adhesion, and external appearance) are obtained after an enameling treatment. The tensile strength of this steel sheet subjected to the enameling treatment is higher than that of a steel sheet for vitreous enameling in the related art subjected to the enameling treatment. For that reason, this steel is suitable as a steel sheet for vitreous enameling that is a substrate of an enameled product to be applied to kitchen appliances, building materials, energy fields, and the like, and contributes to a reduction in the weight of the product.

**[0030]** Further, according to the present invention, it is possible to provide an enameled product having high strength and excellent enamel properties. This enameled product is suitable for applications such as kitchen appliances, building materials, and energy fields.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0031]** FIG. 1 is a diagram showing a relationship between adhesion and “([Sn]+[Sb])/[P]”.

#### EMBODIMENTS OF THE INVENTION

**[0032]** A steel sheet according to an embodiment of the present invention (a steel sheet according to the present embodiment) and an enameled product according to an embodiment of the present invention (an enameled product according to the present embodiment) will be described.

[Steel Sheet]

**[0033]** A steel sheet according to the present embodiment has a predetermined chemical composition to be described later; satisfies “ $2.0 \leq ([\text{Sn}] + [\text{Sb}])/[\text{P}] \leq 11.5$ ” in a case where a Sn content in mass % is denoted by [Sn], a Sb content in mass % is denoted by [Sb], and a P content in mass % is denoted by [P]; and has a tensile strength of 340 MPa or more obtained in a tensile test performed in accordance with JIS Z2241:2011.

<Chemical Composition>

**[0034]** The chemical composition (chemical components) of the steel sheet according to the present embodiment will be described. % regarding the content of each element is mass % unless otherwise specified.

C: 0.0050% or Less

**[0035]** In a case where a C content exceeds 0.0050%, a bubble defect in the enamel tends to occur and press formability also deteriorates. Therefore, it is preferable that the C content be as low as possible in terms of product performance. However, in order to excessively reduce C, a long treatment time is required in a steelmaking step and steelmaking cost also increases. For that reason, the C content is set to 0.0050% or less in consideration of a balance between cost and properties. The C content is preferably 0.0040% or less, more preferably 0.0030% or less, and still more preferably 0.0020% or less.

**[0036]** The C content is preferably as low as possible in terms of product performance. However, the C content may be set to 0.0010% or more in consideration of steelmaking cost.

Si: 0.050% or Less

**[0037]** Si is a deoxidizing element. In a case where a Si content exceeds 0.050% and is excessive, it is difficult to control oxide effective for fish scaling resistance. For that reason, the Si content is set to 0.050% or less. From the viewpoint of improving bubble resistance, black spot resistance, and the like to obtain better surface properties after an enameling treatment, it is preferable that the Si content be set to 0.008% or less.

**[0038]** The Si content may be 0%. However, since an excessive reduction in the Si content causes an increase in cost, the Si content may be set to 0.001% or more.

Mn: 0.007% to 1.00%

**[0039]** Mn is an element that generates inclusions containing oxygen and contributes to the improvement of enamel properties, and is also an element that has an action

of preventing hot embrittlement caused by S. In order to obtain this effect, the Mn content is set to 0.007% or more. The Mn content is preferably 0.010% or more and more preferably 0.10% or more.

**[0040]** On the other hand, Mn is an element that has an action of lowering a transformation point of steel. In a case where the Mn content is excessive, transformation in a baking temperature range occurs. Further, the workability of steel also deteriorates. For that reason, the Mn content is set to 1.00% or less from these viewpoints. The Mn content is preferably 0.50% or less.

P: 0.020% to 0.200%

**[0041]** P is an element that has an action of increasing the strength of the steel sheet through solid solution strengthening. In a case where the P content is less than 0.020%, an effect of increasing strength through solid solution strengthening is small. For that reason, the P content is set to 0.020% or more. The P content is preferably 0.050% or more.

**[0042]** On the other hand, P is also an element that increases the pickling weight loss of the steel sheet during pickling in an enameling pretreatment. Further, P is also an element that significantly reduces the deformability of the steel sheet. For that reason, since these adverse influences are significant in a case where the P content exceeds 0.200%, the P content is set to 0.200% or less. The P content is preferably 0.0150% or less.

S: 0.005% to 0.050%

**[0043]** S is an element that has an effect of increasing pickling rate and roughening the surface of the steel sheet after pickling to improve enamel adhesion. In order to obtain this effect, the S content is set to 0.005% or more. The S content is preferably 0.010% or more.

**[0044]** On the other hand, in a case where the S content is excessive, an effect of Mn required to control oxide contained in steel may be reduced. For that reason, the S content is set to 0.050% or less.

Al: 0.010% or Less

**[0045]** Al is a strong deoxidizing element. In a case where the Al content exceeds 0.010%, it is difficult to retain a required amount of O (oxygen) in steel. As a result, it is difficult to control oxide effective for fish scaling resistance. For that reason, the Al content is set to 0.010% or less. The Al content is preferably 0.005% or less.

**[0046]** A lower limit of the Al content does not need to be limited, but the Al content may be 0.001% or more from the viewpoint of controlling the amount of oxygen.

O: 0.0100% to 0.1000%

**[0047]** O is a constituent element of fine inclusions that capture hydrogen contained in steel to improve fish scaling resistance and is an important element in a steel sheet for vitreous enameling. In the steel sheet according to the present embodiment, the O content is set to 0.0100% or more in order to ensure desired enamel properties. In a case where the O content is less than 0.0100%, inclusions are not sufficiently formed and fish scaling resistance is reduced. The O content is preferably 0.0120% or more, more preferably 0.0150% or more, and still more preferably 0.0200% or more.

**[0048]** On the other hand, in a case where the O content is excessively high, the ductility of the steel sheet deteriorates. For that reason, the O content is set to 0.1000% or less. The O content is preferably 0.0800% or less.

Cu: 0.010% to 0.060%

**[0049]** Cu is an element that reduces pickling weight loss and forms fine irregularities on the surface of the steel sheet subjected to pickling and improves adhesion (enamel adhesion). In a case where the Cu content is less than 0.010%, an effect of improving adhesion is not sufficient. For that reason, the Cu content is set to 0.010% or more. The Cu content is preferably 0.015% or more, and more preferably 0.020% or more.

**[0050]** On the other hand, in a case where the Cu content exceeds 0.060%, the melting rate of steel is too low. As a result, the above-described irregularities are not sufficiently formed. In this case, it is not possible to obtain good enamel adhesion. Therefore, the Cu content is set to 0.060% or less. The Cu content is preferably 0.050% or less.

One or Two of Sn: 0.010% to 1.00% and Sb: 0.010% to 1.00%: 0.11% or More in Total

Sn and Sb are elements that have an effect of increasing the strength of the steel sheet through solid solution strengthening and an effect of reducing pickling rate. For that reason, one or two of Sn and Sb are contained. However, in a case where each of the Sn content and the Sb content is less than 0.010% or the total content of Sn and Sb is less than 0.11%, an effect of increasing the strength of the steel sheet cannot be sufficiently obtained. For that reason, in a case where Sn and Sb are to be contained, each of the Sn content and the Sb content is set to 0.010% or more and the total content of Sn and Sb is set to 0.11% or more. Each of the Sn content and the Sb content is preferably 0.04% or more or 0.07% or more. The total content of Sn and Sb is preferably 0.14% or more.

**[0051]** On the other hand, in a case where the Sn content and the Sb content exceed 1.00%, the deformability of the steel sheet deteriorates. Therefore, each of the Sn content and the Sb content is set to 1.00% or less. Each of the Sn content and the Sb content is preferably 0.80% or less. An upper limit of the total content of Sn and Sb is 2.00%, which is the sum of upper limits of the Sn content and the Sb content.

N: 0.0050% or Less

**[0052]** N is an element that causes strain ageing. In a case where strain ageing is caused, the workability of the steel sheet is impaired. For that reason, the N content is preferably as low as possible. However, since N may be mixed as an impurity, a long treatment time in a steelmaking step is required and steelmaking cost is also increased in order to excessively reduce the N content. For that reason, the N content is set to 0.0050% or less in consideration of a balance between cost and properties. The N content is preferably 0.035% or less. From the viewpoint of steelmaking cost, the N content may be set to 0.0005% or more or 0.0010% or more.

Cr: 0.010% to 1.00%

**[0053]** Cr is an element that generates inclusions containing O and contributes to the improvement of fish scaling

resistance. In a case where the Cr content is less than 0.010%, a sufficient effect cannot be obtained. For that reason, the Cr content is set to 0.010% or more. The Cr content is preferably 0.03% or more.

**[0054]** On the other hand, in a case where the Cr content exceeds 1.00%, workability deteriorates and black spot resistance is reduced. For that reason, the Cr content is set to 1.00% or less. The Cr content is preferably 0.50% or less, more preferably 0.30% or less, and still more preferably 0.08% or less.

$$([\text{Sn}] + [\text{Sb}])/[\text{P}]: 2.0 \text{ to } 11.5$$

**[0055]** In the steel sheet according to the present embodiment, each of the Sn content, the Sb content, and the P content is set in the above-described range in the chemical composition, and “ $([\text{Sn}] + [\text{Sb}])/[\text{P}]$ ” is controlled to satisfy a range of 2.0 to 11.5 in a case where the Sn content is denoted by [Sn], the Sb content is denoted by [Sb], and the P content is denoted by [P] by mass %.

**[0056]** In an enameling pretreatment step including degreasing, pickling, and a Ni treatment. Cu is precipitated on the surface of the steel sheet by the pickling and Ni is precipitated using Cu as a precipitation nucleus in the Ni treatment, so that a local battery is formed using a potential difference between a steel sheet base material and Ni. Accordingly, since an anchor effect in which an enamel layer, which is formed in a case where a glaze is applied to the steel sheet and the steel sheet is then baked, is embedded in a primary phase is obtained, enamel adhesion can be improved. Since the enamel adhesion is affected by the pickling weight loss of the surface of the steel sheet in pickling, the control of the pickling weight loss is important.

**[0057]** Sn and Sb have an action of reducing pickling weight loss. In contrast, P has an action of increasing pickling weight loss. In order to improve adhesion on the basis of the influences of these elements on each other, the Sn content, the Sb content, and the P content are adjusted so that “ $([\text{Sn}] + [\text{Sb}])/[\text{P}]$ ”, which is a ratio of the total content of Sn and Sb to the P content, is 2.0 or more and 11.5 or less.

**[0058]** In a case where “ $([\text{Sn}] + [\text{Sb}])/[\text{P}]$ ” is less than 2.0, pickling weight loss during the enameling pretreatment is small. For this reason, the amount of Cu to be used for displacement plating on the surface of the steel sheet is reduced, so that the amount of Ni to be precipitated using Cu as a nucleus during the Ni treatment is reduced. As a result, an anchor effect caused by the penetration of the enamel layer into a base metal during baking cannot be obtained. “ $([\text{Sn}] + [\text{Sb}])/[\text{P}]$ ” is preferably 2.3 or more, more preferably 2.5 or more, still more preferably 3.0 or more, and even more preferably 3.5 or more.

**[0059]** On the other hand, in a case where “ $([\text{Sn}] + [\text{Sb}])/[\text{P}]$ ” exceeds 11.5, pickling weight loss is increased. For this reason, the surface of the steel sheet is covered with smut containing Cu. As a result, an anchor effect caused by the penetration of the enamel layer into a base metal during baking cannot be obtained. “ $([\text{Sn}] + [\text{Sb}])/[\text{P}]$ ” is preferably 11.0 or less and more preferably 10.0 or less.

**[0060]** FIG. 1 is a diagram showing a relationship between the adhesion (enamel adhesion) and “ $([\text{Sn}] + [\text{Sb}])/[\text{P}]$ ”.

**[0061]** Total content of one or more of B, Ni, Nb, As, Ti, Se, Ta, W, Mo, La, Ce, Ca, and Mg: 0.100% or less

**[0062]** B, Ni, Nb, As, Ti, Se, Ta, W, Mo, La, Ce, Ca, and Mg are elements that react with oxide-forming elements. In a case where the total content of these elements exceeds 0.100%, it is difficult to control oxide to a state where the oxide is preferable for enamel properties. Further, in a case where these elements act as deoxidizing elements, there is a case where these elements affect the value of free oxygen and it is difficult to adjust free oxygen. For that reason, it is preferable that an upper limit of the content of each element be set within a range in which the value of free oxygen in a casting step is not affected.

**[0063]** For that reason, the total content of these elements is set to 0.100% or less. The total content is preferably 0.050% or less and more preferably 0.010% or less.

**[0064]** These elements do not need to be actively contained and may be contained as impurities. However, the elements are allowed to be contained in a range of the upper limit or less as described above. These elements are generally rarely mixed alone and, for example, two or more thereof, such as Mo and Ni, are often mixed.

Remainder: Fe and Impurities

**[0065]** The chemical composition of the steel sheet according to the present embodiment includes the above-described elements, and the remainder includes Fe and impurities. The impurities mean elements that are mixed from ore or scraps as a raw material, manufacturing environments, or the like in a case where a base steel sheet is industrially manufactured and are allowed to be contained within the contents allowing the action of the steel sheet according to the present embodiment not to be adversely affected.

<Metallographic Structure>

**[0066]** A microstructure (metallographic structure) of the steel sheet according to the present embodiment includes ferrite as a main component (for example, 98% or more), as in a steel sheet for vitreous enameling in the related art. For that reason, it is effective to use solid solution strengthening in order to improve a tensile strength.

**[0067]** In a case where the steel sheet according to the present embodiment is worked and applied to an enameled product, grain growth of ferrite occurs due to a heat treatment (enameling treatment) and a grain size is increased. As a result, a yield stress and a tensile strength are reduced. For that reason, it is effective to use solid solution strengthening caused by P in order to ensure the tensile strength of the steel sheet subjected to the heat treatment (subjected to the enameling treatment).

**[0068]** On the other hand, in a case where P is contained, pickling weight loss during the enameling pretreatment is excessive. As a result, it is difficult to obtain excellent enamel properties (fish scaling resistance, adhesion, and external appearance). For that reason, as described above, Sn and Sb are contained as elements for reducing pickling weight loss to adjust pickling weight loss.

<Mechanical Properties>

**[0069]** The tensile strength of the steel sheet according to the present embodiment is set to 340 MPa or more so that a tensile strength of 310 MPa or more is obtained from a steel sheet (enameled product) subjected to the enameling treatment. In a case where the tensile strength of the steel sheet

subjected to the enameling treatment is 310 MPa or more, the steel sheet contributes to a reduction in the weight of a component in the enameled product.

[0070] An upper limit of the tensile strength is not limited, but the tensile strength may be 600 MPa or less from the viewpoint of workability.

[0071] In the present embodiment, the tensile strength is obtained in the tensile test performed in accordance with JIS Z2241:2011.

[0072] It is preferable that the steel sheet according to the present embodiment further have a yield stress (YS) or a 0.2% proof stress (0.2% PS) of 240 MPa or more. In this case, since the plastic deformation of the steel sheet in a case where the steel sheet is used as an enameled product is suppressed, the steel sheet can be thinned.

[0073] In a case where cold rolling is performed, voids are generated at interfaces between oxide and a base metal and fish scaling resistance after the enameling treatment is improved. For that reason, it is preferable that the steel sheet according to the present embodiment be a cold-rolled steel sheet.

[0074] Further, the steel sheet according to the present embodiment is excellent in terms of enamel properties. For that reason, it is preferable that the steel sheet according to the present embodiment be used as a steel sheet for vitreous enameling, which is a material for enameled products.

#### [Enameled Product]

[0075] The enameled product according to the present embodiment includes a steel sheet having the above-described chemical composition. For example, the enameled product according to the present embodiment is an enameled product obtained in a case where the steel sheet according to the present embodiment is subjected to an enameling treatment and is worked as necessary.

#### [Manufacturing Method for Steel Sheet]

[0076] The effects are obtained as long as the steel sheet according to the present embodiment has the above-described properties regardless of a manufacturing method. However, since the steel sheet can be stably manufactured according to a manufacturing method including the following steps, the method is preferable.

[0077] (I) a steelmaking and casting step of manufacturing a steel piece having the above-described chemical composition with melting, refining, and casting;

[0078] (II) a hot rolling step of heating the obtained steel piece, performing hot rolling on the steel piece, and coiling to obtain a steel sheet (hot-rolled steel sheet);

[0079] (III) as necessary, a cold rolling step of performing cold rolling on the steel sheet, which has been subjected to the hot rolling step to obtain a steel sheet (cold-rolled steel sheet);

[0080] (IV) as necessary, an annealing step of annealing the steel sheet, which has been subjected to the cold rolling step (cold-rolled steel sheet) and

[0081] (V) as necessary, a temper rolling step of performing temper rolling on the steel sheet, which has been subjected to the annealing step.

[0082] Preferred conditions for each step will be described. Generally known conditions can be applied as conditions and steps not described.

#### <Steelmaking and Casting Step>

[0083] In the steelmaking and casting step, a steel piece having the above-described chemical composition is manufactured with melting, refining, and casting. Conditions for the steelmaking and casting step are not particularly limited. For example, a steel piece manufactured using a continuously cast slab or a thin slab caster can be used as the steel piece, and is also suitable for a process such as continuous casting-direct rolling (CC-DR) in which hot rolling is performed immediately after casting. Further, a process for directly manufacturing a thin steel sheet with a strip caster and an inline mill can also be applied.

#### <Hot Rolling Step>

[0084] In the hot rolling step, the obtained steel piece is heated, subjected to hot rolling, and coiled to obtain a steel sheet (hot-rolled steel sheet).

[0085] It is preferable that a heating temperature be set to 1150° C. to 1250° C. in the heating of the steel piece performed prior to the hot rolling. Since the amount of generated primary scale is large in a case where the heating temperature exceeds 1250° C., a yield is reduced. On the other hand, in a case where the heating temperature is lower than 1150° C., a rolling load is increased due to a decrease in temperature during rolling.

[0086] In the hot rolling step, oxide, which is generated in the steelmaking and casting step and contains Fe and Mn, is elongated by the hot rolling. In a case where a cumulative rolling reduction in the finish rolling of the hot rolling is set to 30% or more, it is possible to sufficiently elongate the oxide contained in the steel and containing Fe and Mn. In a case where the cumulative rolling reduction exceeds 90%, good fish scaling resistance may not be capable of being obtained since the oxide contained in the steel is excessively elongated. For that reason, it is preferable that the cumulative rolling reduction in the finish rolling be set to 30% to 90%.

[0087] Further, it is preferable that a finish temperature (finish rolling-completion temperature) in the hot rolling be set to 900° C. to 950° C. In a case where the finish temperature in the hot rolling is less than 900° C., rolling is performed at a temperature equal to or lower than a transformation point. For this reason, since mechanical properties, such as ductility, of a product deteriorate and the strength of the steel sheet is significantly changed, rolling is likely to be unstable. Furthermore, in a case where the finish temperature is less than 900° C., the microstructure of the hot-rolled steel sheet becomes a duplex grain including coarse grains. Accordingly, there is also a concern that ridging may occur on a cold-rolled and annealed sheet using this hot-rolled steel sheet after working. For that reason, it is preferable that the finish temperature be 900° C. or higher. On the other hand, in a case where the finish temperature exceeds 950° C. a grain size is coarse. Accordingly, it is difficult to ensure a desired strength. For that reason, it is preferable that the finish temperature be 950° C. or lower.

[0088] In addition, since the steel sheet according to the present embodiment uses solid solution strengthening of P, Sb, and Sn, it is preferable that the steel sheet be cooled at an average cooling rate of 15° C./sec or higher from the completion of the hot rolling to the start of the coiling. In a case where an average cooling rate to the start of coiling is

lower than 15° C./sec, a sufficient amount of solid solution cannot be obtained and the strength of the steel sheet is reduced.

**[0089]** It is preferable that a coiling temperature be 500° C. to 600° C. In a case where the coiling temperature is lower than 500° C., it is difficult for microstructural morphology, which has been subjected to the cold rolling and continuous annealing, to ensure ductility and an r value required for working. On the other hand, in a case where the coiling temperature exceeds 600° C., a large amount of Fe—P-based compounds are precipitated. For this reason, it is difficult to ensure a desired strength of the steel sheet.

#### <Cold Rolling Step>

**[0090]** In a case where the steel sheet according to the present embodiment is a cold-rolled steel sheet, the steel sheet subjected to the hot rolling (hot-rolled steel sheet) is subjected to pickling and then subjected to cold rolling, as necessary.

**[0091]** A cold rolling ratio in cold rolling (a cumulative rolling reduction in the cold rolling step) is important for determining the properties of a product and is preferably 65% to 85%. The oxide, which is formed in the steelmaking and casting step and contains Fe and Mn, is elongated in the hot rolling step according to the cumulative rolling reduction. After that, the oxide is further elongated in the cold rolling step. However, since the cold rolling is working to be performed at a maximum of about 150° C. and the above-described oxide is hard, it is difficult to elongate the oxide. Therefore, in order to appropriately elongate the oxide, it is preferable to perform the cold rolling with a cold rolling ratio of 65% or more. At this time, cavities are generated at both end portions of the oxide in a rolling direction. The presence of the cavities effectively acts on fish scaling resistance, but adversely affects ductility. For that reason, the presence of more cavities than necessary causes a decrease in ductility and thus a decrease in workability. Therefore, the cold rolling ratio is set to 90% or less.

#### <Annealing Step>

**[0092]** Annealing may be performed on the cold-rolled steel sheet. In a case where the annealing is performed, it is preferable that an annealing temperature be set to 650° C. to 850° C. In a case where the annealing temperature is lower than 650° C., recovery and recrystallization are not completed. For this reason, there is a concern that the mechanical properties of the steel sheet may significantly change in a case where the annealing temperature varies. Further, the strength of the steel sheet is increased, so that the ductility of the steel sheet decreases and the workability of the steel sheet deteriorates. On the other hand, the annealing temperature may be set to be lower than 650° C. for the purpose of imparting characteristic mechanical properties, such as strength, to the steel sheet.

**[0093]** Further, in a case where the annealing temperature exceeds 850° C., ductility or the like is improved as mechanical properties. Accordingly, it is preferable that the annealing temperature exceed 850° C. However, the cavities generated in the cold rolling step are likely to be eliminated by diffusion, and fish scaling resistance deteriorates. For this reason, it is preferable that the annealing temperature be 850° C. or lower.

**[0094]** In terms of productivity, it is preferable that the annealing be continuous annealing.

#### <Temper Rolling Step>

**[0095]** After the annealing step, temper rolling may be performed primarily for the purpose of controlling the shape. In the temper rolling, the amount of strain introduced into the steel sheet changes depending on a temper rolling ratio at the same time as the control of the shape. At this time, in a case where the temper rolling ratio is increased, that is, the amount of strain introduced into the steel sheet is increased, abnormal grain growth during the enameling treatment is promoted. For this reason, it is not desirable to apply more strain than necessary in a state where a rolling ratio at which the shape can be controlled is set as an upper limit of the temper rolling ratio. From the viewpoint of controlling the shape, it is desirable that a rolling ratio in the temper rolling be 1.5% or less.

#### [Manufacturing Method for Enameled Product]

**[0096]** The steel sheet according to the present embodiment (for example, the hot-rolled steel sheet subjected to the hot rolling step, or the cold-rolled steel sheet subjected to the annealing step, or the cold-rolled steel sheet subjected to temper rolling) is assembled into a product shape by welding or the like after being worked into a predetermined shape and is subjected to the enameling treatment (baking treatment), so that the enameled product according to the present embodiment is obtained.

**[0097]** In the enameling treatment, for example, the steel sheet coated with a glaze may be heated to a predetermined temperature and held for a predetermined time to cause a glassy substance of the glaze and the steel sheet to adhere to each other. As preferred baking conditions for the steel sheet according to the present embodiment, for example, it is preferable that a baking temperature be in a range of 700° C. to 900° C. and a baking time be in a range of 1.5 to 20 minutes (in a furnace). In addition, baking may be repeated several times for double coating and repair. In a case where a baking treatment is performed under such conditions, grain growth during the enameling treatment is suppressed by oxide and iron carbide and a reduction in strength can be suppressed. The conditions for the baking treatment described herein are merely examples and do not limit the conditions for the enameling treatment for the steel sheet according to the present embodiment.

#### Examples

**[0098]** Steel having a chemical composition (the remainder includes Fe and impurities) including chemical components shown in Tables 1A and 1B was melted in a converter and then cast into slabs by continuous casting.

**[0099]** These slabs were heated to 1200° C., subjected to hot rolling including finish rolling under the conditions shown in Table 2, cooled to coiling temperatures shown in Table 2 at average cooling rates shown in Table 2, and coiled, so that hot-rolled steel sheets were obtained.

**[0100]** Then, the hot-rolled steel sheets were pickled and then subjected to cold rolling with a cumulative rolling reduction of 80%, so that cold-rolled steel sheets were obtained.

**[0101]** After that, continuous annealing was performed in a state where an annealing temperature was set to 750° C.

**[0102]** After the continuous annealing, temper rolling was performed with a rolling ratio of 0.5%, so that steel sheets (cold-rolled steel sheets) having a sheet thickness of 0.7 mm were obtained.

**[0103]** Tensile properties of the obtained steel sheets were evaluated in the following manner.

[Tensile Properties of Steel Sheets]

**[0104]** No. 5 test pieces were collected in the rolling direction and a tensile test was performed in accordance with JIS Z2241:2011 to obtain a tensile strength (TS) and a yield stress (YS) or a 0.2% proof stress (0.2% PS).

**[0105]** In a case where the tensile strength was 340 MPa or more, it was determined that the steel sheet had high strength.

**[0106]** Further, in order to evaluate the properties of the obtained steel sheets subjected to the enameling treatment (corresponding to the properties of the enameled product), tensile properties and enamel properties (fish scaling resistance, enamel adhesion, and external appearance after the enameling treatment) were evaluated in the following manner.

[Tensile Properties after Enameling Treatment]

**[0107]** The obtained steel sheets were subjected to a heat treatment simulating enameling at a furnace temperature of 860° C. for 5 minutes.

**[0108]** A No. 5 test piece was collected in the rolling direction from each of the steel sheets subjected to the heat treatment and a tensile test was performed in accordance with JIS Z2241:2011 to obtain a tensile strength (TS) and a yield stress (YS) or a 0.2% proof stress (0.2% PS).

**[0109]** In a case where the tensile strength was 310 MPa or more, it was determined that the steel sheet had high strength.

[Fish Scaling Resistance]

**[0110]** Samples having a size of 150 mm×100 mm were collected from the obtained steel sheets and, as a pretreatment, the samples were subjected to alkaline degreasing, immersed in a 15 g/L nickel sulfate solution having a temperature of 70° C. for 7 minutes, and then subjected to a neutralization treatment.

**[0111]** After that, both surfaces of the samples were glazed to 100 μm with a 102 #glaze manufactured by Ferro Enamels (Japan) Limited, and the samples were baked at 860° C. for 5 minutes in an atmosphere having a dew point of 35° C.

**[0112]** The baked samples were heated by being held at 150° C. for 20 hours, and the occurrence state of fish scaling was visually observed and evaluated.

**[0113]** Evaluation criteria were as follows: S was defined as “particularly excellent”, A was defined as “excellent”, B was defined as “normal”, and C was defined as “problematic” and determined to be a failure.

**[0114]** S: The number of positions at which fish scaling occurred was 5 or less per surface.

**[0115]** A: The number of positions at which fish scaling occurred was 6 to 10 per surface.

**[0116]** B: The number of positions at which fish scaling occurred was 11 to 20 per surface.

**[0117]** C: The number of positions at which fish scaling occurred was 21 or more per surface.

[Enamel Adhesion]

**[0118]** Samples having a size of 150 mm×100 mm were collected from the obtained steel sheets and, as a pretreatment, the samples were subjected to alkaline degreasing, immersed in a 10% sulfuric acid solution having a temperature of 70° C. for 10 minutes, immersed in a 15 g/L nickel sulfate solution having a temperature of 70° C. for 7 minutes, and then subjected to a neutralization treatment.

**[0119]** After that, both surfaces of the samples were glazed 100 μm with a 102 #glaze manufactured by Ferro Enamels (Japan) Limited, and the samples were baked at 860° C. for 5 minutes in an atmosphere having a dew point of 35° C.

**[0120]** A weight of 2 kg with a spherical head was dropped from a height of 1 m onto the baked sample, and the enamel peeling state of a deformed portion was measured with 169 tactile probes and was evaluated with the area ratio of an unpeeled portion.

**[0121]** Evaluation criteria were as follows: A was defined as “excellent”, B was defined as “normal”, and C was defined as “problematic” and determined to be a failure.

**[0122]** A: The area ratio of the unpeeled portion was 90% or more.

**[0123]** B: The area ratio of the unpeeled portion was 85% or more and less than 90%.

**[0124]** C: The area ratio of the unpeeled portion was less than 85%.

[External Appearance]

**[0125]** Samples having a size of 150 mm×100 mm were collected from the steel sheets and, as a pretreatment, the samples were subjected to alkaline degreasing, immersed in a 15 g/L nickel sulfate solution having a temperature of 70° C. for 7 minutes, and then subjected to a neutralization treatment.

**[0126]** After that, both surfaces of the samples were glazed to 100 μm with a 102 #glaze manufactured by Ferro Enamels (Japan) Limited, and the samples were baked at 860° C. for 5 minutes in an atmosphere having a dew point of 35° C.

**[0127]** The external appearance of the baked sample was visually observed, and the state of bubbles and black spots was evaluated.

**[0128]** A case where even one bubble or black spot was generated was evaluated as the generation of bubbles or black spots, and a case where no bubble or black spot was generated was evaluated as no problem.

TABLE 1A

Steel No.	Chemical component (mass %)														Other elements
	C	Si	Mn	P	S	Al	O	Cu	N	Cr	Sn	Sb	Sn + Sb	([Sn] + [Sb])/[P]	
A1	0.0050	0.012	0.31	0.043	0.006	0.002	0.0154	0.022	0.0033	0.06	0.09	0.07	0.16	3.7	
A2	0.0022	0.001	0.23	0.171	0.012	0.004	0.0623	0.014	0.0021	0.25	0.25	0.10	0.35	2.0	
A3	0.0041	0.050	0.88	0.128	0.009	0.003	0.0345	0.035	0.0014	0.59	0.21	0.38	0.59	4.6	

Nb: 0.05,  
Ti: 0.03

TABLE 1A-continued

Steel No.	Chemical component (mass %)													([Sn] + [Sb])/ [P]	Other elements
	C	Si	Mn	P	S	Al	O	Cu	N	Cr	Sn	Sb	Sn + Sb		
A4	0.0029	0.021	0.007	0.082	0.026	0.005	0.0775	0.053	0.0042	0.31	0.53	0.31	0.84	10.2	
A5	0.0036	0.005	1.00	0.113	0.011	0.008	0.0446	0.035	0.0039	0.07	0.01	0.64	0.65	5.8	
A6	0.0013	0.033	0.54	0.020	0.042	0.004	0.0843	0.053	0.0031	0.28	0.14	0.09	0.23	11.3	
A7	0.0019	0.002	0.23	0.200	0.018	0.005	0.0523	0.042	0.0038	0.47	0.42	0.53	0.95	4.8	B: 0.002, As: 0.002
A8	0.0027	0.015	0.45	0.034	0.005	0.002	0.0420	0.034	0.0029	0.32	0.21	0.13	0.34	10.0	Ca: 0.004, Se: 0.002
A9	0.0031	0.024	0.82	0.121	0.050	0.003	0.0872	0.033	0.0045	0.03	0.13	0.35	0.48	4.0	Mo: 0.008
A10	0.0016	0.009	0.68	0.076	0.036	0.010	0.0557	0.029	0.0035	0.86	0.04	0.53	0.57	7.5	
A11	0.0022	0.008	0.33	0.119	0.019	0.005	0.0100	0.042	0.0031	0.45	0.24	0.23	0.47	3.9	
A12	0.0039	0.003	0.62	0.174	0.038	0.004	0.1000	0.049	0.0012	0.63	0.53	0.65	1.18	6.8	
A13	0.0014	0.035	0.16	0.132	0.009	0.006	0.0489	0.010	0.0043	0.32	0.35	0.64	0.99	7.5	Ni: 0.08, Ce: 0.07
A14	0.0037	0.033	0.011	0.082	0.008	0.002	0.0325	0.060	0.0024	0.04	0.64	0.01	0.65	7.9	
A15	0.0028	0.045	0.59	0.149	0.013	0.008	0.0143	0.034	0.0050	0.19	0.15	0.21	0.36	2.4	W: 0.005, Ta: 0.003
A16	0.0019	0.014	0.42	0.133	0.034	0.003	0.0204	0.049	0.0029	0.010	0.53	0.46	0.99	7.4	
A17	0.0013	0.037	0.25	0.089	0.026	0.004	0.0763	0.034	0.0012	1.00	0.14	0.88	1.02	11.5	
A18	0.0028	0.009	0.79	0.182	0.019	0.006	0.0586	0.041	0.0009	0.42	0.010	0.67	0.68	3.7	
A19	0.0015	0.002	0.29	0.113	0.032	0.003	0.0639	0.033	0.0024	0.32	1.00	0.11	1.11	9.8	Mg: 0.006
A20	0.0044	0.006	0.14	0.098	0.044	0.002	0.0762	0.029	0.0043	0.52	0.53	0.010	0.54	5.5	La: 0.002
A21	0.0024	0.028	0.02	0.115	0.013	0.001	0.0452	0.022	0.0036	0.32	0.04	1.00	1.04	9.0	
A22	0.0011	0.003	0.34	0.127	0.009	0.007	0.0230	0.012	0.0029	0.62	0.35	0.13	0.48	3.8	
A23	0.0033	0.005	0.29	0.082	0.007	0.004	0.0353	0.015	0.0033	0.47	0.21	0.24	0.45	5.5	
A24	0.0019	0.034	0.58	0.035	0.022	0.005	0.0564	0.027	0.0018	0.21	0.04	0.07	0.11	3.1	

TABLE 1B

Steel No.	Chemical component (mass %)													([Sn] + [Sb])/ [P]	Other elements
	C	Si	Mn	P	S	Al	O	Cu	N	Cr	Sn	Sb	Sn + Sb		
a1	0.0100	0.005	0.25	0.039	0.009	0.003	0.0452	0.023	0.0022	0.63	0.11	0.06	0.17	4.4	
a3	0.0012	0.064	0.42	0.032	0.032	0.006	0.0782	0.033	0.0042	0.13	0.21	0.11	0.32	10.0	
a4	0.0023	0.021	0.005	0.148	0.025	0.003	0.0569	0.029	0.0019	0.09	0.04	0.19	0.23	1.6	
a5	0.0029	0.015	1.28	0.042	0.019	0.005	0.0421	0.053	0.0044	0.02	0.09	0.26	0.35	8.3	
a6	0.0015	0.009	0.29	0.017	0.013	0.001	0.0487	0.042	0.0039	0.26	0.06	0.11	0.17	10.0	
a7	0.0039	0.004	0.14	0.208	0.019	0.003	0.0581	0.039	0.0031	0.05	0.27	0.13	0.40	1.9	
a8	0.0028	0.012	0.42	0.138	0.004	0.002	0.0821	0.034	0.0027	0.53	0.34	0.32	0.66	4.8	Mg: 0.008
a9	0.0042	0.037	0.53	0.099	0.055	0.004	0.0482	0.047	0.0038	0.11	0.43	0.64	1.07	10.8	
a10	0.0033	0.043	0.12	0.067	0.023	0.011	0.0572	0.024	0.0017	0.76	0.12	0.32	0.44	6.6	
a11	0.0019	0.010	0.03	0.098	0.043	0.006	0.0095	0.018	0.0018	0.05	0.06	0.53	0.59	6.0	
a12	0.0014	0.009	0.23	0.022	0.029	0.007	0.1142	0.045	0.0025	0.16	0.10	0.04	0.14	6.4	
a13	0.0018	0.004	0.38	0.157	0.011	0.002	0.0532	0.009	0.0027	0.31	0.29	0.34	0.63	4.0	
a14	0.0025	0.003	0.12	0.064	0.019	0.004	0.0248	0.063	0.0017	0.05	0.39	0.33	0.72	11.3	
a15	0.0037	0.021	0.54	0.032	0.006	0.003	0.0482	0.043	0.0054	0.32	0.51	0.02	0.53	16.6	
a16	0.0045	0.035	0.39	0.132	0.028	0.007	0.0398	0.036	0.0034	0.008	0.23	0.67	0.90	6.8	
a17	0.0024	0.029	0.27	0.044	0.031	0.003	0.0830	0.021	0.0029	1.03	0.08	0.15	0.23	5.2	Mo: 0.008
a18	0.0036	0.008	0.32	0.028	0.021	0.002	0.0742	0.011	0.0048	0.43	0.008	0.04	0.05	1.7	
a19	0.0017	0.001	0.88	0.073	0.008	0.006	0.0538	0.038	0.0034	0.32	1.01	0.14	1.15	15.8	
a20	0.0029	0.004	0.22	0.022	0.017	0.004	0.0623	0.046	0.0021	0.48	0.14	0.009	0.15	6.8	
a21	0.0017	0.037	0.38	0.089	0.006	0.007	0.0342	0.033	0.0029	0.21	0.06	1.02	1.08	12.1	
a22	0.0019	0.002	0.68	0.088	0.022	0.003	0.0438	0.048	0.0033	0.12	0.08	0.07	0.15	1.7	
a23	0.0023	0.004	0.35	0.056	0.034	0.005	0.0629	0.019	0.0049	0.33	0.42	0.29	0.71	12.7	
a24	0.0033	0.021	0.150	0.066	0.019	0.008	0.0230	0.031	0.0013	0.07	0.05	0.04	0.09	1.4	

TABLE 2

Manufacturing method No.	Finish rolling				
	Slab heating temperature (° C.)	Cumulative rolling reduction (%)	End temperature (° C.)	Average cooling rate (° C./sec)	Coiling temperature (° C.)
B1	1223	84	900	22	583
B2	1245	65	950	16	534

TABLE 2-continued

Manufacturing method No.	Finish rolling				
	Slab heating temperature (° C.)	Cumulative rolling reduction (%)	End temperature (° C.)	Average cooling rate (° C./sec)	Coiling temperature (° C.)
B3	1194	72	942	15	576
B4	1218	56	928	19	500
B5	1167	38	933	23	600
B6	1230	47	941	25	546
B7	1214	54	918	31	521
b1	1243	75	955	22	572
b2	1228	37	933	13	526
b3	1221	67	924	24	612

TABLE 3A

				Tensile properties of steel sheet		Tensile properties after enameling treatment		Enamel properties		
	Sign	Steel No.	Manufacturing method No.	YS or		YS or		Fish scaling resistance	Adhesion	External appearance
				0.2% PS (MPa)	TS (MPa)	0.2% PS (MPa)	TS (MPa)			
Example of the invention	C1	A1	B2	246	357	221	320	S	A	No problem
	C2	A2	B4	401	486	343	417	S	B	No problem
	C3	A3	B4	446	539	381	451	S	A	No problem
	C4	A4	B1	378	476	306	372	S	A	No problem
	C5	A5	B1	438	533	372	442	S	A	No problem
	C6	A6	B1	252	364	227	327	S	B	No problem
	C7	A7	B1	528	601	429	475	S	A	No problem
	C8	A8	B3	276	388	242	335	S	A	No problem
	C9	A9	B3	410	506	353	429	S	A	No problem
	C10	A10	B3	372	479	317	395	S	A	No problem
	C11	A11	B3	376	470	319	395	A	A	No problem
	C12	A12	B5	563	640	455	495	S	A	No problem
	C13	A13	B5	465	547	376	429	S	A	No problem
	C14	A14	B5	348	443	287	361	S	B	No problem
	C15	A15	B5	410	495	355	431	A	B	No problem
	C16	A16	B4	477	567	388	441	S	A	No problem
	C17	A17	B4	435	528	351	409	S	B	No problem
	C18	A18	B6	502	582	423	482	S	A	No problem
	C19	A19	B6	467	556	374	425	S	A	No problem
	C20	A20	B2	353	450	296	372	S	A	No problem
	C21	A21	B2	446	536	356	410	S	A	No problem
	C22	A22	B7	386	478	328	402	S	A	No problem
	C23	A23	B7	332	433	283	365	S	A	No problem
	C24	A24	B3	251	361	231	333	S	B	No problem

TABLE 3B

				Tensile properties of steel sheet		Tensile properties after enameling treatment		Enamel properties		
	Sign	Steel No.	Manufacturing method No.	YS or		YS or		Fish scaling resistance	Adhesion	External appearance
				0.2% PS (MPa)	TS (MPa)	0.2% PS (MPa)	TS (MPa)			
Comparative Example	c1	a1	B2	242	357	217	316	S	A	Generation of bubbles or black spots
	c3	a3	B6	276	379	243	337	C	A	No problem
	c4	a4	B1	346	434	300	381	C	C	No problem
	c5	a5	B3	337	445	301	392	S	A	Occurrence of strain
	c6	a6	B2	220	336	199	301	S	B	No problem
	c7	a7	B3	440	517	373	440	C	C	No problem
	c8	a8	B7	432	518	361	427	C	C	No problem
	c9	a9	B4	467	553	378	432	C	B	No problem
	c10	a10	B2	312	410	267	351	C	A	No problem

TABLE 3B-continued

Sign	Steel No.	Manufacturing method No.	Tensile properties of steel sheet		Tensile properties after enameling treatment		Enamel properties		
			YS or	TS	YS or	TS	Fish scaling resistance	Adhesion	External appearance
			0.2% PS (MPa)	(MPa)	0.2% PS (MPa)	(MPa)			
c11	a11	B1	353	448	293	367	C	A	No problem
c12	a12	B5	217	332	197	299	S	B	No problem
c13	a13	B2	441	526	369	433	C	C	No problem
c14	a14	B7	344	445	282	355	C	C	No problem
c15	a15	B4	311	418	266	352	C	C	No problem
c16	a16	B6	464	545	379	436	C	A	No problem
c17	a17	B3	263	370	234	330	S	A	Generation of black spots
c18	a18	B2	215	329	199	304	C	C	No problem
c19	a19	B4	471	567	381	437	C	C	No problem
c20	a20	B1	218	334	197	300	S	A	No problem
c21	a21	B2	449	537	362	417	C	C	No problem
c22	a22	B5	312	415	280	373	C	C	No problem
c23	a23	B2	350	453	290	365	C	C	No problem
c24	A6	b1	212	328	187	287	S	B	No problem
c25	A8	b2	197	313	200	302	S	A	No problem
c26	A11	b3	222	340	199	298	A	A	No problem
c27	a24	B2	250	355	225	324	C	C	No problem

**[0129]** As can be seen from Tables 1A to 3B, in C1 to C24 that were examples of the present invention, a chemical composition was within a preferable range, a tensile strength was 340 MPa or more, and fish scaling resistance, adhesion, and external appearance were excellent.

**[0130]** In contrast, in Comparative Examples c1 to c23 and c27, a chemical composition was out of the range of the present invention, and a tensile strength was less than 340 MPa or one or more of fish scaling resistance, adhesion, and external appearance did not achieve the target.

**[0131]** Further, in Comparative Examples c24 to c26, since a chemical composition was within the range of the present invention but manufacturing conditions were out of preferable conditions, a tensile strength was less than 340 MPa.

#### INDUSTRIAL APPLICABILITY

**[0132]** According to the present invention, it is possible to provide a steel sheet in which high strength and excellent enamel properties (fish scaling resistance, adhesion, and external appearance) are obtained after an enameling treatment. The tensile strength of this steel sheet subjected to the enameling treatment is higher than that of a steel sheet for vitreous enameling in the related art subjected to the enameling treatment. For that reason, this steel is suitable as a steel sheet for vitreous enameling that is a substrate of an enameled product to be applied to kitchen appliances, building materials, energy fields, and the like, and contributes to a reduction in the weight of the product.

1. A steel sheet comprising, as a chemical composition, by mass %:

- C: 0.0050% or less;
- Si: 0.050% or less;
- Mn: 0.007% to 1.00%;
- P: 0.020% to 0.200%;
- S: 0.005% to 0.050%;
- Al: 0.010% or less;
- O: 0.0100% to 0.1000%;
- Cu: 0.010% to 0.060%;

N: 0.0050% or less;

Cr: 0.010% to 1.00%;

one or two of Sn: 0.010% to 1.00% and Sb: 0.010% to 1.00%; 0.11% or more in total;

one or more selected from the group consisting of B, Ni, Nb, As, Ti, Mo, Se, Ta, W, La, Ce, Ca, and Mg: 0% to 0.100% in total; and

a remainder: Fe and impurities,

wherein, in a case where a Sn content in mass % is denoted by [Sn], a Sb content in mass % is denoted by [Sb], and a P content in mass % is denoted by [P], Expression (1) is satisfied, and

a tensile strength obtained in a tensile test performed in accordance with JIS Z2241:2011 is 340 MPa or more,

$$2.0 \leq ([\text{Sn}] + [\text{Sb}])/[\text{P}] \leq 11.5. \quad (1)$$

2. The steel sheet according to claim 1, wherein the [Sn], the [Sb], and the [P] satisfy Expression (2),

$$2.3 \leq ([\text{Sn}] + [\text{Sb}])/[\text{P}] \leq 11.0. \quad (2)$$

3. The steel sheet according to claim 1, wherein a yield stress or a 0.2% proof stress obtained in the tensile test is 240 MPa or more.

4. The steel sheet according to claim 2, wherein a yield stress or a 0.2% proof stress obtained in the tensile test is 240 MPa or more.

5. The steel sheet according to claim 1, wherein the steel sheet is a cold-rolled steel sheet.

6. The steel sheet according to claim 1, wherein the steel sheet is a steel sheet for vitreous enameling.

7. The steel sheet according to claim 5, wherein the steel sheet is a steel sheet for vitreous enameling.

8. An enameled product comprising: the steel sheet having the chemical composition according to claim 1.

9. The enameled product according to claim 8, wherein a tensile strength obtained in a tensile test performed in accordance with JIS Z2241:2011 is 310 MPa or more.

10. The steel sheet according to claim 2, wherein the steel sheet is a cold-rolled steel sheet.

11. The steel sheet according to claim 3, wherein the steel sheet is a cold-rolled steel sheet.

12. The steel sheet according to claim 4, wherein the steel sheet is a cold-rolled steel sheet.

13. The steel sheet according to claim 2, wherein the steel sheet is a steel sheet for vitreous enameling.

14. The steel sheet according to claim 3, wherein the steel sheet is a steel sheet for vitreous enameling.

15. The steel sheet according to claim 4, wherein the steel sheet is a steel sheet for vitreous enameling.

16. The steel sheet according to claim 10, wherein the steel sheet is a steel sheet for vitreous enameling.

17. The steel sheet according to claim 11, wherein the steel sheet is a steel sheet for vitreous enameling.

18. The steel sheet according to claim 12, wherein the steel sheet is a steel sheet for vitreous enameling.

19. An enameled product comprising: the steel sheet having the chemical composition according to claim 2.

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