



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

(43) Date of publication:
09.05.2018 Bulletin 2018/19

(51) Int Cl.:
C22C 38/00 ^(2006.01) **C22C 38/50** ^(2006.01)
C22C 38/60 ^(2006.01) **C21D 9/46** ^(2006.01)

(21) Application number: **16850651.7**

(86) International application number:
PCT/JP2016/004336

(22) Date of filing: **26.09.2016**

(87) International publication number:
WO 2017/056471 (06.04.2017 Gazette 2017/14)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

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(30) Priority: **30.09.2015 JP 2015192442**

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(54) **FERRITE STAINLESS STEEL SHEET**

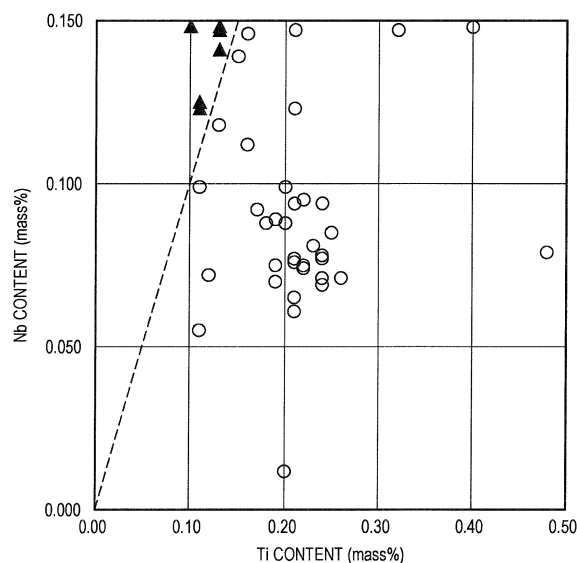
(57) Provided is a ferritic stainless steel sheet excellent in terms of corrosion resistance with which a decrease in the quantity of surface defects and an improvement in toughness are realized at the same time.

The ferritic stainless steel sheet has a chemical composition containing, by mass%, C: 0.020% or less, Si: 0.05% to 0.40%, Mn: 0.05% to 1.00%, P: 0.040% or less, S: 0.030% or less, Al: 0.001% to 0.15%, Cr: 20.0% to 23.0%, Ni: 0.01% to 0.80%, Cu: 0.30% to 0.80%, Ti: 0.10% to 0.50%, Nb: 0.010% to 0.150%, Zr: 0.005% to 0.150%, N: 0.020% or less, and the balance being Fe and inevitable impurities, in which relational expression (1) below is satisfied.

$$\text{Zr} \leq \text{Nb} \leq \text{Ti} \quad (1) \quad (1)$$

(Here, each of Zr, Nb, and Ti in relational expression (1) denotes the content (mass%) of the corresponding chemical element.)

FIG. 1



Description

Technical Field

- 5 **[0001]** The present invention relates to a ferritic stainless steel sheet having excellent corrosion resistance, only a small quantity of surface defects, and excellent toughness.

Background Art

- 10 **[0002]** A ferritic stainless steel sheet, which does not contain Ni in a large amount, is a material having a lower price and more excellent price stability than those of an austenitic stainless steel sheet. In addition, ferritic stainless steel sheets are used in various applications such as building materials, transport machine, home electrical appliances, and kitchen appliances, since they are excellent in terms of rust resistance.

- 15 **[0003]** The kind of ferritic stainless steel sheet which is used particularly in a harsh corrosive environment is a SUS443J1-type stainless steel sheet (JIS G 4305), which has excellent corrosion resistance equivalent to that of a SUS304-type stainless steel sheet (JIS G 4305, 18-mass%-Cr-8-mass%-Ni-based), which is an austenitic stainless steel, as a result of containing 20.0 mass% to 23.0 mass% of Cr, 0.3 mass% to 0.8 mass% of Cu, and sufficient amounts of stabilizing chemical elements (Ti, Nb, and Zr).

- 20 **[0004]** The kind of SUS443J1-type stainless steel which is commonly used is SUS443J1-type stainless steel containing mainly Ti as a stabilizing chemical element. Such steel is excellent in terms of workability because texture growth is promoted as a result of containing Ti. Moreover, since such steel is sufficiently softened even in the case where cold-rolled-sheet annealing is performed at a lower temperature than that for steel containing Nb, it is possible to manufacture such steel by using a cold-rolled-sheet annealing and pickling line which is used for common steel, which results in high productivity. However, in the case of Ti-containing SUS443J1-type stainless steel, there may be a case where streaks (surface defects), which deteriorate aesthetic appearance, occur on the surface. It is known that the above-mentioned streaks are caused by coarse TiN which is formed on the surface when casting is performed. In addition, there is a problem of low toughness with Ti-containing SUS443J1-type stainless steel. This is because coarse TiN, which becomes a preferential starting point at which fracturing occurs, is formed.

- 25 **[0005]** Patent Literature 1 and Patent Literature 2 describe the prevention of surface defects and the improvement of toughness regarding Ti-containing ferritic stainless steel.

- 30 **[0006]** Patent Literature 1 discloses a method for manufacturing Ti-containing ferritic stainless steel having excellent roping resistance and good surface quality. In Patent Literature 1, the surface defect of a cold-rolled and annealed steel sheet is prevented by controlling the solidifying temperature of the steel, casting temperature, and TiN-precipitating temperature in the steel so that a specified relationship is satisfied in order to control the precipitation of TiN when the molten steel is cast.

- 35 **[0007]** Patent Literature 2 discloses a ferritic stainless steel sheet which has excellent toughness and good corrosion resistance and which is excellent in terms of productivity and economic efficiency and a method for manufacturing the steel sheet. In Patent Literature 2, the toughness of a hot-rolled and annealed steel sheet and the toughness of a cold-rolled and annealed steel sheet are improved by allowing nitrides in the steel to exist in the form of ZrN.

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Citation List

Patent Literature

- 45 **[0008]**

PTL 1: Japanese Unexamined Patent Application Publication No. Hei 1-118341

PTL 2: Japanese Unexamined Patent Application Publication No. 2011-214060

- 50 **Summary of Invention**

Technical Problem

- 55 **[0009]** Nowadays, in response to the diversification of home electrical appliances, there is a demand for a ferritic stainless steel sheet with which a decrease in streaks on the surface and excellent toughness are both realized at the same time in addition to excellent corrosion resistance.

- [0010]** However, in the case of the method according to Patent Literature 1, since TiN is purposefully precipitated in order to obtain the effect of increasing the equiaxial crystal ratio of a slab, it is not possible to achieve a sufficient effect

of improving toughness and reducing surface defects. In the case of the method according to Patent Literature 2 also, since it is not possible to sufficiently prevent the formation of TiN in steel, it is not possible to obtain a sufficient effect of improving toughness and reducing surface defects.

[0011] An object of the present invention is to provide a ferritic stainless steel sheet excellent in corrosion resistance in which a decrease in the quantity of surface defects and an improvement in toughness are realized at the same time and which is sufficiently softened even in the case where cold-rolled-sheet annealing is performed at a temperature equivalent to that for conventional Ti-containing SUS443J1-type stainless steel.

Solution to Problem

[0012] The present inventors, in response to the problems described above, conducted comprehensive investigations in order to realize a decrease in the quantity of surface defects and an improvement in toughness at the same time and, as a result, found that it is possible to improve the toughness of Ti-containing SUS443J1-type stainless steel by adding appropriate amounts of Zr and Nb in combination to Ti-containing SUS443J1-type stainless steel in order to change the precipitation form of TiN, which causes a deterioration in toughness, without an increase in cold-rolled-sheet annealing temperature. Moreover, it was found that, since it is possible to precipitate Ti-based inclusions in a finely dispersed form by this effect, it is possible to decrease the quantity of surface defects of a steel sheet caused by TiN.

[0013] Specifically, it was found that, by controlling the contents of the stabilizing chemical elements (Ti, Nb, and Zr) in the chemical composition of a SUS443J1-type ferritic stainless steel sheet so that the content of Ti, which is the main stabilizing chemical element, is 0.10 mass% to 0.50 mass%, the Nb content, which is equal to or less than the Ti content, is 0.010 mass% to 0.150 mass%, and the Zr content, which is equal to or less than the Nb content, is 0.005 mass% to 0.150 mass%, it is possible to allow sufficient softening to occur even when cold-rolled-sheet annealing is performed at a temperature equivalent to that for a case where a stabilizing chemical element is limited to Ti, and it is possible to realize a decrease in the quantity of surface defects and a high toughness at the same time. The mechanism of these is supposed to be as follows.

[0014] As a result of Nb and Zr being contained in combination in steel, since complex carbonitrides of Ti, Zr, and Nb ((Ti, Zr, Nb)(C,N)), whose particle size is smaller than that of TiN formed in ferritic stainless steel containing only Ti, are dispersedly precipitated, an improvement in toughness and a decrease in the quantity of surface defects are realized.

[0015] The present invention is based on the findings described above, and the subject matter of the present invention is as follows.

[0016]

[1] A ferritic stainless steel sheet having a chemical composition containing, by mass%, C: 0.020% or less, Si: 0.05% to 0.40%, Mn: 0.05% to 1.00%, P: 0.040% or less, S: 0.030% or less, Al: 0.001% to 0.15%, Cr: 20.0% to 23.0%, Ni: 0.01% to 0.80%, Cu: 0.30% to 0.80%, Ti: 0.10% to 0.50%, Nb: 0.010% to 0.150%, Zr: 0.005% to 0.150%, N: 0.020% or less, and the balance being Fe and inevitable impurities, in which relational expression (1) below is satisfied.

$$\text{Zr} \leq \text{Nb} \leq \text{Ti} \quad (1)$$

(Here, each of Zr, Nb, and Ti in relational expression (1) denotes the content (mass%) of the corresponding chemical element.)

[2] The ferritic stainless steel sheet according to item [1], the steel sheet having the chemical composition further containing, by mass%, one, two, or more selected from Co: 0.01% to 0.50%, Mo: 0.01% to 0.30%, and W: 0.01% to 0.50%.

[3] The ferritic stainless steel sheet according to item [1] or [2], the steel sheet having the chemical composition further containing, by mass%, one, two, or more selected from V: 0.01% to 0.50%, B: 0.0003% to 0.0030%, Mg: 0.0005% to 0.0100%, Ca: 0.0003% to 0.0030%, Y: 0.001% to 0.20%, and REM (rare-earth metal): 0.001% to 0.10%.

[4] The ferritic stainless steel sheet according to any one of items [1] to [3], the steel sheet having the chemical composition further containing, by mass%, one or both selected from Sn: 0.001% to 0.50% and Sb: 0.001% to 0.50%. Advantageous Effects of Invention

[0017] According to the present invention, it is possible to obtain a ferritic stainless steel sheet having excellent corrosion resistance, only a small quantity of surface defects, and excellent toughness.

[0018] In addition, since sufficient softening occurs by performing cold-rolled-sheet annealing at a temperature equivalent to that for a case where a stabilizing chemical element is limited to Ti, there is an improvement in the productivity

of a ferritic stainless steel sheet. Brief Description of Drawings

[0019]

[Fig. 1] Fig. 1 is a diagram illustrating the influence of the contents of Ti and Nb on toughness and the quantity of surface defects under the condition of $Zr \leq Nb$.

[Fig. 2] Fig. 2 is a diagram illustrating the influence of the contents of Nb and Zr on toughness and the quantity of surface defects under the condition of $Nb \leq Ti$. Description of Embodiments

[0020] Hereafter, the embodiments of the present invention will be described. Here, the present invention is not limited to the embodiments described below.

[0021] The chemical composition of the ferritic stainless steel sheet according to the present invention has a chemical composition containing, by mass%, C: 0.020% or less,

Si: 0.05% to 0.40%, Mn: 0.05% to 1.00%, P: 0.040% or less,

S: 0.030% or less, Al: 0.001% to 0.15%, Cr: 20.0% to 23.0%,

Ni: 0.01% to 0.80%, Cu: 0.30% to 0.80%, Ti: 0.10% to 0.50%,

Nb: 0.010% to 0.150%, Zr: 0.005% to 0.150%, N: 0.020% or

less, and the balance being Fe and inevitable impurities, in which relational expression (1) below is satisfied.

$$Zr \leq Nb \leq Ti \quad (1)$$

[0022] Here, each of Zr, Nb, and Ti in relational expression (1) denotes the content (mass%) of the corresponding chemical element.

[0023] In addition, the chemical composition described above may further contain, by mass%, one, two, or all selected from Co: 0.01% to 0.50%, Mo: 0.01% to 0.30%, and W: 0.01% to 0.50%.

[0024] In addition, the chemical composition described above may further contain, by mass%, one, two, or more selected from V: 0.01% to 0.50%, B: 0.0003% to 0.0030%, Mg: 0.0005% to 0.0100%, Ca: 0.0003% to 0.0030%, Y: 0.001% to 0.20%, and REM (rare-earth metal): 0.001% to 0.10%.

[0025] In addition, the chemical composition described above may further contain, by mass%, one or both selected from Sn: 0.001% to 0.50% and Sb: 0.001% to 0.50%.

[0026] Hereafter, each of the constituent chemical elements will be described. "%" used when describing the content of a constituent chemical element means "mass%", unless otherwise noted.

C: 0.020% or less

[0027] C is a chemical element which is effective for improving the strength of steel. Such an effect is obtained in the case where the C content is 0.001% or more. However, in the case where the C content is more than 0.020%, there is a significant deterioration in corrosion resistance and workability. Therefore, the C content is set to be 0.020% or less, preferably 0.015% or less, or more preferably 0.010% or less.

Si: 0.05% to 0.40%

[0028] Si is a chemical element which is effective as a deoxidizing agent. Such an effect is obtained in the case where the Si content is 0.05% or more. However, in the case where the Si content is more than 0.40%, there is a deterioration in workability due to an increase in the hardness of steel. In addition, in the case where the Si content is more than 0.40%, since there is a decrease in the amount of scale formed on the upper surface of a slab, which has a lubrication effect when hot rolling is performed, there is an increase in the quantity of surface defects. Therefore, the Si content is limited to be in the range of 0.05% to 0.40%, or preferably 0.05% to 0.25%. It is more preferable that the lower limit of the Si content be 0.08% or more. It is more preferable that the upper limit of the Si content be 0.15% or less.

Mn: 0.05% to 1.00%

[0029] Mn has a deoxidizing function. Such an effect of Mn is obtained in the case where the Mn content is 0.05% or more. On the other hand, in the case where the Mn content is more than 1.00%, since the precipitation and coarsening of MnS are promoted, there is a deterioration in corrosion resistance. Therefore, the Mn content is limited to be in the range of 0.05% to 1.00%. It is preferable that the lower limit of the Mn content be 0.10% or more, or more preferably

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0.15% or more. It is preferable that the upper limit of the Mn content be less than 0.30%, or more preferably 0.25% or less.

P: 0.040% or less

5 **[0030]** P is a chemical element which deteriorates corrosion resistance. In addition, there is a deterioration in hot workability as a result of P being segregated at grain boundaries. Therefore, it is desirable that the P content be as small as possible, and the P content is set to be 0.040% or less, or preferably 0.030% or less.

S: 0.030% or less

10 **[0031]** S combines with Mn to form a precipitate, that is, MnS. Since the interface between such MnS and the base metal of stainless steel becomes a starting point at which pitting corrosion occurs, there is a deterioration in corrosion resistance. Therefore, it is preferable that the S content be smaller, and the S content is set to be 0.030% or less, or preferably 0.020% or less.

15 Al: 0.001% to 0.15%

20 **[0032]** Al is a chemical element which is effective for deoxidation. Such an effect is obtained in the case where the Al content is 0.001% or more. On the other hand, in the case where the Al content is more than 0.15%, since there is a decrease in the amount of scale formed on the surface of a slab, which has a lubrication effect when hot rolling is performed, there is an increase in the quantity of surface defects. Therefore, the Al content is limited to be in the range of 0.001% to 0.15%. It is preferable that the lower limit of the Al content be 0.005% or more, or more preferably 0.01% or more. It is preferable that the upper limit of the Al content be 0.10% or less, or more preferably 0.05% or less.

25 Cr: 20.0% to 23.0%

30 **[0033]** Cr is a chemical element which improves corrosion resistance by forming a passive film on the surface. It is not possible to achieve sufficient corrosion resistance in the case where the Cr content is less than 20.0%. On the other hand, in the case where the Cr content is more than 23.0%, there is a tendency for toughness to deteriorate due to a σ phase and 475°C embrittlement. Therefore, the Cr content is set to be 20.0% to 23.0%. It is preferable the lower limit of the Cr content be 20.5% or more. It is preferable that the upper limit of the Cr content be 22.0% or less, or more preferably 21.5% or less.

35 Ni: 0.01% to 0.80%

40 **[0034]** Ni is a chemical element which makes it possible to maintain a passive state even at a lower pH by inhibiting an anode reaction due to acid. That is, Ni improves corrosion resistance by markedly inhibiting the progress of corrosion in an active dissolution state as a result of increasing the effect of crevice corrosion resistance. Such an effect of Ni is obtained in the case where the Ni content is 0.01% or more. On the other hand, in the case where the Ni content is more than 0.80%, there is a deterioration in workability due to an increase in the hardness of steel. Therefore, the Ni content is limited to be 0.01% to 0.80%. It is preferable that the lower limit of the Ni content be 0.05% or more, or more preferably 0.10% or more. It is preferable that the upper limit of the Ni content be 0.40% or less, or more preferably 0.25% or less.

45 Cu: 0.30% to 0.80%

50 **[0035]** Cu is a chemical element which improves corrosion resistance by strengthening a passive film. On the other hand, in the case where the Cu content is excessively large, since ϵ -Cu tends to be precipitated, there is a deterioration in corrosion resistance. Therefore, the Cu content is set to be 0.30% to 0.80%. It is preferable that the lower limit of the Cu content be 0.35% or more, or more preferably 0.40% or more. It is preferable that the upper limit of the Cu content be 0.60% or less, or more preferably 0.45% or less.

Ti: 0.10% to 0.50%

55 **[0036]** Ti is a chemical element which improves corrosion resistance by preventing sensitization due to Cr carbonitrides as a result of fixing C and N. However, TiN, which is formed as a result of containing Ti, causes a deterioration in toughness. In the present invention, the above-mentioned deterioration in toughness due to Ti is suppressed by the combination effect of Nb and Zr as described below. The effect of improving corrosion resistance through the use of Ti is obtained in the case where the Ti content is 0.10% or more. On the other hand, in the case where the Ti content is

more than 0.50%, there is a deterioration in workability due to an increase in the hardness of a stainless steel sheet. In addition, in the case where the Ti content is more than 0.50%, since it is difficult to control the precipitation form of Ti-based inclusions even in the case where Nb and Zr are contained, there is a deterioration in surface quality. Therefore, the Ti content is set to be in the range of 0.10% to 0.50%. It is preferable that the lower limit of the Ti content be 0.15% or more, or more preferably 0.18% or more. It is preferable that the upper limit of the Ti content be 0.35% or less, or more preferably 0.26% or less.

Nb: 0.010% to 0.150%

[0037] Nb is, like Ti, a chemical element which improves corrosion resistance by preventing sensitization due to Cr carbonitrides as a result of fixing C and N. Moreover, Nb improves toughness and inhibits a surface defect from occurring by the combination effect with Zr described below. Such effects are obtained in the case where the Nb content is 0.010% or more. On the other hand, in the case where the Nb content is more than 0.150%, there is a deterioration in workability due to an increase in the hardness of a stainless steel sheet. In addition, in the case where the Nb content is more than 0.150%, since there is an increase in recrystallization temperature, there is a deterioration in manufacturability. Therefore, the Nb content is set to be in the range of 0.010% to 0.150%. It is preferable that the lower limit of the Nb content be 0.030% or more, or more preferably 0.070% or more. It is preferable that the upper limit of the Nb content be less than 0.100%, or more preferably 0.090% or less.

Zr: 0.005% to 0.150%

[0038] Zr is, like Ti, a chemical element which improves corrosion resistance by preventing sensitization due to Cr carbonitrides as a result of fixing C and N. Moreover, Zr improves toughness and inhibits a surface defect from occurring by the combination effect with Nb described below. It is necessary that the Zr content be 0.005% or more in order to obtain such effects. On the other hand, in the case where the Zr content is more than 0.150%, since Zr-based inclusions are precipitated on the surface, there is an increase in the quantity of surface defects. Therefore, the Zr content is limited to be in the range of 0.005% to 0.150%. It is preferable that the lower limit of the Zr content be 0.010% or more, or more preferably 0.030% or more. It is preferable that the upper limit of the Zr content be less than 0.100%, or more preferably 0.080% or less.

[0039] It was found that, in the present invention, by containing Nb and Zr in combination to SUS443J1-type stainless steel which contains only Ti as a stabilizing chemical element, it is possible to allow sufficient softening to occur by performing cold-rolled-sheet annealing even at a temperature equivalent to that for the case where a stabilizing chemical element is limited to Ti, and it is possible to realize a decrease in the quantity of surface defects and a high toughness at the same time. Specifically, it was found that, by controlling the contents of the stabilizing chemical elements (Ti, Nb, and Zr) in the chemical composition of a SUS443J1-type stainless steel so that the Ti content is 0.10% to 0.50%, the Nb content is 0.010% to 0.150%, and the Zr content is 0.005% to 0.150% under the condition expressed by relational expression (1) below, it is possible to allow sufficient softening to occur by performing cold-rolled-sheet annealing even at a temperature equivalent to that for the case where a stabilizing chemical element is limited to Ti, and it is possible to realize a decrease in the quantity of surface defects and a high toughness at the same time. The mechanism of these is supposed to be as follows.

[0040] It is considered that, as a result of Nb and Zr being contained in combination in steel, since complex carbonitrides of Ti, Zr, and Nb ((Ti, Zr, Nb)(C,N)), whose particle size is smaller than that of TiN formed in ferritic stainless steel containing only Ti, are dispersedly precipitated, an improvement in toughness and a decrease in the quantity of surface defects are realized. In order to form the above-mentioned complex carbonitrides ((Ti, Zr, Nb)(C,N)) in sufficient amounts, it is necessary that relational expression (1) below be satisfied.

$$\text{Zr} \leq \text{Nb} \leq \text{Ti} \quad (1)$$

[0041] Here, each of Zr, Nb, and Ti in relational expression (1) denotes the content (mass%) of the corresponding chemical element.

[0042] Regarding the relationship between Ti and Nb, it is preferable that the relational expression $\text{Ti} \geq 1.5\text{Nb}$, or more preferably $\text{Ti} \geq 2\text{Nb}$, be satisfied. Regarding the relationship between Nb and Zr, it is preferable that the relational expression $\text{Nb} \geq 1.3\text{Zr}$, or more preferably $\text{Nb} \geq 1.5\text{Zr}$, be satisfied.

N: 0.020% or less

[0043] N is a chemical element which is inevitably mixed in steel. However, in the case where the N content is more

than 0.020%, there is a significant deterioration in corrosion resistance and workability. Therefore, the N content is set to be 0.020% or less, or preferably 0.015% or less.

[0044] The basic constituent chemical elements are described above, and the chemical elements described below may be appropriately added in addition to the basic constituent chemical elements in the present invention as described above.

Co: 0.01% to 0.50%

[0045] Co is a chemical element which improves the crevice corrosion resistance of stainless steel. Such an effect of Co is obtained in the case where the Co content is 0.01% or more. However, in the case where the Co content is more than 0.50%, such an effect of Co becomes saturated, and there is a deterioration in workability. Therefore, in the case where Co is contained, the Co content is set to be 0.01% to 0.50%. It is preferable that the lower limit of the Co content be 0.02% or more, or more preferably 0.03% or more. It is preferable that the upper limit of the Co content be 0.30% or less, or more preferably 0.10% or less.

Mo: 0.01% to 0.30%

[0046] Mo is effective for improving the crevice corrosion resistance of stainless steel. Such an effect is obtained in the case where the Mo content is 0.01% or more. However, in the case where the Mo content is more than 0.30%, such an effect of Mo becomes saturated, and there is a deterioration in toughness due to the formation of coarse intermetallic compounds. Therefore, in the case where Mo is added, the Mo content is set to be 0.01% to 0.30%. It is preferable that the lower limit of the Mo content be 0.02% or more, or more preferably 0.03% or more. It is preferable that the upper limit of the Mo content be 0.20% or less, or more preferably 0.10% or less.

W: 0.01% to 0.50%

[0047] W is a chemical element which improves the crevice corrosion resistance of stainless steel. Such an effect of W is obtained in the case where the W content is 0.01% or more. On the other hand, in the case where the W content is more than 0.50%, such an effect of W becomes saturated, and there is a deterioration in workability. Therefore, in the case where W is contained, the W content is set to be 0.01% to 0.50%. It is preferable that the lower limit of the W content be 0.02% or more, or more preferably 0.03% or more. It is preferable that the upper limit of the W content be 0.30% or less, or more preferably 0.10% or less.

V: 0.01% to 0.50%

[0048] V is a chemical element which improves the crevice corrosion resistance of stainless steel. Such an effect of V is obtained in the case where the V content is 0.01% or more. On the other hand, in the case where the V content is more than 0.50%, such an effect of V becomes saturated, and there is a deterioration in workability. Therefore, in the case where V is added, the V content is set to be 0.01% to 0.50%, preferably 0.01% to 0.30%, or more preferably 0.01% to 0.10%.

B: 0.0003% to 0.0030%

[0049] Since B is a chemical element which improves hot workability and secondary workability, it is effective to containing B to Ti-containing steel. Such an effect of B is obtained in the case where the B content is 0.0003% or more. On the other hand, in the case where the B content is more than 0.0030%, there is a deterioration in toughness. Therefore, in the case where B is contained, the B content is set to be in the range of 0.0003% to 0.0030%. It is preferable that the lower limit of the B content be 0.0015% or more. It is preferable that the upper limit of the B content be 0.0025% or less.

Mg: 0.0005% to 0.0100%

[0050] Mg functions as a deoxidizing agent along with Al by forming Mg oxides in molten steel. Such an effect of Mg is obtained in the case where the Mg content is 0.0005% or more. On the other hand, in the case where the Mg content is more than 0.0100%, there is a deterioration in manufacturability and a deterioration in the toughness of steel. Therefore, in the case where Mg is contained, the Mg content is limited to be in the range of 0.0005% to 0.0100%. It is preferable that the lower limit of the Mg content be 0.0010% or more. It is preferable that the upper limit of the Mg content be 0.0050% or less, or more preferably 0.0030% or less.

Ca: 0.0003% to 0.0030%

[0051] Ca is a chemical element which improves hot workability. Such an effect of Ca is obtained in the case where the Ca content is 0.0003% or more. On the other hand, in the case where the Ca content is more than 0.0030%, there is a deterioration in the toughness of steel, and there is a deterioration in corrosion resistance due to the precipitation of CaS. Therefore, in the case where Ca is added, the Ca content is limited to be in the range of 0.0003% to 0.0030%. It is preferable that the lower limit of the Ca content be 0.001% or more. It is preferable that the upper limit of the Ca content be 0.002% or less.

Y: 0.001% to 0.20%

[0052] Y is a chemical element which improves cleanliness by inhibiting a decrease in the viscosity of molten steel. Such an effect of Y is obtained in the case where the Y content is 0.001% or more. On the other hand, in the case where the Y content is more than 0.20%, such an effect of Y becomes saturated, and there is a deterioration in workability. Therefore, in the case where Y is added, the Y content is limited to be in the range of 0.001% to 0.20%, or preferably 0.001% to 0.10%.

REM (rare-earth metal): 0.001% to 0.10%

[0053] REM (rare-earth metal: one of the chemical elements having atomic numbers of 57 through 71 such as La, Ce, or Nd) is a chemical element which improves high-temperature oxidation resistance. Such an effect of REM is obtained in the case where the REM content is 0.001% or more. On the other hand, in the case where the REM content is more than 0.10%, such an effect of REM becomes saturated, and a surface defect occurs when hot rolling is performed. Therefore, in the case where REM is contained, the REM content is limited to be in the range of 0.001% to 0.10%. It is preferable the lower limit of the REM content be 0.005% or more. It is preferable that the upper limit of the REM content be 0.05% or less.

Sn: 0.001% to 0.50%

[0054] Sn is effective for improving ridging resistance by promoting the formation of a deformation zone when rolling is performed. Such an effect is obtained in the case where the Sn content is 0.001% or more. However, in the case where the Sn content is more than 0.50%, such an effect of Sn becomes saturated, and there is a deterioration in workability. Therefore, in the case where Sn is added, the Sn content is set to be 0.001% to 0.50%. It is preferable that the lower limit of the Sn content be 0.003% or more. It is preferable that the upper limit of the Sn content be 0.20% or less.

Sb: 0.001% to 0.50%

[0055] Sb is effective for improving ridging resistance by promoting the formation of a deformation zone when rolling is performed. Such an effect is obtained in the case where the Sb content is 0.001% or more. However, in the case where the Sb content is more than 0.50%, such an effect of Sb becomes saturated, and there is a deterioration in workability. Therefore, in the case where Sb is contained, the Sb content is set to be 0.001% to 0.50%. It is preferable that the lower limit of the Sb content be 0.003% or more. It is preferable that the upper limit of the Sb content be 0.20% or less.

[0056] The remainder which is other than the constituent chemical elements described above is Fe and inevitable impurities. Representative examples of the inevitable impurities described here include H, O (oxygen), Zn, Ga, Ge, As, Ag, In, Hf, Ta, Re, Os, Ir, Pt, Au, and Pb. Among these chemical elements, H and O (oxygen) may be contained in an amount of 0.05% or less. Other chemical elements may be contained in an amount of 0.3% or less.

[0057] Hereafter, a preferable method for manufacturing the ferritic stainless steel sheet according to the present invention will be described. Molten steel having the chemical composition described above is prepared by using a known method such as one which utilizes a converter, an electric furnace, or a vacuum melting furnace and made into a steel material (slab) by using a continuous casting method or an ingot casting-slabbing method. This steel material is heated to a temperature of 1000°C to 1200°C and then subjected to hot rolling so as to have a thickness of 2.0 mm to 5.0 mm under the condition of a finishing temperature of 700°C to 1000°C. The hot-rolled steel sheet, which has been obtained as described above, is subjected to annealing at a temperature of 800°C to 1100°C followed by pickling, cold rolling, and cold-rolled-sheet annealing at a temperature of 700°C to 1000°C. After cold-rolled-sheet annealing has been performed, pickling is performed in order to remove scale. The cold-rolled steel sheet from which scale has been removed may be subjected to skin pass rolling.

[0058] In addition, the present invention is effective not only for the above-mentioned cold-rolled sheet product but

also for a hot-rolled sheet product.

EXAMPLES

[0059] After ferritic stainless steels having the chemical compositions given in Table 1 (Table 1-1 and Table 1-2 are combined to form Table 1), Table 2 (Table 2-1 and Table 2-2 are combined to form Table 2), and Table 3 (Table 3-1 and Table 3-2 are combined to form Table 3) had been made into steel ingots having a weight of 100 kg, the ingots were heated to a temperature of 1200°C and subjected to hot rolling in order to obtain hot-rolled steel sheets having a thickness of 4.0 mm. Subsequently, the hot-rolled steel sheets were subjected to annealing at a temperature of 1100°C followed by pickling which utilized a commonly used method and subjected to cold rolling so as to have a thickness of 2.0 mm followed by annealing at a temperature of 900°C and pickling which utilized a commonly used method.

[0060] By determining the pitting potential (JIS G 0577) of the obtained cold-rolled and annealed steel sheet, corrosion resistance was evaluated. A case where the pitting potential was 290 mV (vs. SCE) or more was judged as "○" (satisfactory), and a case where the pitting potential was less than 290 mV (vs. SCE) was judged as "▲"

(unsatisfactory).

[0061] In addition, by performing a Charpy impact test on a test piece (JIS B 7722, V notch) which had been taken from the obtained cold-rolled and annealed steel sheet along the rolling direction, the toughness of the steel sheet was evaluated. A case where the Charpy impact value at 25°C was 200 J/cm² or more was judged as "○" (satisfactory), and a case where the Charpy impact value at 25°C was less than 200 J/cm² was judged as "▲" (unsatisfactory).

[0062] Moreover, by observing the surface of the cold-rolled and annealed steel sheet in order to determine the density of streaks on the surface, the quantity of surface defects was evaluated. By preparing 10 steel sheets having each of the chemical compositions, and by counting the number of streaks having a length in the L-direction of more than 10 mm in a region having a width of 200 mm and a length of 200 mm on the center portion of the upper surface of each of the steel sheets, a case where the average of the counted numbers was 1 or less was judged as "○" (satisfactory), and a case where the average of the counted numbers was more than 1 was judged as "▲" (unsatisfactory).

[0063] Moreover, it was evaluated whether sufficient softening occurred by performing annealing even at a temperature of 880°C for 20 seconds on the cold-rolled steel sheet which had not yet been annealed. The evaluation was performed by comparing the hardness (a) of a steel sheet in the cold-rolled state or as cold-rolled, the hardness (b) of a steel sheet which had been subjected to annealing at a temperature of 880°C for 20 seconds, and the hardness (c) of a steel sheet which had been subjected to annealing at a temperature of 1000°C for 20 seconds as an index of a case where sufficient softening occurred. Three test pieces having a length of 15 mm and a width of 20 mm were taken from the cold-rolled steel sheet, and each of the test pieces for respectively determining b and c was subjected to the corresponding annealing. Subsequently, each of the three test pieces were cut into pieces having a length of 15 mm and a width of 10 mm. Then, the Vickers hardness determined in the cross section of the cut piece was used for the evaluation. As annealing progressed, the hardness of the steel sheet changed from a to c. A case where 90% or more of such a softening process was completed through annealing at a temperature of 880°C for 20 seconds, that is, a case where the relational expression $c + 0.1 \times (a - c) \geq b$ was satisfied, was judged as "○" (satisfactory), and other cases were judged as "▲" (unsatisfactory).

[0064] The obtained results are given in Tables 1, 2, and 3. In the case of the steels of the examples of the present invention, all the judgment results of the determined pitting potential, the Charpy impact value, the surface defect, and the softening temperature were "○", which means that these steels had good corrosion resistance and toughness, only a small quantity of surface defects, and no manufacturing problem.

[0065] Comparative example No. 34, whose Cr content was lower than the range according to the present invention, had poor corrosion resistance.

[0066] Comparative example No. 35, whose Cr content was higher than the range according to the present invention, had poor toughness.

[0067] Comparative example No. 36, whose Ni content was lower than the range according to the present invention, had poor corrosion resistance.

[0068] Comparative example No. 37, whose Ti content was lower than the range according to the present invention, had poor corrosion resistance.

[0069] Comparative example No. 38, whose Ti content was higher than the range according to the present invention, had poor toughness and a large quantity of surface defects.

[0070] Comparative example No. 39, whose Nb content was lower than the range according to the present invention, had poor toughness and a large quantity of surface defects.

[0071] Comparative example No. 40, whose Nb content was higher than the range according to the present invention, had poor manufacturability due to a high softening temperature.

[0072] Comparative example No. 41, whose Zr content was lower than the range according to the present invention,

had poor toughness and a large quantity of surface defects.

[0073] Comparative example No. 42, whose Zr content was higher than the range according to the present invention, had a large quantity of surface defects.

[0074] Comparative example No. 57, whose contents of Nb and Zr were both lower than the range according to the present invention, had poor toughness and a large quantity of surface defects.

[0075] Comparative example No. 58, whose contents of Ti and Zr were both lower than the ranges according to the present invention, and whose contents of Al and Nb were both higher than the ranges according to the present invention, had poor toughness, a large quantity of surface defects, and poor manufacturability due to a high softening temperature.

[0076] Here, comparative example Nos. 43 through 54, 67, and 68 will be described hereafter with reference to Fig. 1 and Fig. 2.

[Table 1-1]

Test No.	Chemical Composition (mass%)															Note
	C	Si	Mn	P	S	Al	Cr	Ni	Cu	Ti	Nb	Zr	N	Other Chemical Element		
1	0.010	0.09	0.21	0.025	0.002	0.020	20.2	0.29	0.43	0.19	0.075	0.031	0.009		Example	
2	0.012	0.12	0.17	0.021	0.002	0.026	21.1	0.30	0.44	0.24	0.071	0.034	0.007		Example	
3	0.011	0.11	0.19	0.029	0.003	0.027	21.2	0.28	0.42	0.19	0.089	0.012	0.008		Example	
4	0.012	0.10	0.22	0.027	0.002	0.035	22.7	0.18	0.41	0.20	0.088	0.011	0.013		Example	
5	0.009	0.11	0.20	0.021	0.002	0.029	20.6	0.02	0.44	0.22	0.095	0.034	0.008		Example	
6	0.008	0.12	0.16	0.028	0.002	0.037	20.6	0.21	0.44	0.21	0.076	0.021	0.008		Example	
7	0.010	0.12	0.20	0.028	0.003	0.032	21.4	0.79	0.41	0.24	0.069	0.023	0.010		Example	
8	0.010	0.09	0.16	0.028	0.003	0.024	20.9	0.27	0.41	0.11	0.055	0.036	0.013		Example	
9	0.011	0.10	0.22	0.020	0.002	0.035	20.9	0.29	0.45	0.22	0.075	0.020	0.010		Example	
10	0.007	0.10	0.16	0.027	0.001	0.031	20.7	0.23	0.42	0.48	0.079	0.023	0.010		Example	
11	0.012	0.12	0.18	0.023	0.003	0.028	20.5	0.19	0.43	0.20	0.012	0.007	0.008		Example	
12	0.011	0.12	0.19	0.030	0.001	0.026	20.9	0.13	0.40	0.21	0.077	0.040	0.013		Example	
13	0.010	0.11	0.19	0.026	0.003	0.031	20.9	0.12	0.43	0.32	0.147	0.032	0.012		Example	
14	0.011	0.11	0.18	0.026	0.002	0.033	21.2	0.24	0.42	0.24	0.094	0.006	0.013		Example	
15	0.008	0.09	0.19	0.028	0.003	0.033	20.7	0.11	0.41	0.23	0.081	0.047	0.010		Example	
16	0.012	0.08	0.17	0.030	0.002	0.036	21.4	0.18	0.43	0.40	0.148	0.146	0.012		Example	
17	0.009	0.09	0.16	0.029	0.002	0.032	21.4	0.24	0.41	0.12	0.072	0.051	0.007		Example	
18	0.013	0.08	0.21	0.021	0.002	0.024	20.9	0.25	0.45	0.17	0.092	0.065	0.008		Example	
19	0.007	0.10	0.20	0.022	0.002	0.148	20.6	0.15	0.42	0.21	0.123	0.090	0.008		Example	
20	0.008	0.08	0.17	0.027	0.002	0.026	21.3	0.21	0.45	0.11	0.099	0.092	0.008		Example	
21	0.009	0.12	0.20	0.026	0.002	0.023	20.8	0.25	0.41	0.16	0.112	0.095	0.012		Example	
22	0.009	0.11	0.15	0.026	0.003	0.037	21.1	0.26	0.43	0.21	0.147	0.118	0.012		Example	
23	0.009	0.10	0.16	0.029	0.002	0.034	20.7	0.18	0.43	0.21	0.061	0.014	0.007	Co:0.07, Mo:0.05, W:0.08	Example	
24	0.007	0.10	0.20	0.021	0.003	0.029	20.7	0.14	0.45	0.19	0.070	0.011	0.010	V:0.07, Ca:0.0012, La:0.03	Example	

(continued)

Test No.	Chemical Composition (mass%)										Other Chemical Element				Note
	C	Si	Mn	P	S	Al	Cr	Ni	Cu	Ti	Nb	Zr	N	Other Chemical Element	
25	0.012	0.09	0.20	0.028	0.002	0.023	20.8	0.27	0.43	0.21	0.065	0.019	0.011	Sn:0.05, Sb:0.08	Example
26	0.007	0.09	0.23	0.029	0.002	0.020	20.8	0.18	0.40	0.22	0.074	0.025	0.013	Co:0.47, M:0.0005	Example
27	0.012	0.08	0.21	0.021	0.002	0.023	21.1	0.22	0.42	0.25	0.085	0.027	0.010	Co:0.25, V:0.28, Sn:0.16	Example
28	0.009	0.08	0.18	0.029	0.002	0.038	21.4	0.15	0.41	0.20	0.099	0.036	0.011	Mo:0.28, B:0.0018, Ca:0.0023	Example
29	0.008	0.11	0.16	0.024	0.002	0.035	21.0	0.27	0.42	0.26	0.071	0.033	0.010	W:0.45, Mg:0.0025, Sb:0.04	Example
30	0.013	0.12	0.22	0.024	0.002	0.021	20.9	0.24	0.41	0.18	0.088	0.031	0.009	Co:0.04, Y:0.003, La:0.007	Example
31	0.008	0.11	0.20	0.026	0.001	0.037	21.3	0.11	0.44	0.24	0.077	0.029	0.011	Mo:0.17, Ce:0.05, Sn:0.001	Example
32	0.008	0.10	0.17	0.026	0.002	0.021	21.3	0.11	0.41	0.21	0.094	0.020	0.013	Sn:0.005	Example
33	0.009	0.11	0.22	0.021	0.003	0.039	20.8	0.22	0.42	0.24	0.078	0.031	0.010	Sb:0.13	Example

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[Table 1-2]

	Test No.	Ti-Nb	Nb-Zr	Corrosion Resistance	Charpy	Surface Defect	Softening Temperature	Note
5	1	0.12	0.044	○	○	○	○	Example
	2	0.17	0.037	○	○	○	○	Example
	3	0.10	0.077	○	○	○	○	Example
10	4	0.11	0.077	○	○	○	○	Example
	5	0.13	0.061	○	○	○	○	Example
	6	0.13	0.055	○	○	○	○	Example
	7	0.17	0.046	○	○	○	○	Example
15	8	0.06	0.019	○	○	○	○	Example
	9	0.15	0.055	○	○	○	○	Example
	10	0.40	0.056	○	○	○	○	Example
20	11	0.19	0.005	○	○	○	○	Example
	12	0.13	0.037	○	○	○	○	Example
	13	0.17	0.115	○	○	○	○	Example
	14	0.15	0.088	○	○	○	○	Example
25	15	0.15	0.034	○	○	○	○	Example
	16	0.25	0.002	○	○	○	○	Example
	17	0.05	0.021	○	○	○	○	Example
30	18	0.08	0.027	○	○	○	○	Example
	19	0.09	0.033	○	○	○	○	Example
	20	0.01	0.007	○	○	○	○	Example
	21	0.05	0.017	○	○	○	○	Example
35	22	0.06	0.029	○	○	○	○	Example
	23	0.15	0.047	○	○	○	○	Example
	24	0.12	0.059	○	○	○	○	Example
40	25	0.15	0.046	○	○	○	○	Example
	26	0.15	0.049	○	○	○	○	Example
	27	0.17	0.058	○	○	○	○	Example
	28	0.10	0.063	○	○	○	○	Example
45	29	0.19	0.038	○	○	○	○	Example
	30	0.09	0.057	○	○	○	○	Example
	31	0.16	0.048	○	○	○	○	Example
50	32	0.12	0.074	○	○	○	○	Example

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(continued)

Test No.	Ti-Nb	Nb-Zr	Corrosion Resistance	Charpy	Surface Defect	Softening Temperature	Note
33	0.16	0.047	○	○	○	○	Example
*[Corrosion Resistance] A case where the pitting potential was 290 mV (vs. SCE) or more was judged as "○" (satisfactory), and a case where the pitting potential was less than 290 mV (vs. SCE) was judged as "▲" (unsatisfactory). *[Charpy Impact Value] A case where the Charpy impact value (of a steel sheet having a thickness of 2 mm) at 25°C was 200 J/cm² or more was judged as "○" (satisfactory), and a case where the Charpy impact value (of a steel sheet having a thickness of 2 mm) at 25°C was less than 200 J/cm² was judged as "▲" (unsatisfactory). *[Surface Defect] A case where the number of streaks in a region of 200 mm^W × 200 mm^L was 1 or less was judged as "○" (satisfactory), and a case where the above-described number was more than 1 was judged as "▲" (unsatisfactory). *[Softening Temperature] A case where the relational expression $c + 0.1 \times (a - c) \geq b$ was satisfied was judged as "○" (satisfactory), and other cases were judged as "▲" (unsatisfactory), where the Vickers hardness of a steel sheet in the cold-rolled state was defined as a, the Vickers hardness of a steel sheet which had been subjected to a heat treatment at a temperature of 880°C for 20 seconds was defined as b, and the Vickers hardness of a steel sheet which had been subjected to a heat treatment at a temperature of 1000°C for 20 seconds was defined as c.							

[Table 2-1]

Test No.	Chemical Composition (mass%)														Note
	C	Si	Mn	P	S	Al	Cr	Ni	Cu	Ti	Nb	Zr	N	Other Chemical Element	
34	0.008	0.10	0.15	0.023	0.002	0.039	<u>19.6</u>	0.29	0.43	0.20	0.090	0.021	0.010		Comparative Example
35	0.012	0.09	0.19	0.025	0.001	0.022	<u>23.2</u>	0.12	0.40	0.20	0.087	0.017	0.009		Comparative Example
36	0.010	0.11	0.18	0.025	0.001	0.034	21.0	-	0.43	0.25	0.063	0.021	0.012		Comparative Example
37	0.008	0.11	0.17	0.022	0.001	0.039	20.8	0.11	0.45	<u>0.09</u>	0.036	0.018	0.013		Comparative Example
38	0.011	0.12	0.19	0.025	0.002	0.030	20.7	0.14	0.44	<u>0.52</u>	0.079	0.018	0.012		Comparative Example
39	0.011	0.11	0.21	0.028	0.002	0.023	20.8	0.28	0.45	0.24	<u>0.008</u>	0.005	0.010		Comparative Example
40	0.007	0.09	0.19	0.025	0.002	0.037	21.4	0.28	0.40	0.42	<u>0.153</u>	0.033	0.013		Comparative Example
41	0.011	0.09	0.21	0.030	0.003	0.030	20.7	0.12	0.43	0.20	0.097	<u>0.003</u>	0.009		Comparative Example
42	0.009	0.11	0.20	0.027	0.003	0.037	20.7	0.24	0.41	0.25	0.071	<u>0.157</u>	0.012		Comparative Example
43	0.008	0.09	0.20	0.025	0.002	0.034	20.9	0.19	0.44	0.13	0.141	0.138	0.010		Comparative Example
44	0.013	0.11	0.21	0.027	0.002	0.035	21.5	0.14	0.45	0.11	0.125	0.094	0.012		Comparative Example
45	0.009	0.11	0.16	0.025	0.002	0.039	21.5	0.13	0.40	0.13	0.147	0.107	0.009		Comparative Example
46	0.008	0.10	0.16	0.024	0.002	0.026	21.1	0.19	0.41	0.10	0.148	0.109	0.008		Comparative Example
47	0.011	0.10	0.16	0.022	0.002	0.039	21.3	0.23	0.42	0.11	0.123	0.018	0.008		Comparative Example

(continued)

Test No.	Chemical Composition (mass%)														Note
	C	Si	Mn	P	S	Al	Cr	Ni	Cu	Ti	Nb	Zr	N	Other Chemical Element	
48	0.007	0.11	0.22	0.021	0.001	0.025	21.3	0.22	0.41	0.13	0.148	0.033	0.009		Comparative Example
49	0.009	0.11	0.21	0.030	0.001	0.022	21.4	0.24	0.40	0.11	0.085	0.098	0.010		Comparative Example
50	0.009	0.09	0.15	0.028	0.001	0.026	21.4	0.27	0.44	0.12	0.103	0.132	0.009		Comparative Example
51	0.011	0.12	0.19	0.021	0.002	0.027	20.6	0.25	0.43	0.10	0.064	0.071	0.010		Comparative Example
52	0.012	0.10	0.19	0.023	0.002	0.029	21.0	0.26	0.42	0.13	0.074	0.144	0.009		Comparative Example
53	0.013	0.08	0.17	0.029	0.001	0.021	21.5	0.24	0.43	0.23	0.032	0.051	0.008		Comparative Example
54	0.013	0.11	0.16	0.020	0.002	0.021	20.9	0.29	0.42	0.11	0.051	0.142	0.010		Comparative Example
55	0.010	0.10	0.20	0.020	0.002	0.037	21.4	0.24	0.44	0.12	0.132	0.145	0.008		Comparative Example
56	0.008	0.11	0.20	0.028	0.002	0.024	20.8	0.24	0.43	0.10	0.118	0.133	0.008		Comparative Example
57	0.011	0.10	0.16	0.022	0.001	0.038	21.0	0.23	0.44	0.31	<u>0.001</u>	<u>0.002</u>	0.009		Comparative Example
58	0.009	0.12	0.16	0.022	0.002	0.035	20.6	0.13	0.40	<u>0.02</u>	<u>0.256</u>	<u>0.003</u>	0.011		Comparative Example

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[Table 2-2]

	Test No.	Ti-Nb	Nb-Zr	Corrosion Resistance	Charpy	Surface Defect	Softening Temperature	Note
5	34	0.11	0.069	▲	○	○	○	Comparative Example
	35	0.11	0.070	○	▲	○	○	Comparative Example
10	36	0.19	0.042	▲	○	○	○	Comparative Example
	37	0.05	0.018	▲	○	○	○	Comparative Example
15	38	0.44	0.061	○	▲	▲	○	Comparative Example
	39	0.23	0.003	○	▲	▲	○	Comparative Example
20	40	0.27	0.120	○	○	○	▲	Comparative Example
	41	0.10	0.094	○	▲	▲	○	Comparative Example
25	42	0.18	-0.086	○	▲	▲	○	Comparative Example
	43	<u>-0.01</u>	0.003	○	▲	▲	○	Comparative Example
30	44	<u>-0.02</u>	0.031	○	▲	▲	○	Comparative Example
	45	<u>-0.02</u>	0.040	○	▲	▲	○	Comparative Example
35	46	<u>-0.05</u>	0.039	○	▲	▲	○	Comparative Example
	47	<u>-0.01</u>	0.105	○	▲	▲	○	Comparative Example
40	48	<u>-0.02</u>	0.115	○	▲	▲	○	Comparative Example
	49	0.03	-0.013	○	▲	▲	○	Comparative Example
45	50	0.02	<u>-0.029</u>	○	▲	▲	○	Comparative Example
	51	0.04	<u>-0.007</u>	○	▲	▲	○	Comparative Example
50	52	0.06	<u>-0.070</u>	○	▲	▲	○	Comparative Example
	53	0.20	<u>-0.019</u>	○	▲	▲	○	Comparative Example
55	54	0.06	<u>-0.091</u>	○	▲	▲	○	Comparative Example

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(continued)

Test No.	Ti-Nb	Nb-Zr	Corrosion Resistance	Charpy	Surface Defect	Softening Temperature	Note
55	<u>-0.01</u>	<u>-0.013</u>	○	▲	▲	○	Comparative Example
56	<u>-0.02</u>	<u>-0.015</u>	○	▲	▲	○	Comparative Example
57	0.31	<u>-0.001</u>	○	▲	▲	○	Comparative Example
58	<u>-0.24</u>	0.253	▲	▲	▲	▲	Comparative Example

*[Corrosion Resistance] A case where the pitting potential was 290 mV (vs. SCE) or more was judged as "○" (satisfactory), and a case where the pitting potential was less than 290 mV (vs. SCE) was judged as "▲" (unsatisfactory).

*[Charpy Impact Value] A case where the Charpy impact value (of a steel sheet having a thickness of 2 mm) at 25°C was 200 J/cm² or more was judged as "○" (satisfactory), and a case where the Charpy impact value (of a steel sheet having a thickness of 2 mm) at 25°C was less than 200 J/cm² was judged as "▲" (unsatisfactory).

*[Surface Defect] A case where the number of streaks in a region of 200 mm^W × 200 mm^L was 1 or less was judged as "○" (satisfactory), and a case where the above-described number was more than 1 was judged as "▲" (unsatisfactory).

*[Softening Temperature] A case where the relational expression $c + 0.1 \times (a - c) \geq b$ was satisfied was judged as "○" (satisfactory), and other cases were judged as "▲" (unsatisfactory), where the Vickers hardness of a steel sheet in the cold-rolled state was defined as a, the Vickers hardness of a steel sheet which had been subjected to a heat treatment at a temperature of 880°C for 20 seconds was defined as b, and the Vickers hardness of a steel sheet which had been subjected to a heat treatment at a temperature of 1000°C for 20 seconds was defined as c.

[Table 3-1]

Test No.	Chemical Composition (mass%)														Note
	C	Si	Mn	P	S	Al	Cr	Ni	Cu	Ti	Nb	Zr	N	Other Chemical Element	
59	0.009	0.08	0.16	0.027	0.002	0.029	20.6	0.28	0.32	0.13	0.118	0.038	0.013	Mo:0.09	Example
60	0.009	0.10	0.17	0.026	0.003	0.029	21.4	0.30	0.33	0.15	0.139	0.022	0.010	V:0.11	Example
61	0.012	0.11	0.21	0.027	0.002	0.024	21.1	0.21	0.44	0.16	0.146	0.029	0.009	Mo:0.26	Example
62	0.010	0.11	0.23	0.026	0.003	0.031	20.9	0.23	0.41	0.22	0.056	0.050	0.010	Ca:0.0024	Example
63	0.008	0.12	0.20	0.029	0.001	0.021	21.0	0.14	0.44	0.26	0.091	0.082	0.011	W:0.33	Example
64	0.012	0.10	0.18	0.025	0.003	0.038	21.3	0.22	0.43	0.25	0.113	0.105	0.011	B:0.0015	Example
65	0.009	0.11	0.23	0.026	0.003	0.037	20.7	0.19	0.57	0.22	0.126	0.102	0.012	Co:0.18	Example
66	0.010	0.12	0.23	0.025	0.001	0.022	20.9	0.22	0.78	0.23	0.128	0.119	0.010	La:0.08	Example
67	0.009	0.09	0.22	0.022	0.002	0.020	21.2	0.27	0.41	0.25	0.116	0.120	0.007		Comparative Example
68	0.008	0.10	0.15	0.029	0.002	0.023	21.5	0.20	0.45	0.21	0.129	0.141	0.013		Comparative Example

[Table 3-2]

Test No.	Ti-Nb	Nb-Zr	Corrosion Resistance	Charpy	Surface Defect	Softening Temperature	Note
59	0.01	0.080	○	○	○	○	Example
60	0.01	0.117	○	○	○	○	Example
61	0.01	0.117	○	○	○	○	Example
62	0.16	0.006	○	○	○	○	Example
63	0.17	0.009	○	○	○	○	Example
64	0.14	0.008	○	○	○	○	Example
65	0.09	0.024	○	○	○	○	Example
66	0.10	0.009	○	○	○	○	Example
67	0.13	-0.004	○	▲	▲	○	Comparative Example
68	0.08	-0.012	○	▲	▲	○	Comparative Example
*[Corrosion Resistance] A case where the pitting potential was 290 mV (vs. SCE) or more was judged as "○" (satisfactory), and a case where the pitting potential was less than 290 mV (vs. SCE) was judged as "▲" (unsatisfactory). *[Charpy Impact Value] A case where the Charpy impact value (of a steel sheet having a thickness of 2 mm) at 25°C was 200 J/cm² or more was judged as "○" (satisfactory), and a case where the Charpy impact value (of a steel sheet having a thickness of 2 mm) at 25°C was less than 200 J/cm² was judged as "▲" (unsatisfactory). *[Surface Defect] A case where the number of streaks in a region of 200 mm^W × 200 mm^L was 1 or less was judged as "○" (satisfactory), and a case where the above-described number was more than 1 was judged as "▲" (unsatisfactory). *[Softening Temperature] A case where the relational expression $c + 0.1 \times (a - c) \geq b$ was satisfied was judged as "○" (satisfactory), and other cases were judged as "▲" (unsatisfactory), where the Vickers hardness of a steel sheet in the cold-rolled state was defined as a, the Vickers hardness of a steel sheet which had been subjected to a heat treatment at a temperature of 880°C for 20 seconds was defined as b, and the Vickers hardness of a steel sheet which had been subjected to a heat treatment at a temperature of 1000°C for 20 seconds was defined as c.							

[0077] Fig. 1 illustrates the evaluation results of Charpy impact values and surface defects of the examples of the present invention and comparative examples (Nos. 43 through 48), whose chemical compositions were within the range according to the present invention, and in which the relational expression $Nb \geq Zr$ was satisfied and the relational expression $Ti \geq Nb$ was not satisfied, in a form of graph in which the horizontal axis indicates the Ti content and the vertical axis indicates the Nb content. Here, for all the steel sheets illustrated in Fig. 1, in a case where the evaluation result regarding a Charpy impact value was satisfactory, the evaluation regarding a surface defect was satisfactory, and in a case where the evaluation result regarding a Charpy impact value was unsatisfactory, the evaluation regarding a surface defect was unsatisfactory. As Fig. 1 indicates, it is necessary that the relational expression $Ti \geq Nb$ be satisfied in order to realize excellent toughness and a decrease in the quantity of surface defects at the same time within the range of the chemical composition according to the present invention.

[0078] Fig. 2 illustrates the evaluation results of Charpy impact values and surface defects of the examples of the present invention and comparative examples (Nos. 49 through 54, 67, and 68), whose chemical compositions were within the range according to the present invention, and in which the relational expression $Ti \geq Nb$ was satisfied and the relational expression $Nb \geq Zr$ was not satisfied, in a form of graph in which the horizontal axis indicates the Nb content and the vertical axis indicates the Zr content. As Fig. 2 indicates, it is necessary that the relational expression $Nb \geq Zr$ be satisfied in order to realize excellent toughness and a decrease in the quantity of surface defects at the same time within the range of the chemical composition according to the present invention. Moreover, as Fig. 1 and Fig. 2 indicate, it is clarified that it is necessary that both the relational expression $Ti \geq Nb$ and the relational expression $Nb \geq Zr$, that is, the relational expression $Zr \leq Nb \leq Ti$, be satisfied in order to realize excellent toughness and a decrease in the quantity of surface defects at the same time within the range of the chemical composition according to the present invention.

[0079] Here, comparative example Nos. 55 and 56, whose chemical compositions were within the range according to

the present invention, and in which the relational expression $Ti \geq Nb$ or the relational expression $Nb \geq Zr$ was not satisfied, were unsatisfactory in the evaluations both regarding a Charpy impact value and regarding a surface defect.

Industrial Applicability

[0080] The ferritic stainless steel sheet according to the present invention, which has excellent toughness and only a small quantity of surface defects, can preferably be used not only for parts which are required to have satisfactory corrosion resistance but also for parts which are required to have satisfactory toughness and surface quality including the inner panels of elevators, interiors, duct hoods, muffler cutters, lockers, the parts of home electrical appliances, the parts of office appliances, the interior parts of automobiles, the exhaust pipes of automobiles, building materials, the lids of drainage channel, maritime containers, house wares, kitchen appliances, the interior and exterior materials of buildings, automobile parts, escalators, railway vehicles, the chassis of electrical apparatuses and the like.

Claims

1. A ferritic stainless steel sheet having a chemical composition containing, by mass%, C: 0.020% or less, Si: 0.05% to 0.40%, Mn: 0.05% to 1.00%, P: 0.040% or less, S: 0.030% or less, Al: 0.001% to 0.15%, Cr: 20.0% to 23.0%, Ni: 0.01% to 0.80%, Cu: 0.30% to 0.80%, Ti: 0.10% to 0.50%, Nb: 0.010% to 0.150%, Zr: 0.005% to 0.150%, N: 0.020% or less, and the balance being Fe and inevitable impurities, in which relational expression (1) below is satisfied:

$$Zr \leq Nb \leq Ti \quad (1),$$

where each of Zr, Nb, and Ti in relational expression (1) denotes the content (mass%) of the corresponding chemical element.

2. The ferritic stainless steel sheet according to Claim 1, the steel sheet having the chemical composition further containing, by mass%, one, two, or more selected from Co: 0.01% to 0.50%, Mo: 0.01% to 0.30%, and W: 0.01% to 0.50%.
3. The ferritic stainless steel sheet according to Claim 1 or 2, the steel sheet having the chemical composition further containing, by mass%, one, two, or more selected from V: 0.01% to 0.50%, B: 0.0003% to 0.0030%, Mg: 0.0005% to 0.0100%, Ca: 0.0003% to 0.0030%, Y: 0.001% to 0.20%, and REM (rare-earth metal): 0.001% to 0.10%.
4. The ferritic stainless steel sheet according to any one of Claims 1 to 3, the steel sheet having the chemical composition further containing, by mass%, one or both selected from Sn: 0.001% to 0.50% and Sb: 0.001% to 0.50%.

FIG. 1

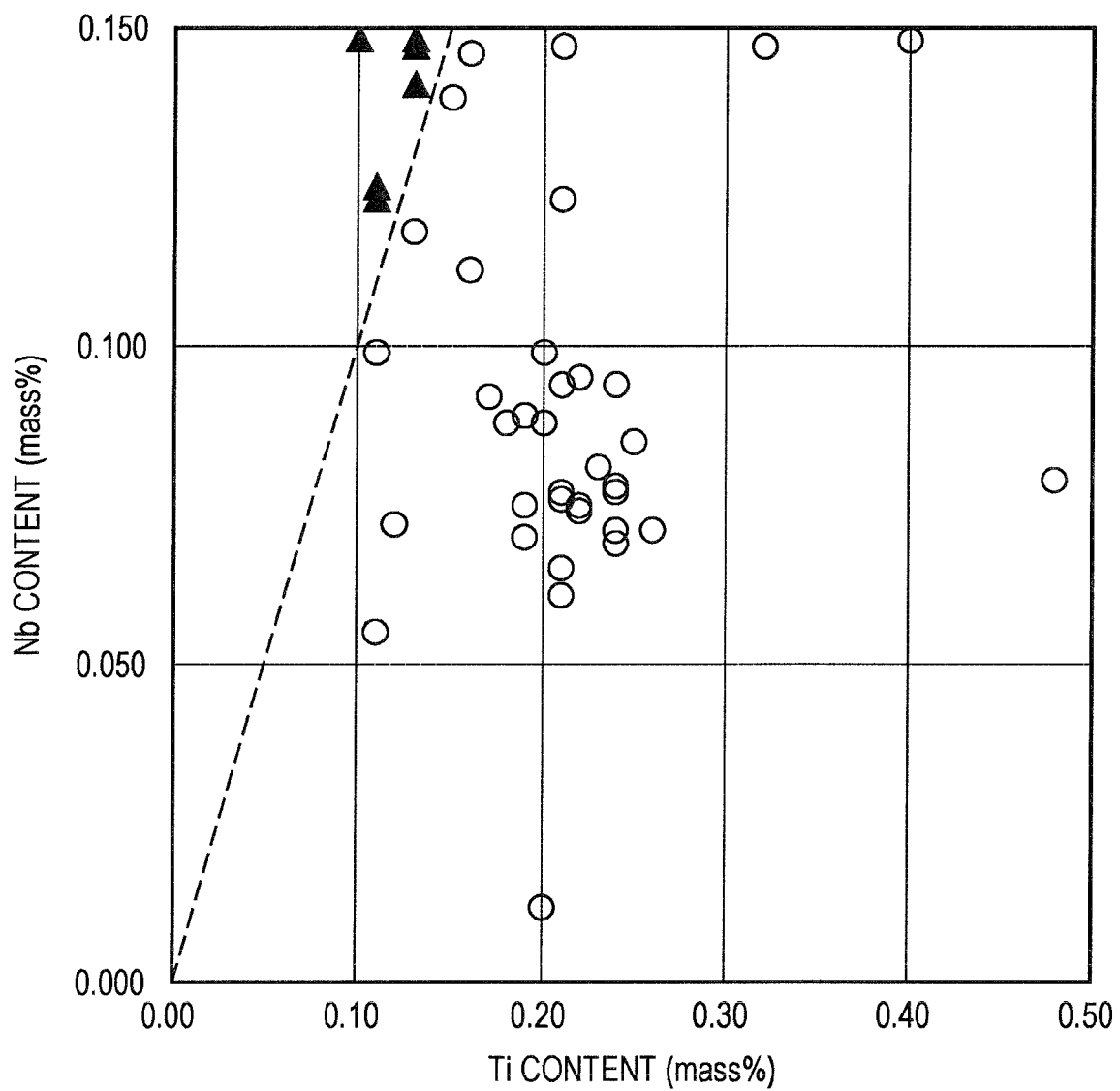
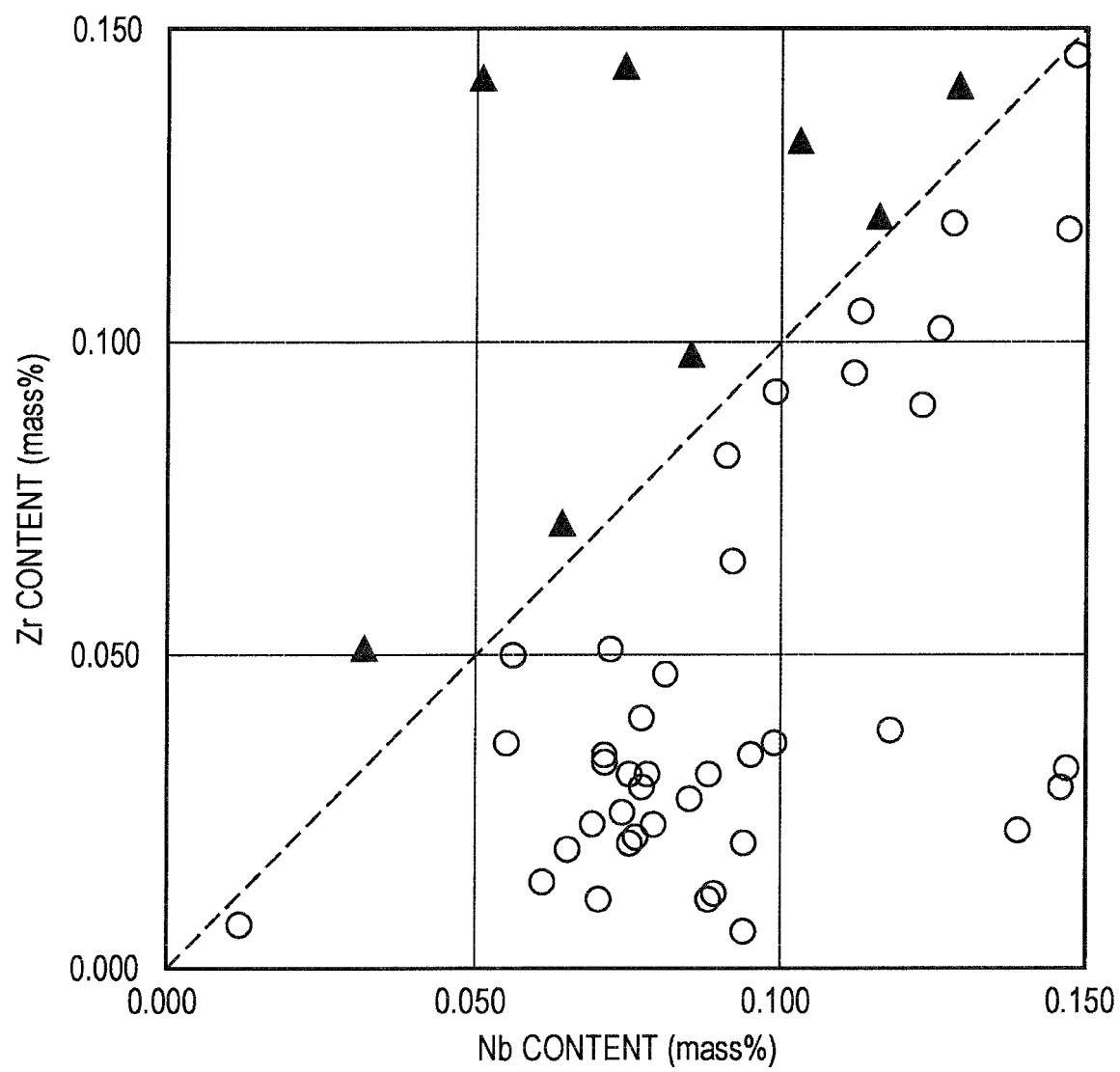


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/004336

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/00(2006.01)i, C22C38/50(2006.01)i, C22C38/60(2006.01)i, C21D9/46(2006.01)n

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)

C22C38/00-C22C38/60, C21D9/46, C21D8/02

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016
Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2011-246814 A (JFE Steel Corp.), 08 December 2011 (08.12.2011), (Family: none)	1-4
A	JP 2010-514924 A (Posco), 06 May 2010 (06.05.2010), & WO 2008/082096 A1 & KR 10-0821060 B1 & CN 101573466 A	1-4
A	JP 2007-270226 A (Nippon Steel & Sumikin Stainless Steel Corp.), 18 October 2007 (18.10.2007), (Family: none)	1-4
A	JP 2001-288544 A (Nippon Steel Corp.), 19 October 2001 (19.10.2001), (Family: none)	1-4



Further documents are listed in the continuation of Box C.



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document member of the same patent family

Date of the actual completion of the international search

06 December 2016 (06.12.16)

Date of mailing of the international search report

20 December 2016 (20.12.16)

Name and mailing address of the ISA/

Japan Patent Office

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Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/004336

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 103510013 A (BAOSTEEL STAINLESS STEEL CO., LTD.), 15 January 2014 (15.01.2014), (Family: none)	1-4

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

REFERENCES CITED IN THE DESCRIPTION

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