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(54) MATERIAL FOR COLD-ROLLED STAINLESS STEEL SHEET, AND PRODUCTION METHOD THEREFOR

(57) A raw material for a steel sheet, the raw material being suitable for manufacturing a cold-rolled ferritic stainless steel sheet having excellent corrosion resistance, formability, and ridging resistance, and a manufacturing method therefor are provided.

A raw material for a cold-rolled stainless steel sheet has a chemical composition containing, in terms of mass%, C: 0.005 to 0.030%, Si: 0.05 to 1.00%, Mn: 0.05 to 1.00%, P: 0.040% or less, S: 0.030% or less, Al: 0.001 to 0.150%, Cr: 10.8 to 14.4%, Ni: 0.01 to 2.50%, and N: 0.005 to 0.060%, with the balance being Fe and incidental impurities, in which the raw material has a structure containing 10 to 90% of a martensite phase in terms of area ratio with the balance being a ferrite phase.

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Description

Technical Field

[0001] The present invention relates to a raw material for a cold-rolled stainless steel sheet, the raw material being suitable for manufacturing a cold-rolled ferritic stainless steel sheet having excellent corrosion resistance, formability, and ridging resistance, and to a method for manufacturing the raw material.

Background Art

[0002] Ferritic stainless steel sheets are low-cost, excellent price-stable material compared to austenitic stainless steel sheets since the Ni content is not high, and have been used in various applications, such as building materials, transportation equipment, and home electric appliances, due to excellent corrosion resistance. In particular, unlike austenitic stainless steel sheets, ferritic stainless steel sheets have magnetism, and, thus, are increasingly used in cooking tools, which are available for induction heating (IH) systems. Cooking tools such as pots are mostly formed by bulging. Thus, sufficient elongation is necessary to obtain a desired shape.

[0003] Meanwhile, ferritic stainless steel sheets have a problem in that, during forming, surface irregularities (ridging) that deteriorate appearance frequently occur on the surfaces. The surface appearance determines commercial value of cooking tools, therefore if ridging occurs on their surface, a polishing step for removing the irregularities must be performed after forming. In other words, there is a problem in that occurrence of extensive ridging increases the manufacturing cost. In general, extensive ridging tends to appear when larger strain is applied to the ferritic stainless steel sheet, in other words, when severe working is performed.

[0004] In recent years, shapes of home cooking tools have become increasingly diverse, and thus ferritic stainless steel sheets that can be subjected to severer working are in demand. In other words, ferritic stainless steel sheets with higher elongation are desirable.

[0005] However, it is also desirable to decrease the manufacturing cost of home cooking tools. In other words, ferritic stainless steel sheets in which ridging that causes the increase in manufacturing cost, is decreased are desired.

[0006] In response to these requests, there is a demand for a ferritic stainless steel sheet that has higher elongation and reduces ridging sufficiently even if strain larger than conventional one is applied.

[0007] Regarding the aforementioned problem, for example, Patent Literature 1 discloses a ferritic stainless steel sheet having excellent formability, characterized in containing, in terms of mass%, C: 0.02 to 0.06%, Si: 1.0% or less, Mn: 1.0% or less, P: 0.05% or less, S: 0.01% or less, Al: 0.005% or less, Ti: 0.005% or less, Cr: 11 to 30%, and Ni: 0.7% or less, and satisfying $0.06 \leq (C + N) \leq 0.12$, $1 \leq N/C$, and $1.5 \times 10^{-3} \leq (V \times N) \leq 1.5 \times 10^{-2}$ (C, N, and V respectively represents contents of the elements in mass%).

[0008] Patent Literature 2 discloses a method for manufacturing a ferritic stainless steel sheet having excellent ridging resistance and formability, characterized in that a hot-rolled sheet of a ferritic stainless steel sheet containing, in terms of weight%, 0.15% or less of C and 13 to 25% of Cr is annealed for 10 minutes or less in a range of 930 to 990°C where austenite and ferrite phases coexist so as to form a two-phase structure of a martensite phase and a ferrite phase, the resulting annealed sheet is cold-rolled, and the resulting cold-rolled sheet is annealed in a range of 750 to 860°C.

[0009] Patent Literature 3 discloses a raw material for a cold-rolled stainless steel sheet, containing, in terms of mass%, C: 0.007 to 0.05%, Si: 0.02 to 0.50%, Mn: 0.05 to 1.0%, P: 0.04% or less, S: 0.01% or less, Cr: 15.5 to 18.0%, Al: 0.001 to 0.10%, and N: 0.01 to 0.06% with the balance being Fe and incidental impurities, in which the raw material has a metal structure containing, in terms of area ratio, 10 to 60% of a martensite phase and the balance being a ferrite phase, the martensite phase has a hardness of the ferrite phase constituting the metal structure, and the martensite phase has a hardness of HV500 or less.

Citation List

Patent Literature

[0010]

PTL 1: Japanese Patent No. 3584881
PTL 2: Japanese Examined Patent Application Publication No. 47-1878
PTL 3: International Publication No. 2015/111403

Summary of Invention

Technical Problem

[0011] In the invention disclosed in Patent Literature 1, ridging evaluation is carried out on a test piece subjected to a prestrain of 20%, and ridging that occurs due to severer working is not sufficiently evaluated. The inventors of the present invention prepared various kinds of steel sheets by methods described in Patent Literature 1, and the ridging height that occurred when a prestrain of 23% was applied was evaluated by the method described below. However, none of the steel sheets exhibited excellent ridging resistance.

[0012] In the invention disclosed in Patent Literature 2, the prestrain applied to evaluate ridging is not described. The inventors of the present invention prepared various kinds of steel sheets by methods described in Patent Literature 2, and the ridging height that occurred when a prestrain of 23% was applied was evaluated by the ridging evaluation method described below. As a result, none of the steel sheets exhibited excellent ridging resistance. In addition, in this invention, the shape of the test piece used for evaluating elongation is not described. It is a well-known fact that the value of elongation obtained changes depending on the shape of the test piece used for evaluation.

[0013] The inventors of the present invention prepared various kinds of steel sheets by methods described in Patent Literature 2, and the elongation after fracture of the steel sheets was evaluated by the tensile test method described below. As a result, none of the steel sheets exhibited excellent formability.

[0014] The inventors of the present invention prepared various kinds of steel sheets by methods described in Patent Literature 3, and the elongation after fracture of the steel sheets was evaluated by the tensile test method described below. As a result, none of the steel sheets exhibited excellent formability.

[0015] The present invention has been developed under the current circumstances described above, and an object thereof is to provide a raw material for a cold-rolled stainless steel sheet, the raw material being suitable for manufacturing a cold-rolled ferritic stainless steel sheet having excellent corrosion resistance, formability, and ridging resistance, and a method for manufacturing the raw material.

[0016] Here, "excellent corrosion resistance" means that the rust area ratio measured by the method described below is 30% or less. Preferably, the rust area ratio is 20% or less. The corrosion test for evaluating the corrosion resistance is carried out in accordance with JASO M609-91. First, in the testing method, a test piece is polished with an emery paper to #600, washed with water, and ultrasonically degreased in ethanol for 5 minutes. Subsequently, a three-cycle corrosion test is carried out, each cycle consisting of salt spraying (5 mass% aqueous NaCl solution, 35°C) 2h $\rightarrow$ drying (60°C, relative humidity: 40%) 4h $\rightarrow$ wetting (50°C, relative humidity: 95% or more) 2h. After the test, the appearance of the corroded surface is photographed, and a 30 mm $\times$ 30 mm region at the center of the test piece in the photographed image is subjected to image analysis to calculate the rust area ratio.

[0017] Furthermore, "excellent formability" means that the elongation after fracture of the steel sheet measured by the method described below is 28% or more. More preferably, the elongation after fracture is 32% or more. In order to evaluate the elongation after fracture, first, JIS No. 13B tensile test pieces are taken in accordance with JIS Z 2241 such that longitudinal directions thereof are, respectively, the rolling direction (L direction), a direction 45 degrees with respect to the rolling direction (D direction), and a direction 90 degrees with respect to the rolling direction (C direction). Subsequently, a tensile test is carried out in accordance with JIS Z 2241, and the elongation after fracture (El) is measured for each test piece. The three-direction average ((L + 2D + C)/4, where L, D, and C respectively represent elongation after fracture (%) in the respective directions) of the obtained elongation after fracture is calculated, and is determined to be the elongation after fracture of the steel sheet.

[0018] Furthermore, "excellent ridging resistance" means that the ridging height of the steel sheet surface measured by the method described below is 3.0 μm or less. More preferably, the ridging height is 2.5 μm or less. Yet more preferably, the ridging height is 2.0 μm or less. To measure the ridging height of the steel sheet surface, first, a JIS No. 5 tensile test piece is taken in a direction parallel to the rolling direction. Next, after the surface of the test piece is polished with a #600 emery paper, a tensile strain of 23% is applied. Next, the surface profile is measured with a laser displacement meter in a direction 90 degrees with respect to the rolling direction on a polished surface of the parallel portion of the test piece. The measurement length is 16 mm per line, and the height is measured with 0.05 mm increments. In addition, the line interval is set to 0.1 mm, and a total of fifty lines are measured. The obtained profile data of each line is smoothed and subjected to a waviness removal process by using a Hanning window function-type finite impulse response (FIR) bandpass filter with a high-cut filter wavelength of 0.8 mm and a low-cut filter wavelength of 8 mm.

[0019] Subsequently, on the basis of the processed profile data of each line, the data corresponding to 2 mm portions at both ends of each line is eliminated, and the arithmetic mean waviness Wa prescribed in JIS B 0601 (2001) is measured for each line. The average value of the values of the arithmetic mean waviness, Wa, of fifty lines is the ridging height of the steel sheet surface.

[0020] Note that, in the ridging resistance evaluation of the related art, test pieces subjected to a 15% or 20% tensile strain are mostly used. However, the assumption of the present invention is that the steel sheet is formed into a shape more complex than that in the related art. Thus, the tensile strain applied to the test pieces is set to 23% for evaluation under the assumption that the steel sheet is formed more severely, in other words, is subjected to higher strain than in the related art.

Solution to Problem

[0021] To address the problems described above, the inventors of the present invention have investigated a raw material for a cold-rolled stainless steel sheet, the raw material being suitable for manufacturing a cold-rolled ferritic stainless steel sheet having excellent corrosion resistance, formability, and ridging resistance, and a method for manufacturing the raw material. As a result, the following was found.

[0022] A cold-rolled ferritic stainless steel sheet having excellent formability and ridging resistance is obtained by using a raw material for a cold-rolled stainless steel sheet prepared by hot-rolling and then annealing a ferritic stainless steel with an appropriate chemical composition in a preferable temperature region that constitutes a ferrite-austenite two-phase region before cold-rolling, and then cold-rolling this raw material and annealing the resulting cold-rolled sheet.

[0023] Specifically, in the steel chemical composition, the C content is set to 0.030% or less, the Cr content is set to 14.4% or less, and the N content is set to 0.060% or less. A steel ingot having the aforementioned composition is hot-rolled, and the hot rolled sheet is annealed at 900 to 1100°C, which is the ferrite-austenite two-phase region. In this hot-rolled sheet annealing, the steel composition is adjusted so that the area ratio of the austenite phase is 10 to 90%. Within the steel chemical composition range of the present invention, nearly all of this austenite phase is transformed into a martensite phase during the cooling process after the hot-rolled sheet annealing. Such a hot-rolled and annealed sheet (raw material for a cold-rolled steel sheet) having a martensite phase is then cold-rolled so as to destroy colonies (crystal grain groups having similar crystal orientations), that cause ridging, and efficiently apply the rolling strain to the ferrite/martensite grain boundaries. Since the rolling strain is efficiently applied as described above and since the Cr content, the C content, and the N content in the steel are sufficiently low, recrystallization is accelerated during the cold-rolled sheet annealing. By the recrystallization accelerating effect, the cold-rolled sheet is recrystallized sufficiently in the temperature range of 780 to 830°C, which is a ferrite single phase region, and a cold-rolled and annealed sheet (cold-rolled ferritic stainless steel sheet) having excellent formability is obtained. Furthermore, by the colony destroying effect described above, the cold-rolled and annealed sheet exhibits excellent ridging resistance.

[0024] The present invention is based on the aforementioned findings, and the features are summarized as follows.

[1] A raw material for a cold-rolled stainless steel sheet, the raw material having a chemical composition containing, in terms of mass%,
C: 0.005 to 0.030%,
Si: 0.05 to 1.00%,
Mn: 0.05 to 1.00%,
P: 0.040% or less,
S: 0.030% or less,
Al: 0.001 to 0.150%,
Cr: 10.8 to 14.4%,
Ni: 0.01 to 2.50%, and
N: 0.005 to 0.060%,
with the balance being Fe and incidental impurities,
in which the raw material has a structure containing 10 to 90% of a martensite phase in terms of area ratio with the balance being a ferrite phase.

[2] The raw material for a cold-rolled stainless steel sheet described in [1], in which the chemical composition further contains, in terms of mass%, one or two or more selected from
Co: 0.01 to 0.50%,
Cu: 0.01 to 0.80%,
Mo: 0.01 to 0.30%, and
W: 0.01 to 0.50%.

[3] The raw material for a ferritic stainless steel sheet described in [1] or [2], in which the chemical composition further contains, in terms of mass%, one or two or more selected from
Ti: 0.01 to 0.30%,
V: 0.01 to 0.10%,
Zr: 0.01 to 0.10%, and
Nb: 0.01 to 0.30%; and
a value of formula (1) below is 0.0 or less:

$$54 \times (Ti + V + Zr + Nb) - 5 \times Mn - 19 \times Ni + 1.0 \cdots \text{formula (1)}$$

where, in formula (1) above, respective element symbols represent contents (mass%) of respective elements, or represent 0 when corresponding elements are not contained.

[4] The raw material for a cold-rolled stainless steel sheet described in any one of [1] to [3], in which the chemical composition further contains, in terms of mass%, one or two or more selected from
B: 0.0003 to 0.0030%,
Mg: 0.0005 to 0.0100%,
Ca: 0.0003 to 0.0030%,
Y: 0.01 to 0.20%, and
REM (rare earth metal): 0.001 to 0.100%.

[5] The raw material for a cold-rolled stainless steel sheet described in any one of [1] to [4], in which the chemical composition further contains, in terms of mass%, one or two selected from
Sn: 0.001 to 0.500% and
Sb: 0.001 to 0.500%.

[6] A method for manufacturing the raw material for a cold-rolled stainless steel sheet described in any one of [1] to [5], the method including:
hot-rolling a steel slab having the chemical composition to prepare a hot-rolled sheet, and performing hot-rolled sheet annealing that involves holding the hot-rolled sheet in a temperature range of 900°C or more and 1100°C or less for 5 seconds to 15 minutes.

Advantageous Effects of Invention

[0025] The present invention provides a raw material for a cold-rolled stainless steel sheet, the raw material being suitable for manufacturing a cold-rolled ferritic stainless steel sheet having excellent corrosion resistance, formability, and ridging resistance, and a method for manufacturing the raw material.

Description of Embodiments

[0026] The present invention will now be specifically described.

[0027] A raw material for a cold-rolled stainless steel sheet according to the present invention has a chemical composition containing, in terms of mass%, C: 0.005 to 0.030%, Si: 0.05 to 1.00%, Mn: 0.05 to 1.00%, P: 0.040% or less, S: 0.030% or less, Al: 0.001 to 0.150%, Cr: 10.8 to 14.4%, Ni: 0.01 to 2.50%, and N: 0.005 to 0.060%, with the balance being Fe and incidental impurities, and has a structure containing 10 to 90% of a martensite phase on an area ratio basis with the balance being a ferrite phase. By using the raw material for a cold-rolled stainless steel sheet of the present invention, a cold-rolled ferritic stainless steel sheet having excellent corrosion resistance, formability, and ridging resistance can be manufactured.

[0028] First, the reasons for limiting the chemical composition to the aforementioned ranges in the present invention are described. Note that % indicating the unit of the content of a composition means mass% unless otherwise noted.

C: 0.005 to 0.030%

[0029] Carbon (C) is an element effective for increasing the strength of the steel. Furthermore, C is an element that improves ridging resistance since it promotes formation of the austenite phase during the hot-rolled sheet annealing. This effect is obtained at a C content of 0.005% or more. However, at a C content exceeding 0.030%, formability deteriorates due to an increase in the hardness of the steel. Thus, the C content is set to 0.005 to 0.030%. The C content is preferably 0.007% or more and more preferably 0.010% or more. The C content is preferably 0.020% or less and more preferably 0.015% or less.

Si: 0.05 to 1.00%

[0030] Silicon (Si) is an element useful as a deoxidant. This effect is obtained at a Si content of 0.05% or more. However, at a Si content exceeding 1.00%, formability deteriorates due to an increase in the hardness of the steel. Furthermore, since the amount of the austenite phase formed during the hot-rolled sheet annealing decreases, the ridging resistance deteriorates. Thus, the Si content is set to 0.05 to 1.00%. The Si content is preferably 0.07% or more,

more preferably 0.10% or more, and yet more preferably 0.20% or more. The Si content is preferably 0.50% or less, more preferably less than 0.40%, and yet more preferably less than 0.30%.

Mn: 0.05 to 1.00%

[0031] Manganese (Mn) has a deoxidizing effect. Furthermore, Mn is an element that improves the ridging resistance since it promotes formation of the austenite phase during the hot-rolled sheet annealing. This effect is obtained at a Mn content of 0.05% or more. However, at a Mn content exceeding 1.00%, precipitation and coarsening of MnS are accelerated, and corrosion resistance deteriorates since MnS serves as a starting point of rust generation. Thus, the Mn content is set to 0.05 to 1.00%. The Mn content is preferably 0.10% or more and more preferably 0.15% or more. The Mn content is preferably 0.80% or less and more preferably 0.60% or less.

P: 0.040% or less

[0032] Phosphorus (P) is an element that deteriorates corrosion resistance. Moreover, P segregates in crystal grain boundaries and deteriorates hot workability. Thus, the P content is preferably as low as possible, and is set to 0.040% or less. Preferably, the P content is 0.030% or less.

S: 0.030% or less

[0033] Sulfur (S) forms a precipitate, MnS, with Mn. Since this MnS serves as a starting point of corrosion pitting, corrosion resistance deteriorates. Thus, the S content is preferably as low as possible, and is set to 0.030% or less. Preferably, the S content is 0.020% or less.

Al: 0.001 to 0.150%

[0034] Aluminum (Al) is an element effective for deoxidation. This effect is obtained at an Al content of 0.001% or more. However, at an Al content exceeding 0.150%, the formability deteriorates due to an increase in the hardness of the steel. Thus, the Al content is set to 0.001 to 0.150%. The Al content is preferably 0.005% or more and more preferably 0.010% or more. The Al content is preferably 0.100% or less and more preferably 0.050% or less.

Cr: 10.8 to 14.4%

[0035] Chromium (Cr) is an element that improves corrosion resistance by forming passive film. At a Cr content less than 10.8%, sufficient corrosion resistance is not obtained. Meanwhile, at a Cr content exceeding 14.4%, since the austenite phase is not formed sufficiently in the steel during the hot-rolled sheet annealing process, the ridging resistance is deteriorated, and the formability deteriorates due to an increase in hardness of the steel. Thus, the Cr content is set to 10.8 to 14.4%. The Cr content is preferably 11.0% or more, more preferably 11.5% or more, and yet more preferably 12.0% or more. The Cr content is preferably 14.0% or less, more preferably 13.5% or less, and yet more preferably 13.0% or less.

Ni: 0.01 to 2.50%

[0036] Nickel (Ni) is an element that suppresses active dissolution in a low pH environment. In a so-called crevice structure in which steel sheets are overlapped each other, a low pH environment, that easily causes corrosion, is sometimes formed. Furthermore, in cases other than the crevice structure formed between the steel sheets as described above, an aqueous solution containing chloride ions, that cause rusting of steel sheets, may become condense on the steel sheets, salt may precipitate from the aqueous solution, and a crevice structure may be formed between the precipitated salt and the steel sheet such that a low pH environment that easily causes corrosion is formed. Ni suppresses progress of corrosion in such environments, and improves corrosion resistance of the steel. In other words, Ni is highly effective for improving the crevice corrosion resistance, suppresses progress of corrosion in an active dissolution state markedly, and thereby improves corrosion resistance. Furthermore, Ni is an element that improves ridging resistance since it promotes formation of the austenite phase during the hot-rolled sheet annealing.

[0037] This effect is obtained at a Ni content of 0.01% or more. However, at a Ni content exceeding 2.50%, formability deteriorates due to an increase in the hardness of the steel. Thus, the Ni content is set to 0.01 to 2.50%. The Ni content is preferably 0.03% or more, more preferably 0.05% or more, and yet more preferably 0.10% or more. The Ni content is preferably 1.20% or less, more preferably 0.80% or less, and yet more preferably 0.25% or less.

N: 0.005 to 0.060%

[0038] Nitrogen (N) is an element effective for increasing the strength of the steel. Furthermore, nitrogen is an element that improves ridging resistance since it promotes formation of the austenite phase during the hot-rolled sheet annealing. This effect is obtained at a N content of 0.005% or more. However, at a N content exceeding 0.060%, formability of the steel deteriorates due to an increase in the hardness of the steel. Thus, the N content is set to 0.005 to 0.060%. The N content is preferably 0.007% or more and more preferably 0.010% or more. The N content is preferably 0.020% or less and more preferably 0.015% or less.

[0039] The balance other than the elements described above is Fe and incidental impurities. Representative examples of the incidental impurities include O (oxygen), Zn, Ga, Ge, As, Ag, In, Hf, Ta, Re, Os, Ir, Pt, Au, and Pb. Among these elements, O (oxygen) can be contained in an amount of 0.02% or less. A total of 0.1% or less of other elements can be contained.

[0040] In the present invention, the following elements may be contained as appropriate in addition to the basic components described above.

Co: 0.01 to 0.50%

[0041] Cobalt (Co) is an element that improves crevice corrosion resistance of stainless steel. However, excessively containing Co results in saturated effects and deterioration of the workability. Thus, if Co is to be contained, the Co content is preferably 0.01 to 0.50%. The Co content is more preferably 0.30% or less and yet more preferably 0.10% or less.

Cu: 0.01 to 0.80%

[0042] Copper (Cu) is an element that improves corrosion resistance by strengthening the passive film. However, excessively containing Cu results in saturated effects and deterioration of the workability; furthermore, ε-Cu tends to precipitate and the corrosion resistance is deteriorated. Thus, if Cu is to be contained, the Cu content is preferably 0.01 to 0.80%. The Cu content is more preferably 0.15% or more and yet more preferably 0.40% or more. The Cu content is more preferably 0.60% or less and yet more preferably 0.45% or less.

Mo: 0.01 to 0.30%

[0043] Molybdenum (Mo) has an effect of improving crevice corrosion resistance of stainless steel. However, excessively containing Mo results in saturated effects and deterioration of the workability. Thus, if Mo is to be contained, the Mo content is preferably 0.01 to 0.30%. The Mo content is more preferably 0.20% or less and yet more preferably 0.10% or less.

W: 0.01 to 0.50%

[0044] Tungsten (W) is an element that improves crevice corrosion resistance of stainless steel. However, excessively containing W results in saturated effects and deterioration of the workability. Thus, if W is to be contained, the W content is preferably 0.01 to 0.50%. The W content is more preferably 0.03% or more and yet more preferably 0.05% or more. The W content is more preferably 0.30% or less and yet more preferably 0.10% or less.

Ti: 0.01 to 0.30%

[0045] Titanium (Ti) is an element that has an effect of improving formability of the cold-rolled and annealed sheet since its precipitation as carbides or nitrides during hot rolling due to its high affinity to C and N decreases the amounts of dissolved C and dissolved N in the base metal. Meanwhile, excessively containing Ti deteriorates the ridging resistance since it suppresses formation of the austenite phase during the hot-rolled sheet annealing. Thus, if Ti is to be contained, the Ti content is preferably 0.01 to 0.30%. More preferably, the Ti content is 0.02% or more. The Ti content is more preferably 0.10% or less and yet more preferably 0.08% or less.

V: 0.01 to 0.10%

[0046] Vanadium (V) is an element that has an effect of improving formability of the cold-rolled and annealed sheet since its precipitation as carbides or nitrides during hot rolling due to its high affinity to C and N decreases the amounts of dissolved C and dissolved N in the base metal. Meanwhile, excessively containing V deteriorates the ridging resistance since it suppresses formation of the austenite phase during the hot-rolled sheet annealing. Thus, if V is to be contained, the V content is preferably 0.01 to 0.10%. The V content is more preferably 0.02% or more and yet more preferably 0.03% or more. The V content is more preferably 0.08% or less and yet more preferably 0.05% or less.

Zr: 0.01 to 0.10%

[0047] Zirconium (Zr) is an element that has an effect of improving formability of the cold-rolled and annealed sheet since its precipitation as carbides or nitrides during hot rolling due to its high affinity to C and N decreases the amounts of dissolved C and dissolved N in the base metal. Meanwhile, excessively containing Zr deteriorates the ridging resistance since it suppresses formation of the austenite phase during the hot-rolled sheet annealing. Thus, if Zr is to be contained, the Zr content is preferably 0.01 to 0.10%. The Zr content is more preferably 0.02% or more and yet more preferably 0.03% or more. The Zr content is more preferably 0.08% or less and yet more preferably 0.05% or less.

Nb: 0.01 to 0.30%

[0048] Niobium (Nb) is an element that has an effect of improving formability of the cold-rolled and annealed sheet since its precipitation as carbides or nitrides during hot rolling due to its high affinity to C and N decreases the amounts of dissolved C and dissolved N in the base metal. Meanwhile, excessively containing Nb deteriorates the ridging resistance since it suppresses formation of the austenite phase during the hot-rolled sheet annealing. Thus, if Nb is to be contained, the Nb content is preferably 0.01 to 0.30%. More preferably, the Nb content is 0.02% or more. The Nb content is more preferably 0.10% or less and yet more preferably 0.08% or less.

[0049] When one or two or more selected from Ti, V, Zr, and Nb is contained, the value of formula (1) below is 0.0 or less.

$$54 \times (Ti + V + Zr + Nb) - 5 \times Mn - 19 \times Ni + 1.0 \cdots \text{formula (1)}$$

In formula (1), respective element symbols represent contents (mass%) of respective elements, or represent 0 when corresponding elements are not contained.

[0050] In embodying the present invention, when one or two or more selected from Ti, V, Zr, and Nb is contained, the contents of the respective elements must satisfy the aforementioned ranges and the value of formula (1) above must be 0.0 or less in order to obtain excellent ridging resistance.

[0051] As mentioned above, Ti, V, Zr, and Nb have an effect of suppressing formation of the austenite phase during the hot-rolled sheet annealing process. Meanwhile, even when these elements are contained, by sufficiently increasing the contents of Mn and Ni that promote formation of the austenite phase, a sufficient amount of austenite phase can be formed in the steel during the hot-rolled sheet annealing process.

[0052] In other words, when one or two or more selected from Ti, V, Zr, and Nb is contained, the steel composition is adjusted so that the value of formula (1) is 0.0 or less. In this manner, it becomes possible to form a sufficient amount of austenite phase in the hot-rolled sheet during the hot-rolled sheet annealing and thus a sufficient amount of martensite phase can exist in the hot-rolled and annealed sheet. Thus, colonies can be sufficiently destroyed in the cold-rolling process, and excellent ridging resistance can be given to the cold-rolled and annealed sheet. However, when the value of formula (1) exceeds 0.0, a sufficient amount of austenite phase is not formed in the hot-rolled sheet during the hot-rolled sheet annealing, the hot-rolled and annealed sheet does not include a sufficient amount of martensite phase, destruction of colonies becomes insufficient during the cold rolling process, and the ridging resistance of the cold-rolled and annealed sheet deteriorates.

B: 0.0003 to 0.0030%

[0053] Boron (B) is an element effective for preventing low-temperature secondary work embrittlement. However, excessively containing B results in deterioration of hot workability. Thus, if B is to be contained, the B content is preferably 0.0003 to 0.0030%. More preferably, the B content is 0.0005% or more. More preferably, the B content is 0.0020% or less.

Mg: 0.0005 to 0.0100%

[0054] Magnesium (Mg) acts as a deoxidant by forming Mg oxides with Al in molten steel. However, excessively containing Mg results in deterioration of toughness of the steel and decreases the productivity. Thus, if Mg is to be contained, the Mg content is preferably 0.0005 to 0.0100%. More preferably, the Mg content is 0.0010% or more. The Mg content is more preferably 0.0050% or less and yet more preferably 0.0030% or less.

Ca: 0.0003 to 0.0030%

[0055] Calcium (Ca) is an element that improves hot workability. However, excessively containing Ca results in deterioration of toughness of the steel, decreases the productivity, and, furthermore, deteriorates corrosion resistance due to precipitation of CaS. Thus, if Ca is to be contained, the Ca content is preferably 0.0003 to 0.0030%. More preferably, the Ca content is 0.0010% or more. More preferably, the Ca content is 0.0020% or less.

Y: 0.01 to 0.20%

[0056] Yttrium (Y) is an element that decreases the viscosity of the molten steel and improves cleanliness. However, excessively containing Y results in saturated effects and deterioration of the workability. Thus, if Y is to be contained, the Y content is preferably 0.01 to 0.20%. More preferably, the Y content is 0.10% or less.

Rare earth metal (REM): 0.001 to 0.100%

[0057] Rare earth metals (REM: elements of atomic numbers 57 to 71 such as La, Ce, and Nd) are elements that improve high-temperature oxidation resistance. However, excessively containing REM results in saturated effects, causes surface defects during hot-rolling, and decreases productivity. Thus, if REM is to be contained, the REM content is preferably 0.001 to 0.100%. More preferably, the REM content is 0.005% or more. More preferably, the REM content is 0.05% or less.

Sn: 0.001 to 0.500%

[0058] Tin (Sn) is effective for improving ridging resistance by promoting formation of the deformation band during rolling. However, excessively containing Sn results in saturated effects and deterioration of the formability. Thus, if Sn is to be contained, the Sn content is preferably 0.001 to 0.500%. More preferably, the Sn content is 0.003% or more. More preferably, the Sn content is 0.200% or less.

Sb: 0.001 to 0.500%

[0059] Antimony (Sb) is effective for improving ridging resistance by promoting formation of the deformation band during rolling. However, excessively containing Sb results in saturated effects and deterioration of the formability. Thus, if Sb is to be contained, the Sb content is preferably 0.001 to 0.500%. More preferably, the Sb content is 0.003% or more. More preferably, the Sb content is 0.200% or less.

Structure containing 10 to 90% of martensite phase in terms of area ratio with the balance being ferrite phase

[0060] In the present invention, it is important that a particular amount of a martensite phase be present in the structure. In the present invention, a particular amount of an austenite phase is formed in the steel by performing hot-rolled sheet annealing. Nearly all of the austenite phase turns into a martensite phase when cooled after the hot-rolled sheet annealing. Due to the presence of the martensite phase, the colonies are destroyed in the cool-rolling process, and the ridging resistance of the cold-rolled and annealed sheet is improved.

[0061] This effect is obtained when the area ratio of the martensite phase after the hot-rolled sheet annealing is 10% or more. Meanwhile, when the area ratio of the martensite phase exceeds 90%, the hot-rolled and annealed sheet becomes hard, the rolling load in the cold-rolling step increases, edge cracking and sheet shape defects occur, and the productivity is decreased. Thus, the area ratio of the martensite phase is set to 10 to 90%. The area ratio of the martensite phase is preferably 15% or more and more preferably 20% or more. The area fraction of the martensite phase is preferably 70% or less and more preferably 50% or less.

[0062] The method for measuring the area ratio of the martensite phase in the present invention is as follows. First, a test piece for structure observation is taken from near the width center portion of a raw material for a cold-rolled steel sheet, and after a section taken in the rolling direction is mirror-polished, the test piece is corroded (etched) with a Murakami reagent (8 mass% KOH-8 mass% [$K_3Fe(CN)_6$] aqueous solution). By using an optical microscope, setting a portion of 1.0 mm depth from the surface layer to the center of the view areas, ten view areas are photographed at a magnification of 400. The obtained structure images are binarized by image analysis, and then one of the values is deemed as the martensite phase and the other as the ferrite phase to identify and separate the martensite phase and the ferrite phase. Then the area ratio of the martensite phase is measured. The measurements results of a total of ten view areas are averaged, and the calculated average is used as the area fraction of the martensite phase.

[0063] Next, a preferable method for manufacturing a raw material for a cold-rolled stainless steel sheet of the present invention is described. A steel having the above-described chemical composition is melted by a known method that uses a converter, an electric furnace, a vacuum melting furnace, or the like, and prepared into a steel (steel slab) by a continuous casting method or an ingoting-slabbing method. After this slab is heated to 1000°C or more and 1200°C or less, the heated slab is hot-rolled to a sheet thickness of 2.0 to 6.0 mm under the condition that the finishing temperature is 700°C or more and 1000°C or less.

[0064] Next, the hot-rolled sheet is subjected to hot-rolled sheet annealing that involves holding the hot-rolled sheet in a temperature range of 900°C or more and 1100°C or less, which is the ferrite-austenite two-phase region, for 5 seconds to 15 minutes. The hot-rolled sheet annealing is an extremely important step for obtaining the structure of the present invention.

[0065] At a hot-rolled sheet annealing temperature less than 900°C, annealing is performed in the ferrite single phase region or a temperature region close thereto, and as a result a sufficient amount of austenite phase is not formed in the hot-rolled sheet. At a hot-rolled sheet annealing temperature exceeding 1100°C also, annealing is performed in the ferrite single phase region or a temperature region close thereto, and as a result a sufficient amount of austenite phase is not formed in the hot-rolled sheet. In addition, when the holding time during hot-rolled sheet annealing is less than 5 seconds, a sufficient amount of austenite phase is not formed in the hot-rolled sheet during the hot-rolled sheet annealing. In contrast, when the holding time in the hot-rolled sheet annealing exceeds 15 minutes, the crystal grains coarsen during the hot-rolled sheet annealing, which results in coarsening of crystal grains of a cold-rolled and annealed sheet obtained by subsequent cold-rolling and annealing for manufacturing the cold-rolled steel sheet. Such a structure causes surface roughening known as orange peel, which is different from ridging, during forming.

[0066] Thus, in the present invention, hot-rolled sheet annealing that involves holding a hot-rolled sheet in a temperature range of 900°C or more and 1100°C or less for 5 seconds to 15 minutes is performed to obtain a hot-rolled and annealed sheet. The hot-rolled sheet annealing is preferably performed in a temperature range of 950°C or more. The hot-rolled sheet annealing is preferably performed in a temperature range of 1050°C or less. The hot-rolled sheet annealing preferably involves holding the sheet in the aforementioned temperature range for 20 seconds or more.

[0067] The hot-rolled sheet annealing preferably involves holding the sheet in the aforementioned temperature range for 1 minute or less.

[0068] The prepared hot-rolled and annealed sheet (raw material for a cold-rolled stainless steel sheet) may be subsequently pickled.

[0069] An example of the method for manufacturing a ferritic stainless steel sheet from a hot-rolled and annealed sheet (raw material for a cold-rolled stainless steel sheet) is a method that involves cold-rolling the raw material for a cold-rolled stainless steel sheet so as to prepare a cold-rolled sheet, and then annealing the cold-rolled sheet to prepare a cold-rolled and annealed sheet. The cold-rolled and annealed sheet can be further pickled in a pickling line to remove the scale. The cold-rolled, annealed, and pickled sheet from which scale is removed may be subjected to skinpass rolling. The cold rolling conditions are not particularly limited, and a common method may be employed. For example, in cold-rolling, the total rolling reduction can be 40 to 90%. The cold-rolled sheet annealing is preferably a process of holding the cold-rolled sheet in a temperature range of 780°C or more and 830°C or less for 5 seconds to 5 minutes. When the cold-rolled sheet annealing temperature is 780°C or more, less unrecrystallized structure remains in the manufactured cold-rolled ferritic stainless steel sheet, which can improves formability further. When the cold-rolled sheet annealing temperature is 830°C or less, since existence of the martensite phase in the structure after annealing can be suppressed by suppressing formation of the austenite phase in the steel during annealing, formability can be further improved. Moreover, when the holding time in cold-rolled sheet annealing is 5 seconds or more, since the martensite phase contained in the cold-rolled sheet can be sufficiently decomposed during annealing and existence of the martensite phase in the structure after annealing can be suppressed, formability can be further improved. When the holding time in cold-rolled sheet annealing is 5 minutes or less, coarsening of the crystal grains during the cold-rolled sheet annealing can be suppressed with result that it becomes easier to suppress surface roughening known as orange peel, which is different from ridging, during forming of the manufactured cold-rolled ferritic stainless steel sheet. Note that the cold-rolled sheet annealing is preferably performed in a continuous annealing line.

EXAMPLE 1

[0070] Each of ferritic stainless steels having chemical compositions (the balance being Fe and incidental impurities) indicated in Nos. 1-1 to 1-3 in Table 1 was prepared into a 100 kg steel ingot, and then hot-rolled under heating at a temperature of 1050°C so as to obtain a hot-rolled sheet having a thickness of 4.0 mm.

[0071] Each of the hot-rolled sheets was divided into five, and four of these were annealed in air for 20 seconds at respective temperatures of 830 to 1200°C indicated in Table 1, and top and bottom surfaces were ground to remove scale to prepare a raw material for a cold-rolled stainless steel sheet. Each of the raw materials for cold-rolled steel sheets was halved by shearing at the longitudinal center portion, one half was used for evaluation described below, and the other half was prepared into a cold-rolled, annealed, and pickled sheet through the steps described below.

[0072] The remaining one of the divided pieces of each hot-rolled sheet was annealed in an air atmosphere at 800°C for 8 hours, and top and bottom surfaces were ground to remove scale to prepare a raw material for a cold-rolled stainless steel sheet. Each of the raw materials for cold-rolled steel sheets was halved by shearing at the longitudinal center portion, one half was used for evaluation described below, and the other half was prepared into a cold-rolled, annealed, and pickled sheet through the processes described below.

[0073] Each of the obtained raw materials for cold-rolled steel sheets was cold-rolled to prepare a cold-rolled sheet having a thickness of 1.0 mm. The obtained cold-rolled sheets were annealed in an air atmosphere at 800°C for 20 seconds to obtain cold-rolled and annealed sheets. The cold-rolled and annealed sheets were pickled by a common method so as to obtain cold-rolled, annealed, and pickled ferritic stainless steel sheets.

[0074] The raw materials for cold-rolled stainless steel sheets and the cold-rolled, annealed, and pickled ferritic stainless steel sheets obtained under the aforementioned manufacturing conditions were subjected to the following evaluations.

[0075] First, a test piece for structure observation was taken from near the width center portion of a raw material for a cold-rolled steel sheet, and after a section taken in the rolling direction was mirror-polished, the test piece was corroded (etched) with a Murakami reagent (8 mass% KOH-8 mass% $[K_3Fe(CN)_6]$ aqueous solution). By using an optical microscope, setting a portion of 1.0 mm depth from the surface layer to the center of the view areas, ten view areas were photographed at a magnification of 400. The obtained structure images were binarized by image analysis to identify and separate the martensite phase and the ferrite phase, and the area ratio of the martensite phase was measured. The measurements results of a total of ten view areas were averaged, and the calculated average was used as the area ratio of the martensite phase.

<Corrosion resistance>

[0076] From each of the manufactured cold-rolled, annealed, and pickled sheets, a 80 mm (length) × 60 mm (width) steel sheet was cut out by shearing, the surface thereof was polished with an emery polishing paper to #600, and, after washing with water, the steel sheet was ultrasonically degreased for 5 minutes in ethanol to obtain a test piece. A corrosion test according to JASO M609-91 was performed on the obtained test piece to evaluate corrosion resistance. After end portions and the rear surface of a test piece were covered with a vinyl tape, the test piece was placed in a tester with a slope of 60° and with the lengthwise direction being set in the vertical direction. A three-cycle corrosion test was carried out, each cycle consisting of salt spraying (5 mass% aqueous NaCl solution, 35°C) 2h → drying (60°C, relative humidity: 40%) 4h → wetting (50°C, relative humidity: 95% or more) 2h. After the test, the appearance of the corroded surface was photographed, and a 30 mm × 30 mm region at the center of the test piece in the photographed image was subjected to image analysis to calculate the rust area ratio. Samples with a rust area ratio of 20% or less were evaluated as "○" (pass, excellent), samples with a rust area ratio exceeding 20% but not exceeding 30% were evaluated as "□" (pass), and samples with a rust area ratio exceeding 30% were evaluated as "▲" (fail).

<Formability>

[0077] From each of the cold-rolled, annealed, and pickled sheets manufactured as above, a JIS No. 13B tensile test piece was taken in accordance with JIS Z 2241 such that longitudinal directions thereof were, respectively, the rolling direction (L direction), a direction 45 degrees with respect to the rolling direction (D direction), and a direction 90 degrees with respect to the rolling direction (C direction), and a tensile test was performed at room temperature according to the same standard to evaluate the formability. Samples having a three-direction average ((L + 2D + C)/4 where L, D, and C represent elongations after fracture (%) of respective directions) of total elongation after fracture (%) of 32% or more were evaluated as "○" (pass, excellent), samples with an average of less than 32% but not less than 28% were evaluated as "□" (pass), and samples with an average of less than 28% were evaluated as "▲" (fail).

<Ridging resistance>

[0078] Furthermore, from each of the cold-rolled, annealed, and pickled sheets manufactured as above, a JIS No. 5 test piece specified in JIS Z 2241 was taken so that the rolling direction was the longitudinal direction of the test piece, and, after the surface thereof was polished with a #600 emery paper, a tensile test was performed in accordance with the same standard to apply a tensile strain of 23%. Subsequently, the surface profile was measured with a laser displacement meter in a direction 90 degrees with respect to the rolling direction on a polished surface at the center of the parallel portion of the test piece. The measurement length was 16 mm per line, and the height was measured with 0.05 mm increments. The obtained profile data was smoothed and subjected to a waviness removal process by using a Hanning window function-type finite impulse response (FIR) bandpass filter with a high-cut filter wavelength of 0.8 mm and a low-cut filter wavelength of 8 mm. Subsequently, on the basis of the processed profile data of each line, the data corresponding to 2 mm portions at both ends of each lines was eliminated, and the arithmetic mean waviness, Wa, specified in JIS B 0601 (2001) was measured for each line. Note that the line interval was set to 0.1 mm, and a total of fifty lines were measured. The average of the values of the arithmetic mean waviness, Wa, of fifty lines was used as the ridging height of the steel sheet surface, and the ridging resistance was evaluated.

[0079] The case in which the ridging height was 2.0 μm or less was evaluated as "◇" (pass, particularly excellent), the case in which the ridging height was more than 2.0 μm but not more than 2.5 μm was evaluated as "○" (pass, excellent), the case in which the ridging height was more than 2.5 μm but not more than 3.0 μm was evaluated as "□" (pass), and the case in which the ridging height was more than 3.0 μm was evaluated as "▲" (fail).

[0080] The obtained results are indicated in Table 1. The cold-rolled, annealed, and pickled sheets prepared from the raw materials for cold-rolled steel sheets having a martensite phase area ratio within the range of the present invention, in other words, the raw materials for cold-rolled steel sheets of the invention examples, were evaluated as "○" or "□" for corrosion resistance, "○" for formability, and "◇" or "○" for ridging resistance, indicating excellent corrosion resistance as well as excellent formability and ridging resistance.

[0081] The cold-rolled, annealed, and pickled sheets prepared from the raw materials for cold-rolled steel sheets having a martensite phase area ratio outside the range of the present invention, in other words, the raw materials for cold-rolled steel sheets of the comparative examples, were evaluated as "▲" for ridging resistance. These cold-rolled, annealed, and pickled sheets exhibited poor ridging resistance because the amount of the martensite phase contained in the raw materials for cold-rolled steel sheets were insufficient and the colonies were not satisfactorily destroyed by cold rolling.

[Table 1]

Test No.	Chemical composition (mass%)										Hot-rolled sheet annealing conditions		Martensite area fraction (%) of raw material for cold-rolled steel sheet	Evaluation results of cold-rolled, annealed, and pickled sheet			Remarks
	C	Si	Mn	P	S	Al	Cr	Ni	N	Other elements	Temperature (°C)	Time		Corrosion resistance	Formability	Ridging resistance	
1-1	0.008	0.37	0.20	0.016	0.005	0.016	13.3	0.25	0.010	-	800	8hr	0	○	○	▲	Comparative Example
											850	20S	7	○	○	▲	Comparative Example
											900	20S	28	○	○	○	Invention Example
											1000	20S	35	○	○	○	Invention Example
											1150	20S	0	○	○	▲	Comparative Example
1-2	0.015	0.15	0.23	0.019	0.003	0.042	12.4	0.82	0.005	-	800	8hr	0	○	○	▲	Comparative Example
											830	20S	6	○	○	▲	Comparative Example
											900	20S	87	○	○	◇	Invention Example
											1050	20S	80	○	○	◇	Invention Example
											1200	20S	8	○	○	▲	Comparative Example

(continued)

Test No.	Chemical composition (mass%)										Hot-rolled sheet annealing conditions		Martensite area fraction (%) of raw material for cold-rolled steel sheet	Evaluation results of cold-rolled, annealed, and pickled sheet			Remarks
	C	Si	Mn	P	S	Al	Cr	Ni	N	Other elements	Temperature (°C)	Time		Corrosion resistance	Formability	Ridging resistance	
1-3	0.019	0.43	0.52	0.024	0.006	0.003	11.5	0.12	0.013	-	800	8hr	0	□	○	▲	Comparative Example
											840	20S	9	□	○	▲	Comparative Example
											900	20S	84	□	○	◇	Invention Example
											1100	20S	70	□	○	◇	Invention Example
											1200	20S	3	□	○	▲	Comparative Example

* The balance other than the above-described chemical composition is Fe and incidental impurities.
*[Hot-rolled sheet annealing time] In examples involving 800°C, annealing was performed for 8 hours in a batch annealing furnace, and in examples not involving 800°C, annealing was performed for 20 seconds in a continuous annealing furnace.
*[Corrosion resistance] After three corrosion test cycles, samples with a rust area ratio of 20% or less were evaluated as "○" (pass, excellent), samples with a rust area ratio exceeding 20% but not exceeding 30% were evaluated as "□" (pass), and samples with a rust area ratio exceeding 30% were evaluated as "▲" (fail).
*[Formability] A tensile test was performed at room temperature, and samples having a three-direction average of total elongation after fracture (%) of 32% or more were evaluated as "○" (pass, excellent), samples with an average of less than 32% but not less than 28% were evaluated as "□" (pass), and samples with an average of less than 28% were evaluated as "▲" (fail).
*[Ridging resistance] After 23% tensile strain was applied, the case in which the ridging height on the surface of the center of the parallel portion of a test specimen was 2.0 μm or less was evaluated as "◇" (pass, particularly excellent), the case in which the ridging height was more than 2.0 μm but not more than 2.5 μm was evaluated as "○" (pass, excellent), the case in which the ridging height was more than 2.5 μm but not more than 3.0 μm was evaluated as "□" (pass), and the case in which the ridging height was more than 3.0 μm was evaluated as "▲" (fail).
* Underlines indicate items outside the scope of the present invention.

EXAMPLE 2

[0082] Raw materials for cold-rolled steel sheets and cold-rolled, annealed, and pickled sheets having the chemical compositions indicated in Nos. 2-1 to 2-57 in Tables 2-1 and 2-2 were manufactured under the conditions indicated in Example 1. However, for the hot-rolled sheet annealing conditions, annealing was performed in an air atmosphere at 1000°C for 20 seconds. These raw materials for cold-rolled steel sheets and the cold-rolled, annealed, and pickled sheets were subjected to the tests indicated in Example 1, and the martensite phase area ratio in the structure of the raw material for a cold-rolled steel sheet, corrosion resistance, formability, and ridging resistance of the cold-rolled, annealed, and pickled sheet were evaluated.

[0083] The obtained results are indicated in Tables 2-1 and 2-2.

[Table 2-1]

Test No.	Chemical composition (mass%)										Formula (1)	Martensite area fraction (%) of raw material for cold-rolled steel sheet	Evaluation results of cold-rolled, annealed, and pickled sheet			Remarks
	C	Si	Mn	P	S	Al	Cr	Ni	N	Other elements			Corrosion resistance	Formability	Ridging resistance	
2-1	0.005	0.37	0.24	0.017	0.005	0.016	11.1	0.21	0.008	-	-	85	□	○	◇	Invention Example
2-2	0.020	0.45	0.54	0.022	0.006	0.002	11.5	0.09	0.011	-	-	88	□	○	◇	Invention Example
2-3	0.007	0.31	0.20	0.018	0.007	0.011	11.7	0.15	0.010	-	-	66	□	○	◇	Invention Example
2-4	0.012	0.36	0.17	0.016	0.007	0.007	12.5	0.16	0.006	-	-	40	○	○	◇	Invention Example
2-5	0.014	0.31	0.21	0.021	0.007	0.025	13.2	0.18	0.005	-	-	27	○	○	○	Invention Example
2-6	0.015	0.35	0.15	0.019	0.004	0.038	14.4	0.18	0.011	-	-	15	○	□	□	Invention Example
2-7	0.005	0.34	0.16	0.020	0.004	0.019	12.9	0.03	0.008	-	-	25	○	○	◇	Invention Example
2-8	0.007	0.26	0.15	0.020	0.007	0.001	12.7	0.07	0.008	-	-	36	○	○	◇	Invention Example
2-9	0.014	0.30	0.20	0.015	0.006	0.028	12.5	0.12	0.010	-	-	56	○	○	◇	Invention Example
2-10	0.005	0.22	0.19	0.020	0.006	0.030	12.9	0.77	0.007	-	-	68	○	○	◇	Invention Example
2-11	0.014	0.31	0.19	0.018	0.005	0.014	12.6	2.46	0.005	-	-	88	○	○	◇	Invention Example
2-12	0.018	0.39	0.24	0.017	0.006	0.030	13.5	0.21	0.013	-	-	33	○	○	○	Invention Example
2-13	0.029	0.29	0.18	0.023	0.007	0.026	12.9	0.17	0.014	-	-	56	○	○	◇	Invention Example
2-14	0.015	0.37	0.24	0.023	0.004	0.018	13.2	0.19	0.019	-	-	39	○	○	○	Invention Example
2-15	0.006	0.22	0.22	0.024	0.004	0.024	12.5	0.17	0.057	-	-	84	○	○	◇	Invention Example
2-16	0.006	0.07	0.18	0.020	0.007	0.029	12.9	0.23	0.008	-	-	30	○	○	◇	Invention Example
2-17	0.006	0.48	0.21	0.021	0.004	0.003	13.1	0.10	0.009	-	-	21	○	○	○	Invention Example
2-18	0.013	0.95	0.18	0.024	0.005	0.019	12.8	0.20	0.014	-	-	31	○	○	◇	Invention Example
2-19	0.009	0.30	0.08	0.015	0.005	0.031	13.4	0.20	0.007	-	-	16	○	○	○	Invention Example
2-20	0.012	0.29	0.76	0.024	0.006	0.021	12.7	0.22	0.008	-	-	57	○	○	◇	Invention Example
2-21	0.013	0.35	0.96	0.023	0.006	0.014	12.6	0.16	0.007	-	-	64	○	○	◇	Invention Example
2-22	0.012	0.32	0.23	0.019	0.006	0.024	13.3	0.24	0.013	Cu:0.42	-	35	○	○	○	Invention Example
2-23	0.005	0.29	0.16	0.016	0.005	0.025	13.4	0.20	0.008	Mo:0.06	-	26	○	○	○	Invention Example
2-24	0.007	0.38	0.22	0.024	0.008	0.005	13.5	0.24	0.006	Ti:0.04	-2.5	28	○	○	○	Invention Example
2-25	0.012	0.33	0.17	0.024	0.004	0.007	12.9	0.22	0.013	Nb:0.05	-1.3	39	○	○	◇	Invention Example
2-26	0.008	0.28	0.21	0.021	0.006	0.015	12.9	0.15	0.010	Sn:0.005	-	32	○	○	◇	Invention Example
2-27	0.009	0.29	0.23	0.022	0.006	0.018	12.6	0.24	0.009	Co:0.03, W:0.07	-	35	○	○	◇	Invention Example
2-28	0.009	0.25	0.17	0.015	0.005	0.016	12.6	0.21	0.006	V:0.04, Mg:0.0021	-1.7	32	○	○	◇	Invention Example
2-29	0.005	0.22	0.21	0.023	0.008	0.010	12.9	0.11	0.005	Sn:0.008, Sb:0.010	-	27	○	○	◇	Invention Example
2-30	0.008	0.33	0.25	0.023	0.006	0.024	12.9	0.18	0.006	Cu:0.22, Y:0.04, La:0.05	-	30	○	○	◇	Invention Example
2-31	0.011	0.24	0.16	0.015	0.006	0.037	12.9	0.11	0.015	Ca:0.0014, Ce:0.02, Sn:0.121	-	36	○	○	◇	Invention Example
2-32	0.007	0.31	0.17	0.025	0.005	0.003	12.5	0.24	0.015	Mo:0.15, Zr:0.05, Sb:0.248	-1.7	31	○	○	◇	Invention Example
2-33	0.010	0.31	0.23	0.019	0.005	0.026	12.9	0.17	0.014	W:0.18, B:0.0011, Sn:0.195	-	34	○	○	◇	Invention Example
2-34	0.007	0.29	0.18	0.022	0.005	0.037	12.8	0.21	0.009	Ti:0.03, Nb:0.04	-0.1	30	○	○	◇	Invention Example

* The balance other than the above-described chemical composition is Fe and incidental impurities.

*[Corrosion resistance] After three corrosion test cycles, samples with a rust area ratio of 20% or less were evaluated as "○" (pass, excellent), samples with a rust area ratio exceeding 20% but not exceeding 30% were evaluated as "□" (pass), and samples with a rust area ratio exceeding 30% were evaluated as "▲" (fail).

*[Formability] A tensile test was performed at room temperature, and samples having a three-direction average of total elongation after fracture (%) of 32% or more were evaluated as "○" (pass, excellent), samples with an average of less than 32% but not less than 28% were evaluated as "□" (pass), and samples with an average of less than 28% were evaluated as "▲" (fail).

*[Ridging resistance] After 23% tensile strain was applied, the case in which the ridging height on the surface of the center of the parallel portion of a test specimen was 2.0 μm or less was evaluated as "◇" (pass, particularly excellent), the case in which the ridging height was more than 2.0 μm but not more than 2.5 μm was evaluated as "○" (pass, excellent), the case in which the ridging height was more than 2.5 μm but not more than 3.0 μm was evaluated as "□" (pass), and the case in which the ridging height was more than 3.0 μm was evaluated as "▲" (fail).

*[Formula (1)] $54 \times (Ti + V + Zr + Nb) - 5 \times Mn - 19 \times Ni + 1.0$ where the respective element symbols represent the contents (mass%) of the respective elements and represent 0 when the corresponding elements are not contained.

* Underlines indicate items outside the scope of the present invention.

[Table 2-2]

Test No.	Chemical composition (mass%)										Formula (1)	Martensite area fraction (%) of raw material for cold-rolled steel sheet	Evaluation results of cold-rolled, annealed, and pickled sheet			Remarks
	C	Si	Mn	P	S	Al	Cr	Ni	N	Other elements			Corrosion resistance	Formability	Ridging resistance	
2-35	0.012	0.33	0.22	0.017	0.005	0.026	10.6	0.18	0.008	-	-	100	▲	○	◇	Comparative Example
2-36	0.005	0.22	0.18	0.016	0.004	0.025	15.5	0.23	0.005	-	-	0	○	□	▲	Comparative Example
2-37	0.005	0.28	0.23	0.022	0.006	0.031	12.7	-	0.010	-	-	35	▲	○	◇	Comparative Example
2-38	0.006	0.28	0.17	0.016	0.006	0.007	12.8	2.63	0.013	-	-	96	○	▲	◇	Comparative Example
2-39	0.002	0.32	0.20	0.017	0.005	0.009	13.5	0.15	0.013	-	-	9	○	○	▲	Comparative Example
2-40	0.033	0.36	0.16	0.019	0.004	0.010	13.5	0.24	0.006	-	-	39	○	▲	◇	Comparative Example
2-41	0.007	0.24	0.15	0.022	0.007	0.017	13.4	0.19	0.003	-	-	8	○	○	▲	Comparative Example
2-42	0.012	0.31	0.16	0.016	0.004	0.015	12.8	0.23	0.065	-	-	83	○	▲	◇	Comparative Example
2-43	0.011	1.14	0.20	0.019	0.004	0.024	12.8	0.15	0.009	-	-	6	○	▲	▲	Comparative Example
2-44	0.013	0.27	0.18	0.022	0.006	0.012	16.5	0.17	0.010	-	-	9	○	□	▲	Comparative Example
2-45	0.006	0.46	0.06	0.021	0.005	0.024	10.8	0.82	0.007	-	-	85	○	○	◇	Invention Example
2-46	0.008	0.23	0.43	0.025	0.002	0.023	11.0	0.78	0.008	Ti:0.27	-1.4	64	○	○	◇	Invention Example
2-47	0.006	0.35	0.99	0.022	0.003	0.024	11.7	0.39	0.007	Nb:0.21	0.0	12	○	○	○	Invention Example
2-48	0.012	0.25	0.38	0.018	0.004	0.017	11.4	0.42	0.021	V:0.06, Zr:0.08	-1.3	47	○	○	◇	Invention Example
2-49	0.012	0.39	0.79	0.022	0.006	0.026	12.7	0.48	0.009	Mo:0.23, Ti:0.22, Y:0.08, Sb:0.031	-0.2	27	○	○	○	Invention Example
2-50	0.007	0.42	0.18	0.020	0.008	0.038	13.3	0.13	0.008	Cu:0.04, Mo:0.02, V:0.03	-0.8	35	○	○	◇	Invention Example
2-51	0.005	0.25	0.45	0.018	0.005	0.037	11.2	0.81	0.008	Cu:0.02, Mo:0.03, V:0.04, Ti:0.25	-1.0	43	□	○	◇	Invention Example
2-52	0.011	0.28	0.49	0.024	0.004	0.022	13.3	0.93	0.012	Ti:0.34	-0.8	2	○	○	▲	Comparative Example
2-53	0.007	0.24	0.13	0.023	0.006	0.046	12.4	0.27	0.006	V:0.09	0.1	8	○	○	▲	Comparative Example
2-54	0.006	0.08	0.19	0.020	0.007	0.028	11.3	0.17	0.007	Nb:0.03, Zr:0.03	0.1	7	○	○	▲	Comparative Example
2-55	0.005	0.44	0.34	0.021	0.001	0.057	10.7	0.07	0.010	Ti:0.18, V:0.05	10.4	9	▲	○	▲	Comparative Example
2-56	0.007	0.11	0.14	0.023	0.002	0.043	11.3	0.08	0.010	Ti:0.16, V:0.05	10.1	5	○	○	▲	Comparative Example
2-57	0.009	0.38	0.56	0.015	0.005	0.005	13.3	0.88	0.011	Nb:0.33	-0.7	7	○	○	▲	Comparative Example

* The balance other than the above-described chemical composition is Fe and incidental impurities.

*[Corrosion resistance] After three corrosion test cycles, samples with a rust area ratio of 20% or less were evaluated as "○" (pass, excellent), samples with a rust area ratio exceeding 20% but not exceeding 30% were evaluated as "□" (pass), and samples with a rust area ratio exceeding 30% were evaluated as "▲" (fail).

*[Formability] A tensile test was performed at room temperature, and samples having a three-direction average of total elongation after fracture (%) of 32% or more were evaluated as "○" (pass, excellent), samples with an average of less than 32% but not less than 28% were evaluated as "□" (pass), and samples with an average of less than 28% were evaluated as "▲" (fail).

*[Ridging resistance] After 23% tensile strain was applied, the case in which the ridging height on the surface of the center of the parallel portion of a test specimen was 2.0 µm or less was evaluated as "◇" (pass, particularly excellent), the case in which the ridging height was more than 2.0 µm but not more than 2.5 µm was evaluated as "○" (pass, excellent), the case in which the ridging height was more than 2.5 µm but not more than 3.0 µm was evaluated as "□" (pass), and the case in which the ridging height was more than 3.0 µm was evaluated as "▲" (fail).

*[Formula (1)] $54 \times (Ti + V + Zr + Nb) - 5 \times Mn - 19 \times Ni + 1.0$ where the respective element symbols represent the contents (mass%) of the respective elements and represent 0 when the corresponding elements are not contained.

* Underlines indicate items outside the scope of the present invention.

[0084] The cold-rolled, annealed, and pickled sheets prepared from the raw materials for cold-rolled steel sheets of the invention examples were evaluated as "○" or "□" for corrosion resistance, "○" or "□" for formability, and "◇", "○", or "□" for ridging resistance, indicating excellent corrosion resistance as well as excellent formability and ridging resistance.
[0085] Test No. 2-35 had poor corrosion resistance since it was prepared from a raw material for a cold-rolled steel sheet of a comparative example in which the Cr content was lower than the component range of the present invention.
[0086] Test No. 2-36 had poor ridging resistance since it was prepared from a raw material for a cold-rolled steel sheet of a comparative example in which the Cr content was higher than the component range of the present invention.
[0087] Test No. 2-37 had poor corrosion resistance since it was prepared from a raw material for a cold-rolled steel sheet of a comparative example in which the Ni content was lower than the component range of the present invention.
[0088] Test No. 2-38 had poor formability since it was prepared from a raw material for a cold-rolled steel sheet of a comparative example in which the Ni content was higher than the component range of the present invention.
[0089] Test Nos. 2-39 and 2-41 had poor ridging resistance since they were prepared from raw materials for cold-rolled steel sheets of comparative examples in which the C content and the N content, respectively, were lower than the component ranges of the present invention.
[0090] Test Nos. 2-40 and 2-42 had poor formability since they were prepared from raw materials for cold-rolled steel sheets of comparative examples in which the C content and the N content, respectively, were higher than the component ranges of the present invention.
[0091] Test No. 2-43 had poor formability and ridging resistance since it was prepared from a raw material for a cold-rolled steel sheet of a comparative example in which the Si content was higher than the component range of the present invention.
[0092] Test No. 2-44 had poor ridging resistance since it was prepared from a raw material for a cold-rolled steel sheet of a comparative example in which the Cr content was higher than the component range of the present invention.
[0093] Test No. 2-52 had poor ridging resistance since it was prepared from a raw material for a cold-rolled steel sheet of a comparative example in which the Ti content was higher than the component range of the present invention.
[0094] Test Nos. 2-53, 2-54, and 2-56 had poor ridging resistance since they were prepared from raw materials for cold-rolled steel sheets of comparative examples in which the value of formula (1) exceeded 0.0.
[0095] Test No. 2-55 had poor corrosion resistance and ridging resistance since it was prepared from a raw material for a cold-rolled steel sheet of a comparative example in which the Cr content was lower than the component range of the present invention and the value of formula (1) exceeded 0.0.
[0096] Test No. 2-57 had poor ridging resistance since it was prepared from a raw material for a cold-rolled steel sheet of a comparative example in which the Nb content was higher than the component range of the present invention.

Industrial Applicability

[0097] A raw material for a cold-rolled stainless steel sheet of the present invention is preferable for manufacturing a cold-rolled ferritic stainless steel sheet having excellent corrosion resistance, formability, and ridging resistance. Since a cold-rolled ferritic stainless steel sheet manufactured from a raw material for a cold-rolled stainless steel sheet of the present invention has excellent corrosion resistance, formability, and ridging resistance, it can be used in home cooking tolls, parts of home electric appliances, parts of office and stationery supplies, parts of automobile interiors, pipes for automobile exhaust, building materials, and the like.

Claims

1. A raw material for a cold-rolled stainless steel sheet, the raw material having a chemical composition containing, in terms of mass%,
C: 0.005 to 0.030%,
Si: 0.05 to 1.00%,
Mn: 0.05 to 1.00%,
P: 0.040% or less,
S: 0.030% or less,
Al: 0.001 to 0.150%,
Cr: 10.8 to 14.4%,
Ni: 0.01 to 2.50%, and
N: 0.005 to 0.060%,
with the balance being Fe and incidental impurities,
wherein the raw material has a structure containing 10 to 90% of a martensite phase in terms of area ratio with the

balance being a ferrite phase.

2. The raw material for a cold-rolled stainless steel sheet according to Claim 1, wherein the chemical composition further contains, in terms of mass%, one or two or more selected from
Co: 0.01 to 0.50%,
Cu: 0.01 to 0.80%,
Mo: 0.01 to 0.30%, and
W: 0.01 to 0.50%.

3. The raw material for a cold-rolled stainless steel sheet according to Claim 1 or 2, wherein the chemical composition further contains, in terms of mass%, one or two or more selected from
Ti: 0.01 to 0.30%,
V: 0.01 to 0.10%,
Zr: 0.01 to 0.10%, and
Nb: 0.01 to 0.30%; and
a value of formula (1) below is 0.0 or less:

$$54 \times (Ti + V + Zr + Nb) - 5 \times Mn - 19 \times Ni + 1.0 \quad \cdots \text{formula (1)}$$

where, in formula (1) above, respective element symbols represent contents (mass%) of respective elements, or represent 0 when corresponding elements are not contained.

4. The raw material for a cold-rolled stainless steel sheet according to any one of Claims 1 to 3, wherein the chemical composition further contains, in terms of mass%, one or two or more selected from
B: 0.0003 to 0.0030%,
Mg: 0.0005 to 0.0100%,
Ca: 0.0003 to 0.0030%,
Y: 0.01 to 0.20%, and
REM (rare earth metal): 0.001 to 0.100%.

5. The raw material for a cold-rolled stainless steel sheet according to any one of Claims 1 to 4, wherein the chemical composition further contains, in terms of mass%, one or two selected from
Sn: 0.001 to 0.500% and
Sb: 0.001 to 0.500%.

6. A method for manufacturing the raw material for a cold-rolled stainless steel sheet according to any one of Claims 1 to 5, the method comprising:
hot-rolling a steel slab having the chemical composition to prepare a hot-rolled sheet, and performing hot-rolled sheet annealing that involves holding the hot-rolled sheet in a temperature range of 900°C or more and 1100°C or less for 5 seconds to 15 minutes.

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2018/015579

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. C22C38/00(2006.01)i, C21D9/46(2006.01)i, C22C38/40(2006.01)i, C22C38/60(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl. C22C38/00-38/60, C21D9/46, C21D9/48

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2018
Registered utility model specifications of Japan	1996-2018
Published registered utility model applications of Japan	1994-2018

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.
X A	JP 2016-180143 A (JFE STEEL CORPORATION) 13 October 2016, examination no. P of table 2, paragraphs [0032], [0036], [0043]-[0046], table 1 (Family: none)	3-5 1-2, 6
A	JP 2010-001568 A (JFE STEEL CORPORATION) 07 January 2010 & US 2004/0226634 A1	1-6
A	JP 2015-218384 A (JFE STEEL CORPORATION) 07 December 2015 (Family: none)	1-6
A	WO 2015/064077 A1 (JFE STEEL CORPORATION) 07 May 2015 & US 2016/0289786 A1 & EP 3029170 A1	1-6
A	WO 2017/002148 A1 (JFE STEEL CORPORATION) 05 January 2017 & TW 201702407 A & KR 10-2018-0009775 A & CN 107709591 A	1-6

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

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 July 2018 (04.07.2018)	17 July 2018 (17.07.2018)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/015579

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2016/035235 A1 (JFE STEEL CORPORATION) 10 March 2016 & US 2017/0275744 A1 & EP 3181714 A1	1-6
A	JP 2002-275596 A (NISSHIN STEEL CO., LTD.) 25 September 2002 (Family: none)	1-6

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

REFERENCES CITED IN THE DESCRIPTION

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- JP 3584881 B **[0010]**
- JP 47001878 A **[0010]**
- JP 2015111403 A **[0010]**