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(54) **FERRITIC STAINLESS STEEL**

(57) Object is to provide a ferritic stainless steel excellent in surface quality, and excellent in corrosion resistance in a part welded with an austenitic stainless steel.

A ferritic stainless steel having a chemical composition consisting of, by mass%, C: 0.003% or more and 0.015% or less, Si: 0.05% or more and 0.30% or less, Mn: 0.10% or more and 0.35% or less, P: 0.06% or less,

S: 0.02% or less, Cr: 17.0% or more and 19.0% or less, Ni: more than 0.10% and 0.30% or less, Ti: 0.10% or more and 0.40% or less, Nb: 0.005% or more and less than 0.050%, Mo: less than 0.20%, N: 0.005% or more and 0.015% or less, Cu: 0.30% or more and 0.50% or less, Mg: less than 0.0005% and the balance being Fe and inevitable impurities.

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Description

Technical Field

5 **[0001]** The present invention relates to a ferritic stainless steel excellent in surface quality, and excellent in corrosion resistance in a part welded with an austenitic stainless steel.

Background Art

10 **[0002]** Although, among stainless steels, SUS304 (18%Cr-B%Ni) (Japanese Industrial Standard, JIS G 4305), which is an austenitic stainless steel, is widely used because of its good corrosion resistance, this kind of steel is expensive because a large amount of Ni is contained therein. Therefore, the stainless steel according to Patent Literature 1 was developed as a steel having good corrosion resistance equivalent to that of SUS304.

15 **[0003]** Patent Literature 1 discloses a ferritic stainless steel having a chemical composition consisting of, by mass%, C: 0.03% or less, Si: 1.0% or less, Mn: 0.5% or less, P: 0.04% or less, S: 0.02% or less, Al: 0.1% or less, Cr: 20.5% or more and 22.5% or less, Cu: 0.3% or more and 0.8% or less, Ni: 1.0% or less, Ti: 4(C%+N%) or more and 0.35% or less, Nb: 0.01% or less, N: 0.03% or less, C+N: 0.05% or less and the balance being Fe and inevitable impurities.

20 **[0004]** Ferritic stainless steels such as JIS-SUS444 and JIS-SUS430J1L are characterized by having low stress corrosion cracking sensitivity in comparison to austenitic stainless steels and not containing a large amount of Ni which is subject to wide price fluctuations, and are widely used as materials for exhaust system parts of automobiles, water tanks and building constructions.

25 **[0005]** However, since ferritic stainless steels have inferior formability, especially poor ductility, comparing to austenitic stainless steels, austenitic stainless steels are used for parts which are too difficult to be formed with ferritic stainless steels. Therefore, there are many cases where one component is formed by combining austenitic stainless steels and ferritic stainless steels. Among these cases, most parts are joined together by welding, and, among welding methods, TIG welding (Tungsten Inert Gas welding) is mainly used. And good corrosion resistance is required for welded parts as well as base steels.

Citation List

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Patent Literature

[0006]

35 PTL 1: Japanese Unexamined Patent Application Publication No. 2007-77496
PTL 2: Japanese Unexamined Patent Application Publication No. 8-10823

Summary of Invention

40 Technical Problem

[0007] The ferritic stainless steel according to Patent Literature 1 has good corrosion resistance in a part welded with a stainless steel of the same kind. However, there is a problem in that the corrosion resistance in a welded part is inferior to that in a base steel in the case where the ferritic stainless steel is welded with a stainless steel of the different kind such as SUS304 by performing TIG welding.

[0008] This problem is caused as follows; C or N in a steel combines with Cr, precipitating chromium carbides such as Cr_{23}C_6 or chromium nitrides such as CrN_2 at grain boundaries in the thermal history of welding. These precipitations form chromium depletion layers, where Cr content is less than the base steel, in the vicinity of the grain boundaries. This phenomenon, called sensitization, causes deterioration in corrosion resistance at the grain boundaries.

50 **[0009]** Generally, in order to prevent deterioration in corrosion resistance in a welded part due to sensitization, the formation of chromium carbides and chromium nitrides are prevented by adding an appropriate amount of Ti to steel and stabilizing C and N as titanium carbonitrides with decreasing C and N contents in steel. By this method, the welded part which is formed by performing TIG welding using the same ferritic stainless steels according to Patent Literature 1 has good corrosion resistance.

55 **[0010]** However, since SUS304 has C content of from 0.04% to 0.05%, which is more than that of this ferritic stainless steel sheet whose C content is about 0.01%, in order to similarly prevent sensitization by adding Ti in the case where this ferritic stainless steel sheet is welded with a high carbon stainless steel such as SUS304, it is necessary to increase Ti content to about 1.0%.

[0011] However, in the case where the Ti content of ferritic stainless steel is increased up to about 1.0%, Ti and N in molten steel react with each other to form and precipitate TiN during solidification. Since TiN has low ductility at a high temperature, it causes defects in a hot rolling process and deteriorates surface quality. Since the defects formed as described above are too deep to be eliminated during subsequent processes such as annealing of hot-rolled steel sheet, pickling of hot-rolled steel sheet, cold rolling of hot-rolled steel sheet, annealing of cold-rolled steel sheet and pickling of cold-rolled steel sheet. The defects become surface defects called stringers caused by titanium nitrides, resulting in significant deterioration in surface quality of the cold-rolled, annealed and pickled steel sheet, unless performing a treatment in which a thick layer is scraped off the surface of the hot-rolled, annealed and pickled steel sheet by a grinder or the like.

[0012] In addition, although TIG welding is generally performed under conditions in which both front and back sides of steel sheet are shielded with an inert gas so that the formation of thin oxidized layer called temper color is prevented as much as possible. Since, in a practical process, this gas shield is not sufficient, there is a problem in that sensitization described above is facilitated due to mixing of N from air.

[0013] In addition, there is also a problem in that adding expensive Ti in a large amount decreases the advantage of the ferritic stainless steel which does not use expensive Ni.

[0014] The present invention has been completed in view of the situation described above, and an object of the present invention is to provide a ferritic stainless steel excellent in surface quality, and corrosion resistance in a welded part in the case that the ferritic stainless steel is welded not only with a ferritic stainless steel but also with an austenitic stainless steel.

Solution to Problem

[0015] The present inventors conducted exhaustive experimentations and investigations not only on the influence of the chemical composition of steel on the corrosion resistance of base steel and welded part, but also on the surface quality (stringer flaw caused by titanium nitrides) of steel sheet in order to solve the problems described above, and, as a result, obtained the following findings.

[0016]

(1) Sensitization can be prevented by adjusting the contents of ferritic former elements and by making the micro-structure of a part welded with a ferritic stainless steel and an austenitic stainless steel a martensite phase. This is because the solubility limits of C and N are large in a martensite phase.

[0017]

(2) By adding a very small amount of Nb, Nb nitrides are precipitated at a temperature higher than a temperature at which Ti nitrides are precipitated. In a cooling process thereafter, these Nb nitrides become nucleation sites of Ti carbonitrides. This phenomenon enhances an effect of Ti to prevent sensitization.

[0018]

(3) The crystallization temperature of steel sheet is generally raised by adding Nb. Since there is almost no negative effect that the crystallization temperature of steel sheet is raised when a very small amount of Nb is added, an inexpensive high-speed pickling process used in a manufacturing line of carbon steel disclosed in Patent Literature 2 can be applied.

[0019]

(4) Even if N in air is mixed in a welded part due to incomplete gas shield during welding, sensitization can be avoided by the formation of AlN in the welded part in the case where an appropriate amount of Al is added to steel. In addition, sensitization can be avoided due to the formation of compounds of Sb and N in a welded part in the case where an appropriate amount of Sb is added to steel.

[0020]

(5) A stringer flaw caused by titanium nitrides is mainly caused by TiN of a large size existing in an outermost layer of steel sheet. A stringer flaw caused by titanium nitrides can be avoided by adjusting Ti content.

[0021] From the findings described above, a ferritic stainless steel which has excellent corrosion resistance in a welded

part and excellent surface quality of a cold-rolled, annealed and pickled steel sheet without having to grind the surface of a hot-rolled, annealed and pickled steel sheet and is less expensive than austenitic stainless steels containing Ni, can be achieved.

[0022] The present invention has been completed on the basis of the findings described above and the present invention is as follows.

[0023]

[1] A ferritic stainless steel having a chemical composition consisting of, by mass%, C: 0.003% or more and 0.015% or less, Si: 0.05% or more and 0.30% or less, Mn: 0.10% or more and 0.35% or less, P: 0.06% or less, S: 0.02% or less, Cr: 17.0% or more and 19.0% or less, Ni: more than 0.10% and 0.30% or less, Ti: 0.10% or more and 0.40% or less, Nb: 0.005% or more and less than 0.050%, Mo: less than 0.20%, N: 0.005% or more and 0.015% or less, Cu: 0.30% or more and 0.50% or less, Mg: less than 0.0005% and the balance being Fe and inevitable impurities.

[0024]

[2] The ferritic stainless steel according to [1], the steel having a chemical composition further containing, by mass%, Al: 0.02% or more and 0.50% or less.

[0025]

[3] The ferritic stainless steel according to [2], the steel having a chemical composition containing, by mass%, Al: 0.10% or more and 0.50% or less.

[0026]

[4] The ferritic stainless steel according to any one of [1] to [3], the steel having a chemical composition further containing, by mass%, Sb: 0.005% or more and 0.300% or less.

[0027]

[5] The ferritic stainless steel according to any one of [1] to [4], the steel having a chemical composition further containing, by mass%, at least one of Zr: 0.05% or more and 0.60% or less and V: 0.02% or more and 0.50% or less.

Advantageous Effects of Invention

[0028] The ferritic stainless steel can be ideally used as materials for kitchen instruments, architectural interiors, industrial machines and automobile parts, because the ferritic stainless steel has excellent corrosion resistance in a part welded even with an austenitic stainless steel and has excellent surface quality.

Description of Embodiments

[0029] The limitations on the factors constituting the present invention will be described hereafter.

1. Regarding a chemical composition

[0030] The reason for the limitations on the chemical composition of steel according to the present invention will be described. Here, % used when describing a chemical composition always means mass%.

C: 0.003% or more and 0.015% or less

[0031] It is preferable that C content be as small as possible, because C tends to combine with Cr to form Cr carbides, and intergranular corrosion is caused by Cr carbides which are formed in a heat affected zone during welding. Therefore, the C content is confined to be 0.015% or less. On the other hand, since a long time is necessary for smelting in the case where the C content is excessively small, the C content is confined to be 0.003% or more and 0.015% or less, preferably 0.003% or more and 0.012% or less from the viewpoint of corrosion resistance in a welded part, more preferably 0.003% or more and 0.010% or less.

Si: 0.05% or more and 0.30% or less

[0032] Since Si is a chemical element which is effective as a deoxidizing agent, the Si content is confined to be 0.05% or more. On the other hand, in the case where the Si content is more than 0.30%, the high-speed pickling performance in a manufacturing line of carbon steel is decreased, which results in a decrease in productivity. Therefore, the Si content is confined to be 0.05% or more and 0.30% or less, preferably 0.05% or more and 0.20% or less.

Mn: 0.10% or more and 0.35% or less

[0033] Since Mn is effective for deoxidation, the Mn content is confined to be 0.10% or more. In addition, since Mn is an austenite former element, Mn promotes the formation of a martensite phase in a part welded with an austenitic stainless steel (hereinafter, called the welded part of different steels). However, since, in the case where the Mn content is excessively large, Mn combines with S in steel to form MnS which is a soluble sulfide, which results in a deterioration in corrosion resistance, the Mn content is confined to be 0.10% or more and 0.35% or less, preferably 0.10% or more and 0.25% or less.

P: 0.06% or less

[0034] In the case where P content is more than 0.06%P, P not only has a negative effect on corrosion resistance, but also deteriorates formability due to solid solution strengthening. Therefore, the P content is confined to be 0.06% or less, preferably 0.04% or less from the viewpoint of corrosion resistance.

S: 0.02% or less

[0035] S is a chemical element which has a negative effect on corrosion resistance. In particular, in the case where S is present together with Mn, S becomes a source of pitting as a result of forming MnS, resulting in deterioration in corrosion resistance. This negative effect becomes significant in the case where S content is more than 0.02%. Therefore, the S content is confined to be 0.02% or less, preferably 0.01% or less from the viewpoint of corrosion resistance, more preferably 0.006% or less.

Cr: 17.0% or more and 19.0% or less

[0036] Cr is a chemical element which is essential for increasing corrosion resistance of a base stainless steel by forming a passivation film on the surface of steel. Cr content of 17.0% or more is necessary in order to achieve good corrosion resistance. However, in the case where the Cr content is more than 19.0%, deterioration in corrosion resistance in the welded part with SUS304 cannot be prevented, because a martensite phase is not formed in that part. Therefore, the Cr content is confined to be 17.0% or more and 19.0% or less, preferably 17.5% or more and 18.5% or less.

Ni: more than 0.10% and 0.30% or less

[0037] Ni is a chemical element which contributes to improving crevice corrosion resistance. Moreover, since Ni is an austenite former element like Mn, Ni promotes the formation of a martensite phase in the welded part of different steels. However, there is deterioration in Stress Corrosion Cracking sensitivity in the case where Ni content is more than 0.30%. In addition, Ni is an expensive chemical element. Therefore, the Ni content is confined to be more than 0.10% and 0.30% or less, preferably 0.20% or more and 0.30% or less.

Ti: 0.10% or more and 0.40% or less

[0038] Ti is a chemical element which is essential for achieving good corrosion resistance in the welded part of different steels when it is welded with an austenitic stainless steel as described above. However, excessive Ti content causes an increase in the amount of precipitated TiN, which results in a significant number of stringer flaws caused by titanium nitrides, making it impossible to achieve good surface quality for a product (cold-rolled, annealed and pickled steel sheet) without performing a treatment such as grinding the surface of a hot-rolled, annealed and pickled steel sheet. Therefore, the Ti content is confined to be 0.10% or more and 0.40% or less, preferably 0.20% or more and 0.40% or less from the viewpoint of corrosion resistance in the welded part of different steels.

Nb: 0.005% or more and less than 0.050%

[0039] Small Nb adding is also one of the important factors for the present invention. Nb forms carbonitrides more readily than Cr and Ti. In particular, in the case of the welded part of different steels, in weld metal and a heat affected zone, the formation of Nb carbonitrides begins at a temperature higher than the temperature at which Ti carbonitrides are formed. In a cooling process thereafter, although the reason for this is not clear, the Nb carbonitrides become nucleation sites of Ti carbonitrides. That is to say, since small Nb content accelerates the formation of Ti carbonitrides, the ability of Ti to stabilize C and N in weld metal and a heat affected zone of the welded part of different steels becomes stronger in comparison to the case where Nb is not contained, causing sensitization to be prevented more effectively. Therefore, the lower limit of the Nb content is confined to be 0.005% or more. On the other hand, since excessive Nb content causes an increase in recrystallization temperature of a cold-rolled steel sheet, it is necessary to anneal the steel sheet at a high temperature in order to achieve sufficient mechanical properties. This increases the thickness of an oxidized layer, which is formed during finishing annealing, in comparison to the case where Nb is not contained. This deteriorates the pickling performance of a cold-rolled steel sheet in a high-speed pickling process which is used in a manufacturing line of carbon steel described above, resulting in deterioration in productivity. Therefore, the Nb content is confined to be 0.005% or more and less than 0.050%, more preferably 0.010% or more and less than 0.050% from the viewpoint of corrosion resistance in the welded part of different steels.

Mo: less than 0.20%

[0040] Mo strengthens a passivation film and significantly improves corrosion resistance. However, since Mo is a ferrite former element, even in the case where Mo content is small, a martensite phase is not formed in the welded part of different steels when it is welded with an austenitic stainless steel. This forms the welded part of different steels consisting of a ferrite phase and causes sensitization. Therefore, the Mo content is confined to be less than 0.20%. In addition, since Mo causes deterioration in the toughness of a hot-rolled steel sheet, it is preferable that the Mo content be less than 0.10%. Incidentally, the lower limit of the Mo content is confined to be 0%.

N: 0.005% or more and 0.015% or less

[0041] N easily combines with Cr to form Cr nitrides. It is preferable that N content be as small as possible, because Cr nitrides cause intergranular corrosion in the case where the Cr nitrides are formed in the welded part of different steels and in a heat affected zone when welding is performed. In addition, it is preferable that the N content be as small as possible in order to decrease the amount of precipitated TiN which becomes the source of stringer flaws caused by titanium nitrides. However, since smelting takes a long time in the case where the N content is excessively reduced, the N content is confined to be 0.005% or more and 0.015% or less, preferably 0.005% or more and 0.012% or less from the viewpoint of corrosion resistance in the welded part of different steels, more preferably 0.005% or more and 0.010% or less.

Cu: 0.30% or more and 0.50% or less

[0042] Cu is a chemical element which improves corrosion resistance, in particular, in the case where a steel is placed in an aqueous solution or covered with weakly acidic water drops. This is because Cu which covers the surface of the base steel after dissolving in the aqueous solution or the water drops prevents the dissolution of the base steel. However, in the case where Cu content is more than 0.50%, there is deterioration in formability at a high temperature and surface defects are caused by jelly-like oxides which are called red scales and which are formed on the surface of hot-rolled steel sheet due to Cu. Therefore, the Cu content is confined to be 0.30% or more and 0.50% or less, preferably 0.30% or more and 0.40% or less from the viewpoint of formability at a high temperature.

Mg: less than 0.0005%

[0043] Mg is an impurity which is mixed in mainly from the bricks of converter furnace. Mg becomes the source of various kinds of inclusion and nucleation sites of other kinds of inclusion. In addition, since the inclusions are less likely to be dissolved, even when performing a treatment such as annealing, Mg deteriorates the surface quality of not only hot-rolled, annealed and pickled steel sheet and but also product (cold-rolled, annealed and pickled steel sheet). Therefore, the Mg content is confined to be less than 0.0005%, preferably less than 0.0003%.

[0044] Although the basic chemical composition according to the present invention is as described above and the balance consists of Fe and inevitable impurities, Al and Sb may be further contained from the viewpoint of preventing sensitization of the welded part of different steels caused by insufficient gas shielding of TIG welding. Moreover, Zr and

V may be contained in order to improving corrosion resistance of the welded part of different steels. Here, examples of acceptable inevitable impurities include Ca: 0.0020% or less but it is not necessary to limit to Ca.

Al: 0.02% or more and 0.50% or less

[0045] Al is a chemical element which is important in particular in the case where a gas shield for TIG welding is not satisfactory. Generally, the back side of steel sheet is shielded with gas when TIG welding is performed as described above. However, in the case where the shape of the welded part of different steels is complicated, gas shield is not sufficiently effective and N in air may be mixed into weld metal. In this case, sensitization cannot be completely prevented through adding Ti only, if the content of C and N is more than the solid solubility limit of martensite phase. In this case, it is effective to add Al in advance to prevent sensitization. This is because Al stabilizes N in weld metal as AlN. This effect can be realized by confining Al content to be 0.02% or more. However, in the case where the Al content is more than 0.50%, non-metal inclusions are formed in a slab, which results in deterioration in surface quality of hot-rolled steel sheet and cold-rolled steel sheet. Therefore, in the case where Al is contained, it is preferable that the Al content be 0.02% or more and 0.50% or less. A more preferable lower limit of the Al content is 0.10%, further more preferably 0.15%. A more preferable upper limit of the Al content is 0.30%.

Sb: 0.005% or more and 0.30% or less

[0046] Sb is a chemical element which is better to add in the case where a component has a complicated shape, since Sb is, like Al, effective for stabilizing N mixed from air in the case where a gas shield of TIG welding is not sufficiently effective. However, in the case where Sb content is excessively large, non-metal inclusions are formed in a slab, which results in deterioration in surface quality of hot-rolled steel sheet and cold-rolled steel sheet. Therefore, in the case where Sb is contained, it is preferable that the Sb content be 0.005% or more and 0.30% or less, more preferably 0.005% or more and 0.10% or less from the viewpoint of the surface quality of product (cold-rolled, annealed and pickled steel sheet).

Zr: 0.05% or more and 0.60% or less

[0047] Zr is a chemical element which is effective for improving corrosion resistance in the welded part not only of same steels but also of different steels by forming, like Ti, carbonitrides more readily than Cr. However, Zr is more expensive than Ti and, in the case where Zr content is excessively large, Zr forms intermetallic compounds, which results in deterioration in toughness of hot-rolled steel sheet. Therefore, in the case where Zr is contained, it is preferable that the Zr content be 0.05% or more and 0.60% or less, more preferably 0.15% or more and 0.35% or less.

V: 0.02% or more and 0.50% or less

[0048] V is also a chemical element which is effective for improving corrosion resistance in the welded part not only of same steels but also of different steels by forming, like Ti, carbonitrides more readily than Cr. However, this effect of V is smaller than that of Ti. Also, V is expensive. Therefore, in the case where V is contained, it is preferable that the V content be 0.02% or more and 0.50% or less, more preferably 0.02% or more and 0.05% or less.

2. Regarding manufacturing conditions

[0049] Subsequently, the preferable method for manufacturing the steel according to the present invention will be described. Steel having a chemical composition described above is smelted using a well-known method such as a converter furnace, an electric furnace or a vacuum melting furnace, and the smelted steel is made into a steel material (slab) using a continuous casting method or an ingot casting-blooming method. This steel material is heated at a temperature in the range from 1100°C to 1250°C for a duration of from 1 hour to 24 hours and, or directly without heating, hot-rolled into a hot-rolled steel sheet.

[0050] Although the hot-rolled steel sheet is generally subjected to annealing at a temperature in the range from 800°C to 1100°C for a duration of from 1 minute to 10 minutes, this annealing may be omitted depending on use application. Then, after being subjected to pickling, the hot-rolled steel sheet is cold-rolled into a cold-rolled steel sheet, and the cold-rolled steel sheet is made a product by performing finishing annealing. It is preferable that cold rolling is performed with a rolling reduction ratio of 50% or more from the viewpoint of elongation performance, bending performance, press forming performance and shape leveling. It is preferable that finishing annealing of cold-rolled steel sheet be generally performed at a temperature in the range from 800°C to 950°C in the case of No. 2B finish in accordance with JIS G 0203.

[0051] However, in the case of manufacturing a product using tandem cold rolling line and continuous annealing line at a high productivity, it is most preferable that the product be manufactured in an inexpensive process using a high-

speed pickling method (refer to Patent Literature 2) of annealing and pickling line for carbon steel as described above, and, in this case, it is preferable that annealing temperature be in the range from 800°C to 900°C. In addition, in the case of a product for parts in which luster is more required, finishing annealing using BA annealing method is effective. As described above, there is no problem in that a treatment such as polishing is performed after cold rolling or forming has been performed in order to achieve further better surface quality.

EXAMPLE 1

[0052] The present invention will be described more in detail in reference to examples hereafter.

[0053] Steels having a chemical composition of examples No. 1 through No. 8 and No. 33 and comparative examples No. 9 through No. 12 given in Table 1 were smelted using a small vacuum melting furnace having a capacity of 50 kg. The ingots of these steels were heated at a temperature of 1150°C in a furnace under an Ar gas purge and hot-rolled into hot-rolled steel sheets having a thickness of 4.0 mm.

[0054] Subsequently, these hot-rolled sheets were subjected to annealing in air at a temperature of 950°C for a duration of 1 minute, followed by a surface treatment using shot blasting with glass beads, and descaling by pickling in which the steel sheets were dipped in a sulfuric acid solution containing sulfuric acid in a concentration of 20 mass% at a temperature of 80°C for a duration of 120 seconds and then in a mixed acid solution containing nitric acid in a concentration of 15 mass% and hydrofluoric acid in a concentration of 3 mass% at a temperature of 55°C for a duration of 60 seconds.

[0055] Then, the hot-rolled steel sheets were cold-rolled into cold-rolled steel sheets having a thickness of 1.0 mm, subjected to annealing in a furnace in air at a temperature of 900°C for a duration of 1 minute and made cold-rolled and annealed steel sheets. These cold-rolled and annealed steel sheets were subjected to electrolytic descaling with the steel sheet being a positive electrode for three times in a solution containing NaSO₄ in a concentration of 20 mass% at a temperature of 80°C with a current of 3 A/dm² for a duration of 10 seconds, and descaling in a mixed acid solution containing nitric acid in a concentration of 5 mass% and hydrofluoric acid in a concentration of 3 mass% at a temperature of 55°C for a duration of 30 seconds in order to have cold-rolled, annealed and pickled steel sheets.

[0056] [Table 1]

Table 1

No.	Chemical Composition (mass%)																	Note
	C	Si	Mn	P	S	Cr	Ni	Cu	Ti	Nb	Mo	N	Mg	Al	Sb	Zr	V	
1	0.010	0.05	0.18	0.023	0.004	18.8	0.23	0.36	0.22	0.020	0.06	0.009	0.0003	0.028	-	-	-	Example
2	0.003	0.10	0.15	0.024	0.003	18.4	0.12	0.35	0.14	0.030	0.02	0.008	0.0001	0.030	-	-	-	
3	0.012	0.14	0.25	0.020	0.003	18.3	0.20	0.33	0.29	0.040	0.10	0.012	0.0002	0.025	-	-	-	
4	0.006	0.18	0.21	0.021	0.002	17.3	0.26	0.41	0.20	0.040	0.08	0.009	0.0004	0.031	-	-	-	
5	0.003	0.12	0.13	0.025	0.004	18.4	0.13	0.40	0.15	0.020	0.05	0.007	0.0003	0.150	-	-	-	
6	0.008	0.08	0.19	0.026	0.005	18.2	0.15	0.34	0.19	0.010	0.07	0.008	0.0002	0.240	-	-	0.20	
7	0.007	0.21	0.33	0.019	0.002	18.0	0.27	0.50	0.24	0.030	0.08	0.012	0.0002	0.024	0.110	0.12	-	
8	0.014	0.29	0.22	0.022	0.003	17.9	0.11	0.31	0.21	0.020	0.03	0.005	0.0003	0.160	0.006	-	-	
33	0.005	0.15	0.15	0.024	0.004	18.1	0.22	0.37	0.20	0.030	0.04	0.007	0.0004	-	-	-	-	Comparative Example
9	0.009	0.11	0.19	0.025	0.002	16.2	0.20	0.41	0.27	0.020	0.09	0.008	0.0003	0.026	-	-	-	
10	0.005	0.23	0.22	0.029	0.003	19.4	0.17	0.34	0.34	0.030	0.11	0.010	0.0003	0.210	-	-	-	
11	0.012	0.18	0.20	0.024	0.004	18.2	0.21	0.38	0.07	0.020	0.13	0.015	0.0002	0.032	-	0.05	-	
12	0.005	0.34	0.21	0.020	0.002	18.5	0.24	0.32	0.29	0.060	0.06	0.013	0.0004	0.110	-	-	0.10	
Notation: <u>Under line</u> indicates a value out of the range of the present invention.																		

[0057] Firstly, the surface quality of the obtained cold-rolled, annealed and pickled steel sheets was evaluated by a visual inspection.

[0058] Subsequently, using the obtained cold-rolled, annealed and pickled steel sheets, two kinds of samples for evaluating the corrosion resistance of the base steel sheet were prepared. One was a sample in a pickled state obtained from the as pickled steel sheet after descaling and another was a polished sample obtained by polishing the surface of the as pickled steel sheet with a #600 emery paper.

[0059] Moreover, using the same steel sheets, a test on the welded part formed by TIG welding was carried out. In this test, two pieces cut out of each steel sheet were welded by TIG welding and polished with a #600 emery paper for evaluating the corrosion resistance in the welded part of same steels.

[0060] In addition, using the same steel sheets, a TIG welding test with a SUS304 as a different steel was carried out. In this test, a piece cut out of each steel sheet and a piece of SUS304 sheet having a thickness of 1.0 mm were welded by TIG welding for evaluating the corrosion resistance in the welded part of different steels. The surface of the welded part was polished with a #600 emery paper. The conditions of welding of the same steels and different steels will be described below. Welding current was controlled so that the width of the back bead was 3 mm or more. The surface on the back bead side was evaluated.

[0061]

Welding voltage: 10 V

Welding current: from 90 A to 110 A

Welding speed: 600 mm/min

Electrode: tungsten electrode of 1.6 mm

Shield gas: front bead side Ar 20 L/min,

back bead side Ar 20 L/min

Using the two kind of samples (sample in a pickled state and sample in a polished state), the welded part of same steels and the welded part of different steels, a neutral salt spray cyclic corrosion test (CCT) was carried out in accordance with JIS H 8502 (1999). In the CCT, a cycle in which spraying a solution containing NaCl in a concentration of 5 mass% (35°C, 2 hours), drying (60°C, 4 hours, relative humidity: from 20% to 30%) and wetting (40°C, 2 hours, relative humidity: 95% or more) were performed in this order was repeated for 15 cycles. The obtained results are given in Table 2. Here, the evaluation standards of the tests will be described hereafter.

[0062]

(a) Surface appearance after cold rolling, annealing and pickling: evaluated by means of the ratio of the length of portions in which surface defects (scab, pin hole, linear scab, stringer flaw caused by titanium nitrides, abnormal color of white streak) were found to the total length of the sample. The surface appearance was evaluated in the following way; ⊙ indicates the case where a defect ratio is less than 5%, ○ indicates the case where a defect ratio is 5% or more and less than 10%, Δ indicates the case where a defect ratio is 10% or more and less than 20% and × indicates the case where a defect ratio is 20% or more, where ⊙ and ○ indicate satisfactory cases and Δ and × indicate unsatisfactory cases.

[0063]

(b) Corrosion resistance by CCT of the samples in a pickled state and in a polished state with a #600 emery paper: evaluated by means of an area in which rust occurred after the 15 cycle test. The result of the CCT was evaluated in the following way; ⊙ indicates the case where a rust area ratio is less than 10%, ○ indicates the case where a rust area ratio is 10% or more and less than 20%, Δ indicates the case where a rust area ratio is 20% or more and less than 30% and × indicates the case where a rust area ratio is 30% or more, where ⊙ and ○ indicate satisfactory cases and Δ and × indicate unsatisfactory cases.

[0064]

(c) Corrosion resistance by CCT of the welded part of same steels: evaluated by means of a rust area ratio after 15 cycles of the CCT which was performed on the samples obtained by TIG butt welding the samples of same steels and by eliminating the temper color of the welded part with a #600 emery paper. The results of the corrosion resistance was evaluated in the following way; ⊙ indicates the case where a rust area ratio is less than 10%, ○ indicates the case where a rust area ratio is 10% or more and less than 20%, Δ indicates the case where a rust area ratio is 20% or more and less than 30% and × indicates the case where a rust area ratio is 30% or more, where

⊙ and ○ indicate satisfactory cases and Δ and × indicate unsatisfactory cases.

[0065]

(d) Corrosion resistance by CCT of the welded part of different steels: evaluated by means of a rust area ratio after 15 cycles of the CCT which was performed on the samples obtained by TIG butt welding each sample and SUS304 and by eliminating the temper color of the welded part with #600 emery paper. The results of the corrosion resistance was evaluated in the following way; ⊙ indicates the case where a rust area ratio is less than 10%, ○ indicates the case where a rust area ratio is 10% or more and less than 20%, Δ indicates the case where a rust area ratio is 20% or more and less than 30% and × indicates the case where a rust area ratio is 30% or more, where ⊙ and ○ indicate satisfactory cases and Δ and × indicate unsatisfactory cases.

[0066] [Table 2]

Table 2

No.	Surface Quality of Cold-Rolled, Annealed and Pickled Sheet	Corrosion Resistance of Cold-Rolled, Annealed and Pickled Sheet (Pickled State) in CCT	Corrosion Resistance of Cold-Rolled, Annealed and Pickled Sheet (Polished State) in CCT	Corrosion Resistance in Weld Zone of Same Steel Grades in CCT	Corrosion Resistance in Weld Zone of Different Steel Grades in CCT	Note	Note
1	⊙	⊙	⊙	⊙	○	-	Example
2	⊙	⊙	⊙	⊙	○	-	
3	○	⊙	⊙	⊙	○	-	
4	⊙	○	⊙	⊙	○	-	
5	⊙	⊙	⊙	⊙	○	-	
6	⊙	⊙	⊙	⊙	⊙	-	
7	⊙	⊙	⊙	⊙	⊙	-	
8	○	⊙	⊙	⊙	⊙	-	
33	⊙	⊙	⊙	⊙	○	-	
9	⊙	×	×	×	×	-	Comparative Example
10	○	⊙	⊙	○	×	-	
11	⊙	○	○	×	×	-	
12	Δ	Δ	⊙	⊙	○	Decreased Ductility Residual Scale	
Notation: ⊙, ○; satisfactory, Δ, x; unsatisfactory							

[0067] Examples No. 1 through No. 8 and No. 33 having a chemical composition in the range according to the present invention were excellent in corrosion resistance and surface quality in all evaluation items. On the other hand, comparative example No. 9 having low Cr content of 16.2% was poor in corrosion resistance, as indicated by its large rust areas.

[0068] Comparative example No. 10 having high Cr content of 19.4% was poor in corrosion resistance, as indicated by its large rust area in the welded part of different steels. This is thought to be because a martensite phase is not formed in the welded part of different steels due to the large content of Cr which is a ferrite former element.

[0069] Comparative example No. 11 having low Ti content of 0.07% was poor in corrosion resistance, as indicated by its large rust area in the welded part of different steels.

[0070] In the case of comparative example No. 12 having Si content and Nb content more than the range according to the present invention, some residual scale was found on the surface of the base steel sheet, and it was poor in corrosion resistance after cold rolling, annealing and pickling.

EXAMPLE 2

[0071] Steels having a chemical composition of examples No. 13 through No. 18 and comparative examples No. 19 through No. 22 given in Table 3 were smelted using a VOD (Vacuum Oxygen Decarburization) having a capacity of 150 ton and cast into slabs by continuous casting. These slabs were heated at a temperature of 1150°C and hot-rolled into hot-rolled steel sheet coil having a thickness of 4.0 mm. Then, these hot-rolled steel sheet coils were subjected to annealing in an atmosphere of a coke oven gas having an air ratio of 1.3 at a temperature of 950°C for a duration of from 1 minute to 5 minutes. These hot-rolled and annealed steel sheet coils were shot blasted with iron beads, descaled by pickling in which the steel sheet coils were dipped in a sulfuric acid solution containing sulfuric acid in a concentration of 20 mass% at a temperature of 80°C for a duration of 120 seconds and then in a mixed acid solution containing nitric acid in a concentration of 15 mass% and hydrofluoric acid in a concentration of 3 mass% at a temperature of 55°C for a duration of 60 seconds. And these hot-rolled and annealed steel sheets coils were cold-rolled into cold-rolled steel sheet coils having a thickness of 1.0 mm, subjected to annealing in a furnace in an atmosphere of a coke oven gas having an air ratio of 1.3 at a temperature of 900°C for a duration of 2 minutes, electrolytic descaling with the steel sheet being a positive electrode for three times in a solution containing NaSO₄ in a concentration of 20 mass% at a temperature of 80°C with a current of 3 A/dm² for a duration of 10 seconds, and descaling in a mixed acid solution containing nitric acid in a concentration of 5 mass% and hydrofluoric acid in a concentration of 3 mass% at a temperature of 55°C for a duration of 30 seconds in order to obtain cold-rolled, annealed and pickled steel sheets.

[0072] [Table 3]

Table 3

No.	Chemical Composition (mass%)																	Note
	C	Si	Mn	P	S	Cr	Ni	Cu	Ti	Nb	Mo	N	Mg	Al	Sb	Zr	V	
13	0.009	0.06	0.21	0.024	0.006	18.6	0.20	0.34	0.21	0.020	0.05	0.008	0.0002	0.029	-	-		Example
14	0.005	0.11	0.23	0.025	0.003	18.4	0.12	0.35	0.16	0.030	0.07	0.008	0.0003	0.030	-	-	-	
15	0.006	0.13	0.19	0.023	0.008	17.9	0.19	0.46	0.23	0.040	0.08	0.012	0.0004	0.027	-	-	-	
16	0.006	0.10	0.22	0.025	0.004	18.5	0.15	0.34	0.17	0.030	0.12	0.009	0.0004	0.140	-	-	-	
17	0.010	0.28	0.20	0.019	0.003	18.3	0.23	0.36	0.37	0.020	0.06	0.014	0.0003	0.028	-	-	0.10	
18	0.004	0.19	0.33	0.030	0.005	18.2	0.24	0.31	0.20	0.030	0.08	0.010	0.0002	0.031	0.100	0.12	-	Comparative Example
19	0.007	0.15	0.19	0.023	0.003	18.2	0.18	0.34	0.24	0.020	0.40	0.010	0.0004	0.025	-	-	-	
20	0.004	0.26	0.24	0.029	0.004	19.5	0.23	0.32	0.33	0.020	0.15	0.008	0.0001	0.026	-	-	-	
21	0.011	0.33	0.20	0.021	0.006	17.8	0.20	0.37	0.37	0.003	0.08	0.015	0.0003	0.032	-	-	-	
22	0.005	0.45	0.23	0.019	0.004	18.4	0.14	0.41	0.20	0.010	0.09	0.008	0.0010	0.200	-	-	0.20	
Notation: <u>Under line</u> indicates a value out of the range of the present invention.																		

[0073] Firstly, the surface quality of the cold-rolled, annealed and pickled steel sheets obtained as described above was evaluated by a visual inspection.

[0074] Subsequently, samples of the base steel sheet, the welded part of same steels and the welded part of different steels were prepared in manners similar to the ways described in Example 1, a neutral salt spray cyclic corrosion test was carried out in accordance with JIS H 8502 (1999) as was done in Example 1 and corrosion resistance was evaluated. The obtained results are given in Table 4. Here, the evaluation standards of the tests were similar to those in Example 1.

[0075] [Table 4]

Table 4

No.	Surface Quality of Cold-Rolled, Annealed and Pickled Sheet	Corrosion Resistance of Cold-Rolled, Annealed and Pickled Sheet (Pickled State) in CCT	Corrosion Resistance of Cold-Rolled, Annealed and Pickled Sheet (Polished State) in CCT	Corrosion Resistance in Weld Zone of Same Steel Grades in CCT	Corrosion Resistance in Weld Zone of Different Steel Grades in CCT	Note	Note
13	⊙	⊙	⊙	⊙	○	-	Example
14	⊙	⊙	⊙	⊙	○	-	
15	⊙	⊙	⊙	⊙	○	-	
16	⊙	⊙	⊙	⊙	○	-	
17	○	⊙	⊙	⊙	⊙	-	
18	⊙	⊙	⊙	⊙	⊙	-	
19	⊙	⊙	⊙	⊙	×	-	Comparative Example
20	○	⊙	⊙	⊙	×	-	
21	×	Δ	⊙	⊙	○	-	
22	×	×	⊙	⊙	○	-	
Notation: ⊙, ○; satisfactory, Δ, x; unsatisfactory							

[0076] Examples No. 13 through No. 18 having a chemical composition in the range according to the present invention were excellent in corrosion resistance and surface quality in all evaluation items.

[0077] On the other hand, since comparative example No. 19 had Mo content of 0.40% more than the range according to the present invention, and since comparative example No. 20 had Cr content of 19.5% more than the range according to the present invention, both were poor in corrosion resistance, as indicated by their large rust area in the welded part of different steels. This is thought to be because a martensite phase is not formed in the welded part of different steels due to the large contents of Mo and Cr, which are ferrite former elements.

[0078] In addition, since comparative example No. 21 had Si content of 0.33% and Nb content of 0.003% out of the range according to the present invention, and since comparative example No. 22 had Si content of 0.45% and Mg content of 0.0010% more than the range according to the present invention, some residual scale was found, and both were poor in corrosion resistance after cold rolling, annealing and pickling.

EXAMPLE 3

[0079] Steels having a chemical composition of examples No. 23 through No. 28 and comparative examples No. 29 through No. 32 given in Table 5 were smelted using a small vacuum melting furnace having a capacity of 50 kg. These ingots of these steels were heated at a temperature of 1150°C in a furnace under an Ar gas purge and hot-rolled into hot-rolled steel sheets having a thickness of 4.0 mm.

[0080] Then, these hot-rolled sheets were subjected to annealing in air at a temperature of 950°C for a duration of 1 minute, followed by a surface treatment using shot blasting with glass beads, and descaling by pickling in which the steel sheets were dipped in a sulfuric acid solution containing sulfuric acid in a concentration of 20 mass% at a temperature of 80°C for a duration of 120 seconds and then in a mixed acid solution containing nitric acid in a concentration of 15 mass% and hydrofluoric acid in a concentration of 3 mass% at a temperature of 55°C for a duration of 60 seconds.

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[0081] Then, the hot-rolled steel sheets were cold-rolled into cold-rolled steel sheets having a thickness of 1.0 mm, subjected to annealing in a reducing atmosphere (H₂: 5 volume%, N₂: 95 volume%, dewpoint: -40°C) at a temperature of 900°C for a duration of 1 minute and made cold-rolled and annealed steel sheets. These cold-rolled and annealed steel sheets were subjected to descaling using electrolysis (10 A/dm² for 2 seconds) with the steel sheet being a positive electrode for two times in a solution containing nitric acid in a concentration of 15 mass% and hydrochloric acid in an concentration of 0.5 mass% at a temperature of 50°C in order to have cold-rolled, annealed and pickled steel sheets.

[0082] [Table 5]

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Table 5

No.	Chemical Composition (mass%)																	Note
	C	Si	Mn	P	S	Cr	Ni	Cu	Ti	Nb	Mo	N	Mg	Al	Sb	Zr	V	
23	0.010	0.18	0.28	0.024	0.004	18.7	0.15	0.36	0.23	0.020	0.11	0.012	0.0004	0.028	-	-	-	Example
24	0.005	0.11	0.21	0.025	0.002	18.4	0.16	0.34	0.16	0.030	0.07	0.008	0.0002	0.030	-	-	-	
25	0.006	0.09	0.19	0.023	0.003	18.5	0.20	0.35	0.17	0.030	0.09	0.007	0.0003	0.150	-	-	-	
26	0.009	0.06	0.23	0.024	0.005	17.3	0.13	0.32	0.20	0.010	0.13	0.010	0.0002	0.027	0.180	0.20	-	
27	0.013	0.28	0.20	0.025	0.003	18.2	0.18	0.40	0.35	0.040	0.06	0.013	0.0003	0.190	-	-	0.10	Comparative Example
28	0.003	0.12	0.23	0.024	0.004	17.9	0.21	0.37	0.12	0.030	0.05	0.008	0.0004	0.160	0.050	-	0.40	
29	0.010	0.18	0.20	0.029	0.005	<u>16.7</u>	0.15	0.43	0.27	0.020	0.11	0.010	0.0003	-	-	-	-	
30	0.005	0.20	0.24	0.027	0.001	<u>19.7</u>	0.23	0.31	0.32	0.020	0.15	0.008	0.0001	0.210	-	-	-	
31	0.012	<u>0.36</u>	0.21	0.024	0.003	18.0	0.24	0.36	0.25	0.020	<u>0.40</u>	0.011	0.0004	-	-	-	-	
32	0.005	<u>0.50</u>	0.25	0.026	0.004	18.4	0.18	0.32	0.23	<u>0.100</u>	0.09	0.008	0.0003	-	-	-	0.20	

Notation: Under line indicates a value out of the range of the present invention.

[0083] Firstly, the surface quality of the obtained cold-rolled, annealed and pickled steel sheets was evaluated by a visual inspection.

[0084] Subsequently, using the cold-rolled, annealed and pickled steel sheets, two kinds of samples for evaluating the corrosion resistance of the base steel sheet were prepared as was done in Example 1. One was a sample in a pickled state obtained from the as pickled steel sheet after descaling and another was a polished sample obtained by polishing the surface of the as pickled steel sheet with a #600 emery paper.

[0085] In preparation of samples of welded part of same steels and welded part of different steels using a SUS304, considering the case where gas shield is not sufficiently effective during TIG welding, welding test was carried out using a shield gas of Ar + 20 volume% N₂ on both the front and back bead sides.

[0086] The conditions of welding will be described below. The surface on the back bead side was evaluated.

[0087]

Welding voltage: 10 V

Welding current: from 90 A to 110 A

Welding speed: 600 mm/min

Electrode: tungsten electrode of 1.6 mm

Shield gas: front bead side Ar + 20 volume% N₂ 20 L/min,

back bead side Ar + 20 volume% N₂ 20 L/min

[0088] Using the two kind of samples (sample in a pickled state and sample in a polished state), the welded part of same steels and the welded part of different steels, a neutral salt spray cyclic corrosion test (CCT) was carried out in accordance with JIS H 8502 (1999). In the CCT, a cycle in which spraying a solution containing NaCl in a concentration of 5 mass% (35°C, 2 hours), drying (60°C, 4 hours, relative humidity: from 20% to 30%) and wetting (40°C, 2 hours, relative humidity: 95% or more) were performed in this order was repeated for 15 cycles. The obtained results are given in Table 6. Here, the evaluation standards were similar to those in Example 1.

[0089] [Table 6]

Table 6

No.	Surface Quality of Cold-Rolled, Annealed and Pickled Sheet	Corrosion Resistance of Cold-Rolled, Annealed and Pickled Sheet (Pickled State) in CCT	Corrosion Resistance of Cold-Rolled, Annealed and Pickled Sheet (Polished State) in CCT	Corrosion Resistance in Weld Zone of Same Steel Grades in CCT	Corrosion Resistance in Weld Zone of Different Steel Grades in CCT	Note	Note
23	⊙	⊙	⊙	○	○	-	Example
24	⊙	⊙	⊙	○	○	-	
25	⊙	⊙	⊙	⊙	⊙	-	
26	○	○	⊙	⊙	⊙	-	
27	⊙	⊙	⊙	⊙	⊙	-	
28	⊙	⊙	⊙	⊙	⊙	-	
29	⊙	×	×	×	×	-	Comparative Example
30	⊙	⊙	○	Δ	×	-	
31	Δ	Δ	○	○	×	-	
32	×	×	⊙	○	×	Decreased Ductility Residual Scale	
Notation: ⊙, ○; satisfactory, Δ, x; unsatisfactory							

[0090] Examples No. 23 through No. 28 were excellent in corrosion resistance and surface quality in all evaluation items. Examples No. 25 through 28 to which Al, Sb, Zr and V were added were significantly excellent in corrosion resistance even in the welded part of different steels using a SUS304.

[0091] On the other hand, since comparative example No. 29 had Cr content of 16.7% less than the range according to the present invention, it was poor in corrosion resistance, as indicated by its large rust area.

[0092] In addition, since comparative example No. 30 had Cr content of 19.7% more than the range according to the present invention, it was poor in corrosion resistance, as indicated by its large rust area in the welded part with different steels. This is because a martensite phase is not formed in the welded part of different steels due to the large content of Cr, which is a ferrite former element.

[0093] In addition, comparative example No. 31 had Si content of 0.36% and Mo content of 0.40% more than the range according to the present invention, some residual scale was found on the surface of the base steel sheet. And it was poor not only in corrosion resistance after cold rolling, annealing and pickling, but also in corrosion resistance in the welded part of different steels using a SUS304 in which, in particular, gas shield was not sufficient.

[0094] Moreover, comparative example No. 32 had Si content of 0.50% and Nb content of 0.10% more than the range according to the present invention, some residual scale was found on the surface of the base steel sheet, and it was poor in corrosion resistance after cold rolling, annealing and pickling.

[0095] As described above, it has been clarified that, according to the present invention, a ferritic stainless steel excellent in corrosion resistance of base steel sheet, corrosion resistance in the welded part of same steels, corrosion resistance in the welded part of different steels using a SUS304 and the surface quality of cold-rolled, annealed and pickled sheet can be obtained without grinding the surface of hot-rolled, annealed and pickled steel sheet.

Industrial Applicability

[0096] The ferritic stainless steel according to the present invention can be preferably used as a material for parts which need corrosion resistance such as kitchen and house wares, architectural interior and exterior, building parts, the interior of an elevator and an escalator, electric appliances and automobile parts.

Claims

1. A ferritic stainless steel having a chemical composition consisting of, by mass%, C: 0.003% or more and 0.015% or less, Si: 0.05% or more and 0.30% or less, Mn: 0.10% or more and 0.35% or less, P: 0.06% or less, S: 0.02% or less, Cr: 17.0% or more and 19.0% or less, Ni: more than 0.10% and 0.30% or less, Ti: 0.10% or more and 0.40% or less, Nb: 0.005% or more and less than 0.050%, Mo: less than 0.20%, N: 0.005% or more and 0.015% or less, Cu: 0.30% or more and 0.50% or less, Mg: less than 0.0005% and the balance being Fe and inevitable impurities.
2. The ferritic stainless steel according to Claim 1, the steel having a chemical composition further containing, by mass%, Al: 0.02% or more and 0.50% or less.
3. The ferritic stainless steel according to Claim 2, the steel having a chemical composition containing, by mass%, Al: 0.10% or more and 0.50% or less.
4. The ferritic stainless steel according to any one of Claims 1 to 3, the steel having a chemical composition further containing, by mass%, Sb: 0.005% or more and 0.300% or less.
5. The ferritic stainless steel according to any one of Claims 1 to 4, the steel having a chemical composition further containing, by mass%, at least one of Zr: 0.05% or more and 0.60% or less and V: 0.02% or more and 0.50% or less.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/001462

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)

C22C1/00-49/14, C21D9/46

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 1996-2013

Kokai Jitsuyo Shinan Koho 1971-2013 Toroku Jitsuyo Shinan Koho 1994-2013

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 11-106875 A (Kawasaki Steel Corp.), 20 April 1999 (20.04.1999), & US 6113710 A & EP 930375 A1 & WO 1999/007909 A1 & DE 69824384 D & TW 452599 B & ES 2222598 T & CN 1088764 C	1-5
A	JP 2003-201547 A (JFE Steel Corp.), 18 July 2003 (18.07.2003), & US 2003/0094217 A1 & US 2004/0055674 A1 & EP 1308532 A2 & DE 60228186 D & KR 10-2003-0035972 A	1-5
A	JP 2007-119856 A (Nisshin Steel Co., Ltd.), 17 May 2007 (17.05.2007), (Family: none)	1-5

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search
28 May, 2013 (28.05.13)

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