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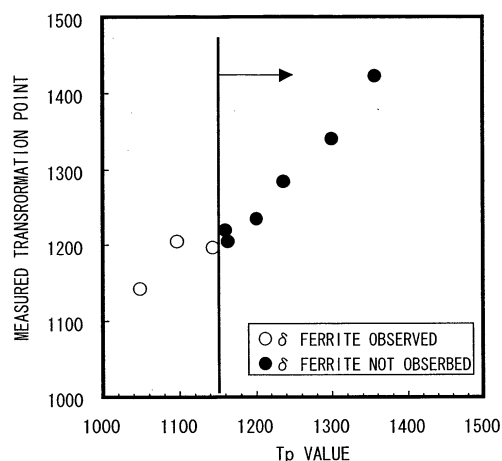
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(54) **CORROSION-RESISTANT STEEL EXCELLENT IN TOUGHNESS OF BASE METAL AND WELD AND PROCESS FOR PRODUCING THE SAME**

(57) A corrosion-resistant steel excellent in toughness of a base metal and a weld portion said steel slab contains, in % by weight, C: 0.2% or less; Si: 0.01 to 2.0%; Mn: 0.1 to 4% or less; P: 0.03% or less; S: 0.01% or less; Cr: 3 to 11%; Al: 0.1 to 2%; and N: 0.02%, and has values of 1150 or more, and 600 or more respectively for Tp and Tc expressed by the equations below using concentrations of Cr, Al, C, Mn, Cu and Ni respectively given as %Cr, %Al, %C, %Mn, %Cu and %Ni. $T_p = 1601 - (34\%Cr + 287\%Al) + (500\%C + 33\%Mn + 60\%Cu + 107\%Ni)$; and $T_c = 910 + 80\%Al - (300\%C + 80\%Mn + 15\%Cr + 55\%Ni)$.

FIG. 1



DescriptionTechnical Field

5 **[0001]** The present invention relates to a corrosion-resistant steel excellent in toughness of a base metal and a weld portion, and a method of manufacturing the same, and more specifically, a corrosion-resistant steel used in various forms under various corrosive environments, such as various containers, vacuum vessels, low-temperature heat exchangers and bathroom components used under corrosive environment with dewing or under indoor environment; such as bridge, support columns, tunnel reinforcing components, interior and exterior materials for buildings, roof materials and fittings used under aerial corrosive environment; such as various reinforcing structures and support columns used under corrosive environment with concrete; and such as marine vessels, bridges, piles, sheet piles and marine structures used under corrosive environments with seawater.

Background Art

15 **[0002]** Steels used under various corrosive environments, such as high-temperature and high-humidity corrosive environment, corrosive environment with dewing, aerial corrosive environment, corrosive environment with city water, corrosive environment with soil, corrosive environment with concrete, and corrosive environment with seawater, are generally provided with some anti-corrosion measures. In recent years, in view of improving reliability, simplifying manufacturing and application processes, achieving maintenance-free, saving resources and the like, there have been increasing trends in using Cr-containing steels and stainless steels, for the purpose of improving corrosion resistance of the steel base. Most of conventional techniques have, however, failed in providing a practical measure from an economical point of view, because improvement in the corrosion resistance has resulted in increase in material cost, and have sometimes resulted in only a limited range of applications due to poor strength when austenitic steels were used.

20 **[0003]** As seen in the above-described examples, any steels containing certain levels of Cr generally became more likely to cause local corrosion as the corrosive environment became more severe, so that as a countermeasure for this problem, further increase in the concentration of Cr or Mo has been a most general technical means for improving the resistivity against corrosion.

25 **[0004]** In recent years, there have been proposed steels added with Al besides Cr, aiming at improving the corrosion resistance, or both of the corrosion resistance and workability, as disclosed in Japanese Patent Application Laid-Open Nos. 5-279791, 6-179949, 6-179950, 6-179951, 6-212256, 6-212257, 7-3388 and 11-350082 and the like. These steels may be effective to some degree in terms of improvement in the corrosion resistance or both of the corrosion resistance and the workability, but poor in toughness of the base metal and the heat affected zone (HAZ), and this raises a tough obstacle for the steel to be applied to weld structures.

Disclosure of the Invention

30 **[0005]** After considering the above-described situations, the present invention is aimed at providing a low-cost, corrosion-resistant steel showing a large corrosion resistance under various corrosive environments such as corrosive environment with dewing, aerial corrosive environment, corrosive environment with city water, and corrosive environment with seawater, and excellent in the toughness in the heat affected zone (HAZ).

35 **[0006]** Aiming at achieving the above-described objects, the present inventors made extensive studies from every aspect, in order to develop a steel showing excellent corrosion resistance under various corrosive environments such as corrosive environment with dewing, aerial corrosive environment, corrosive environment with city water, corrosive environment with concrete, and corrosive environment with seawater. First, after extensive investigations into techniques for improving the corrosion resistance under the above-described various environments, as well as the toughness of the weld portion, the present inventors found that a steel containing 3 to 11% of Cr, added with 0.1 to 2% of Al, showed a very excellent corrosion resistance under the above-described various corrosive environments. However, this sort of steel typically produces coarse ferrite when heated at 1200°C or more during welding, due to its wide range of ferrite phase transformation, so that the toughness may degrade to a considerable degree, and may cause cracks and the like after welding. The present inventors then further went through a series of experiments, and found out that a mode of generation of the coarse ferrite phase transformation during welding can be estimated based on a parameter T_p below, expressed using amounts of addition of alloying elements. The parameter T_p can be expressed using concentrations of ferrite-forming elements (Cr, Al) and austenite-forming elements (Mn, Ni, for example) which suppress production of ferrite phase. The present inventors found out that production of ferrite at higher temperatures can be suppressed, when the parameter T_p has a value of not smaller than a predetermined level.

40 **[0007]** On the other hand, addition of some austenite-forming elements described in the above can suppress production of the coarse ferrite phase in the weld portion, but addition of large amounts of the alloying elements may promote

formation of a low-temperature-transformation-forming phase with poor toughness in the process of cooling after rolling of the base metal, and thereby tends to lower the toughness of the base metal. The present inventors then made extensive studies on preventing such embrittlement, defined a parameter T_c which specifies concentrations of the alloying elements capable of ensuring a desirable level of toughness of the base metal after rolling, and found out that a desirable level of toughness can be ensured when the parameter T_c has a value of not smaller than a predetermined level.

[0008] Basic concepts of the present invention are as follows.

(1) A corrosion-resistant steel excellent in toughness of a base metal and a weld portion, containing, in % by weight:

C: 0.2% or less;
 Si: 0.01 to 2.0%;
 Mn: 0.1 to 4%;
 P: 0.03% or less;
 S: 0.01% or less;
 Cr: 3 to 11%;
 Al: 0.1 to 2%; and
 N: 0.02%, and

having values of 1150 or more, and 600 or more respectively for T_p and T_c expressed by the equations below using concentrations of Cr, Al, C, Mn, Cu and Ni respectively given as %Cr, %Al, %C, %Mn, %Cu and %Ni.

$$T_p = 1601 - (34\%Cr + 287\%Al) + (500\%C + 33\%Mn + 60\%Cu + 107\%Ni);$$

and

$$T_c = 910 + 80\%Al - (300\%C + 80\%Mn + 15\%Cr + 55\%Ni).$$

(2) The corrosion-resistant steel excellent in toughness of a base metal and a weld portion according to (1), further containing, in % by weight, any one of, or two or more elements selected from the group consisting of:

Cu: 0.1 to 4%;
 Ni: 0.1 to 4%;
 Mo: 0.01 to 1%;
 V: 0.01 to 0.1%;
 Nb: 0.005 to 0.050%;
 Ti: 0.005 to 0.03%;
 Ca: 0.0005 to 0.05%;
 Mg: 0.0005 to 0.05%; and
 REM: 0.001 to 0.1%.

(3) A method of manufacturing a corrosion-resistant steel excellent in toughness of a base metal and a weld portion, including the steps of:

heating a steel slab;
 the steel slab containing, in % by weight:
 C: 0.2% or less;
 Si: 0.01 to 2.0%;
 Mn: 0.1 to 4%;
 P: 0.03% or less;
 S: 0.01% or less;
 Cr: 3 to 11%;

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Al: 0.1 to 2%; and
N: 0.02%, and

having values of 1150 or more, and 600 or more respectively for T_p and T_c expressed by the equations below using concentrations of Cr, Al, C, Mn, Cu and Ni respectively given as %Cr, %Al, %C, %Mn, %Cu and %Ni, forming a steel plate by hot rolling of the steel slab; and cooling the steel plate by air.

$$T_p = 1601 - (34\%Cr + 287\%Al) + (500\%C + 33\%Mn + 60\%Cu + 107\%Ni);$$

and

$$T_c = 910 + 80\%Al - (300\%C + 80\%Mn + 15\%Cr + 55\%Ni).$$

(4) The method of manufacturing a corrosion-resistant steel excellent in toughness of a base metal and a weld portion according to (3), wherein the steel slab further contains, in % by weight, any one of, or two or more elements selected from the group consisting of:

Cu: 0.1 to 4%;
Ni: 0.1 to 4%;
Mo: 0.01 to 1%;
V: 0.01 to 0.1%;
Nb: 0.005 to 0.050%;
Ti: 0.005 to 0.03%;
Ca: 0.0005 to 0.05%;
Mg: 0.0005 to 0.05%; and
REM: 0.001 to 0.1%.

(5) The method of manufacturing a corrosion-resistant steel excellent in toughness of a base metal and a weld portion according to (3), further including, after the step of cooling the steel plate by air, tempering the steel plate at a temperature of A_{c1} transformation point or below.

(6) The method of manufacturing a corrosion-resistant steel excellent in toughness of a base metal and a weld portion according to (4), further including, after the step of cooling the steel plate by air, tempering the steel plate at a temperature of A_{c1} transformation point or below.

Brief Description of the Drawings

[0009]

Fig. 1 is a graph showing relations between the T_p values (calculated values of A_4 transformation point) and measured transformation points, and relations between the T_p values and presence or absence of δ ferrite; and Fig. 2 is a graph showing relations between the T_c values and the toughness (vE_{-5}) of the base metal.

Detailed Description of the Preferred Embodiments

[0010] Paragraphs below will explain constitutive elements of the inventive corrosion-resistant steel, concentrations thereof and the like.

[0011] C: C is an element improving the strength, but addition to an amount exceeding a predetermined level results in degradation of the toughness in the heat affected zone (HAZ). The upper limit of the C concentration is therefore set to 0.2%.

[0012] Si: Si is effectively added to a steel containing 2% or more of Cr, as a deoxidizer and a strengthening element,

wherein the concentration thereof less than 0.01% results in only an insufficient effect of deoxidization, whereas the concentration exceeding 2.0% not only saturates the effect but also adversely degrades the toughness of the heat affected zone (HAZ). The range of Si concentration is therefore limited from 0.01% and 2.0%, both ends inclusive.

5 [0013] Cr: Cr is added in order to ensure a desirable level of corrosion resistance, similarly to Al, wherein an amount of addition of 3% or more exhibits the effect, whereas the amount of addition exceeding 11% not only increases the cost, but also impairs again the toughness of the heat affected zone (HAZ). The upper limit of the Cr concentration is set to 11%.

10 [0014] Al: Al is an important element, similar to Cr, in view of ensuring a desirable level of corrosion resistance in the present invention, wherein the concentration of Al is necessarily set to 0.1% or more in view of ensuring a desirable level of corrosion resistance. On the other hand, the amount of addition exceeding 2% extremely widens a temperature range causing the ferrite phase transformation. The concentration of Al is therefore limited to 0.1% to 2%, both ends inclusive.

15 [0015] Mn: Mn in the present invention functions mainly as improving the strength and as an austenite-forming element, and is added to suppress generation of coarse ferrite promoted by Cr and Al added in view of improving the corrosion resistance. More specifically, Cr and Al are ferrite-forming elements as well-known, wherein large amounts of addition of these elements may give a ferrite single phase structure over a range from solidification point to room temperature, without causing transformation, and may considerably degrade the toughness not only in the base metal, but also in the heat affected zone (HAZ). The present inventors made systematic experiments aiming at improving the toughness of the heat affected zone (HAZ) without causing the corrosion resistance, and found out that addition of Mn can avoid the problem. Specific conditions for limitation therefor will be described later, wherein Mn is necessarily added to as much as 0.1% or more, but the amount of addition exceeding 4% enhances the hardening property, so that the addition is limited up to 4%.

20 [0016] N: The less N is contained, the more preferable, because a large amount of addition thereof to steel plate may lower the toughness of the base metal and the heat affected zone (HAZ), so that the upper limit of concentration thereof is set to 0.02%.

25 [0017] P: The less P is contained, the more preferable, because abundance thereof lowers the toughness, so that the upper limit of concentration thereof is set to 0.03%. The concentration thereof ascribable to inevitable contamination is preferably minimized as possible.

30 [0018] S: The less S is contained, the more preferable, too, because abundance thereof lowers pitting resistance, so that the upper limit of concentration thereof is set to 0.01%. Similarly to P, also the concentration of S ascribable to inevitable contamination is preferably minimized as possible.

[0019] The present invention further allows addition of the elements below.

35 [0020] Cu, Ni: Both of Cu and Ni exhibit effects of improving the strength, and of suppressing the ferrite generation. In particular, Ni has an effect of improving the toughness of the base metal and the heat affected zone (HAZ). Addition to as much as 0.1% or more is necessary for both of Cu and Ni in order to obtain these effects, wherein the amounts of addition of the both exceeding 4% enhances the hardenability and causes embrittlement. Both of the concentrations of Cu and Ni are therefore set to 0.1 to 4%.

40 [0021] Mo: Mo added to as much as 0.01% or more to a steel added with Cr and Al exhibits an effect of suppressing generation and growth of pitting, without impairing the toughness of the base metal, whereas an amount of addition exceeding 1.0% not only saturates the effect but also degrades the toughness. The concentration of Mo is therefore set to 0.01% to 1.0%.

45 [0022] Nb: Nb is an element improving the strength and toughness without impairing the corrosion resistance, wherein the effect thereof is recognizable at a concentration of as small as 0.005%, whereas the concentration exceeding 0.05% considerably degrades the toughness of the heat affected zone (HAZ). The concentration of Nb is therefore set to 0.005% to 0.05%.

[0023] V: V is an element improving the strength without impairing the corrosion resistance, similar to Nb, wherein the effect thereof is recognizable at a concentration of as small as 0.01% or more, whereas a large amount of addition degrades the toughness as well-known. The upper limit of the V concentration is set to 0.1%.

50 [0024] Ti: Ti is an element contributive to refinement of crystal grains at high temperatures through production of nitride, and can particularly improve the toughness of the heat affected zone (HAZ), without impairing the corrosion resistance. Both of refinement of the crystal grains and improvement in the toughness are recognizable at a concentration of as small as 0.005% or more, whereas addition to as much as exceeding 0.03% adversely degrades the toughness of the base metal and the heat affected zone (HAZ), due to deposition of a large amount of carbide. The range of concentration is therefore set to 0.005% to 0.03%.

55 [0025] Ca, Mg: Ca and Mg are elements capable of improving the corrosion resistance in a steel containing Cr and Al. Although much of the mechanism thereof remain unclear at present, it has been made clear that improvement in the corrosion resistance is recognizable at a concentration of as small as 5 ppm or more for the both, whereas the amount of addition exceeding 500 ppm not only saturates the effect of improving the corrosion resistance, but also tends to

degrade the toughness. The concentrations of these elements are therefore set to 5 ppm to 500 ppm, both ends inclusive.

[0026] REM: In the present invention, also appropriate addition of rare earth metals (REM) can improve the toughness of the base metal and the weld portion, without impairing the corrosion resistance. An amount of addition of 0.001% or more is necessary, whereas a large amount of addition degrades the toughness, so that the upper limit thereof is set to 0.1%.

[0027] In the present invention, the parameter T_p expressed by the equation (1) is introduced, in order to improve the toughness of the weld portion, as one major object of the present invention.

Equation (1)

$$T_p = 1601 - (34\%Cr + 287\%Al) + (500\%C + 33\%Mn + 60\%Cu + 107\%Ni)$$

where, %Cr, %Al, %C, %Mn, %Cu and %Ni are concentrations of Cr, Al, C, Mn, Cu and Ni (% by weight), respectively.

[0028] Fig. 1 shows results of measurement and observation of transformation point and generation behavior of coarse ferrite, obtained when materials composed of a 0.015%C-0.15%Si steel (P, S and N are within the ranges of the present invention) as a base, added with Mn, Cr and Al, and for some cases with Cu and/or Ni, were subjected to welding cycles. It is found from Fig. 1 that generation of the coarse ferrite phase is suppressed when value of the parameter T_p , plotted on the abscissa, reaches and exceeds 1150.

[0029] The present inventors further investigated into relations between concentrations of the alloying elements and the toughness, for the purpose of ensuring a desirable level of toughness of the base metal, and found out that the toughness of the base metal can be evaluated based on the parameter T_c expressed by the equation (2).

Equation (2)

$$T_c = 910 + 80\%Al - (300\%C + 80\%Mn + 15\%Cr + 55\%Ni)$$

[0030] Fig. 2 shows, together with values of the parameter T_c , results of measurement of the toughness of a 0.02 to 0.05%C-0.25%Si steel as a base, added with Mn: 1.50 to 3.72%, Cr: 5.1 to 10.3% and Al: 0.8 to 1.5%, wherein a 20-mm-thick steel plate was manufactured by hot rolling, and test pieces were collected from a portion having a quarter thickness (5 mm) in the longitudinal direction. It is found from Fig. 2 that a range of the parameter T_c of 600 or more can ensure an absorption energy at -5°C (vE_{-5}) of as desirable as 100 J or more. The present invention therefore sets the lower limit thereof to 600.

[0031] As for corrosion-resistant steel of the present invention, the steel slab can be made by the ingot making/breaking down method, continuous casting method and the like. The steel slab may further be processed to give a steel plate by hot rolling, hot forging or the like, or may be hot-worked to give an arbitrary geometry corresponding to a user's need, such as steel pipes represented by seamless steel pipe, shape steels and the like. The hot working can be followed by air-cooling, for example. Tempering at a temperature not higher than A_{c1} transformation point, aiming at further improving the strength, will never interfere the effects of the present invention.

[0032] The corrosion-resistant steel according to the present invention is applicable, for example, to various corrosive environments, such as high-temperature and high-humidity corrosive environment, corrosive environment with dewing, aerial corrosive environment, corrosive environment with city water, corrosive environment with soil, corrosive environment with concrete, corrosive environment with seawater, and corrosive environments based on any combinations of them.

(Examples)

[0033] Each of steels having compositions listed in Table 1 was melted and cast, hot rolled to give a 15-mm-thick steel plate, wherein some of them were further tempered, and subjected to the tests described below.

(1) Toughness Evaluation Test for Heat Affected Zone (HAZ)

[0034] All test pieces were collected from the center-thickness portion of the plate in the longitudinal direction.

[0035] Evaluation of Toughness of Base Metal: Evaluation was carried out based on absorbed energy observed in

the Charpy test at -5°C.

[0036] Evaluation of Toughness of Heat Affected Zone (HAZ): Impact test of the heat affected zone (HAZ) after being subjected to the welding heat cycles was carried out. The maximum heating temperature and the cooling rate in the test were set to 1400°C and 15°C/s, respectively. The base metal was also subjected to the impact test. Transition temperatures were determined for the both, and $\Delta vTrs = ([\text{transition temperature of base metal}] - [\text{transition temperature after heat cycles}])$ was determined.

(2) Corrosion Test

[0037] 5-mm-thick corrosion test pieces were collected by cutting from a test steel plate, wherein some of them were provided with Zn-base coating (coating thickness: 15 to 25 μm), and then subjected to the test under conditions described below.

[0038] Indoor Environment: The uncoated pieces were subjected to a one-hundred-day exposure test in a room with an air conditioner.

[0039] Humid Environment: The test pieces were kept at -20°C for 2 hours, and then kept in an environment of 95% humidity at 25°C for 4 hours, and this cycle was repeated 13000 times. Size of rust spot was scored for all samples.

[0040] Salt Damage Environment: The test pieces were exposed to a coastal splash zone for 17 months.

[0041] Results of these tests are shown in Table 2. All of steels marked with A to K are those within the scope of the present invention, and every one of them showed a toughness of the base metal of 100 J or more, and a toughness of the heat affected zone (HAZ), evaluated in terms of $\Delta vTrs$, of -15°C or more, proving only a small lowering in the toughness. As for corrosion resistance, only a slight rusting of as small as 2 mm or less was observed on some of the pieces, and all pieces showed desirable characteristics.

[0042] On the contrary, all of the steels marked with L to U are those according to comparative examples out of scope of the present invention. More specifically, steels L, M and N, having the concentrations of C, Si and Mn, respectively, exceeding the upper limits specified by the present invention, showed almost desirable corrosion resistance, but showed considerable degradation in the toughness. The steel marked with L showed a toughness ($\Delta vTrs$) of the heat affected zone (HAZ) of -40°C, indicating a large decrease. The steels marked with O and P, having amounts of addition of Cr and Al, which are elements contributive to improvement in the corrosion resistance, fallen below the lower limits, showed considerable decrease in the corrosion resistance. The steel marked with Q, having the Al concentration exceeding the upper limit, showed a desirable corrosion resistance, but was degraded in the toughness of the base metal. The steel marked with R, having Ni added as exceeding the upper limit, again showed a desirable corrosion resistance, but was poor in the toughness of the base metal. All of the steels marked with S, T and U have the concentrations of the individual element fallen within the ranges of the present invention, but have value(s) of the parameter(s) T_p and/or T_c out of the ranges of the present invention. More specifically, the steel marked with S is an example having only the parameter T_p fallen out of the range of the present invention, showing a degraded toughness of the heat affected zone (HAZ) of -55°C. The steel marked with T is an example having only the parameter T_c fallen out of the range of the present invention, showing a degraded toughness of the base metal of 83 J. The last steel marked with U is an example having both of the parameters T_p and T_c fallen out of the ranges of the present invention, showing degradation both in the toughness of the base metal and the heat affected zone (HAZ).

Industrial Applicability

[0043] The present invention can provide, at low costs, a steel excellent not only in the corrosion resistance in corrosive environment with dewing, and in other various corrosive environments such as indoor environment, aerial corrosive environment and corrosive environment with seawater, but also in the toughness of the heat affected zone (HAZ) which is important for weld structures, and can make a huge contribution to industrial development.

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TABLE 1 (1)

SYMBOL	C	Si	Mn	P	S	Cr	Al	N		
A	0.012	0.15	2.06	0.003	0.002	5.36	0.85	0.0045	WITHIN SCOPE OF THE PRESENT INVENTION	
B	0.015	0.26	2.53	0.001	0.001	6.32	1.15	0.0077		
C	0.18	0.19	3.86	0.002	0.004	3.12	1.88	0.0056		
D	0.012	0.46	2.02	0.001	0.003	10.58	0.18	0.0045		
E	0.023	0.06	0.16	0.006	0.001	5.93	0.72	0.0054		
F	0.027	1.26	2.23	0.002	0.002	6.98	0.32	0.0085		
G	0.038	0.28	2.88	0.002	0.001	4.89	1.13	0.0036		
H	0.037	0.22	2.19	0.006	0.003	5.12	0.56	0.0136		
I	0.019	0.87	2.38	0.003	0.002	4.44	1.02	0.0175		
J	0.044	1.86	2.46	0.006	0.005	5.44	0.78	0.0056		
K	0.025	0.55	2.04	0.004	0.002	4.22	1.65	0.0132		
L	0.29	0.26	2.33	0.006	0.0004	6.12	0.78	0.0069		COMPARATIVE EXAMPLE
M	0.035	2.86	2.12	0.003	0.0007	5.66	1.23	0.0065		
N	0.18	0.75	4.26	0.002	0.001	3.02	1.66	0.0113		
O	0.018	0.26	2.46	0.002	0.0008	2.10	1.23	0.0056		
P	0.025	0.39	2.12	0.003	0.0008	8.23	0.06	0.0068		
Q	0.048	0.38	3.43	0.004	0.001	3.88	2.41	0.0098		
R	0.023	0.23	0.58	0.001	0.0008	6.12	1.12	0.0075		
S	0.026	0.28	3.35	0.003	0.001	6.28	1.35	0.0058		
T	0.036	0.21	3.73	0.002	0.002	6.38	0.52	0.0068		
U	0.045	0.63	3.68	0.006	0.003	6.88	1.71	0.0068		
									(mass%)	

TABLE 1 (2)

SYMBOL	Cu	Ni	Mo	T	Nb	V	Ca	Mg	REM	Tp	Tc
A										1249	729
B	0.22									1160	700
C		0.59								1236	618
D			0.12							1262	601
E		1.26								1344	790
F					0.042					1359	644
G				0.015						1224	685
H		0.22					0.004			1381	680
I	0.86	0.96			0.028					1400	676
J								0.001		1295	681
K		3.68							0.0036	1458	606
L			0.15							1391	607
M		1.82					0.001			1338	643
N									0.0012	1252	603
O					0.016					1267	775
P									0.0036	1386	614
Q		2.23					0.002			1153	633
R	0.12	4.52								1593	606
S				0.012						1124	648
T						0.012				1376	547
U		0.75				0.011				1101	594

WITHIN SCOPE OF THE PRESENT INVENTION

COMPARATIVE EXAMPLE

(mass%)

TABLE 2

STEEL	MANUFACTURING METHOD OF BASE METAL	TOUGHNESS OF BASE METAL VE ₅ (J)	TOUGHNESS OF WELDING-HEAT-AFFECTED PORTION (TOUGHNESS OF BASE METAL) - (TOUGHNESS OF WELD PORTION) ΔvTrs (°C)	CORROSION RESISTANCE		
				INDOOR ENVIRONMENT	HUMID ENVIRONMENT	SALT DAMAGE ENVIRONMENT
				NO COATING	NO COATING	Zn-BASE COATING
A	AS-ROLLED	223	-10	⊙	⊙	○
B	AS-ROLLED	253	-15	⊙	⊙	⊙
C	AS-ROLLED	132	0	○	○	⊙
D	AS-ROLLED + TEMPERED	122	-5	⊙	⊙	⊙
E	AS-ROLLED	201	-10	⊙	⊙	○
F	AS-ROLLED	248	-5	⊙	○	⊙
G	AS-ROLLED	263	-5	⊙	○	○
H	AS-ROLLED	230	-15	○	○	⊙
I	AS-ROLLED	213	-10	⊙	⊙	⊙
J	AS-ROLLED + TEMPERED	183	-15	○	○	○
K	AS-ROLLED	198	-10	⊙	⊙	⊙

WITHIN SCOPE OF THE PRESENT INVENTION

5
10
15
20
25
30
35
40
45
50
55

(continued)

STEEL	MANUFACTURING METHOD OF BASE METAL	TOUGHNESS OF BASE METAL vE_{-5} (J)	TOUGHNESS OF WELDING-HEAT-AFFECTED PORTION (TOUGHNESS OF WELD BASE METAL) - $\Delta vTrs$ (°C)	CORROSION RESISTANCE			
				INDOOR ENVIRONMENT	HUMID ENVIRONMENT		SALT DAMAGE ENVIRONMENT
				NO COATING	NO COATING	Zn-BASE COATING	Zn-BASE COATING
L	AS-ROLLED	43	-40	⊙	○	⊙	Δ
M	AS-ROLLED	65	-15	⊙	⊙	⊙	⊙
N	AS-ROLLED + TEMPERED	58	-15	⊙	○	○	⊙
O	AS-ROLLED	216	-15	▲	×	Δ	×
P	AS-ROLLED	263	-15	Δ	×	Δ	×
Q	AS-ROLLED + TEMPERED	93	-20	⊙	⊙	⊙	⊙
R	AS-ROLLED	83	-10	⊙	⊙	⊙	⊙
S	AS-ROLLED	213	-55	⊙	⊙	⊙	⊙
T	AS-ROLLED	83	-15	⊙	⊙	⊙	Δ
U	AS-ROLLED	76	-50	⊙	⊙	⊙	⊙

COMPARATIVE EXAMPLE

- ⊙ : NO RUSTING
 - : RUST OF 2mm OR SMALLER
 - Δ : RUST OF 5mm OR SMALLER
 - ▲ : RUST OF 10mm OR SMALLER
 - ×
- X : RUSTED ALMOST OVER ENTIRE SURFACE

Claims

1. A corrosion-resistant steel excellent in toughness of a base metal and a weld portion, containing, in % by weight:

5 C: 0.2% or less; ,
 Si: 0.01 to 2.0%;
 Mn: 0.1 to 4%;
 P: 0.03% or less;
 S: 0.01% or less;
 10 Cr: 3 to 11%;
 Al: 0.1 to 2%; and
 N: 0.02%, and

15 having values of 1150 or more, and 600 or more respectively for T_p and T_c expressed by the equations below using concentrations of Cr, Al, C, Mn, Cu and Ni respectively given as %Cr, %Al, %C, %Mn, %Cu and %Ni.

$$T_p = 1601 - (34\%Cr + 287\%Al) + (500\%C + 33\%Mn + 60\%Cu + 107\%Ni);$$

and

$$T_c = 910 + 80\%Al - (300\%C + 80\%Mn + 15\%Cr + 55\%Ni).$$

2. The corrosion-resistant steel excellent in toughness of a base metal and a weld portion according to claim 1, further containing, in % by weight, any one of, or two or more elements selected from the group consisting of:

35 Cu: 0.1 to 4%;
 Ni: 0.1 to 4%;
 Mo: 0.01 to 1%;
 V: 0.01 to 0.1%;
 Nb: 0.005 to 0.050%;
 Ti: 0.005 to 0.03%;
 Ca: 0.0005 to 0.05%;
 Mg: 0.0005 to 0.05%; and
 40 REM: 0.001 to 0.1%.

3. A method of manufacturing a corrosion-resistant steel excellent in toughness of a base metal and a weld portion, comprising the steps of:

45 heating a steel slab;
 the steel slab containing, in % by weight:
 C: 0.2% or less;
 Si: 0.01 to 2.0%;
 Mn: 0.1 to 4%;
 50 P: 0.03% or less;
 S: 0.01% or less;
 Cr: 3 to 11%;
 Al: 0.1 to 2%; and
 N: 0.02%, and

55 having values of 1150 or more, and 600 or more respectively for T_p and T_c expressed by the equations below using concentrations of Cr, Al, C, Mn, Cu and Ni respectively given as %Cr, %Al, %C, %Mn, %Cu and %Ni, forming a steel plate by hot rolling of the steel slab; and

cooling the steel plate by air.

$$T_p = 1601 - (34\%Cr + 287\%Al) + (500\%C + 33\%Mn +$$

$$60\%Cu + 107\%Ni);$$

and

$$T_c = 910 + 80\%Al - (300\%C + 80\%Mn + 15\%Cr + 55\%Ni).$$

4. The method of manufacturing a corrosion-resistant steel excellent in toughness of a base metal and a weld portion according to claim 3, wherein the steel slab further contains, in % by weight, any one of, or two or more elements selected from the group consisting of:

Cu: 0.1 to 4%;
 Ni: 0.1 to 4%;
 Mo: 0.01 to 1%;
 V: 0.01 to 0.1%;
 Nb: 0.005 to 0.050%;
 Ti: 0.005 to 0.03%;
 Ca: 0.0005 to 0.05%;
 Mg: 0.0005 to 0.05%; and
 REM: 0.001 to 0.1%.

5. The method of manufacturing a corrosion-resistant steel excellent in toughness of a base metal and a weld portion according to claim 3, further comprising, after said step of cooling the steel plate by air, tempering the steel plate at a temperature of A_{c1} transformation point or below.
6. The method of manufacturing a corrosion-resistant steel excellent in toughness of a base metal and a weld portion according to claim 4, further comprising, after said step of cooling the steel plate by air, tempering the steel plate at a temperature of A_{c1} transformation point or below.

FIG. 1

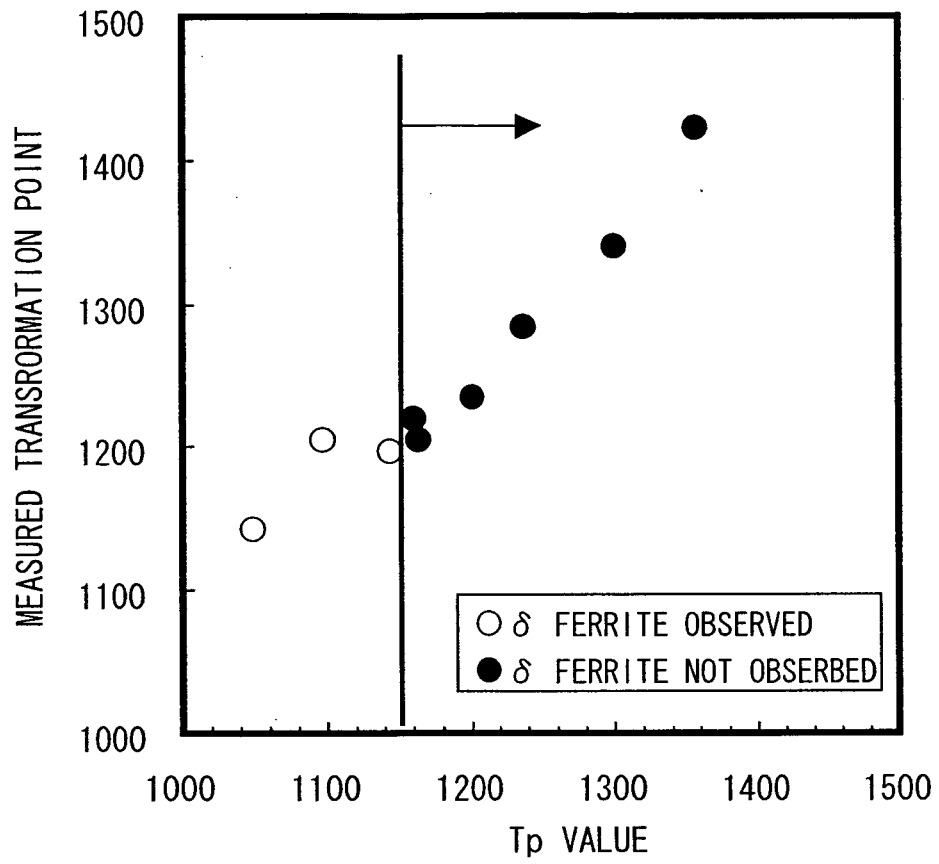
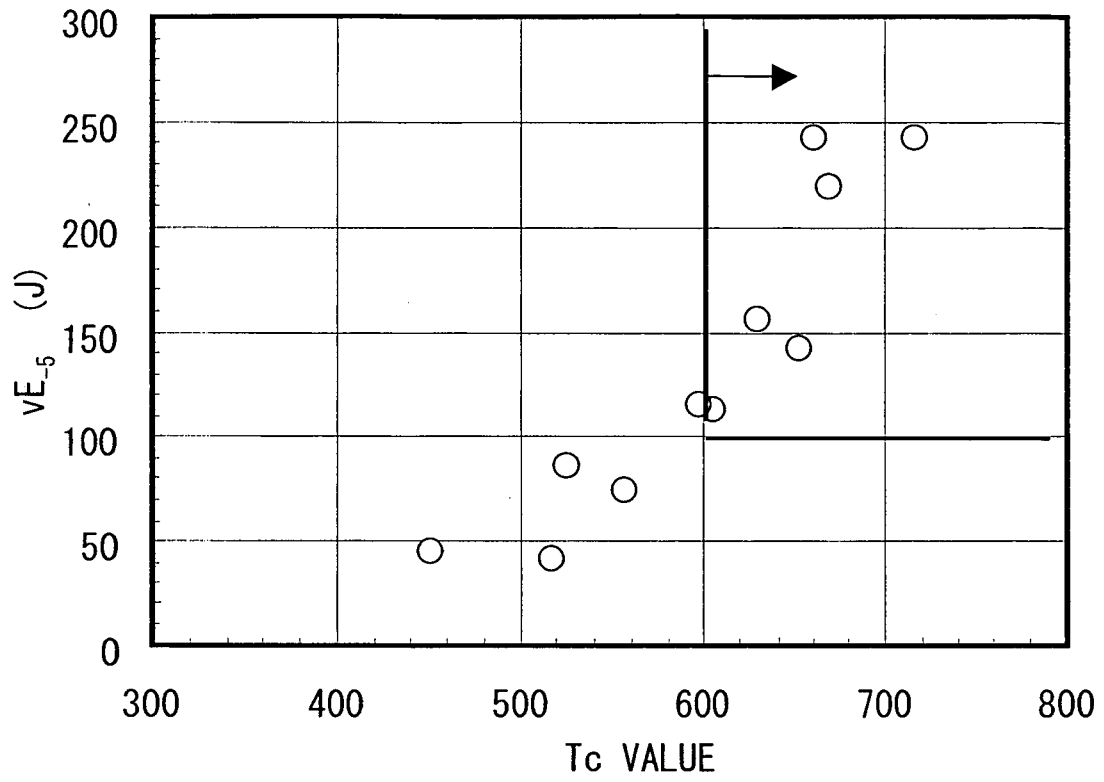


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/006663

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁷ C22C38/00, C22C38/38, C22C38/58, C21D8/02		
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 ⁷ C22C38/00-60, C21D8/00-10		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-2004 Kokai Jitsuyo Shinan Koho 1971-2004 Jitsuyo Shinan Toroku Koho 1996-2004		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) WPI		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 10-237600 A (Sumitomo Metal Industries, Ltd.), 08 September, 1998 (08.09.98), Examples (steel 15); Par. Nos. [0044], [0049] (Family: none)	1-6
X	JP 6-179949 A (Nippon Steel Corp.), 28 June, 1994 (28.06.94), Examples (steel 10) & EP 674015 A1 & US 5609818 A & WO 94/13848 A1 & AU 9456589 A	1,2
X	JP 7-3388 A (Nippon Steel Corp.), 06 January, 1995 (06.01.95), Examples (teel 9); Par. No. [0014] (Family: none)	1-4
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents:		
"A"	document defining the general state of the art which is not considered to be of particular relevance	"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
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"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is considered with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed	
Date of the actual completion of the international search 17 August, 2004 (17.08.04)	Date of mailing of the international search report 31 August, 2004 (31.08.04)	
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer	
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/006663

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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E, X	JP 2004-162119 A (Nippon Steel Corp.), 10 June, 2004 (10.06.04), Examples (steel D); Par. No. [0027] (Family: none)	1-4
E, X	JP 2004-162121 A (Nippon Steel Corp.), 10 June, 2004 (10.06.04), Examples (steel I); Par. No. [0024] (Family: none)	1-4

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REFERENCES CITED IN THE DESCRIPTION

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