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(54) **HIGH STRENGTH STAINLESS STEEL, AND PROCESS FOR ITS PRODUCTION.**

(57) Austenite stainless steel containing, by weight, 0.03% or less C, 2.00% or less Si, 5.0% or less Mn, 0.030% or less S, 16 to 20% Cr, 6 to 13% Ni, 0.15 to 0.28% N, 0.05 to 0.25% Nb, 0.0020% or less B, the balance of Fe and impurity elements and, optionally, 4% or less Mo, 4% or less Cu, and 0.005 to 0.080% Se, and process for its production. This stainless steel has excellent strength, excellent grain boundary resistance, stress-corrosion cracking resistance, and excellent hot workability, thus being useful as strength-providing members for use in various chemical plants, desalination plants, nuclear plants, etc.

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SPECIFICATION

High Strength Stainless Steel and Method of Producing the Same

Industrial Field of the Invention

This invention relates to high strength, corrosion resistant austenitic stainless steel for use in chemical, seawater, nuclear power plants, etc.

Prior Art

Austenitic stainless steel is in wide use as it offers excellent corrosion resistance - heat resistance, workability and mechanical properties. SUS304, SUS316, SUS304L and SUS316L are typical of the sort.

With increasing large - sized machinery production and large building construction recently, there is a strong demand on improvement in the strength of structural stainless steel, which has resulted in the introduction of stainless steel such as $SUS304N_1$ $SUS304N_2$, SUS304LN, SUS316N and SUS316LN reinforced by the addition of N, Nb, etc.

As for the strength of the above-described stainless steel after solution heat treatment, SUS304LN and SUS316LN showed over 25 kg/mm^2 of proof stress, and SUS304N and SUS316 over 28 kg/mm^2, i.e., the results were found unsatisfactory. In the case of $SUS304N_2$, the stress was over 35 kg/mm^2, which was relatively high but still considered not always satisfactory.

Various methods of improving the strength of stainless steel are being studied, whereas there have been proposed methods of increasing the strength thereof by, for instance, cold working and controlled rolling.

However, because over 20%-rolling reduction is required to obtain the desired strength by cold working, the disadvantage is that it is only applicable to sheet metal and wire rod.

In controlled rolling, SUS316LN, 316N, 316L, 316, 304LN, $304N_1$, 304 and 304L do not have a sufficient strength, and $SUS304N_2$ has problems and disadvantages in that cracks are produced during hot working and sufficient corrosion resistance is not obtained. Accordingly, they have not yet been put to practical use.

Moreover, they are inferior in strength, whereas SUS304N, $SUS304N_2$ and SUS316N are inferior in intergranular corrosion resistance, sensitivity to anti-stress corrosion cracking. Furthermore, problematical is sharp reduction in their corrosion resistance after welding.

Disclosure of the Invention

The present invention is intended to remedy the shortcomings of conventional stainless steel and has succeeded in not only providing satisfactory strength with, and improving the corrosion resistance of, austenitic stainless steel by adding a proper quantity of N, Nb, restricting the quantity of an impurity B and decreasing C content but also increasing the strength further by subjecting the steel to controlled rolling or thus rolled steel to thermo-mechanical treatment such as low temperature solution heat treatment.

The present inventors have studied the effects of C, N, Nb, B and roll finishing temperatures on the strength and corrosion resistance of austenitic stainless steel and found in the first place that, as shown in Fig. 1, intergranular corrosion resistance greater than that of SUS304L can be obtained by simultaneously adding 0.15 - 0.28% of N and 0.05 - 0.25% of Nb and limiting C to 0.03% or lower and B to 20 ppm.

Secondly, they have also found that, although it is said that the reinforcing action of Nb is generally attributable to the fineness of crystal grains due to the precipitation of NbC and its precipitation hardening, the reinforcing action of Nb is still conspicuous in the steel containing 0.15 - 0.28% of N even though the quantity of C is reduced to 0.03% or lower.

That is because the rifining of the crystal grain size and precipitation hardening seem to be effected by the precipitation of NbN or Nb (C,N).

Thirdly, they have further found that the reinforcing action of Nb is still exerted after the controlled rolling, and strength equivalent to that of steel of $SUS304N_2$ resulting from controlled rolling is obtainable, provided that steel containing 0.15 - 0.28% of N, 0.05 - 0.25% of Nb, 0.03% or lower of C and 20 ppm or less of B is subjected to controlled rolling at temperatures of 600 - 1,000°C as shown in Fig. 2.

Their findings further include, as shown in Fig. 3, hot workability by far greater than that of $SUS304N_1$ and $SUS304N_2$ within the controlled rolling temperature range of 600 - 1,000°C, whereby the occurrence of craking by rolling is prevented and, as shown in Fig. 4, corrosion resistibility equivalent to that of stainless steel subjected to solution heat treatment, irrespective of the presence of recrystallized microstructure or unrecrystallized reduced structure after controlled rolling.

Steel and the method of producing the same in accordance with the present invention will be described in detail.

A first example of steel embodying the present invention contains 0.03% or lower by weight C (hereinafter % refers to % by weight), 2.00% or lower of Si, 5.0% or lower of Mn, 0.030% or lower of S, 16 - 20% of Cr, 6 - 13% of Ni, 0.15 - 0.28% of N, 0.05 - 0.25% of Nb, 0.0020% or lower of B, remaining Fe and impurity elements. A second example of steel according to the present invention contains either or both of 4% or lower of Mo and 4% or lower of Cu in addition to the elements contained in the first example or otherwise 0.005% or lower of S so as to improve the corrosion resistance of the first example. A third example of steel according to the present invention contains either or both of 0.030-0.080% of S and 0.005 - 0.080% of Se to improve the machinability of the first example.

Fourth, seventh and nineth examples of steel according to the present invention are obtained by heating the first, second and third examples of steel according to the present invention to 950 - 1,300°C, then rolling them at rolling temperatures of 900 - 1,250°C, controlling the roll finishing temperature so that it may be within the range of 900 - 1,000°C, subsequently cooling them at a rate of 4°C/min or higher, setting the total reduction quantity at 30% or higher, letting them have recrystallized microstructure and a proof stress of greater than 50kg/mm^2 to improve the strength of the first, second and third examples. Fifth, eighth and tenth examples of steel according to the present invention are obtained by heating the first, second and third examples according to the present invention to 950 - 1,300°C, then rolling them at rolling temperatures of 600 - 1,250°C, controlling the roll finishing temperature so that it may be within the range of 600 - 900°C, subsequently cooling them at a rate of 4°C/min or higher, setting the total reduction quantity at 30% or higher, letting them have unrecrystallized reduced structure and a proof stress of greater than 60 kg/mm^2 to improve the strength of the first, second and third examples. Sixth example of steel according to the present invention is obtained by heating the first example according to the present invention to 950 - 1,300°C, then rolling it at rolling temperatures of 900 - 1,250°C, controlling the roll finishing temperature so that it may be lower than 1,000°C, subsequently subjecting it to low temperature solution heat treatment at 900 - 1,010°C, letting it have a grain size number of greater than 7.5 and a proof stress of greater than 40 kg/mm^2 to improve the strength of the first example.

The reasons for restricting the elements contained in the steel according to the present invention will be described.

The element C in the present invention is important because it reduces the corrosion resistance after controlled rolling, and hot workability during controlled rolling to a large extent; consequently, it must be decreased to 0.03% or lower, so that an upper limit is set at 0.03%.

The element Si is added as a deoxidizer and also used to improve the strength, however it causes cracking at high temperatures at the time of welding and reduce the quantity N of the solid solution at the time of solidification; accordingly, it must be decreased to 2.0% or lower with 2.0% as an upper limit to obtain good steel ingots.

The element Mn is added as a deoxidizer and used to increase the solubility of N but it will impair the corrosion resistance and hot workability if the content of Mn increases; consequently, the upper limit is set at 5.0%.

Cr is the basic element of stainless steel and over 16% of it is at least required to provide superior corrosion resistance. However, because the excessive content of Cr will damage the balance between δ/γ structure at high temperatures, the upper limit is set at 20%.

Ni is the basic element of austenitic stainless steel and over 6% of it is required to obtain excellent corrosion resistance and austenitic structure. However, because the excessive content of Ni will cause weld cracks and reduce hot workability and corrosion resistance after controlled rolling, the upper limit is set at 13%.

N is the most important reinforcing element according to the present invention since it has penetration type solution strengthening action, crystal grain micronizing action resulting from Nb (C, N) precipitation and precipitation accelerating action, and contributes to improvement in corrosion resistance after controlled rolling. As over 0.15% of N content is required to obtain the aforementioned effects, the lower limit was set at 0.15%. However, because the excessive content of N will reduce hot workability and allow the generation of a blowhole easily at the time of solidification and welding, the upper limit is set at 0.28%.

Nb is an important element in the present invention for fixing the remaining C in the form of NbC, improving corrosion resistance after controlled rolling, rifining of crystal grain because of Nb (C, N) precipitation and increasing strength after controlled rolling; thus over 0.05% of Nb content is at least required. However, Nb is an expensive element and, because the excessive content of it will damage hot workability, the upper limit is set at 0.25%.

B is the element to reduce the intergranular corrosion resistance of the steel according to the present invention and, also to reduce the corrosion resistance after controlled rolling. Thus, its content must strictly be limited, the upper limit is set at 0.0020% and preferably 0.005% or lower.

Both of Mo and Cu are the elements to improve the corrosion resistance of the steel according to the present invention. However, Mo and Cu are expensive elements and the content exceeding 4% will damage hot workability. Thus the upper limits are set at 4% each.

S is the element to improve corrosion resistance provided that its content is reduced by a large amount, ductility and toughness (particularly in the direction perpendicular to that of rolling) after controlled rolling. The smaller its content, the better. Consequently, it should be 0.005% or lower and preferably 0.001% or lower.

S and Se are the elements used to improve the machinability of the steel according to the present invention, and 0.030% or higher of S and 0.005% or higher of Se must be contained therein. However, because hot workability and corrosion resistance will decrease if the content of each of S and Se exceeds 0.080%, the upper limit is set at 0.080%.

The reason why the heating temperatures were set at 950 - 1,300°C during controlled rolling is to reduce deformation resistance at the controlled rolling. The rolling will become difficult because of large deformation resistance if the temperature is lower than 950°C and, if it exceeds 1,300°C, the rolling will also become difficult because partial intergranular fusion is developed or coarse crystal grains are produced. The roll finishing temperatures are set at 900 - 1,000°C so as to control the strength of the steel according to the present invention; the lower the roll finishing temperature, the greater the strength thereof becomes. The temperature exceeding 1,000°C will make recrystallized grains coarse and satisfactory strength unavailable, whereas the temperature lower than 900°C will make recrystallized microstructure unavailable and act to form unrecrystallized reduced structure, so that ductility and toughness in the direction perpendicular to that of rolling are reduced.

In other words, there are provided excellent ductility and toughness in the perpendicular direction, to say nothing of the rolling direction within the roll finishing temperature range of 900 - 1,000°C, and high strength recrystallized microstructure offering excellent corrosion resistance is consequently obtained.

The roll finishing temperatures are set at 600 - 900°C because unrecrystallized reduced structure will be present at lower than 900°C and the strength of the steel will increase as the roll finishing temperature becomes lower. On the other hand, its ductility and toughness will decrease. Accordingly, it is preferred to set the percentage of S at 0.005 or lower during rolling at 600 - 900°C.

Moreover, since the temperature lower than 600°C is lower than the recovery temperature of the steel according to the present invention, the deformation resistance during rolling will be raised sharply and thus undesirable because rolling becomes difficult.

The low temperature solution heat treatment temperatures are set at 900 - 1,010°C because the solid solubility of C is possible with heat addition at 900 - 1,010°C and, when the recrystallization temperature is higher than 900°C, the crystal grain size, if treated at lower temperatures, will be minimized, whereas the strength will be increased.

However, C will not be solid - soluble nor recrystallized at temperatures lower than 900°C, whereas its crystal grain will become as coarse as 7.5 or smaller if the temperature exceeds 1,010°C and the strength will thus decrease.

The reason why the cooling rate after rolling is set at higher than 4°C/min is that the intergranular precipitation of $Cr_{23}C_6$ or Cr_2N will be caused by slow cooling at a rate lower than 4°C/min and the corrosion resistance will decrease.

Moreover, the reason why the total reduction ratio within the rolling temperature range of 900°C - 1,250°C is set at 30% is that the desired structure is unobtainable because the scarcity of the lattice defect and the accumulated energy introduced into the crystal as the result of working will allows coarse structure to remain while heated if the total reduction ratio is lower than 30%.

Brief Description of the Drawings

Fig. 1 is a graph illustrating the relation between sensitizing temperatures affecting intergranular corrosion resistance and retention time.

Fig. 2 is a graph illustrating roll finishing temperatures affecting strength.

Fig. 3 is a graph illustrating working temperatures affecting hot workability.

Fig. 4 is a graph illustrating roll finishing temperatures affecting corrosion resistance.

Description of the Preferred Embodiment

Referring now to examples in comparison with comparative conventional steel, features of the steel according to the present invention will be described.

Table 1 shows chemical components of test pieces.

In Table 1, there are shown examples A - G of conventional steel: A = SUS304, B = SUS316, C = SUS304L, D = SUS316L, E = SUS304N_1, F = SUS304N_2, G = SUS316N; and examples H - Q of steel according to the present invention: H - K = first examples, L - N = second examples, P, Q = third examples.

Table 2 shows the strength, corrosion resistance and hot workability of the examples A - Q of steel subjected to solution heat treatment (1,050°C x 30 min → W, Q) shown in Table 1.

Respecting the strength, JIS No. 4 test pieces were used to measure proof stress.

Regarding the intergranular corrosion resistance, the structure subjected to sensitizing treatment at 800°C x 2 Hr was assessed, where STEP (step structure) is represented by ○, DUAL (composite structure) by △ and DITCH (ditch structure) by X.

Concerning the sensitivity to anti-stress corrosion cracking, the U-bending method was employed, wherein U-bent test pieces were immersed in a boiling aqueous solution containing 20% NaCl + 1%$Na_3Cr_2O_7$ for 50 Hr to evaluate them in terms of the presence and absence of cracking. What has no crack is marked with ○ and what has a crack with X.

Relating to the hot workability, high temperature tensile testing was made at 850°C and 50 mm/sec to measure the contraction of area.

As to the corrosion resistance of the base material and the portions affected by welding heat, the pitting corrosion potential in an aqueous solution containing 3.5% NaCl at 30°C was measured.

TABLE 1

	Chemical Components (% by weight)											
	C	Si	Mn	S	Ni	Cr	N	Nb	B	Mo	Cu	Se
A	0.07	0.68	1.23	0.011	8.87	18.74	0.02					
B	0.06	0.62	1.15	0.010	12.48	17.69	0.02			2.12		
C	0.02	0.59	1.27	0.013	10.27	18.50	0.02					
D	0.02	0.56	1.04	0.010	13.52	17.95	0.02			2.25		
E	0.06	0.63	1.20	0.011	8.55	18.56	0.22					
F	0.06	0.66	1.17	0.011	8.69	18.73	0.20	0.10				
G	0.07	0.64	1.28	0.012	12.73	17.39	0.17			2.13		
H	0.02	0.57	1.23	0.010	6.92	18.63	0.18	0.10	0.0008			
J	0.02	0.54	2.20	0.006	9.11	18.27	0.21	0.09	0.0005			
K	0.03	0.65	2.58	0.007	8.23	18.52	0.25	0.18	0.0002			
L	0.02	0.63	2.36	0.001	8.06	18.36	0.22	0.13	0.0003			
M	0.01	0.67	2.29	0.001	7.59	18.76	0.21	0.12	0.0002	2.57		
N	0.02	0.61	1.17	0.008	7.75	18.12	0.18	0.10	0.0005		1.89	
P	0.02	0.64	2.23	0.052	7.92	18.71	0.17	0.08	0.0007			
Q	0.02	0.57	1.89	0.012	8.13	19.52	0.16	0.08	0.0005			0.037

TABLE 2

	0.2% proof stress (kg/mm²)	Intergranular corrosion resistance	Sensitivity to anti-stress corrosion cracking	Hot working contraction of area (%)	Pitting corrosion potential in portion affected by welding heat (Vvs SCE)	Pitting corrosion potential of base material (Vvs SCE)
A	25.0	X	X	82	0.12	0.27
B	25.2	X	X	72	0.31	0.46
C	22.8	△	X	85	0.25	0.28
D	23.4	△	○	75	0.45	0.48
E	32.1	X	X	64	0.22	0.36
F	40.7	X	X	62	0.27	0.37
G	39.2	X	X	60	0.39	0.54
H	48.7	○	○	80	0.37	0.37
J	50.1	○	○	79	0.39	0.38
K	51.9	○	○	76	0.34	0.35
L	49.7	○	○	82	0.40	0.40
M	49.0	○	○	77	0.55	0.56
N	49.7	○	○	74	0.41	0.40
P	48.1	○	○	70	0.31	0.32
Q	48.2	○	○	72	0.33	0.34

As shown in Table 2, the examples A, C of conventional steel were superior in hot workability but inferior in proof stress, e.g., 25.0, 22.8 kg/mm^2, also the examples A, C are inferior in inter granular corrosion resistance, sensitivity to anti-stress corrosion cracking, and the portion affected by welding heat. The example B was superior in hot workability and the corrosion resistance of the base material and the portion affected by welding heat but inferior in proof stress, e.g., affected by welding heat but inferior in strength, e.g., 25.2 kg/mm^2, intergranular corrosion resistance, and sensitivity to anti-stress corrosion cracking. The example D was superior in sensitivity to anti-stress corrosion cracking, hot workability and the corrosion resistance of the base material and the portion affected by welding heat but inferior in proof stress, e.g., 23.4 kg/mm^2 and intergranular corrosion resistance. The example E prepared by adding 0.22% of N to the example A showed substantial improvement in proof stress., e.g., 32.1 kg/mm^2 compared with the example A but a shortage of strength as high strength stainless steel. The example F prepared by adding 0.10% of Nb to the example E showed further improvement in proof stress, e.g., 40.7 kg/mm^2 and had satisfactory strength as high strength stainless steel but indicated reduced hot workability. The example G prepared by adding 0.17% of N to the example B showed improvement in proof stress, e.g., 39.2 kg/mm^2 and excellent strength but still reduced intergranular corrosion resistance and sensitivity anti-stress corrosion cracking in addition to reduced hot workability like the example F.

In comparison with the examples of conventional steel, the examples H - Q of the steel according to the present invention, being prepared by simultaneously adding 0.15 - 0.28% of N and 0.05 - 0.25% of Nb and limiting the quantity of C to 0.03% or lower and the quantity of B to 20 ppm or less, showed such strength as a stress proof of 48 kg/mm^2 or greater, STEP (step structure) respecting intergranular corrosion resistance, no cracking regarding sensitivity to anti-stress corrosion cracking despite immersion for 50 Hr, no reduction in hot workability unlike the conventional steet, a contraction of area of over 70%, and excellent corrosion resistance of the base material and the portion affected by welding heat at 0.3V or higher. In other words, each of the steel according to the present invention is superior in all of the strength, intergranular corrosion resistance, sensitivity to anti-stress corrosion cracking, hot workability, the corrosion resistance of the base material and the portion affected by welding heat.

Table 3 illustrates the strength and corrosion resistance of the examples A, C, E, F, J, M and P shown in Table 1 and, as for those subjected to low temperature solution heat treatment, and their crystal grain sizes. In that case, the flat steel by 10 x 40 mm was heated to 1,150°C and then rolled with the roll finishing temperature controlled at about 950°C or 800°C, before being cooled at 50°C/min or higher and the total reduction ratio of 96%. Otherwise, the steel thus heated and rolled with the roll finishing temperature controlled at 950°C was cooled at 50°C/min and the total reduction ratio of 96% and then subjected to low temperature solution heat treatment for holding it at 980°C x 30 min.

Their strength and corrosion resistance were examined under the same conditions as those in the case of above-described examples.

TABLE 3

	Roll finishing temperature (950°C)		Roll finishing temperature (800°C)		Roll finishing temperature (950°C) Low temperature solution heat treatment (980°C x 30 min)		
	0.2% proof stress kg/mm^2	Pitting corrosion potential (Vvs SCE)	0.2% proof stress (kg/mm^2)	Pitting corrosion potential (Vvs SCE)	0.2% proof stress (Kg/mm^2)	Pitting corrosion potential (Vvs SCE)	Crystal grain size (No)
A	33	0.15	42	0.12	30	0.18	5.0
C	25	0.24	31	0.23	24	0.27	4.8
E	44	0.16	53	0.12	40	0.20	5.2
F	65	0.18	77	0.16	50	0.22	7.2
J	66	0.37	77	0.36	51	0.37	7.8
M	67	0.54	78	0.55	52	0.55	7.7
P	65	0.32	77	0.32	–	–	–

With respect to the examples A, C, E of conventional steel, the roll finishing temperature controlled at 950°C or 800°C resulted, as shown in Table 3, in causing the proof stress of the example A to increase from 25 kg/mm^2 to 33, 42 kg/mm^2, that of the example C from 22.8 kg/mm^2 to 25, 31 kg/mm^2 and that of that of the example E from 32.1 kg/mm^2 to 44, 53 kg/mm^2 but still failing to attaining the desired 50, 60 kg/mm^2. Moreover, all of the examples A, C, E subjected to controlled rolling showed reduction in corrosion resistance by a large margin.

Although the proof stress of the example F subjected to controlled rolling sharply increased from 40.7 kg/mm^2 to 65, 77 kg/mm^2, its corrosion resistance considerably decreased from 0.37V to 0.18, 0.16V in turn.

On the contrary, the roll finishing temperature controlled at 950°C allowed the examples J, M, P of the steel according to the present invention to have recrystallized microstructure and improved the proof stress of each from about 50 kg/mm^2 to 65 kg/mm^2, whereas the roll finishing temperature controlled at 800°C permitted them to have uncrystallized reduced structure and considerably improved the proof stress of each up to about 77 kg/mm^2; in other words, controlled rolling applied to the steel according to the present invention obviously acted to improve its proof stress by a large amount. With respect to corrosion resistance, the examples J, M, P according to the present invention showed pitting corrosion potential equivalent to what was not subjected to controlled rolling and, unlike the conventional steel, no reduction in corrosion resistance because of the controlled rolling applied.

Moreover, in the case of the examples A, C, E of conventional steel roll-finished at 950°C, cooled at the rate of 50°C/min and subjected to low temperature solution heat treatment for holding them at 980°C x 30 min, they showed slightly improved proof stress as aforementioned but failed to obtain the desired proof stress and indicated reduced corrosion resistance. Although the proof stress of the example F was improved up to 50 kg/mm^2 by controlled rolling and low temperature solution heat treatment, its corrosion resistance also reduced as in the case of the above-described steel.

On the contrary, each of the examples J, M, P according to the present invention was allowed to have recrystallized microstructure with a crystal grain size of over 7.5 by that treatment and showed the proof stress raised up to over 50 kg/mm^2 and pitting corrosion potential roughly equivalent to what was subjected to solution heat treatment (1,050°C x 30 min → W,Q.) and no reduction in corrosion resistance due to controlled rolling and low temperature solution heat treatment.

Industrial Utilizability

The present invention relates to economical stainless steel and a process for manufacturing the same having high strength, e.g., over 35 kg/mm^2 in terms of proof stress, the strength being improvable up to 50 kg/mm^2 or greater and further 70 kg/mm^2 or greater by controlled rolling; excellent corrosion resistance, particularly intergranular corrosion resistance and sensitivity to anti-stress corrosion clacking; pitting corrosion and acid resistance superior to SUS_{304}; corrosion resistance without being reduced after welding; excellent hot workability; and producibility through the same process as that of SUS_{304} manufacture.

The corrosion resistance of the steel according to the present invention is made further improvable by adding Mo, Cu as occasion demands and its machinability is also improvable by adding small quantities of S, Se.

As set forth above, the steel according to the present invention is superior in strength and corrosion resistance and suitable for use as a high strength member in various plants such as chemical seawater and nuclear power plants.

WHAT IS CLAIMED IS:

1. A high strength stainless steel comprising, by weight, 0.03% or lower of C, 2.00% or lower of Si, 5.0% or lower of Mn, 0.030% or lower of S, 16 -20% of Cr, 6 - 13% of Ni, 0.15 - 0,28% of N, 0.05 - 0.25% of Nb, 0.0020% or lower of B, the remainder being Fe together with impurity elements.

2. A high strength stainless steel comprising, by weight, 0.03% or lower of C, 2.00% or lower of Si, 5.0% or lower of Mn, 16 - 20% of Cr, 6 - 13% of Ni, 0.15 - 0.28% of N, 0.05 - 0.25% of Nb, 0.0020% or lower of B, at least one selected from the group consisting of 4% or lower of Mo, 4% or lower of Cu and 0.005% or lower of S, the remainder being Fe together with impurity elements.

3. A high strength stainless steel comprising, by weight, 0.03% or lower of C, 2.00% or lower of Si, 5.0% or lower of Mn, 16 - 20% of Cr, 6 -13% of Ni, 0.15 - 0.28% of N, 0.05 - 0.25% of Nb, 0.0020% or lower of B, at least one selected from the group consisting of 0.030 - 0.080% of S, 0.005 - 0.008% of Se, the remainder being Fe together with impurity elements.

4. A method for manufacturing a high strength stainless steel having a recrystallized microstructure, said steel comprising, by weight, 0.03% or lower of C, 2.00% or lower of Si, 5.0% or lower of Mn, 0.030% or lower of S, 16 - 20% of Cr, 6 - 13 of Ni, 0.15 - 0.28 of N, 0.05 - 0.25%

of Nb, 0.0020% or lower of B, the remainder being Fe together with impurity elements, comprising the steps of: heating said steel at temperature of 950 - 1,300°C, rolling said steel at temperature of 900 - 1,250°C, controlling the temperatures of finish rolling for said steel at 900 - 1,000°C, the total reduction ratio of said steel of 30% or higher, and cooling said rolled steel at the rate of 4°C/min or higher.

5. A method for manufacturing a high strength stainless steel having an uncrystallized processed structure, said steel comprising, by weight, 0.03% or lower of C, 2.00% or lower of Si, 5.0% or lower of Mn, 0.030% or lower of S, 16 -20% of Cr, 6 - 13% of Ni, 0.15 - 0.28% of N, 0.05 - 0.25% of Nb, 0.0020% or lower of B, the remainder being Fe together with impurity elements, comprising the steps of: heating said steel at temperature of 950 - 1,300°C, rolling said steel at temperature of 600 - 1,250°C, controlling the temperatures of finish rolling for said steel at 600 - 900°C, the total reduction ratio of said steel of 30% or higher, and cooling said rolled steel at the rate of 4°C/min or higher.

6. A method for manufacturing a high strength stainless steel having a ctystal grain size number of 7.5 or greater, said steel comprising, by weight, 0.03% or lower of C, 2.00% or lower of Si, 5.0% or lower of Mn, 0.030% or lower of S, 16 - 20% of Cr, 6 - 13% of Ni, 0.15 - 0.28% of N,

0.05 - 0.25% of Nb, 0.0020% or lower of B, the remainder being Fe together with impurity elements, comprising the steps of: heating said steel at temperature of 950 - 1,300°C, rolling said steel at temperature of 900 - 1,250°C, controlling the temperatures of finish rolling for said steel at lower than 1,000°C, cooling said rolled steel at the rate of 4°C/min or higher, the total reduction ratio of said steel of 30% or higher and subjecting to low temperature solution heat treatment to said steel at temperature of 900 - 1,010°C.

7. A method for manufacuting a high strength stainless steel having a recrystallized microstructure, said steel comprising, by weigth, 0.03% or lower of C, 2.00% or lower of Si, 5.0% or lower of Mn, 16 - 20% of Cr, 6 - 13% of Ni, 0.15 - 0.28% of N, 0.05 - 0.25% of Nb, 0.0020% or lower of B, at least one selected from the group consisting of 4% or lower of Mo, 4% or lower of Cu and 0.005% or lower of S, the remainder being Fe together with impurity elements, comprising the steps of: heating said steel at temperature of 950 - 1,300°C, rolling said steel at temperature of 900 - 1,250°C, controlling the temperatures of finish rolling for said steal at 900 - 1,000°C, the total reduction ratio of said steel of 30% or higher, and cooling said rolled steel at the rate 4°C/min or higher.

8. A method for manufacuring a high strength stainless steel having an uncrystallized processed structure, said steel comprising, by weight, 0.03% or lower of C, 2.00% or

lower of Si, 5.0% or lower of Mn, 16 - 20% of Cr, 6 - 13% of Ni, 0.15 - 0.28% of N, 0.05 - 0.25% of Nb, 0.0020% or lower or B, at least one selected from the group consisting of 4% or lower of Mo, 4% or lower of Cu and 0.005% or lower of S, the remainder being Fe together with impurity elements, comprising the steps of: heating said steel at temperature of 950 - 1,300°C, rolling said steel at temperature of 600 - 1,250°C, controlling the temperature of finish rolling for said steel at 600 - 900°C, the total reduction ratio of said steel of 30% or higher, and cooling said rolled steel at the rate of 4°C/min or higher.

9. A method for manufacturing a high strength stainless steel having a recrystallized microstructure, said steel comprising, by weight, 0.03% or lower of C, 2.00% or lower of Si, 5.0% or lower of Mn, 16 - 20% of Cr, 6 - 13% of Ni, 0.15 - 0.28% of N, 0.05 - 0.25% of Nb, 0.0020% or lower of B, at least one selected from the group consisting of 0.030 - 0.080% of S and 0.005 - - 0.080% of Se, the remainder being Fe together with impurity elements, cpmprising the steps of: heating said steel at temperature of 950 - 1,300°C, rolling said steel at temperature of 900 - 1,250°C , controlling the temperature of finish rolling for said steel at 900 - 1,000°C, the total reduction ratio of said steel of 30% or higher, and cooling said rolled steel at a rate of 4°C/min or higher.

10. A method for manufacturing a high strength

stainless steel having an uncrystallized processed structure, said steel comprising, by weight, 0.03% or lower of C, 2.00% or lower of Si, 5.0% or lower of Mn, 16 - 20% of Cr, 6 - 13% of Ni, 0.15 - 0.28% of N, 0.05 - 0.25% of Nb, 0.0020% or lower of B, at least one selected from the group consisting of 0.030 - 0.080% of S and 0.005 - 0.080% of Se, the remainder being Fe together with impurity elements, comprising the steps of: heating said steel at temperature of 950 - 1,300°C, rolling said steel at temperature of 600 - 1,250°C, controlling the temperatures finish rolling for said steel at 600 - 900°C, the total reduction ratio of said steel of 30% or higher, and cooling said rolled steel at the rate of 4°C/min or higher.

FIG. 1

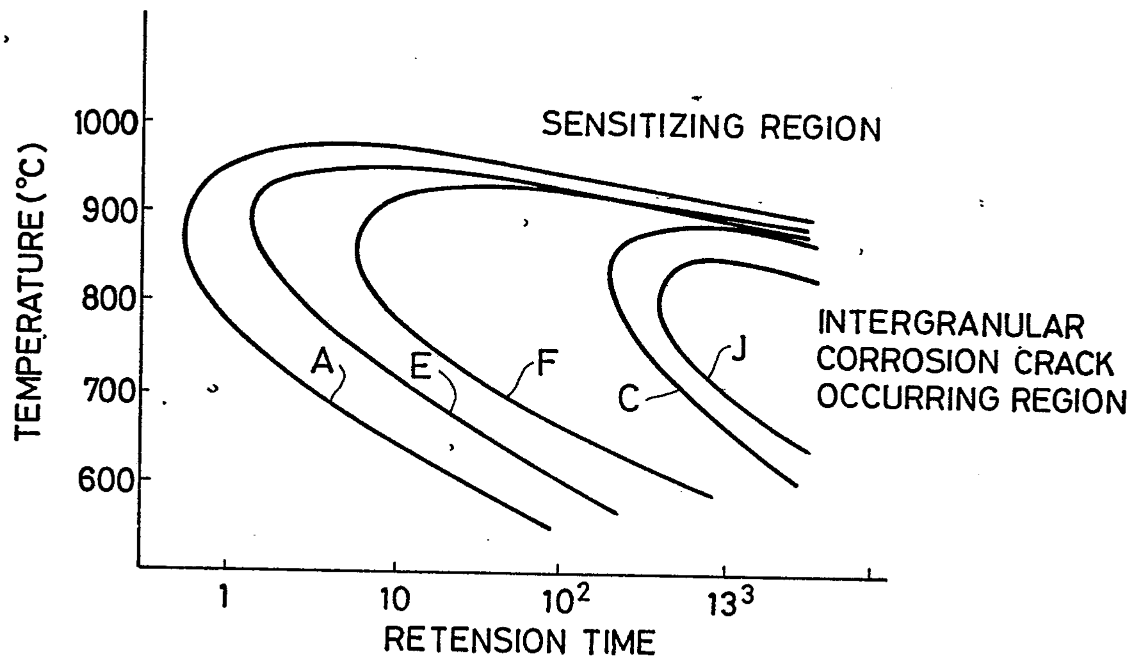

SENSITIZING REGION
1000
900
800
700
600
TEMPERATURE (°C)
A
E
F
C
J
INTERGRANULAR
CORROSION CRACK
OCCURRING REGION
1
10
10^2
13^3
RETENSION TIME

FIG. 2

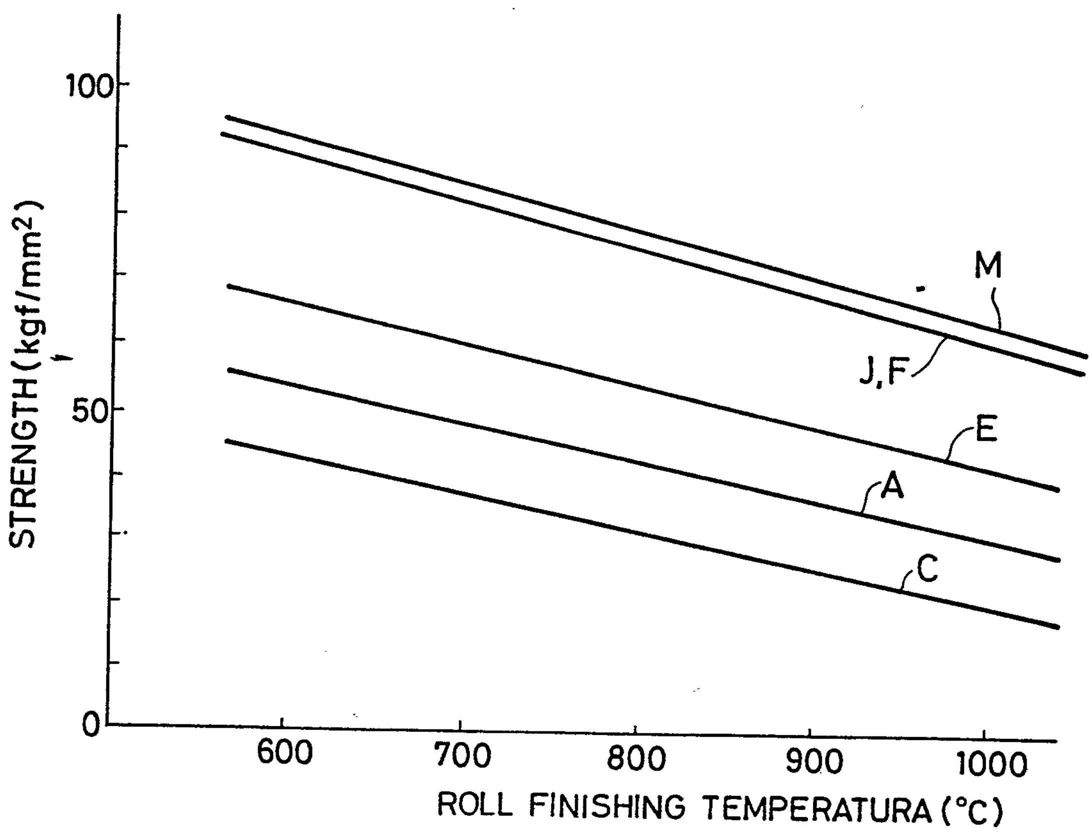

100
50
0
STRENGTH (kgf/mm^2)
M
J,F
E
A
C
600
700
800
900
1000
ROLL FINISHING TEMPERATURA (°C)

FIG. 3

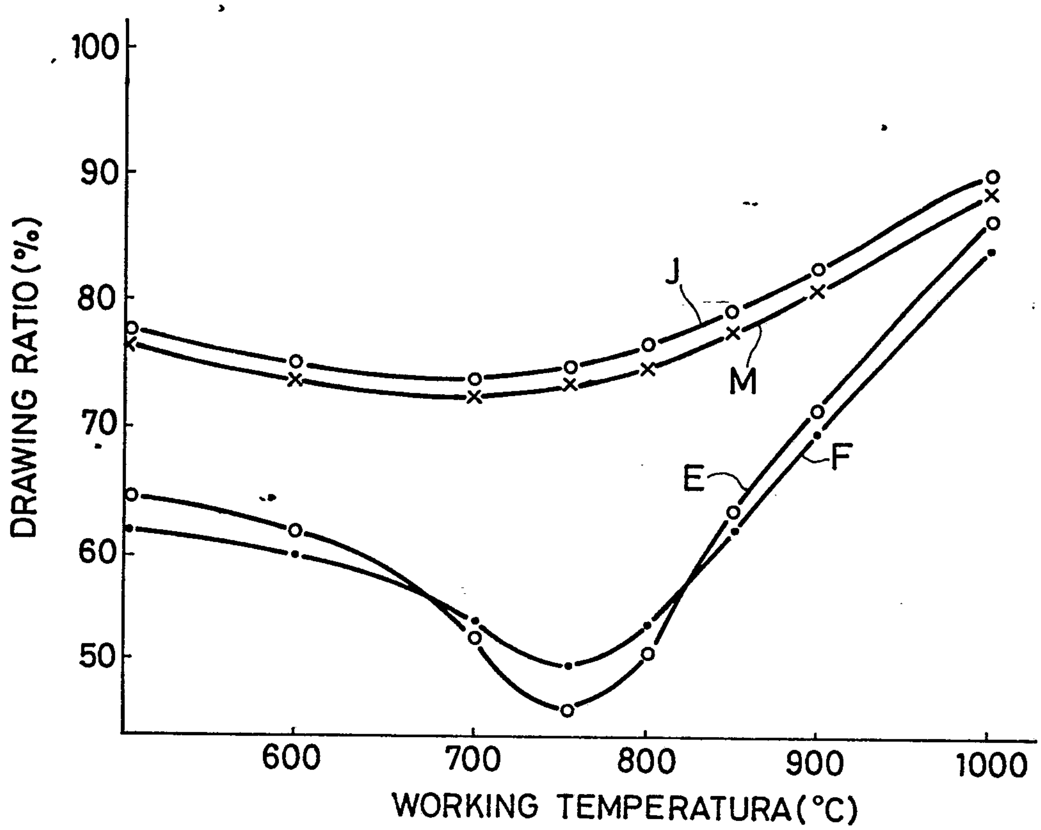
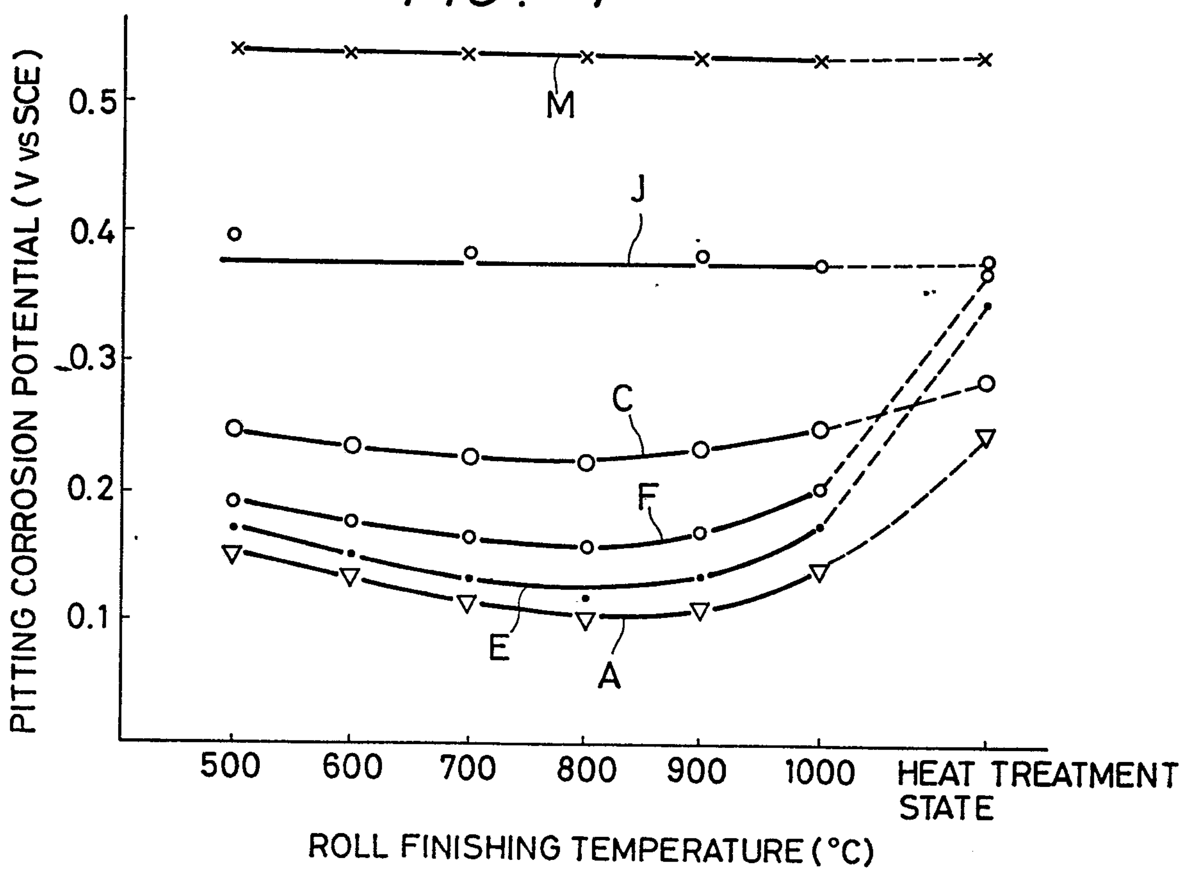

100
90
80
70
60
50
DRAWING RATIO (%)
J
M
E
F
600
700
800
900
1000
WORKING TEMPERATURA (°C)

FIG. 4


0.5
0.4
0.3
0.2
0.1
PITTING CORROSION POTENTIAL (V vs SCE)
M
J
C
F
E
A
500
600
700
800
900
1000
HEAT TREATMENT STATE
ROLL FINISHING TEMPERATURE (°C)

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP85/00573

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl^4 C22C38/54, 38/58, C21D8/00

II. FIELDS SEARCHED

Minimum Documentation Searched[4]

Classification System	Classification Symbols
IPC	C22C38/00-38/60, C21D8/00-8/10

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[14]

Category*	Citation of Document,[16] with indication, where appropriate, of the relevant passages[17]	Relevant to Claim No.[18]
X	JP, A, 58-25460 (Nippon Stainless Steel Co., Ltd.), 15 February 1983 (15. 02. 83), Column 1, lines 6 to 17 (Family: none)	1
X	JP, A, 58-81956 (Aichi Steel Works, Ltd.), 17 May 1983 (17. 05. 83), Column 2, lines 11 to 20 (Family: none)	2
X	JP, A, 57-158359 (Nippon Stainless Steel Co., Ltd.), 30 September 1982 (30. 09, 82), Column 1, lines 5 to 20 (Family: none)	1, 2
Y	JP, A, 53-26215 (Daido Steel Co., Ltd.), 10 March 1978 (10. 03. 78), Column 1, lines 5 to 20, line 2, lines 1 to 2 (Family: none)	1 - 3
Y	JP, A, 55-107729 (Sumitomo Metal Industries, Ltd.), 19 August 1980 (19. 08. 80), Column 1, lines 5 to 14, Fig. 2 (Family: none)	4, 5, 7-10

* Special categories of cited documents:[15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"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)

"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

"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

IV. CERTIFICATION

Date of the Actual Completion of the International Search[2]	Date of Mailing of this International Search Report[2]
December 16, 1985 (16. 12. 85)	December 23, 1985 (23. 12. 85)
International Searching Authority[1]	**Signature of Authorized Officer**[20]
Japanese Patent Office	

International Application No. PCT/JP85/00573

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

Y	JP, A, 60-197817 (Nippon Kokan Kabushiki Kaisha), 7 October 1985 (07. 10. 85), Column 1, lines 6 to 14, Figs. 1 to 3 (Family: none)	4, 5, 7-10
Y	JP, A, 55-8404 (Nippon Steel Corporation), 22 January 1980 (22. 01. 80), Column 1, line 6 to column 3, line 7 (Family: none)	6

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers............ because they relate to subject matter [12] not required to be searched by this Authority, namely:

2.☐ Claim numbers............ because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.