(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 025 770 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
18.02.2009 Bulletin 2009/08

(21) Application number: **08014087.4**

(22) Date of filing: **06.08.2008**

(51) Int Cl.:
C22C 38/00 *(2006.01)* ***C22C 38/02*** *(2006.01)*
C22C 38/42 *(2006.01)* ***C22C 38/58*** *(2006.01)*
C21D 8/02 *(2006.01)*

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

(30) Priority: **09.08.2007 JP 2007207482**

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(54) **Ni-reduced austenite stainless steel**

(57) Provided is an Ni-reduced austenite stainless steel having excellent recyclability with no problem of producibility depression to be caused by the surface property thereof and having good workability, season cracking resistance, corrosion resistance and stress corrosion cracking resistance in point of the material characteristics thereof. The steel comprises C in an amount of more than 0.05 % (by mass) and within a range of from 0.15 to 0.3 % as (C+N), Si in an amount of at most 1 %, Mn in an amount of from 0.5 to 2.5 %, Ni in an amount of from 3 to 6 %, Cr in an amount of from more than 16 to 25 % and Cu in an amount of from 0.8 to 4 %, and has Md30 of the following formula (1) of from -50 to 10 and SFE of the following formula (2) of at least 5:

$$Md30 = 551-462(C+N)-9.2Si-8.1Mn-29(Ni+Cu)-13.7Cr \quad (1),$$

$$SFE = 2.2Ni+6Cu-1.1Cr-13Si-1.2Mn+32 \quad (2).$$

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Description

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The present invention relates to austenite stainless steel in which the content of Ni indispensable to austenite stainless steel is reduced to the minimum quantity thereof and which is excellent in the workability, the season cracking resistance, the corrosion resistance and the stress corrosion cracking resistance, not detracting from the surface quality thereof.

BACKGROUND ART

[0002] Austenite stainless steel such as typically SUS304 has been much used in various fields of western tableware and pans, kitchen utensils, building materials, household electrical appliances and others, as having excellent workability and corrosion resistance. In these applications, not only workability and corrosion resistance but also designability is often required; and the nickel silver color peculiar to stainless steel is essential for industrial product materials in point of both interior and exterior aspects.
However, as Ni raw material prices are rising up these days, SUS301 having an Ni content of more than 6 % and SUS304 having an Ni content of at least 8 % could not be used in some applications owing to their costs. To solve the problem, recently, 200-series stainless steel-based steels have been being provided as a substituent for 300-series stainless steel (Patent References 1 to 6). These contain a large quantity (generally at least about 3 % by mass) of Mn, as an austenite-forming element in place of Ni, thereby reducing the Ni content therein. There are known other cases not containing too much Mn for Ni saving (Patent References 7 and 8).

Patent Reference 1: JP-B 2-29048
Patent Reference 2: JP-A 6-271995
Patent Reference 3: JP-A 2006-219751
Patent Reference 4: JP-A 2006-219743
Patent Reference 5: JP-A 2006-111932
Patent Reference 6: JP-B 6-86645
Patent Reference 7: JP-B 60-33186
Patent Reference 8: JP-A 2005-154890

[0003] In producing a high-Mn austenite stainless steel having an Mn content of more than 2.5 % by mass, harmful Mn oxide fine particles are formed during its steelmaking and refining, and therefore some measures may be often needed from the viewpoint of the environmental protection. In recycling stainless steel, non-magnetic ones have heretofore been processed as 300-series scraps; however, since high-Mn steel is also non-magnetic, expensive high-Ni scraps and low-Ni and high-Mn scraps are difficult to fractionate, therefore causing some confusion in the scrap market. Further, the high Mn content may cause surface quality depression of the steels, therefore often bringing about the load increase in annealing and pickling them and the coloration trouble in bright annealing. In the case, even though Ni is reduced, its effect may be cancelled in the total cost owing to the producibility depression.
[0004] On the other hand, in the technique of Mn-reduced low-Ni steel as in Patent References 7 and 8, the cost reduction is attained, after all with sacrificing any of the corrosion resistance and the workability that are excellent characteristics of 300-series stainless steel. Concretely, in the steel of Patent Reference 7, the austenite phase is excessively unstable in drawing, and after worked, season cracking may occur therein. Accordingly, the steel could not gain a sufficient degree of workability. The steel of Patent Reference 8 is disadvantageous in point of the corrosion resistance as its Cr content is low; and according to the present inventors' investigations, it has been known that, since the solid solution content of C and N is small therein, the steel is also disadvantageous in point of obtaining sufficient ductility.

SUMMARY OF THE INVENTION

[0005] The present invention is to provide an Ni-reduced austenite stainless steel having excellent recyclability with no problem of producibility depression to be caused by the surface property thereof and having good workability, season cracking resistance, corrosion resistance and stress corrosion cracking resistance in point of the material characteristics thereof.
[0006] The above object can be attained by an Ni-reduced austenite stainless steel having excellent workability,

corrosion resistance, stress corrosion cracking resistance and surface property, which comprises, by mass %, C in an amount of more than 0.05 % and within a range satisfying the following formula (3), Si in an amount of at most 1 %, Mn in an amount of from 0.5 to 2.5 %, Ni in an amount of from 3 to 6 %, Cr in an amount of from more than 16 to 25 %, Cu in an amount of from 0.8 to 4 %, N in an amount within a range satisfying the following formula (3), and a balance of Fe and inevitable impurities, and which is so constituted that the austenite stability index defined by the following formula (1), Md30 is from -50 to 10 and the index value of stacking fault energy defined by the following formula (2), SFE is at least 5:

$$Md30 = 551-462(C+N)-9.2Si-8.1Mn-29(Ni+Cu)-13.7Cr \quad (1),$$

$$SFE = 2.2Ni+6Cu-1.1Cr-13Si-1.2Mn+32 \quad (2),$$

$$0.15 \leq C+N \leq 0.3 \quad (3).$$

[0007] In this, in the site of the symbol of each element in the above formulae (1) to (3), the content of the corresponding element as a value in terms of % by mass thereof is substituted.
According to the invention, there is provided an Ni-reduced austenite stainless steel which has a reduced Mn content of at most 2.5 % by mass and has good recyclability with no problem of producibility depression to be caused by the surface property thereof, and which has good corrosion resistance, workability and stress corrosion cracking resistance. As a substituent for 300-series stainless steel, this steel may be used in various applications. Accordingly, the invention may solve the problem of remarkable rise of Ni material cost both in the aspect of material expense and in the aspect of product quality.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0008] The present inventors have assiduously studied for the purpose of attaining the above-mentioned object of providing an austenite stainless steel having a reduced Ni content of at most 6 % by mass, and have reached the following findings. [Workability, Shapability]

[0009] Regarding austenite stainless steel, there is known a phenomenon of transformation induced plasticity (TRIP) of such that the austenite phase in the steel is transformed into a hard, work-induced martensite (α') phase owing to work strain whereby the strain is dispersed to be in uniform strain distribution. The present inventors' studies have clarified that, in the steel of the invention having a reduced Ni content, in particular, the α' phase formation by work strain and the content of the solid solution-reinforcing elements C and N having a significant influence on the α' phase strength deeply participate in the improvement of the ductility by TRIP. Specifically, when the Md30 of formula (1), which is the index of the austenite stability, is at least -50, and the content of C is more than 0.05 % by mass, and when the content of (C+N) is at least 0.15 % by mass, then the α' phase having a suitable intensity effective for ductility improvement may be suitably formed.

[Season Cracking Resistance]

[0010] Heretofore, it is known that austenite stainless steel such as typically SUS304 undergoes delayed fracture often referred to as season cracking, after deep drawn and left as such in an atmospheric environment at room temperature for a few hours to a few days. Ni-reduced austenite stainless steel also undergoes the same phenomenon. However, the present inventors have found that, when Md30 defined by the formula

(1) is at most 10, then the α' phase is not formed too much and the season cracking can be remarkably inhibited.

[Corrosion Resistance]

[0011] A pitting potential as one index of corrosion resistance evaluation generally depends on the Cr content. Merely for increasing the pitting potential alone, the lowermost limit of the Cr content of Ni-reduced austenite stainless steel may be increased. However, in the invention, the Ni-reduced austenite stainless steel must have good workability and season cracking resistance, and therefore, in this, the lowermost limit of the Cr content is defined to be 16 % by mass

with taking a good balance to the other alloying ingredients, as will be described hereinunder.

[Stress Corrosion Cracking Resistance]

[0012] Austenite stainless steel is often problematic in point of the stress corrosion cracking at the worked part and the welded part thereof. The present inventors have made various studies how to impart stress corrosion cracking resistance to Ni-reduced austenite stainless steel. As a result, the inventors have found that the stress corrosion cracking behavior depends on the stacking fault energy of steel. As a result of further detailed experiments, the inventors have found that, when the stacking fault energy SFE of steel defined by the formula (2) is at least 5, then the steel may prevent the formation of stacking faults in its working mode to have a problem of stress corrosion cracking, and therefore the steel may have excellent stress corrosion cracking resistance.

[Surface Quality]

[0013] Stainless steel is required to have designability in various applications, in addition to corrosion resistance and workability. Accordingly, it is desired to efficiently produce stainless steel having a homogeneous surface, and in its turn, it may greatly contribute toward the production cost reduction. In an AP (annealing and pickling) line with continuous pickling to get 2D finishing after continuous atmospheric annealing, the homogeneousness of the scale forming in the annealing and the peelability of the scale in the pickling are important factors in determining the producibility. The present inventors have found that, when the Mn content is regulated to be at most 2.5 % by mass in a steel having an Ni content of at most 6 % by mass, then the scale removal' in the AP line for the steel can be attained smoothly like that for conventional SUS304 in the same working condition as that for SUS304. Accordingly, the production cost increase owing to the Mn content increase can be prevented.

In case where the Mn content is more than 2.5 % by mass, the load in pickling may increase and the cost reduction may be difficult. The load increase mechanism in picking may be as follows: Ordinary austenite stainless steel such as typically SUS304 homogeneously forms a Cr oxide on the surface of the steel sheet during annealing, and it may be pickled efficiently. However, the steel having a reduced Ni content of at most 6 % by mass and an Mn content of more than 2.5 % by mass forms an Cr oxide and may often form a Cr-Mn composite oxide unevenly during atmospheric annealing, and the site with the formed Cr oxide having therein and the site with the formed Cr-Mn composite oxide having therein differ in the pickling operability. In other words, the steel has uneven pickling operability. In order to obtain a favorably-pickled surface of steel under that condition, pickling for a longer period of time is needed, therefore bringing about the load increase in pickling and after all the producibility depression. As a result of various investigations, the present inventors have known that the problem can be evaded when the Mn content of the steel which has a reduced Ni content of at most 6 % by mass is less than 2.5 % by mass.

The increase in the Mn content causes the producibility depression also in bright annealing. Specifically, when the steel is annealed in a reductive atmosphere mainly comprising hydrogen, it may often color in blue yellow. This may be considered as follows: In general, with the increase in the Mn content, the proportion of Mn in the steel sheet surface increases. As compared with Cr, Mn is more readily oxidized at an annealing temperature, and therefore, in the gas atmosphere in bright annealing having a relatively low reducing potency (in which the dew point is relatively high), an Mn oxide film layer may be readily formed on the steel sheet surface, and in many cases, the steel colors in blue yellow. When the Mn content is defined to be at most 2.5 % by mass, then the coloration to be caused by the Mn oxide film may be evaded, and the steel may have a good surface property on the same level as that of SUS304 not detracting from the production efficiency thereof.

[0014] The alloying ingredients of the steel of the invention are described below.

[Alloying Ingredients]

[0015] C and N are elements useful for strengthening the work-induced martensite (α') phase with solid solution strengthening. In the steel of the invention, the total content of C and N (hereinafter referred to as " (C+N) content") is defined to be at least 0.15 % by mass to make sure sufficient ductility by TRIP in formation of the α' phase. It is important to secure the C content of more than 0.05 % by mass for stably attaining remarkable ductility improvement. When the content of C and N is too much, then the steel may be too hard and its workability may be worsened. Accordingly, the (C+N) content is preferably defined to be at most 0.3 % by mass. Regarding the individual content of C and N, C is preferably controlled to be at most 0.15 % by mass, more preferably at most 0.1 % by mass. N is defined to be at most 0.25 % by mass, but in general, it may be controlled to fall within a range of from 0.04 to 0.2 % by mass.

[0016] Mn is a useful austenite-forming element which is more inexpensive than Ni and which may be substitutable for the function of Ni. For taking advantage of its function in the invention, the Mn content must be at least 0.5 % by mass. On the other hand, when the Mn content is too much, then there may occur a problem of environmental protection

in the steel-producing process as mentioned above. In addition, it may bring about the producibility depression (as so mentioned in the above) owing to the surface property. Accordingly, the Mn content is defined to be at most 2.5 % by mass, preferably less than 2.5 % by mass.

[0017] Ni is an element indispensable for austenite stainless steel; however, in the invention, the steel composition is so planned as to reduce the Ni content as much as possible from the viewpoint of cost reduction. Concretely, the Ni content is reduced to be at most 6 % by mass. It may be less than 6 % by mass. However, for realizing the composition balance capable of satisfying the producibility, the workability and the corrosion resistance within the above-mentioned Mn content range, the Ni content must be at least 3 % by mass.

[0018] Cr is an element indispensable for formation of passive film to secure the corrosion resistance of stainless steel. When the Cr content is not more than 16 % by mass, then the corrosion resistance required for conventional austenite stainless steel, for which the invention is substitutable, could not be sufficiently secured. However, since Cr is a ferrite forming element, addition of too much Cr is unfavorable as resulting in the formation of much δ-ferrite phase at a high temperature and therefore detracting from the hot workability of steel. As a result of various investigations, the inventors have noted that the Cr content in the invention may be up to 25 % by mass. Accordingly, the Cr content is defined to be from more than 16 to 25 % by mass.

[0019] Si is an element useful for deoxidation in steelmaking; however, too much Si content may harden steel and may detract from the workability of steel. In addition, since Si is a ferrite-forming element, too much addition thereof may result in the formation of much δ-ferrite phase at a high temperature, therefore detracting from the hot workability of steel. Accordingly, the Si content is limited to be at most 1 % by mass.

[0020] Cu is an element that inhibits work hardening to be caused by the formation of a work-induced martensite phase, therefore contributing toward softening the austenite stainless steel. Since Cu is an austenite-forming element, the latitude in planning the Ni content in accordance with the increase in the Cu content may broaden, therefore facilitating the Ni-reduced alloy composition planning. Further, Cu is an element extremely effective for increasing the value of SFE, and therefore greatly contributes toward improving the stress corrosion cracking resistance by inhibiting the formation of stacking faults. For sufficiently securing these effects, the Cu content must be at least 0.8 % by mass. However, too much Cu over 4 % by mass may detract from the hot workability of steel. Accordingly, the Cu content is defined to be from 0.8 to 4 % by mass.

[0021] P and S may be mixed in steel as inevitable impurities; and P is allowable in an amount of approximately up to 0.045 % by mass, and S is approximately up to 0.03 % by mass.

[0022] The steel of the invention may be prepared as a melt according to a steelmaking process for ordinary stainless steel. Next, according to a production method for ordinary austenite stainless steel sheets, for example, cold-rolled annealed steel sheets having a thickness of from 0.1 to 3.5 mm may be produced.

Example 1:

[0023]

A molten austenite stainless steel having the composition shown in Table 1 was prepared, then continuously cast into a slab, and thereafter hot-rolled at a slab extrusion temperature of 1230°C to produce a hot-rolled steel strip having a thickness of 3 mm. The hot-rolled steel strip was annealed at 1100°C for 1 minute for soaking, then cold-rolled to be a cold-rolled steel strip having a thickness of 1 mm, and annealed at 1050°C for 1 minute for soaking, and pickled to produce an annealed pickled steel strip.

Table 1

Group	Stee l Code	Chemical Ingredients (mass %)							C+N	Md30 *1	SFE *2
		C	Si	Mn	Ni	Cr	Cu	N			
Samples of the Invention	A	0.060	0.55	1.50	5.02	18.10	2.50	0.101	0.161	-6.6	29.2
	B	0.055	0.43	1.62	5.92	17.93	2.61	0.097	0.152	-29.3	33.4
	C	0.051	0.61	1.98	5.84	18.33	2.65	0.123	0.174	-48.4	30.3
	D	0.052	0.56	1.54	5.08	18.21	1.95	0.100	0.152	9.8	25.7
Comparative Samples	E	0.057	0.56	3.65	4.81	17.97	1.48	0.098	0.155	16.1	20.0
	F	0.051	0.56	2.48	5.30	18.90	2.90	0.095	0.146	-38.4	30.0

(continued)

Group	Stee l Code	Chemical Ingredients (mass %)							C+N	Md30 *1	SFE *2
		C	Si	Mn	Ni	Cr	Cu	N			
Sample of the Invention	G	0.052	0.62	2.32	5.49	18.20	3.20	0.099	0.151	-44.6	32.4
Comparative Sample	H	0.081	0.43	2.32	5.92	15.82	3.12	0.078	0.159	-24.1	38.0
Samples of the Invention	I	0.053	0.81	1.91	5.89	16.03	3.05	0.103	0.156	-22.9	32.8
	J	0.057	0.98	1.98	4.21	24.10	1.11	0.101	0.158	-31.5	6.3
Comparative Samples	K	0.067	0.92	2.49	4.32	24.82	0.82	0.093	0.160	-40.6	4.2
	L	0.051	0.62	2.53	4.81	17.89	2.34	0.132	0.183	-12.2	25.8
	M	0.052	0.53	2.42	3.98	18.21	2.41	0.110	0.162	16.9	25.4
	N	0.051	0.96	0.82	4.02	24.98	0.82	0.109	0.160	-21.0	4.8
	O	0.035	0.82	1.91	4.80	17.41	2.69	0.151	0.186	-13.7	26.6

Underline: outside the defined scope of the invention.

[0024]

* 1: Md30 = 551-462(C+N)-9.2Si-8.1Mn-29(Ni+Cu)-13.7Cr.
* 2: SFE = 2.2Ni-1.1Cr-13Si-1.2Mn+6Cu+32.

[0025] The steels C, F and G having the Md30 value of about from

- 50 to -40, and the steel O having the Md30 value of -13.7 were cut to give sample pieces for JIS 13B test, and these were tested for the tensile strength in the direction parallel to the rolling direction of the steels. The original gauge length was 50 mm, the speed of testing rate of stressing was 40 mm/min, and the fractured specimens were re-jointed to measure the gauge length, thereby determining the fracture elongation of each specimen. For substituting them for conventional ordinary austenite stainless steel sheets with no Ni reduction therein, the annealed austenite stainless steel sheets having the thickness as above are desired to have good workability, concretely having the fracture elongation of at least 40 %. The results are shown in Table 2.

Table 2

Group	Steel Code	C (mass %)	C+N (mass %)	Md30	Fracture Elongation
Sample of the Invention	C	0.051	0.174	-48.4	51
Comparative Sample	F	0.051	0.146	-38.4	35
Sample of the Invention	G	G 0.052	0.151	-44.6	40
Comparative Sample	O	0.035	0.186	-13.7	38
Underline: outside the defined scope of the invention.					

[0026] As known from Table 2, the samples of the invention having a C content of more than 0.05 % by mass and a (C+N) content of at least 0.15 % by mass had a high fracture elongation of at least 40 %. As opposed to these, the fracture elongation of the steel F having a (C+N) content of less than 0.15 % by mass was 35 % and was low. The steel O having a low C content of less than 0.05 % by mass, though having a (C+N) content of more than 0.15 % by mass, could not realize an fracture elongation of at least 40 %.

Example 2:

[0027]

From the annealed pickled steel strips A to E and M produced in Example 1, circular discs were blanked out, having a different outer diameter ϕ within a range of from 76 to 84 mm at regular intervals of 2 mm, and these were deep-drawn into cups, using a deep-drawing machine. Concretely, using a dice having an inner diameter Dd ϕ of 43 mm and a corner curvature rd of 4 mm and using a punch having an outer diameter Dp ϕ of 40 mm and a corner curvature rp of 3 mm, the disc blank was completely deep-drawn under a condition of blank holding pressure of 5 tons, with applying a lubricant oil having a viscosity of 60 mm^2/sec onto the surface of the blank kept in contact with the dice.

[0028] The shaped article was left in air at room temperature for 24 hours, and then this was checked for the presence or absence of cracking at the edge of the shaped cup. The season cracking susceptibility limit drawing ratio of each steel was determined according to the following formula (4):

[0029] [Season Cracking Susceptibility Limit Drawing Ratio] = Db_{max}/Dp (4)

[0030] In this, Db_{max} means the maximum disc diameter (mm) not causing season cracking; and Dp means the punch outer diameter (mm).

[0031] For substituting them for conventional ordinary austenite stainless steel sheets with no Ni reduction therein, the steels are desired to have good season cracking resistance, concretely having the season cracking susceptibility limit drawing ratio of at least 2.0. The results are shown in Table 3.

Table 3

Group	Steel Code	C+N (mass %)	Md30	Season Cracking Susceptibility Limit Drawing Ratio
Sample of the Invention	A	0.161	-6.6	≥2.1
Sample of the Invention	B	0.452	-29.3	≥2.1
Sample of the Invention	C	0.174	-48.4	≥2.1
Sample of the Invention	D	0.152	9.8	2.05
Comparative Sample	E	0.155	16.1	1.80
Comparative Sample	M	0.162	16.9	1.60
Underline: outside the defined scope of the invention.				

[0032] As known from Table 3, the samples having an Md30 value of at most 10 realized good season cracking resistance, as having a season cracking susceptibility limit drawing ratio of at least 2.0.

Example 3:

[0033]

The pitting potential of the steels B, H and I produced in Example 1 was measured according to JIS G0577. Concretely, the test solution was aqueous 3.5 % NaCl solution and the temperature was 30°C. Using a potentiostat, the potential of each sample was increased from the natural potential at a sweep rate of 0.33 mV/sec, and the potential (mV vs S.C.E) at which the corrosion current in the passive region became at least 100 mA/cm^2 was read as the pitting potential. For substituting them for conventional ordinary austenite stainless steel sheets with no Ni reduction therein, the steels are desired to have good corrosion resistance, concretely having the pitting potential of at least 200 mV. The results are shown in Table 4.

Table 4

Group	Steel Code	Cr (mass %)	C+N (mass %)	Md30	Pitting Potential (mV vs. SCE)
Sample of the Invention	B	17.93	0.152	-29.3	235
Comparative Sample	H	15.82	0.159	-24.1	185

(continued)

Group	Steel Code	Cr (mass %)	C+N (mass %)	Md30	Pitting Potential (mV vs. SCE)
Sample of the Invention	I	16.03	0.156	-22.9	201
Underline: outside the defined scope of the invention.					

[0034] As known from Table 4, the samples having a Cr content of at least 16 % by mass had a high pitting potential.

Example 4:

[0035]

From the steels B, J, K and N produced in Example 1, circular discs were blanked out, having an outer diameter ϕ of 80 mm. Using a deep-drawing machine having a punch diameter ϕ of 40 mm, these were deep-drawn into cups. Using a precision cutter, the cup edge was cut off at a height of 15 mm from the cup bottom, and this was tested according to the 42 % magnesium chloride boiling test stipulated in JIS G0576. For substituting them for conventional ordinary austenite stainless steel sheets with no Ni reduction therein, the steels are desired to have good stress corrosion cracking resistance, not cracked even after 24 hours in this boiling test. The results are shown in Table 5.

Table 5

Group	Steel Code	SFE	Time taken before cracking (hr)
Sample of the Invention	B	33.4	120
Sample of the Invention	J	6.3	36
Comparative Sample	K	4.2	20
Comparative Sample	N	4.8	22
Underline: outside the defined scope of the invention.			

[0036] As known from Table 5, the samples of the invention having an SFE value of at least 5 did not crack even after 24 hours from the start of the test, and showed good stress corrosion cracking resistance.

Example 5:

[0037]

The cold-rolled steel sheets (steel strips before annealed) B, C, I, J and L produced in Example 1 were cut into 50 mm $\times$ 50 mm square plates, and tested in an annealing test in air in a laboratory. In an atmospheric annealing furnace set at 1100°C, the samples were heated for 60 seconds, then rapidly sandwiched between water-cooled copper plates and quenched as therebetween. This was dipped in an aqueous mixed acid solution of 2 mass % hydrofluoric acid and 10 mass % nitric acid at 60°C, and the time for scale removal to give a homogeneous surface (this is referred to as "pickling time") was determined. The results are shown in Table 6.

Table 6

Group	Steel Code	Mn (mass %)	Pickling Time (sec)
Sample of the Invention	B	1.62	22
Sample of the Invention	C	1.98	23
Sample of the Invention	I	1.91	25
Sample of the Invention	J	1.98	28

(continued)

Group	Steel Code	Mn (mass %)	Pickling Time (sec)
Comparative Sample	L	2.53	65
Underline: outside the defined scope of the invention.			

[0038] As known from Table 6, the samples of the invention having an Mn content of at most 2.5 % by mass took the pickling time of not longer than 30 seconds, and it is judged that the samples could be well pickled in an ordinary continuous annealing/pickling line with no specific line speed depression.

Example 6:

[0039]

Like in Example 5, the cold-rolled steel sheets B, C, I, J and L were cut into 50 mm x 50 mm square plates, and tested for bright annealing in a laboratory. The test is as follows:

The sample was held in a quartz tube, to which 100 % hydrogen gas controlled to have a dew point of from -40°C to -60°C was continuously fed, and the quartz tube was wholly put into a heating furnace at 1100°C, heated therein for 60 seconds, and then the quartz tube was immediately taken out of the furnace and then left cooled. After cooled, the surface of the sample was visually checked for the presence or absence of coloration. The uppermost limit of the dew point at which the sample did not color (this is referred to as "uppermost dew point temperature") was determined. For substituting them for conventional ordinary austenite stainless steel sheets with no Ni reduction therein, the steels are desired to have good coloration resistance, concretely having the uppermost dew point temperature in this bright annealing test of not lower than -50°C. The results are shown in Table 7.

Table 7

Group	Steel Code	Mn (mass %)	Uppermost Dew Point Temperature (°C)
Sample of the Invention	B	1.62	-40
Sample of the Invention	C	1.98	-40
Sample of the Invention	I	1.91	-43
Sample of the Invention	J	1.98	-45
Comparative Sample	L	2.53	-60
Underline: outside the defined scope of the invention.			

[0040] As known from Table 7, the samples of the invention having an Mn content of at most 2.5 % by mass had good coloration resistance, as well clearing the condition of "uppermost dew point temperature of not lower than -50°C", and the samples are free from the problem of producibility depression in bright annealing.

Claims

1. An Ni-reduced austenite stainless steel having excellent workability, season cracking resistance, corrosion resistance, stress corrosion cracking resistance and surface property, which comprises, by mass %, C in an amount of more than 0.05 % and within a range satisfying the following formula (3), Si in an amount of at most 1 %, Mn in an amount of from 0.5 to 2.5 %, Ni in an amount of from 3 to 6 %, Cr in an amount of from more than 16 to 25 %, Cu in an amount of from 0.8 to 4 %, N in an amount within a range satisfying the following formula (3), and a balance of Fe and inevitable impurities, and which is so constituted that the austenite stability index defined by the following formula (1), Md30 is from -50 to 10 and the index value of stacking fault energy defined by the following formula (2), SFE is at least 5:

$$Md30 = 551-462(C+N)-9.2Si-8.1Mn-29(Ni+Cu)-13.7Cr \quad (1),$$

$$SFE = 2.2Ni+6Cu-1.1Cr-13Si-1.2Mn+32 \quad (2),$$

$$0.15 \leq C+N \leq 0.3 \quad (3).$$

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EUROPEAN SEARCH REPORT

Application Number
EP 08 01 4087

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP 01 165750 A (KAWASAKI STEEL CO) 29 June 1989 (1989-06-29) * the whole document *	1	INV. C22C38/00 C22C38/02 C22C38/42 C22C38/58 C21D8/02
D,X	GB 2 071 147 A (ARMCO INC) 16 September 1981 (1981-09-16) * claims 1-9 * * page 1, line 1 - line 22 * * page 1, line 91 - page 2, line 109 * * table I *	1	
X	US 3 282 684 A (ALLEN PAUL M) 1 November 1966 (1966-11-01) * claims 1-8 * * table I * * column 6, line 63 - column 7, line 47 *	1	
X	CH 277 069 A (ARMCO INTERNATIONAL CORP [US]) 15 August 1951 (1951-08-15) * page 3, line 91 - page 4, line 67 * * page 2, line 2 - line 46 *	1	
A	EP 1 156 125 A (NISSHIN STEEL CO LTD [JP]) 21 November 2001 (2001-11-21) * claims 1-3 * * examples 1-3 * * tables 1-5 *	1	TECHNICAL FIELDS SEARCHED (IPC) C22C C21D
A	EP 1 249 513 A (NISSHIN STEEL CO LTD [JP]) 16 October 2002 (2002-10-16) * claims 1-6 * * examples 1-4 * * tables 1-11 *	1	
A	JP 08 120419 A (NISSHIN STEEL CO LTD) 14 May 1996 (1996-05-14) * the whole document *	1	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	12 November 2008	Vlassi, Eleni

CATEGORY OF CITED DOCUMENTS

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Application Number
EP 08 01 4087

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	JP 09 263905 A (NISSHIN STEEL CO LTD) 7 October 1997 (1997-10-07) * the whole document * -----	1	
A	JP 02 305940 A (NIPPON STEEL CORP) 19 December 1990 (1990-12-19) * the whole document * -----	1	
			TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	12 November 2008	Vlassi, Eleni

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 08 01 4087

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12-11-2008

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 1165750 A	29-06-1989	NONE	
GB 2071147 A	16-09-1981	BE 887688 A1	26-08-1981
		BR 8101118 A	01-09-1981
		ES 8301506 A1	01-03-1983
		FR 2477179 A1	04-09-1981
		IT 1144102 B	29-10-1986
		JP 1313153 C	28-04-1986
		JP 56152951 A	26-11-1981
		JP 60033186 B	01-08-1985
		NL 8100933 A	01-10-1981
		SE 440796 B	19-08-1985
		SE 8101094 A	29-08-1981
		US 4295769 A	20-10-1981
US 3282684 A	01-11-1966	BE 651248 A	16-11-1964
		GB 1071809 A	14-06-1967
CH 277069 A	15-08-1951	NONE	
EP 1156125 A	21-11-2001	CN 1327078 A	19-12-2001
		DE 60122618 T2	27-09-2007
		ES 2270918 T3	16-04-2007
		JP 3691341 B2	07-09-2005
		JP 2001323342 A	22-11-2001
		SG 108254 A1	28-01-2005
		TW 500811 B	01-09-2002
		US 2002015655 A1	07-02-2002
EP 1249513 A	16-10-2002	CN 1380150 A	20-11-2002
		DE 60205798 D1	06-10-2005
		DE 60205798 T2	08-06-2006
		ES 2248434 T3	16-03-2006
		JP 3696552 B2	21-09-2005
		JP 2002371339 A	26-12-2002
		KR 20020079596 A	19-10-2002
		TW 528622 B	21-04-2003
		US 2003102058 A1	05-06-2003
JP 8120419 A	14-05-1996	JP 3464297 B2	05-11-2003
JP 9263905 A	07-10-1997	JP 3637991 B2	13-04-2005
JP 2305940 A	19-12-1990	JP 2043102 C	09-04-1996
		JP 7068603 B	26-07-1995

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2029048 B **[0002]**
- JP 6271995 A **[0002]**
- JP 2006219751 A **[0002]**
- JP 2006219743 A **[0002]**
- JP 2006111932 A **[0002]**
- JP 6086645 B **[0002]**
- JP 60033186 B **[0002]**
- JP 2005154890 A **[0002]**