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(54) **ATMOSPHERE CORROSION RESISTING STEEL PLATE HAVING HIGH STRENGTH AND EXCELLENT BENDING FORMABILITY AND METHOD FOR PRODUCTION THEREOF**

GEGEN ATMOSPHÄREKORROSION BESTÄNDIGE STAHLPLATTE MIT HOHER FESTIGKEIT UND HERVORRAGENDER BIEGEUMFORMBARKEIT UND HERSTELLUNGSVERFAHREN DAFÜR

TOLE D'ACIER RESISTANTE A LA CORROSION ATMOSPHERIQUE, PRESENTANT UNE RESISTANCE ELEVEE ET UNE EXCELLENTE FORMABILITE PAR PLIAGE, ET PROCEDE DE PRODUCTION DE LADITE TOLE D'ACIER

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Description

[0001] The present invention relates to a steel material, used for railcars and containers for land or marine transportation, required to have strength, workability after blasting or the like and weather resistance, and a method for producing the steel material.

[0002] A material having the properties of low weight, long life and weather resistance has heretofore been desired for containers and thus a material produced using aluminum has mainly been used for such applications. However, such a material has the disadvantages of a high cost and low strength and therefore a steel material having both high strength and weather resistance has been sought. As a conventional weather-resistant steel material, there is a highly-weather-resistant rolled steel material of the 50 kgf/mm^2 (490 MPa) class in tensile strength as stipulated in JIS G3125. With regard to a steel material having a higher strength than that, Japanese Unexamined Patent Publication No. H3-2321 discloses a method for producing a weather-resistant steel sheet having a tensile strength of 60 kgf/mm^2 or higher and good cold-workability.

[0003] In the meantime, with the increasing use of marine containers, the environment becomes even move sever and instances where even a painted container suffers local corrosion and cannot withstand long-term use are increasing. To cope with the problem, JP-A-63-72853 discloses that a life-span increase can be realized by adding Nb, Ti, V and B to a high-P steel.

[0004] In recent years, however, a high strength and low weight container is further desired and an ultra-high strength weather-resistant steel material having a yield strength of 700 MPa or higher and good bendability has been sought. Moreover, as bending work is applied after a steel material is subjected to blasting or the like, with the aim of improving paintability at the time of painting, fatigue properties and surface hardenability, the levels of both the strength and workability required of the steel material are very high. The reason why the required strength is not expressed in terms of tensile strength but yield strength is that it must be assured to maintain stiffness even when the thickness of a material is reduced in order to obtain both ultra-high strength and low weight. Therefore, such specifications are not fulfilled by the components and production method disclosed in Japanese Unexamined Patent Publication No. H3-2321.

[0005] Further, with such component types as proposed in JP-A-63-72853 that is aimed at a longer life, though the longer life due to weather resistance is secured, cracking occurs during blasting and bending in the process of the manufacturing of a container and therefore the requirements have not been satisfied. The object of the present invention is, by solving the aforementioned problems, to provide: a steel material withstanding bending work after blasting or the like and having weather resistance while securing an ultra-high strength of 700 MPa or higher in yield strength; and a method for producing the steel material.

[0006] JP-A-3-2321 discloses a method for manufacturing high-strength weather resistant hot-rolled steel, and discloses a method comprising the steps of: producing a slab containing C: 0.02-0.12%, Si ≤ 0.50%, Mn: 0.10-2.00%, P: 0.070-0.150%, S ≤ 0.020%, A1: 0.010-0.050%, Cu: 0.25-0.55%, Cr: 0.30-1.25%, N ≤ 0.0060%, Ti: 0.06-0.20% and 12.1 x Ti_{eff}(%) / Mn(%) ≥ 1.0, (where, Ti_{eff}(%) = Ti(%) - 3.4 x N(%) - 1.5 x 0(%)), and the balance Fe with unavoidable impurities by continuously casting, heating the slab to 1180˚C or higher, hot rolling the slab at the finishing temperature of 880-950˚C, and coiling at 650˚C or lower, to obtain a weather resistant hot-rolled steel sheet having tensile strength of 60 kgf/mm^2 or greater and good cold-workability.

JP-A-2000-63981 discloses a weather resistant steel showing blackish color tone from initial stage of rusting and excellent in external appearance and stability of color tone, and further discloses a steel comprising, by weight, C: 0.01-0.15%, Si: 0.01-1.0%, Mn: 0.8-3.0%, Cu: 0.05-1.0%, Ni: 0.25-5.0%, Al: more than 0.1% to 0.2% with the balance consisting of Fe and inevitable impurities satisfying Mn + Ni ≥ 1.8, and further optionally comprising one or more of Cr: 25-5.0%, Mo: 0.25-1.0%, P: 0.03-1.0%, Nb: 0.01-0.05%, V: 0.01-0.1%, Ti: 0.005-0.05%, Zr: 0.01-0.1%.

[0007] The means for attaining the above object according to the present invention is;

(1) a weather-resistant high strength steel sheet excellent in bendability, containing, in mass,

C:0.05 to 0.15%,
Si: 0.5% or less,
Mn: 0.5 to 2.0%,
P: 0.02% or less,
S: 0.005% or less,
Ni: 0.2 to 2.0%,
Cu: 0.2 to 0.5%, and
Cr: 0.2 to 1.0%, and
Ti: 0.03 to 0.2%
optionally one or more of
Nb: 0.01 to 0.07%,

V: 0.01 to 0.07%, and
B: 0.0005 to 0.0050%,
with the balance of Fe and unavoidable impurities, and having a yield strength of 700 MPa or higher, and the production method thereof is;
(2) a method for producing a weather-resistant high strength steel sheet excellent in bendability, having a yield strength of 700 MPa or higher the method comprising the steps of:

heating a steel material containing, in mass,

C: 0.05 to 0.1%,
Si: 0.5% or less,
Mn: 0.5 to 2.0%,
P: 0.02% or less,
S: 0.005% or less,
Ni: 0.2 to 2.0%,
Cu: 0.2 to 0.5%, and
Cr: 0.2 to 1.0%, and
Ti: 0.03 to 0.2%,
optionally one or more of
Nb: 0.01 to 0.07%,
V: 0.01 to 0.07%, and
B: 0.0005 to 0.0050%,
with the balance Fe and unavoidable impurities to a temperature of 1,200˚C or higher;
thereafter, finish-rolling the steel material in the temperature range from 850˚C to 950˚C; and
coiling the rolled steel material in the temperature range from 500˚C to 650˚C.

[0008] The reasons for limiting a steel sheet and a production method according to the present invention are hereunder explained in detail, in conjunction with the drawings, in which:

Fig. 1 is a graph showing the effects of an Ni amount and a P amount on a corrosion loss,
Fig. 2 is a schematic showing the outline of a press bending test, and
Fig. 3 is a graph showing the influence of a P amount on a corrosion loss and a bend R (radius).

[0009] The present inventors investigated and studied methods for producing steel sheets comprising various kinds of steels in order to solve the aforementioned problems and thus established the present invention. The present invention is hereunder explained in detail.

[0010] In general, the same kind of rust appears on a weather-resistant steel material as appears on an ordinary steel during an early stage of exposure in the atmosphere. However, it is said that, thereafter, some of the rust of a weather-resistant steel material forms dense rust closely adhering to the base material, the rust plays the role of a protective film and, as a result the progress of rust caused by an environment is prevented. It is also said that it is effective to contain Cu, Cr and P in order to create such rust.

[0011] In the case of a conventional material having a tensile strength of 50 to 60 kgf/mm^2 (490 to 590 MPa), by containing such types of components, the material has been applicable to a container as a weather-resistant steel material. In recent years, coupled with global environmental issues, the weight reduction of an automobile aimed at the improvement of a fuel efficiency has been publicized and there is a strong need also for the weight reduction of a container used for land or marine transportation. The target thickness of a steel material has become thinner for the purpose of a greater weight reduction than ever and a yield strength of 700 MPa or higher is required for the purpose of the securement of stiffness. Meanwhile, in the production of a container, roughness is applied on the surface of a steel sheet, by blasting, wherein shot, sand, grit or the like is blown on the steel sheet in order to improve descaling performance and paintability. The process makes the surface thereof hard and therefore bend cracking tends to occur at the subsequent bend forming. In the case of a steel material having a yield strength exceeding 700 MPa, in particular, cracking susceptibility appears conspicuously and the selection of additive elements has a large influence.

[0012] As it has been explained above, in order to produce a weather-resistant steel material, having a yield strength exceeding 700 MPa and capable of withstanding bending work after subjected to blasting, it is necessary to fulfill the following requirements simultaneously;
① Enhancement of material strength,
② Securement of bendability, and

③ Securement of weather resistance.

[0013] When P is used abundantly in the production of such a high strength steel material having weather resistance, various problems arise. Firstly, when a slab 200 to 300 mm in thickness is cast in a production process, P tends to cause center segregation and concentrates at the thickness center portion which is the finally solidified portion. The portion where P concentrates is likely to cause embrittlement cracking. Further, as a high strength steel material itself has a high cracking susceptibility, a P-added weather-resistant high-strength steel sheet causes slab cracking frequently and also a very low yield.

[0014] Furthermore, even if a steel sheet can be produced, the material is brittle because of the addition of P and therefore the workability thereof is poor. Generally speaking, as the strength of a steel material increases, the elongation thereof lowers. Therefore, the workability of a P-added material further lowers and moreover, as the object material is subjected to bending work after shot blasting or the like, the material is very susceptible to bend cracking. In addition, weld cracking is likely to occur when such a steel material is fabricated into a container by welding. As a result of investigating precisely the characteristics of Cu, Cr and P that have been utilized as weather-resistant elements in a conventional steel, it has been clarified that P adversely influences the above requirement ② very much and cannot be utilized in a high strength steel material. The present inventors investigated the relationship between a P amount and the conditions of generating bend cracking in the 90-degree press bending test shown in Fig. 2 while the R (radius) of the punch tip was varied. At the same time, the present inventors investigated the relationship between P addition and a corrosion loss and showed the results in Fig. 3. It is obvious that, though a corrosion loss decreases and weather resistance improves as a P amount increases, the increase of a P amount causes the critical bend R (radius), below which bend cracking occurs, to increase and the bendability of a steel sheet deteriorates. Therefore, in order to secure bendability, it is necessary to study a method of securing weather resistance without the use of P. Cu and Cr less adversely influence bendability. However, merely with the increase of their amounts, weather resistance is hardly secured. Moreover, the steel material cannot withstand bending work after blasting or the like.

[0015] In this light, as a result of repeating various tests, the present inventors have found that: weather resistance can be secured by the use of Ni instead of P; bendability can be secured by lowering C to improve workability, reducing the addition of P to the utmost, and reducing S to the utmost to suppress the formation of MnS that adversely affects bendability; and the adjustment of strength can be attained by utilizing a precipitation effect caused by combining one or more of Ti, Nb, V and B.

[0016] Fig. 1 shows the effect of an Ni amount on a corrosion loss in comparison with the effect of a P amount. It has been found that, as an Ni amount increases, a corrosion loss decreases and an effect similar to the case of P addition is obtained.

[0017] Further, Ni, in contrast with P, does not segregate during the casting of a slab, slab cracking does not matter, and also a yield is good. Furthermore, Ni causes no problem in workability and weldability and therefore bending work after shot blasting or the like and weld cracking do not matter. Accordingly, Ni is an element very suitable for the production of a weather-resistant high strength steel sheet excellent in bendability. With regard to weather resistance, Ni exhibits the effect by the joint use with Cu and Cr.

[0018] The present inventors repeated experiments on the basis of the above conditions and established the present invention. The reasons for limiting the additive elements according to the present invention are hereunder described in detail.

C:

[0019] C is exploited as an element for enhancing strength. It is utilized not only as a solid solution strengthening element but also, by combining with Ti and Nb and forming carbide, as a precipitation strengthening element. However, when C is used excessively, workability deteriorates. Since workability lowers as the strength of a steel material increases, a low C amount is desirable. The reason why the lower limit of a C amount is set at 0.05% is that, when it is lower than that amount, a yield strength of 700 MPa or higher is hardly secured. On the other hand, the reason why a C amount is limited to 0.15% or lower is to prevent cracking caused by bending work.

Si:

[0020] Si is an element that is likely to form fayalite (2reO-SiO_2) on the surface of a steel sheet, make fine Fe_2O_3 remain on the most surface, and generate red scale. When red scale is created on the surface of a steel sheet, mottling appears and the product is not accepted by users. In order to avoid the problem, the upper limit of an Si amount is set at 0.5%.

Mn:

[0021] Mn is an element necessary for enhancing the strength of a steel material. When an Mn amount is less than 0.5%, a high strength steel material is hardly produced. In contrast, when Mn is added in excess of 2.0%, workability is hardly secured. For those reasons, an Mn amount is limited in the range from 0.5 to 2.0%.

P:

[0022] P is an element effective in the enhancement of strength and beneficial to the improvement of weather resistance and has heretofore been exploited for a weather-resistant steel material. However, in the production of an ultra-high strength steel material having a yield strength exceeding 700 MPa, P causes slab embrittlement during the production of the steel material and also deteriorates weldability. On top of that, P also deteriorates bendability, and therefore a P amount should be as low as possible. Accordingly, the upper limit of a P amount is set at 0.02%.

S:

[0023] S forms sulfide MnS combining with Mn. This sulfide is easy to deform, is elongated by rolling and is present in a steel material. MnS deteriorates the bendability and workability of a steel material. In the case of a high strength steel material in particular, S should be reduced to the utmost because it raises cracking susceptibility. Therefore, the upper limit of an S amount is set at 0.005% as the commercially attainable limit.

Ni:

[0024] Ni is an element that enhances strength and weather resistance and is also effective in the prevention of embrittlement. In particular, Ni is effective in weather resistance under an environment largely influenced by salinity. As it has been explained earlier, in a high strength steel material, P that is effective in weather resistance badly affects workability and thus cannot be utilized. Ni can be utilized as an element substituting for P and neither causes slab cracking nor deteriorates the workability of a steel material in contrast with P. Ni must be added by 0.2% or more in order to effectively utilize the feature of weather resistance. On the other hand, Ni is an expensive metal and moreover the effect does not improve any more even when an Ni amount exceeds 2.0%. Therefore, the upper limit of an Ni amount is set at 2.0%. Containers are used for both land and marine transportation and are affected by the salinity of seawater in the case of the marine transportation and by salinity from snowmelt salt scattered in a cold region in the case of land transportation. Therefore, Ni is an element important for weather resistance. In an environment other than a saline environment, the elements Cu and Cr, which are described below, are effective and therefore the combined addition of those elements is also effective.

Cu:

[0025] Cu is important in improving weather resistance and is an element effective in forming stable rust. A Cu amount of 0.2% or more is necessary for securing the effect against a corrosive environment. However, when a Cu amount exceeds 0.5%, surface defects are likely to appear. For those reasons, a Cu amount is limited in the range from 0.2 to 0.5%.

Cr:

[0026] Cr is also important in improving weather resistance and is an element effective in forming stable rust. A Cr amount of 0.2% or more is necessary for securing the effect against a corrosive environment. However, the effect does not improve any more even if a Cr amount exceeds 1.0%. For those reasons, a Cr amount is limited in the range from 0.2 to 1.0%. When a steel material having a yield strength of 700 MPa or higher is produced, the exploitation of precipitation strengthening is effective. The following four elements that allow a precipitation effect to appear compensate the insufficiency of strength and the compensation can be attained by using one or more of those elements.

Tit

[0027] Ti forms a carbide and a nitride by combining with C and N and thus enhances the strength of a steel material. The effect appears when Ti is added by 0.03% or more and does not improve any more even if Ti is added by 0.2% or more.

Nb:

[0028] Nb also forms a carbide and a nitride by combining with C and N and thus enhances the strength of a steel material. The effect appears when Nb is added by 0.01% or more and does not improve any more even if Nb is added by 0.07% or more.

V:

[0029] V also forms a carbide and a nitride by combining with C and N and thus enhances the strength of a steel material. The effect appears when V is added by 0.01% or more and does not improve any more even if V is added by 0.07% or more.

B:

[0030] B is an element that forms a carbide and a nitride and is effective in enhancing hardenability and strength. The effect appears when B is added by 0.0005% or more and the effect does not improve any more even if B is added by 0.0050% or more.

[0031] Next, the reasons for limiting production conditions are explained hereunder.

[0032] The purpose of limiting a reheating temperature to 1,200˚C or higher is to dissolve carbide and nitride at the stage of a slab in order to make use of the precipitation effect of Ti, Nb, V and B, and by so doing to form fine precipitates during the production of a steel sheet so that the precipitation effect may be fully utilized.

[0033] It is necessary to keep a rolling finish temperature at 850˚C or higher in order to fractionize precipitates. However, when a rolling finish temperature exceeds 950˚C, problems such as increased likeliness of the coarsening of crystal grains, the formation of scale defects, etc. arise. Therefore, a rolling finish temperature is limited in the range from 850˚C to 950˚C.

[0034] A coiling temperature affects the size of precipitates and the degree of precipitation effect varies in accordance with a coiling temperature. When a coil is coiled at a high temperature, precipitates grow too large and a strengthening effect lowers. In contrast, when a coiling temperature is too low, the growth of precipitates is insufficient and the enhancement of strength is not expected. For those reasons, a coiling temperature is limited in the range from 500˚C to 650˚C as an appropriate temperature range wherein the enhancement of strength is expected.

[0035] In production processes, there is no restriction on the use of a high-pressure descaling device and a bar heater, and the application of continuous-continuous hot rolling wherein bar-joint materials after subjected to rough rolling are rolled continuously. Rather, by using those apparatuses, it is possible to prevent scale defects from forming and to improve a yield while improving process capability in temperature control.

Examples

[0036] Steels of Steel Nos. 1 to 12 having various components as shown in Table 1 were tapped and, thereafter, steel materials were produced under the rolling conditions shown in Table 2, samples were taken and shot blasting treatment was applied to the surfaces thereof, and subsequently properties of the samples were evaluated. In the evaluation, tensile tests were applied and yield strength, tensile strength and total elongation were measured. In addition, bending work was applied with the bend angle of 90 degrees by using a punch the tip radius (R) of which was 3 mm and the existence of cracks at a bent portion was examined.

[0037] Weldability was judged by the existence of weld cracks after arc welding was applied. With regard to weather resistance, salt water spray treatment was applied and, thereafter, corrosion accelerating tests, wherein wet and dry were alternately repeated, were applied, the weight of each sample was measured before the test was applied and after rust was removed after the test, and resultantly each corrosion loss was obtained. As a comparative example, a commercially available 490 MPa class Corten steel was employed and the data thereof were used as the standard, and then each sample was evaluated as X when the corrosion loss of the sample was larger than the standard and as ○ when the corrosion loss thereof was equal to or smaller than the standard.

[0038] Further, a surface appearance was evaluated by observing the surface of each steel material after rolling. The rolling conditions of Test Nos. 1 to 12 were all within the ranges stipulated in the present invention. In the case of Test No. 7, the Ni amount was small and thus the weather resistance thereof was poor. In the case of Test No. 8, though the weather resistance was good, the P amount was large and therefore the weldability was poor and cracking appeared at the bending work. As the Si amount was large in the case of Test No. 9 and the Cu amount was too large in the case of Test No. 10, scabs and mottling appeared on the surfaces and thus surface appearance was poor in both the cases. In the case of Test No. 11, the amounts of C and Mn were too large and therefore the bendability and the weldability were poor. In the case of Test No. 12, the S amount was large and therefore cracking appeared at the bending test.

[0039] In the cases of Test Nos. 13 to 17, the steel material of Steel No. 2 produced within the ranges stipulate in the present invention was used and the rolling conditions were varied. In the case of Test No. 13, the reheating temperature was too low, and therefore precipitation strengthening could not be utilized and the yield strength thereof could not exceed the target value 700 MPa. In the case of Test No. 14, the rolling temperature was high and therefore the surface appearance was poor. In the case of Test No. 15, the rolling temperature was low and therefore the strengthening by the fractionization of precipitates did not show up and the target strength could not be obtained. In the case of Test No. 16, the coiling temperature was high and therefore the steel material softened and the target strength could not be obtained likewise. In the case of Test No. 17, the coiling temperature was too low, and therefore; though the strength increased, a hardened layer developed and cracking occurred after bending work.

[0040] In the cases of Test Nos.1 to 6 that fulfilled the ranges of components and the rolling conditions stipulated in the present invention, any of the properties was acceptable and good evaluation results were obtained.

[0041] Further, Test Nos. 18 to 20 according to the present invention were the cases where, in the hot rolling process, descaling treatment was utilized in order to remove surface scale from each of the rough bars by high-pressure descaling after rough rolling and further continuous-continuous hot rolling was utilized, wherein rough bars were heated with a bar heater and jointed. In any of the cases, the material properties stipulated in the present invention were satisfied and the effects of the utilization of the above process means were obtained. In the case of Test No. 18, the bar heater was used, and resultantly the temperature of a rough bar before finish rolling was high and uniform, thus precipitation was controlled evenly, the quality deviation of the material decreased, and the deviation of elongation was reduced to 3.8% whereas the elongation deviation of a steel of this class was usually about 6%. Test No. 19 was the case where a high-pressure descaling apparatus and continuous-continuous hot rolling were applied. By the adoption of the high-pressure descaling, the surface appearance of the steel material improved remarkably. In addition, by the adoption of continuous-continuous hot rolling, the shapes at the ends of a coil improved and the material yield improved up to 97% whereas the material yield was usually about 95%. Further, Test No. 20 was the case where a bar heater and continuous-continuous hot rolling were utilized. The deviation of elongation decreased to 3.2% and the material yield improved up to 98%.

Table 1: Material components (mass %)

	Steel No.	C	Si	Mn	P	S	Al	N	Cu	Ni	Cr	Ti	Nb	V	B
Invented Examples	1	0.07	0.29	0.006	1.41	0.002	0.033	0.006	0.25	1.80	0.25	0.078	0.031	-	-
	2	0.11	0.18	0.88	0.011	0.0001	0.025	0.110.	0.28	1.00	0.39	0.085	0.037	-	-
	3	0.08	0.10	1.22	0.008	0.002	0.011	0.003	0.23	0.50	0.39	0.082	0.024	0.025	0.0012
	4	0.09	0.03	1.11	0.006	0.002	0.030	0.004	0.48	0.25	0.81	0.142	0.055	-	-
	5	0.14	0.43	0.016	0.62	0.004	0.022	0.003	0.44	0.65	0.30	0.180	-	-	-
	6	0.05	0.04	1.546	0.05	0.003	0.056	0.005	0.31	1.20	0.52	0.052	0.043	0.045	-
Comparative Examples	7	0.08	0.22	1.33	0.012	0.002	0.032	0.004	0.42	0.18	0.17	0.089	0.033	-	-
	8	0.09	0.30	2.10	0.091	0.004	0.017	0.006	0.27	0.35	0.38	0.080	0.040	-	-
	9	0.12	0.75	0.95	0.011	0.002	0.043	0.004	0.41	0.62	0.82	0.090	0.033	0.033	-
	10	0.09	0.25	0.20	0.005	0.001	0.020	0.003	0.55	0.23	0.30	0.120	0.052	-	0.0036
	11	0.23	0.48	2.50	0.028	0.004	0.017	0.006	0.48	1.90	0.90	-	-	-	-
	12	0.08	0.21	1.50	0.007	0.008	0.380	0.005	0.38	0.85	0.55	0.090	0.041	-	0.0008

Note: underlined numerals mean that the numerals are outside the relevant ranges stipulated in the present invention.

Table 2: Production conditions and evaluation

	Test No.	Steel No.	Reheating temp. °C	Rolling temp. °C	Coiling temp. °C	YS (MPa)	TS (MPa)	El (%)	Bendability	Weldability	Weather resistance	Surface appearance	Remarks
Invented examples	1	1	1,220	900	530	740	830	22	○	○	○	○	
	2	2	1,220	910	520	746	857	22	○	○	○	○	
	3	3	1,220	870	550	708	805	23	○	○	○	○	
	4	4	1,250	920	620	878	1,009	20	○	○	○	○	
	5	5	1,250	900	590	876	1,007	20	○	○	○	○	
	6	6	1,230	900	520	712	814	23	○	○	○	○	
Comparative examples	7	7	1,230	890	510	707	813	23	○	○	X	○	Ni: small amount
	8	8	1,250	880	630	711	818	19	X	X	○	○	P: large amount
	9	9	1,210	910	550	776	892	21	○	○	○	X	Si: large amount
	10	10	1,210	910	600	834	959	20	○	○	○	X	Cu: large amount
	11	11	1,230	900	530	537	618	18	X	X	○	○	C, Mn: large amounts
	12	12	1,260	900	520	771	886	21	X	○	○	○	S: large amount
	13	2	1,150	900	530	680	755	24	○	○	○	○	Low reheating temp.
	14	2	1,220	980	520	692	807	23	○	○	○	X	High rolling temp.
	15	2	1,230	820	590	672	805	19	X	○	○	○	Low rolling temp.
	16	2	1,220	930	680	690	782	21	○	○	○	○	High coiling temp.
	17	2	1,240	920	450	802	890	17	X	○	○	○	Low coiling temp
Invented examples	18	2	1,210	870	530	752	862	23	○	○	○	○	El deviation decreased to 3.8% by the use of the bar heater.
	19	3	1,220	920	560	705	810	21	○	○	○	○	Surface appearance improved remarkably by the high-pressure descaling. The material yield improved to 97% by continuous-continuous hot rolling.
	20	5	1,210	920	600	877	982	20	○	○	○	○	El deviation decreased to 3.2% by the simulta-neous use of the bar heater and continuous-continuous hot rolling

Bendability: Judged by the existence of cracking at a bent portion after 90-degree press bending. The bend R (radius) was set at 3 mm, and expressed by "X" when cracking occurred and "○" when did not.
Weldability: Expressed by "X" when weld cracking occurred after arc welding and "○" when it didn't occur.
Weather resistance: Expressed by "X" when a corrosion loss was larger and "○" when smaller than the standard corrosion loss defined by the conventional 490 MPa Corten steel.
Note: Underlined numerals mean that the numerals are outside the relevant ranges stipulated in the present invention.

[0042] A steel material according to the present invention has bendability and weather resistance simultaneously while also having a high strength. By using the steel material, the weight reduction of a steel material for a container or the like that requires weather resistance can be realized and a longer service life is also realized because of the weather resistance. Therefore, the present invention makes it possible to provide environment-friendliness by the weight reduction and economic effect by the longer service life.

Claims

1. A weather-resistant high strength steel sheet excellent in bendability, containing, in mass,
C: 0.05 to 0.15%,
Si: 0.5% or less,
Mn: 0.5 to 2.0%,
P: 0.02% or less,
S: 0.005% or less,
Ni: 0.2 to 2.0%,
Cu: 0.2 to 0.5%,
Cr: 0.2 to 1.0%,
Ti: 0.03 to 0.2%, and
optionally one or more of
Nb: 0.01 to 0.07%,
V: 0.01 to 0.07%, and
B: 0.0005 to 0.0050%,
with the balance of Fe and unavoidable impurities, and
having a yield strength of 700MPa or higher.

2. A method for producing a weather-resistant high strength steel sheet excellent in bendability, having a yield strength of 700MPa or higher,
the method comprising the steps of:

heating a steel material containing, in mass,
C: 0.05 to 0.15%,
Si: 0.5% or less,
Mn: 0.5 to 2.0%,
P: 0.02 or less,
S: 0.005% or less,
Ni: 0.2 to 2.0%,
Cu: 0.2 to 0.5%,
Cr: 0.2 to 1.0%,
Ti: 0.03 to 0.2%, and

optionally one or more of
Nb: 0.01 to 0.07%,
V: 0.01 to 0.07%, and
B: 0.0005 to 0.0050%,
with the of Fe and unavoidable impurities to a temperature of 1,200˚C or higher;
thereafter, finish-rolling the steel material in the temperature range from 850˚C to 950˚C; and
coiling the rolled steel material in the temperature range from 500˚C to 650˚C.

Patentansprüche

1. Witterungsbeständiges hochfestes Stahlblech mit ausgezeichneter Biegbarkeit, das massebezogen enthält:

C: 0,05 bis 0,15 %,
Si: höchstens 0,5 %,
Mn: 0,5 bis 2,0 %,
P: höchstens 0,02 %,
S: höchstens 0,005 %,
Ni: 0,2 bis 2,0 %,
Cu: 0,2 bis 0,5 %,
Cr: 0,2 bis 1,0 %,
Ti: 0,03 bis 0,2 % sowie
optional eines oder mehrere aus
Nb: 0,01 bis 0,07 %,

V: 0,01 bis 0,07 % und
B: 0,0005 bis 0,0050 %
und als Rest Fe und unvermeidliche Verunreinigungen und
das eine Streckgrenze von mindestens 700 MPa hat.

2. Verfahren zur Herstellung eines witterungsbeständigen hochfesten Stahlblechs mit ausgezeichneter Biegbarkeit, das eine Streckgrenze von mindestens 700 MPa hat,
wobei das Verfahren die Schritte aufweist:
Erwärmen eines Stahlmaterials, das massebezogen enthält:
C: 0,05 bis 0,15 %,
Si: höchstens 0,5 %,
Mn: 0,5 bis 2,0 %,
P: höchstens 0,02 %,
S: höchstens 0,005 %,
Ni: 0,2 bis 2,0 %,
Cu: 0,2 bis 0,5 %,
Cr: 0,2 bis 1,0 %,
Ti: 0,03 bis 0,2 % sowie
optional eines oder mehrere aus
Nb: 0,01 bis 0,07 %,
V: 0,01 bis 0,07 % und
B: 0,0005 bis 0,0050 %
und als Rest Fe und unvermeidliche Verunreinigungen, auf eine Temperatur von mindestens 1200 ˚C;
anschließendes Fertigwalzen des Stahlmaterials im Temperaturbereich von 850 ˚C bis 950 ˚C; und
Wickeln des gewalzten Stahlmaterials im Temperaturbereich von 500 ˚C bis 650 ˚C.

Revendications

1. Tôle d'acier hautement résistante à résistance aux intempéries, à excellente aptitude au pliage, contenant, en masse,
C : 0,05 à 0,15 %,
Si : 0,5 % ou moins,
Min : 0,5 à 2,0 %,
P : 0,02 % ou moins,
S : 0,005 % ou moins,
Ni : 0,2 à 2,0 %,
Cu:0,2 à 0,5%,
Cr: 0,2 à 1,0 %,
Ti : 0,03 à 0,2 %, et
optionnellement un ou plusieurs parmi
Nb : 0,01 à 0,07 %,
V : 0,01 à 0,07 %, et
B : 0,0005 à 0,0050 %,
le reste étant Fe et des impuretés inévitables, et ayant une limite d'élasticité de 700 MPa ou plus.

2. Procédé de production d'une tôle d'acier hautement résistante à résistance aux intempéries, à excellente aptitude au pliage, ayant une limite d'élasticité de 700 MPa ou plus,
le procédé comprenant les étapes consistant à :

chauffer un matériau en acier contenant, en masse,
C : 0,05 à 0,15 %,
Si : 0,5 % ou moins,
Mn : 0,5 à 2,0 %,
P : 0,02 ou moins,
S : 0,005 % ou moins,
Ni : 0,2 à 2,0 %,
Cu: 0,2 à 0,5%,
Cr: 0,2 à 1,0 %,

Ti : 0,03 à 0,2 %, et
optionnellement un ou plusieurs parmi
Nb : 0,01 à 0,07 %,
V : 0,01 à 0,07 %, et
B : 0,0005 à 0,0050 %,
le reste étant Fe et des impuretés inévitables, à une température de 1 200 ˚C ou plus ;
par la suite soumettre le matériau en acier à un laminage de finition dans la plage de températures allant de 850 ˚C à 950 ˚C ; et
enrouler le matériau en acier laminé dans la plage de températures allant de 500 ˚C à 650 ˚C.

Fig.1

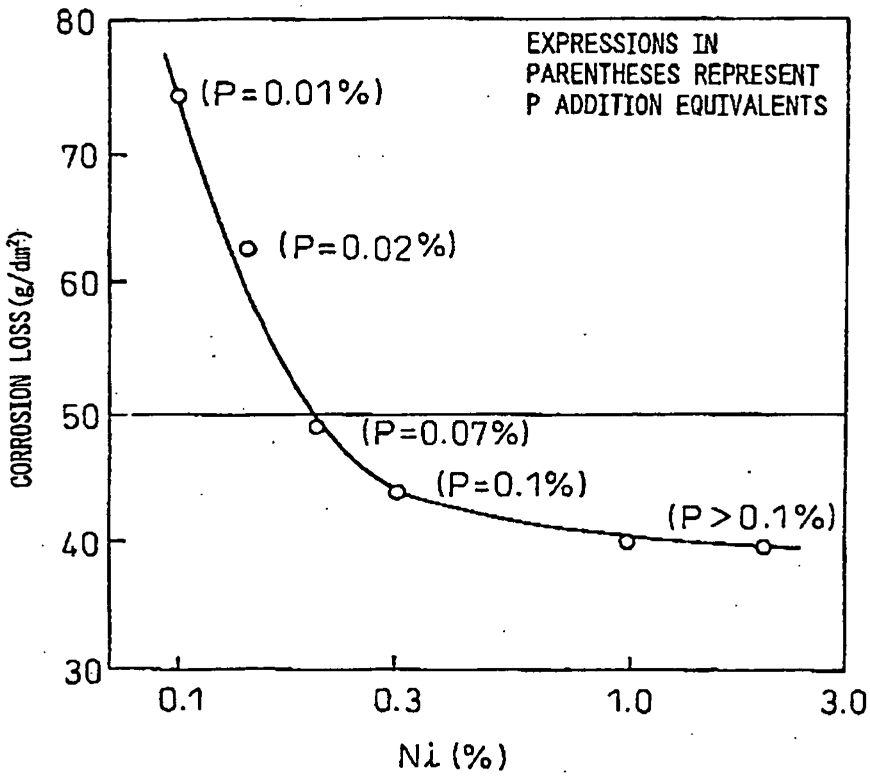

80
70
60
50
40
30
CORROSION LOSS (g/dm²)
EXPRESSIONS IN PARENTHESES REPRESENT P ADDITION EQUIVALENTS
(P=0.01%)
(P=0.02%)
(P=0.07%)
(P=0.1%)
(P>0.1%)
0.1
0.3
1.0
3.0
Ni (%)

Fig.2

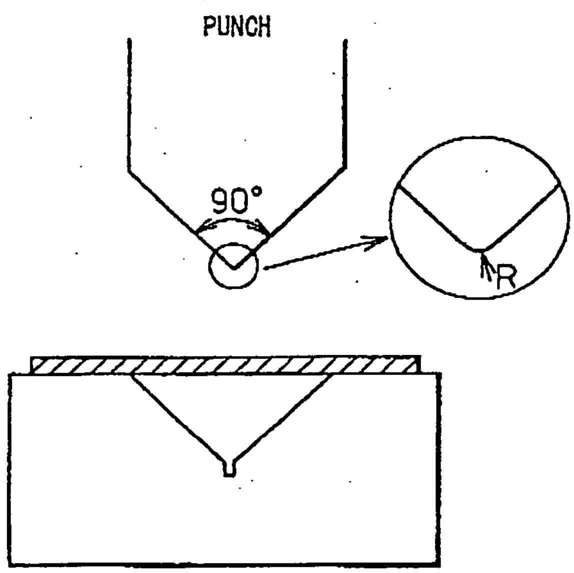
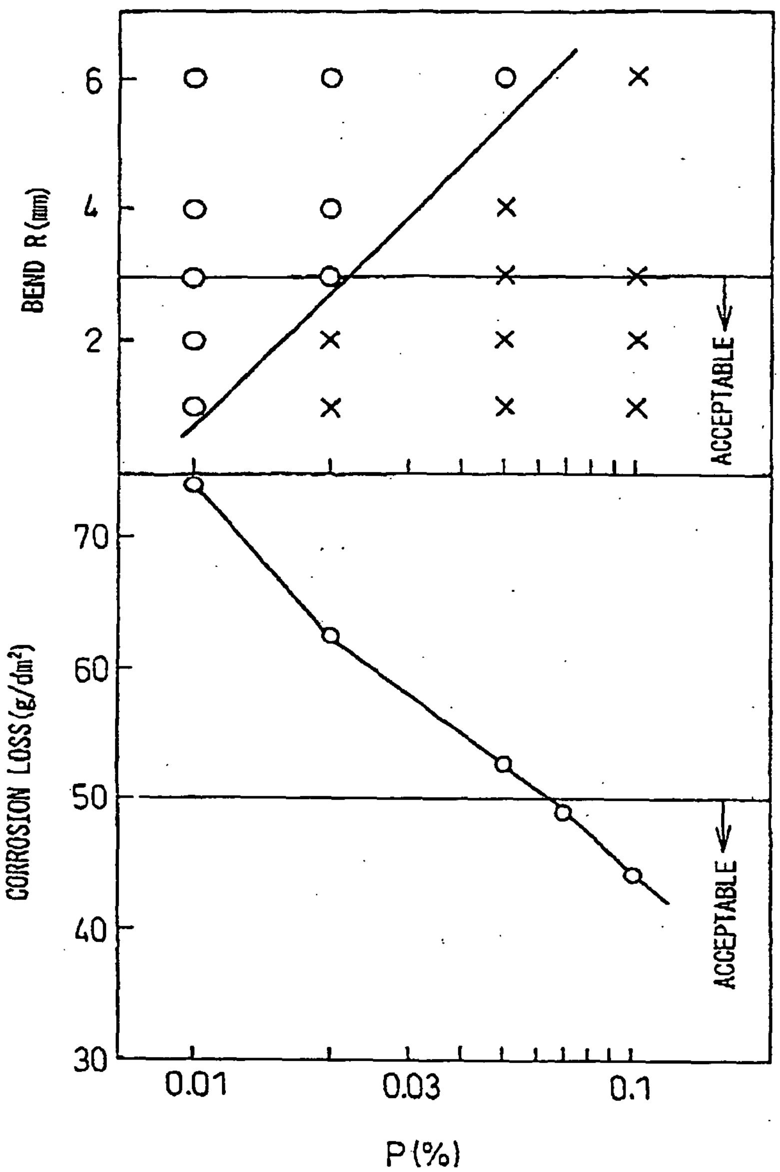


Fig.3


6
4
2
BEND R (mm)
ACCEPTABLE
70
60
50
40
30
CORROSION LOSS (g/dm²)
ACCEPTABLE
0.01
0.03
0.1
P (%)

REFERENCES CITED IN THE DESCRIPTION

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