

DESCRIPTION

[Title of Invention] HOT ROLLED STEEL SHEET WITH EXCELLENT FORMABILITY AND METHOD FOR MANUFACTURING THE SAME

[Technical Field]

[0001]

The present invention relates to a hot rolled steel sheet used for materials for automobiles, home electric appliances, and the like, and more particularly relates to a hot rolled steel sheet having formability suitable for press forming and the like and also being excellent in aging-resistance and in-plane anisotropy.

[Background Art]

[0002]

A hot rolled steel sheet used for automobiles, electric goods, and the like is required to have high formability, and in particular, development to impart soft properties and high ductility to a hot rolled steel sheet used for deep drawing application, such as a compressor cover, has been aggressively carried out. In addition, as times necessary for transportation and storage are increased concomitant with recent trend of globalization of manufacturing bases, the stability in material quality, in particular, aging-resistance has also been increasingly considered as

important.

[0003]

As for a hot rolled steel sheet for deep drawing which is excellent in aging-resistance, Patent Literature 1 has proposed a technique in which soft/high ductile properties are ensured by defining upper limits of reinforcing elements, such as C and Mn, and the aging-resistance is enhanced by adding 0.001% or more of B to fix N in steel. However, according to the technique described above, since the addition amount of B of the hot rolled steel sheet is as high as 0.001% or more, a problem in that a $|\Delta r|$ (planar anisotropy of r-value), which is an index indicating the in-plane anisotropy of deep drawing, is increased may arise.

[0004]

In order to overcome the above problem of a hot rolled steel sheet added with B, Patent Literature 2 has proposed a technique in which finish rolling is performed at a temperature higher than the Ar_3 point + 20°C or more by specifying the addition amount of B to improve the $|\Delta r|$. In addition, Although not relating a hot rolled steel sheet added with B, a technique has been proposed in Patent Literature 3 in which in order to improve the $|\Delta r|$ of a hot rolled steel sheet having a specified P content, finish rolling is performed at the Ar_3 point or more.

[0005]

However, as disclosed in Non-Patent Literature 1, a hot rolled steel sheet added with B tends to form coarse grains and is greatly dependent on hot rolling conditions. Therefore, if finish rolling is simply performed at a high temperature as proposed in Patent Literatures 2 and 3, coarse grains are excessively formed, and rough surfaces are generated on the steel sheet after press forming. In addition, although the hot rolled steel sheet proposed in Patent Literature 3 is not added with B, since grain growth properties are enhanced when the content of P is extremely decreased (0.005% or less), as in the case of the hot rolled steel sheet proposed in Patent Literature 2, the generation of rough surfaces due to excessive coarse grain formation may cause a problem.

[0006]

On the other hand, Patent Literature 4 has disclosed a technique in which in order to suppress an excessive growth of grains, Ti and/or Nb is added to a hot rolled steel sheet. However, Ti and Nb each have significantly high effects of suppressing recrystallization and suppressing grain growth. Hence, in order to improve the $|\Delta r|$ of a hot rolled steel sheet added with Ti and/or Nb and also to ensure appropriate grain diameters, the hot rolled steel sheet must be held at a high temperature region for a long period of time. In addition, since B is not added in the technique disclosed in

Patent Literature 4, aging in a low C region inevitably occurs, and hence, a problem of inferior aging-resistance may also arise.

[Citation List]

[Patent Literatures]

[0007]

[PTL 1] Japanese Unexamined Patent Application
Publication No. 52-125411

[PTL 2] Japanese Unexamined Patent Application
Publication No. 2-209423

[PTL 3] Japanese Unexamined Patent Application
Publication No. 2-209424

[PTL 4] Japanese Unexamined Patent Application
Publication No. 2-30713

[Non-Patent Literature]

[0008]

[NPL 1] Yo Ito et al., "Hot Rolled Steel Sheet KFN For Press Forming", KAWASAKI STEEL GIHO, published by Kawasaki Steel Corp., 1973, Vol. 5, No. 2, pp. 224 to 234

[Summary of Invention]

[Technical Problem]

[0009]

As described above, although several techniques for improving the $|\Delta r|$ of a hot rolled steel sheet for deep drawing have been disclosed, since incidental problems, such

as generation of rough surfaces and degradation of aging-resistance, occur, there has been room for improvement. The present invention was made in consideration of this situation, and an object of the present invention is to provide a hot rolled steel sheet having an improved $|\Delta r|$ without causing excessive coarse grain formation as well as having excellent formability and aging-resistance, and an advantageous method for manufacturing the same.

[Solution to Problem]

[0010]

In order to achieve the above object, the present inventors carried out intensive research on recrystallization behavior and grain growth behavior of B-added aluminum killed steel. As a result, a new finding was obtained that when the component composition of steel, finish rolling temperature and reduction rate, cooling conditions after finish rolling, and the like were controlled, in particular, when a relatively large amount of P was added as a component, and a step of spontaneous cooling treatment for a short period of time was performed after hot rolling was completed, in a hot rolled steel sheet having aging-resistance and soft/high ductile properties, the $|\Delta r|$ could be reduced without causing excessive coarse grain formation which would generate rough surfaces and the like.

[0011]

The present invention was made based on the above finding, and according to one aspect of the present invention, there is provided:

(1) a hot rolled steel sheet containing, on a percent by mass basis,
0.03% to 0.07% of C,
0.1% or less of Si,
0.05% to 0.5% of Mn,
0.01% to 0.03% of P,
0.03% or less of S,
0.02% to 0.1% of sol. Al,
0.005% or less of N,
less than 0.005% of Nb+Ti
0.0003% to 0.0020% of B, and
the balance being Fe and inevitable impurities,
wherein an average crystal grain diameter is in a range of
12 to 25 μm , and $|\Delta r| \leq 0.25$ and $AI \leq 20$ MPa hold.

[0012]

According to another aspect of the present invention, there is provided:

(2) a method for manufacturing a hot rolled steel sheet comprising the steps of performing a final pass of hot rolling on a steel slab which contains, on a percent by mass basis,

0.03% to 0.07% of C,
0.1% or less of Si,
0.05% to 0.5% of Mn,
0.01% to 0.03% of P,
0.03% or less of S,
0.02% to 0.1% of sol. Al,
0.005% or less of N,
less than 0.005% of Nb+Ti,
0.0003% to 0.0020% of B, and
the balance being Fe and inevitable impurities at a rolling
temperature of $A_{r3}+50^{\circ}\text{C}$ or more and a reduction rate of 15%
or more; performing spontaneous cooling for 0.5 to 10
seconds after the hot rolling; performing cooling to 700°C
or less at a cooling rate of $20^{\circ}\text{C}/\text{sec}$ or more; and
performing coiling at a temperature in a range of 590°C to
 700°C .

[Advantageous Effects of Invention]

[0013]

According to the present invention, sufficient aging-resistance and soft/high ductile properties are imparted to a hot rolled steel sheet, and in addition, the in-plane anisotropy can be reduced while the crystal grain diameter suitable for press forming is maintained. Hence, according to the hot rolled steel sheet of the present invention, a product, such as a compressor cover, which requires highly

complicated processing and which is difficult to be formed from a related hot rolled steel sheet can be manufactured without any quality degradation, such as rough surfaces, generated in forming.

[Description of Embodiments]

[0014]

Reasons for limiting component compositions and manufacture conditions of the present invention will be described. Although the content of every element in a steel sheet is on a "percent by mass" basis, it is simply represented by "%" unless otherwise particularly noted.

(1) Component composition range

C: 0.03% to 0.07%

When the content of C is high, since a large amount of carbide is generated, the elongation of a hot rolled steel sheet is reduced, and the formability thereof is degraded; hence, the content of C is set to 0.07% or less. On the other hand, when the content of C is extremely decreased, manufacturing cost is increased, and hence, the lower limit is set to 0.03%.

[0015]

Si: 0.1% or less

If the content of Si is excessive, since the strength is increased, and the formability is degraded, the content is set to 0.1% or less. In the present invention, Si is an

element which degrades the formability, and hence the content thereof is preferably decreased.

[0016]

Mn: 0.05% to 0.5%

Since Mn fixes S in the form of MnS and functions to improve hot ductility, the content of Mn must be set to 0.05% or more. On the other hand, since an excessive addition not only hardens steel but also degrades the formability thereof, the upper limit of the content is set to 0.5%.

[0017]

P: 0.01% to 0.03%

P is a characteristic element in the present invention. That is, when the content of P is small, the grain growth is enhanced, and the probability of generating rough surfaces caused by coarse grain formation may be increased. Hence, in the present invention, at least 0.01% of P is contained. However, P is a solid-solution-strengthening element and hardens steel when the content thereof is excessive, and hence the upper limit is set to 0.03%.

[0018]

S: 0.03% or less

S is an element which degrades hot ductility and formability, and hence the content thereof is preferably decreased. In addition, although S is fixed in the form of

MnS in order to improve hot ductility and formability, the elongation is decreased when the amount of MnS is excessive, and hence the upper limit of the content of S is set to 0.03%.

[0019]

sol. Al: 0.02% to 0.1%

Al is not only effective as a deoxidizing agent but also enhances the aging-resistance by fixing N, which is not fixed by B, in the form of AlN. As the content of sol. Al, 0.02% or more is required. On the other hand, since excessive addition increases manufacturing cost, the upper limit of sol. Al is set to 0.1%.

[0020]

N: 0.005% or less

N is an element of aging a hot rolled steel sheet, and a smaller content thereof is more preferable; however, an excessive decrease causes a remarkable cost increase. In the present invention, since B and Al are added to fix N, when the content of N is 0.005% or less, its adverse influence can be ignored, and hence the upper limit is set to 0.005%.

[0021]

Nb+Ti: less than 0.005%

Since Nb and Ti are each a powerful recrystallization suppressing element, if these elements are excessively

contained, the reduction of the $|\Delta r|$ is difficult to perform. In addition, since these elements are each also a powerful grain growth suppressing element, if these elements are excessively contained, crystal grains of a hot rolled steel sheet are formed to have a smaller grain diameter, and the elongation thereof is decreased. Although a smaller amount of Nb+Ti is more preferable from the point described above, when the total content of Nb and Ti is less than 0.005%, the above adverse effect can be ignored; hence, the upper limit of Nb+Ti is set to less than 0.005%.

[0022]

B: 0.0003% to 0.0020%

B is an element to improve the aging-resistance by fixing N. In addition, since B has a function of appropriately coarsening crystal grains and also has an effect of suppressing a decrease in elongation caused by decreasing the size of crystal grains, the content of B must be 0.0003% or more. On the other hand, since the $|\Delta r|$ is increased when B is excessively added, the upper limit thereof is set to 0.0020%.

In addition, the balance other than the above components includes Fe and inevitable impurities. As the impurities, for example, 0.02% or less of Cu and 0.02% or less of Ni may be contained.

[0023]

(2) Average crystal grain diameter

The average crystal grain diameter must be set in a range of 12 to 25 μm . The reasons for this are that when the average crystal grain diameter is less than 12 μm , the yield strength is increased, and the formation is difficult to perform, and when the average crystal grain diameter is more than 25 μm , rough surfaces are generated in press forming. In addition, the average crystal grain diameter is more preferably in a range of 12 to 23 μm .

[0024]

(3) $|\Delta r| \leq 0.25$

When the planar anisotropy $|\Delta r|$ of the average Lankford Value represented by the following formula (1) is more than 0.25, the yield of draw forming decreases, and hence the $|\Delta r|$ must be set to 0.25 or less.

Note

$$|\Delta r| = |(r_0 + r_{90} - 2r_{45}) / 2| \quad \text{Formula (1)}$$

In this formula, r_0 represents the Lankford Value in a rolling direction (RD), r_{90} represents the Lankford Value in a direction (TD) perpendicular to the rolling direction, and r_{45} represents the Lankford Value in a direction (DD) at 45° to the rolling direction. The average Lankford Value is preferably set to 0.8 or more in terms of reduction of forming load. In addition, the steel sheet of the present invention is a hot rolled steel sheet, and the average

Lankford Value is approximately 1.0 or less.

[0025]

(4) $AI \leq 20$ MPa

An aging index AI indicates, after a hot rolled steel sheet is pulled at an elongation rate of 7.5%, the difference in tensile stress before and after an aging treatment performed at 100°C for 30 minutes. In addition, since a yield-elongation phenomenon may occur in some cases after the aging treatment, strictly, a lower yield stress after the aging treatment or 0.2% proof stress is used. When the aging index AI exceeds 20 MPa, since the material quality is changed during transportation or coil storage, the press forming conditions must be optimized; hence, the product cost is increased. On the other hand, if the AI is 20 MPa or less, since the change in material quality causes no problems, the AI is set to 20 MPa or less and more preferably set to 10 MPa or less.

[0026]

(5) Manufacturing process

On a steel slab obtained by casting steel prepared to have the component composition ranges described above, a final pass of hot rolling was performed at a rolling temperature of $A_{r3} + 50^\circ\text{C}$ or more and a reduction rate of 15% or more immediately after casting or after reheating, spontaneous cooling is performed for 0.5 to 10 seconds after

the hot rolling is completed, cooling is subsequently performed to 700°C or less at a cooling rate of 20°C/sec or more, and coiling is then performed at a temperature of 590°C to 700°C. Although it is not necessary to particularly define the above reheating temperature, reheating must be performed under condition which can ensure a finish rolling temperature and is generally performed at a temperature of 1,050°C to 1,300°C.

[0027]

In a hot rolled steel sheet added with B as disclosed in the present invention, in order to reduce the in-plane anisotropy thereof while the crystal grain diameter suitable for press forming is maintained, it is important to optimize the finish rolling temperature and reduction rate, the cooling condition after the finish rolling, and the coiling temperature.

[0028]

The present inventors investigated the relationship between the $|\Delta r|$ of a B-containing hot rolled steel sheet having the composition as described above and the rolling temperature of the final pass of hot rolling. In this embodiment, the final pass of hot-rolling indicates a final pass, that is, a final reducing stand, in finish rolling of hot-rolling, and the rolling temperature (also called a finish rolling temperature) is a temperature at an outlet

side of this reducing stand. As a result, it was found that the $|\Delta r|$ of the hot rolled steel sheet decreased as the rolling temperature of the final pass was increased from the Ar_3 point, and at a temperature of $Ar_3+50^\circ\text{C}$ or more, the $|\Delta r|$ showed an approximately constant value. Although the reason for this has not been clearly understood, when the rolling temperature of the final pass is in the vicinity of the Ar_3 point, the r_{45} value of the formula (1) is larger than the r_0 value and the r_{90} value, and as the rolling temperature of the final pass is increased, the r_0 value and the r_{90} value are increased while the r_{45} value is decreased, so that the $|\Delta r|$ of the formula (1) decreases; hence, it is estimated that the effect of reducing the $|\Delta r|$ is saturated at a temperature of the Ar_3 point + 50°C .

[0029]

Accordingly, in the present invention, in order to reduce the $|\Delta r|$, the final pass is performed at a high rolling temperature of $Ar_3+50^\circ\text{C}$ or more. However, the finish rolling temperature is preferably set to 950°C or less in terms of reduction of scale layers. In addition, in the present invention, after the finish rolling, spontaneous cooling is performed for a predetermined time. The reason for this is that in order to decrease the $|\Delta r|$, a processed austenite structure formed by finish rolling is recrystallized in an austenite region to randomize the

aggregate structure. At this stage, since the recrystallization of the processed austenite structure is not enough when the spontaneous cooling is performed for less than 0.5 seconds after the finish rolling, in the present invention, the cooling time is set to 0.5 seconds or more.

[0030]

When the finish rolling is performed at a high temperature, and the spontaneous cooling is then performed for a long period of time as described above, the $|\Delta r|$ is decreased; however, excessive coarse grain formation, which is a character of B-added steel, occurs, and as a result, a press formed product has rough surfaces. In order to solve this problem, the final pass reduction rate (reduction rate in the final pass) is set to 15% or more and more preferably 20% or more to increase the number of recrystallization nuclei, and the cooling time after the final rolling is further set to 10 seconds or less and preferably less than 5 seconds to suppress the grain growth of austenite grains, so that the size of crystal grains after the ferrite transformation is controlled in an appropriate range.

In addition, the above reduction rate is preferably set to less than 25% in order to improve the steel-sheet shape.

[0031]

After a predetermined holding (spontaneous cooling)

time passes, cooling is performed to 700°C or less at a cooling rate of 20°C/sec or more, and coiling is then performed at 590°C to 700°C. In order to suppress the grain growth during cooling, the cooling rate must be set to 20°C/sec or more. In addition, when the coiling temperature is more than 700°C, the surface conditions are degraded by scales generated during coiling, and when the coiling temperature is less than 590°C, since the AI exceeds 20 MPa, the change in material quality occurs during transportation and storage. Therefore, the coiling temperature is set in a range of 590°C to 700°C. The coiling temperature is preferably 625°C or more. In addition, in order to avoid a large cost increase, in general, the upper limit of the above cooling rate is approximately 500°C/sec.

[0032]

For the hot rolled steel sheet of the present invention, properties of a pickled material are not different from those of a black material. In addition, even when hot dip galvanizing is performed after pickling or on a black material which is not processed by pickling, no problems occur. Although conditions for temper rolling are not particularly limited, since the elongation performance of a steel material is degraded when the elongation rate thereof is too high, the elongation rate of temper rolling is preferably set to 2% or less.

[0033]

In addition, the hot rolled steel sheet of the present invention is a soft hot rolled steel sheet suitable for deep drawing application having a yield stress of approximately 250 MPa or less and a sheet thickness of approximately 2 to 6 mm.

[Examples]

[0034]

(Example 1)

After steel having components shown in Table 1 was formed, and a working Formaster test piece having a diameter of 8 mm and a height of 12 mm was obtained therefrom by cutting, heating to 1,200°C, cooling to 950°C at a cooling rate of 10°C/sec, compression at 950°C at a strain of 30%, and cooling to 200°C at a cooling rate of 10°C/sec were performed on the above test piece in this order. The Ar_3 point measured from a thermal expansion curve in cooling was 823°C. After this steel was heated to 1200°C, hot rolling was performed under the conditions shown in Table 2, so that a hot rolled steel sheet having a thickness of 3.2 mm was obtained.

[0035]

After the hot rolled steel sheet thus obtained was processed by pickling, temper rolling at an elongation rate of 1% was performed, and evaluation of mechanical properties

and texture observation were performed. For the evaluation of mechanical properties, a No. 5 test piece of JIS Z 2201 (1998) was obtained along a rolling direction (RD), and a tensile test was performed in accordance with JIS Z 2241 (1998).

[0036]

For measurement of the Lankford Value, No. 5 test pieces of JIS Z 2201 (1998) were obtained along the rolling direction (RD), a direction perpendicular thereto (TD), and a direction at 45° to the rolling direction (DD), and measurement was performed at a strain of 15%. In addition, according to the formula (1), the $|\Delta r|$ was obtained.

[0037]

For evaluation of the AI, after a No. 5 test piece of JIS Z 2201 (1998) was obtained along the rolling direction (RD), a heat treatment was performed for 30 minutes at 100°C after a pre-strain of 7.5% was applied, and evaluation was performed by the difference between the stress (stress when a pre-strain of 7.5% was applied) before the heat treatment and the yield stress after the heat treatment.

[0038]

The steel sheet at a position of 1/4 thickness in a depth direction was etched using a nital solution, and the average crystal grain diameter was measured in accordance with a cutting method described in JIS G 0552 (1998). The

results are also shown Table 2.

[0039]

Table 1

STEEL NO.	CHEMICAL COMPOSITION (mass%)										A _{r3} (°C)
	C	Si	Mn	P	S	sol.Al	N	Nb	Ti	B	
1	0.039	0.01	0.22	0.016	0.005	0.031	0.0021	0.001	0.001	0.0009	823

[0040]

Table 2

CONDITION	FINAL PASS OF HOT ROLLING		SPONTANEOUS COOLING TIME (sec.)	COOLING RATE (°C/sec.)	COILING TEMPERATURE (°C)	YP (MPa)	EL (%)	$ \Delta r $	AI (MPa)	AVERAGE CRYSTAL GRAIN DIAMETER (μm)	REMARKS
	REDUCTION RATE (%)	TEMPERATURE (°C)									
A	23	890	<u>0.2</u>	150	670	231	47	<u>0.35</u>	5	13.4	COMPARATIVE EXAMPLE
B	23	890	1.2	150	670	218	48	0.22	4	15.8	INVENTION EXAMPLE
C	23	890	3.9	150	670	206	48	0.18	6	17.2	INVENTION EXAMPLE
D	23	890	<u>18</u>	150	670	193	50	0.19	1	<u>33.2</u>	COMPARATIVE EXAMPLE
E	28	<u>842</u>	4.4	23	670	202	49	<u>0.29</u>	9	18.9	COMPARATIVE EXAMPLE
F	28	900	4.4	23	<u>580</u>	229	48	0.17	<u>27</u>	18.2	COMPARATIVE EXAMPLE
G	28	900	4.4	23	600	219	49	0.18	17	18.8	INVENTION EXAMPLE
H	28	900	4.4	23	640	212	49	0.18	9	19.7	INVENTION EXAMPLE
I	<u>13</u>	890	3.9	150	670	211	48	<u>0.33</u>	9	17.5	COMPARATIVE EXAMPLE
J	23	890	3.9	<u>5</u>	670	191	49	0.13	5	<u>31.4</u>	COMPARATIVE EXAMPLE
K	23	<u>860</u>	3.9	150	640	215	48	<u>0.28</u>	6	17.6	COMPARATIVE EXAMPLE

[0041]

According to conditions B, C, G, and H of the examples of the present invention, there was obtained a hot rolled steel sheet of soft/high ductile properties having a yield stress YP of 220 MPa or less and an elongation El of 48% or more; sufficient aging-resistance having an AI of 20 MPa or less; and a small anisotropy having a $|\Delta r|$ of 0.25 or less. In addition, the average crystal grain diameters of the hot rolled steel sheets manufactured under the conditions B, C, G, and H of the examples of the present invention were each within a range of 12 to 25 μm , and hence the generation of rough surfaces may not occur in press forming. Furthermore, it was found that since the coiling temperatures under the conditions B, C, and H of the examples of the present invention were each 625°C or more, the AI of each of the hot rolled steel sheets thus obtained was 10 MPa or less, and the aging-resistance was particularly superior.

[0042]

On the other hand, under a condition A in which the spontaneous cooling time was short, conditions E and K in which the rolling temperature of the final pass of the finish rolling was low, and a condition I in which the reduction rate of the final pass of the finish rolling was low, since the recrystallization in the austenite region did not sufficiently progress, the anisotropy of each of the hot

rolled steel sheets manufactured under these conditions was high, and the $|\Delta r|$ was more than 0.25. In addition, in the hot rolled steel sheets manufactured under a condition D in which the spontaneous cooling time was long and a condition J in which the cooling rate was low, large and coarse grains were formed. In addition, in the hot rolled steel sheet manufactured under a condition F in which the coiling temperature was less than 590°C, the AI was more than 20 MPa.

[0043]

(Example 2)

Steel containing components shown in Table 3-1 was formed, and the Ar_3 point was measured in a manner similar to that of Example 1. Subsequently, after the steel was heated to 1,200°C, the final pass of the finish rolling of hot rolling was performed at a reduction rate of 22% and a temperature of 875°C, spontaneous cooling was then performed for 4.2 seconds after the finish rolling, cooling was subsequently performed to 630°C at a cooling rate at 25°C/sec, and coiling was then performed without any additional steps.

[0044]

The mechanical properties, the Lankford Value, the AI, and the average crystal grain diameter of each of the obtained hot-rolled steel sheets were measured by methods similar to those of Example 1. The results are also shown in Table 3-2.

[0045]

Table 3-1

STEEL NO.	COMPONENT COMPOSITION (mass%)										Ar ₃ (°C)	REMARKS
	C	Si	Mn	P	S	sol.Al	N	Nb	Ti	B		
2	<u>0.081</u>	0.01	0.25	0.015	0.005	0.031	0.0021	0.001	0.001	0.0006	810	COMPARATIVE EXAMPLE
3	0.045	0.01	0.22	0.017	0.006	0.033	0.0026	0.001	0.001	0.0010	825	INVENTION EXAMPLE
4	0.039	0.01	0.22	0.016	0.006	0.034	0.0023	tr	tr	0.0009	820	INVENTION EXAMPLE
5	0.031	0.01	0.25	<u>0.003</u>	0.004	0.035	0.0022	tr	0.001	0.0015	820	COMPARATIVE EXAMPLE
6	0.040	0.01	0.21	0.017	0.004	0.037	0.0020	<u>0.004</u>	<u>0.003</u>	0.0013	830	COMPARATIVE EXAMPLE
7	0.045	tr	0.20	0.019	0.005	0.040	0.0022	0.001	0.001	<u>0.0001</u>	825	COMPARATIVE EXAMPLE
8	0.042	tr	0.22	0.018	0.014	0.039	0.0024	0.001	0.001	<u>0.0032</u>	835	COMPARATIVE EXAMPLE

Table 3-2

STEEL NO.	YP (MPa)	EL (%)	$ \Delta\tau $	AI (MPa)	AVERAGE CRYSTAL GRAIN DIAMETER (μm)	REMARKS
2	262	43	0.21	7	<u>9.8</u>	COMPARATIVE EXAMPLE
3	212	48	0.16	4	16.2	INVENTION EXAMPLE
4	208	49	0.15	5	20.8	INVENTION EXAMPLE
5	200	48	0.19	7	<u>26.1</u>	COMPARATIVE EXAMPLE
6	228	45	<u>0.41</u>	3	12.8	COMPARATIVE EXAMPLE
7	231	47	0.10	<u>46</u>	13.1	COMPARATIVE EXAMPLE
8	206	48	<u>0.31</u>	1	18.3	COMPARATIVE EXAMPLE

[0046]

According to steel Nos. 3 and 4 in which the component composition of the present invention was satisfied, there was obtained a hot rolled steel sheet of soft/high ductile properties having a yield stress YP of 220 MPa or less and an elongation El of 48% or more; sufficient aging-resistance having an AI of 20 MPa or less; and a small anisotropy having a $|\Delta r|$ of 0.25 or less. In addition, since the average crystal grain diameter of the hot rolled steel sheet of steel No. 3 was 20 μm or less, the probability of formation of rough surfaces was smaller.

[0047]

On the other hand, in steel No. 2 in which the amount of C was high, the average crystal grain of the hot rolled steel sheet was fine, and the yield strength was increased. In steel No. 5 in which the amount of P was small, the average crystal grain of the hot rolled steel sheet was large and coarse. In steel No. 6 in which the amounts of Nb and Ti were large and steel No. 8 in which the amount of B was large, since the recrystallization in the austenite region did not sufficiently progress, the anisotropy of the hot rolled steel sheet was high, and the $|\Delta r|$ was more than 0.25. In addition, in steel No. 7 in which the amount of B was small, the AI of the hot rolled steel sheet was more than 20 MPa.

[Industrial Applicability]

[0048]

According to the present invention, when a B-added hot rolled steel sheet for processing is added with 0.01% to 0.03% of P, is then processed by a final pass at a reduction rate of 15% or more, and is subsequently processed by spontaneous cooling for 0.5 to 10 seconds, a hot rolled steel sheet having, besides aging-resistance and soft/high ductile properties, an improved $|\Delta r|$ without causing excessive coarse grain formation can be obtained.

CLAIMS

[Claim 1]

A hot rolled steel sheet containing, on a percent by mass basis,
0.03% to 0.07% of C,
0.1% or less of Si,
0.05% to 0.5% of Mn,
0.01% to 0.03% of P,
0.03% or less of S,
0.02% to 0.1% of sol. Al,
0.005% or less of N,
less than 0.005% of Nb+Ti,
0.0003% to 0.0020% of B, and
the balance being Fe and inevitable impurities, wherein an average crystal grain diameter is in a range of 12 to 25 μm , and $|\Delta r| \leq 0.25$ and $AI \leq 20$ MPa hold.

[Claim 2]

A method for manufacturing a hot rolled steel sheet comprising the steps of performing a final pass of hot rolling on a steel slab which contains, on a percent by mass basis,
0.03% to 0.07% of C,
0.1% or less of Si,
0.05% to 0.5% of Mn,

0.01% to 0.03% of P,
0.03% or less of S,
0.02% to 0.1% of sol. Al,
0.005% or less of N,
less than 0.005% of Nb+Ti,
0.0003% to 0.0020% of B, and
the balance being Fe and inevitable impurities at a rolling
temperature of $A_{r3}+50^{\circ}\text{C}$ or more and a reduction rate of 15%
or more; performing spontaneous cooling for 0.5 to 10
seconds after the hot rolling; then performing cooling to
 700°C or less at a cooling rate of $20^{\circ}\text{C}/\text{sec}$ or more; and
performing coiling at a temperature in a range of 590°C to
 700°C , wherein an average crystal grain diameter is in a
range of 12 to 25 μm , and $|\Delta r| \leq 0.25$ and $AI \leq 20$ MPa hold.