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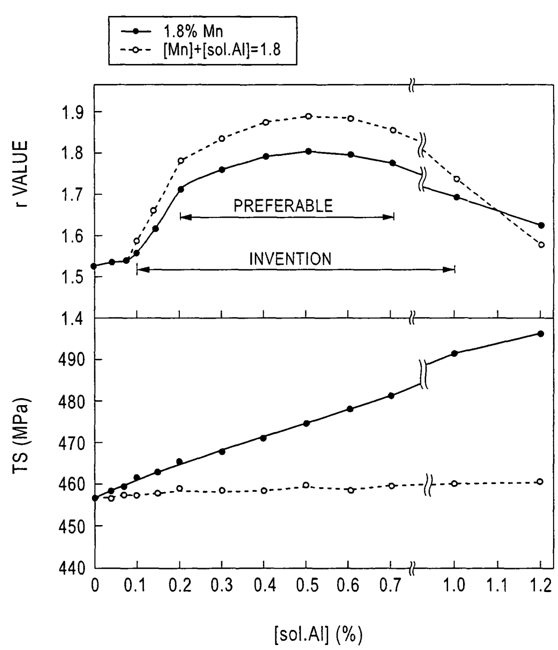
(54) High strength cold rolled steel sheet and method for manufacturing the same

(57) The present invention relates to a high strength cold rolled steel sheet consisting of 0.015 % or less of C, 1.5 % or less of Si, 0.4 to 3 % of Mn, 0.15 % or less of P, 0.02 % or less of S, 0.1 to 1 % of sol.Al, 0.01 % or less of N, 0.2 % or less of Ti, by mass %, and the balance of Fe and inevitable impurities. In this steel sheet, $1 \leqq ([Ti]/48)/([C]/12+[N]/14)$ is satisfied, in which [M] represents the content of the element M. Since having the superior deep drawability and the TS of 340 to 590 MPa, the high strength cold rolled steel sheet of the present invention is preferably used for automobiles parts difficult to be press formed, such as a side outer panel and a door inner panel.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a high strength cold rolled steel sheet used for automobiles, home appliances, and the like, more particularly to a high strength cold rolled steel sheet having the superior deep drawability and the tensile strength TS of 340 to 590 MPa, and to a manufacturing method thereof.

2. Description of Related Arts

[0002] Heretofore, for automobile parts having a complicated shape such as a side outer panel or a door inner panel, which are difficult to be press formed, the interstitial free (IF) mild cold rolled steel sheets (SPC270E,F) having the TS of approximately 270 MPa and the r value of 1.8 to 2.0, namely the superior deep drawability have been used. In recent years, due to the further increasing needs of the lighter automobile bodies, the high strength cold rolled steel sheets having the TS of 340 to 590 MPa have been progressively applied to those parts difficult to be press formed. However, when those parts are press formed by using the high strength cold rolled steel sheets, such as a steel sheet having the TS of 340 to 390 MPa and the r value of approximately 1.7, a steel sheet having the TS of approximately 440 MPa and the r value of approximately 1.5, or a steel sheet having the TS of approximately 590 MPa and the r value of approximately 1.0, cracking tends to occur at the parts where the deep drawing is performed. Hence, the high strength cold rolled steel sheet having the TS of 340 to 590 MPa and the higher r value is required. That is, the high strength cold rolled steel sheet having the TS of 340 to 400 MPa and the r value of 1.8 or more and the high strength cold rolled steel sheet having the TS of 400 to 590 MPa and the r value of 1.6 or more, preferably 1.7 or more, are desired.

[0003] In order to increase the r value, a method has been known comprising the steps of: preparing the IF steel in which the contents of C and N are decreased as small as possible and large amounts of Ti and Nb are added; coiling a hot rolled steel sheet of the IF steel at a high temperature of 680 °C or more so as to decrease the amounts of solute C and N as small as possible, accompanied by the coarsening of the carbides and nitrides; and annealing the cold rolled steel sheet produced from the hot rolled steel sheet so as to promote the nucleation and the growth of the recrystallized grains having the texture preferable to the r value. A method to improve the r value has been also disclosed in Japanese Unexamined Patent Application Publication No. 6-108155 and Japanese Patent No. 3291639, in which the texture preferable to the r value is developed by the formation of Ti(C,S) precipitates, using the Ti bearing IF steel in which the amounts of C and N are decreased as small as possible.

[0004] The method disclosed in Japanese Unexamined Patent Application Publication No. 6-108155 is primarily applied to a mild cold rolled steel sheet having the TS of 260 to 300 MPa, and when the method is applied to the IF high strength cold rolled steel sheet containing the large amounts of P and Mn and having the TS of 340 MPa or more, the large amounts of the phosphides such as Fe-Ti-P and Fe-Nb-P are formed in grain boundaries at coiling after hot rolling. As a result, the r value is extremely decreased. In the method disclosed in Japanese Patent No. 3291639, it has been proposed that the high strength cold rolled steel sheet with the amount of P has the TS of 340 MPa or more and the deep drawability. However, it is believed that the cracking at press forming is caused by the non-uniform microstructure resulting from the segregation of P at casting.

[0005] On the other hand, some manufacturing methods for improving the r value have also been proposed. For example, in Japanese Unexamined Patent Application Publication No. 7-188776, a method has been disclosed in which the finish rolling is performed with the lubrication below Ar3 transformation temperature. In Japanese Unexamined Patent Application Publication No. 9-279249, a method has been disclosed in which the rolling with the reduction of 1 to 50 % is performed during annealing at the temperature of 550 to 750 °C. In Japanese Unexamined Patent Application Publication No. 2001-131643, a method has been disclosed in which the Nb and B bearing steel, in which the amounts of Si, Mn, and P are controlled, is pickled followed by cold rolling, annealing, and rolling with the reduction of 0.3 to 5 %, subsequently followed by pickling again performed and hot-dip galvanizing.

[0006] However, the above-mentioned methods need the special manufacturing step, resulting in the increase in the manufacturing cost and the decrease in the productivity. That is, by the method disclosed in Japanese Unexamined Patent Application Publication No. 7-188776, the recrystallization annealing of the hot rolled steel sheet is required. In the method disclosed in Japanese Unexamined Patent Application Publication No. 9-279249, a rolling mill which can be used at the high temperature is required in the annealing furnace. In the method disclosed in Japanese Unexamined Patent Application Publication No. 2001-131643, the pickling, the annealing and the skin pass rolling must be performed twice, respectively.

SUMMARY OF THE INVENTION

[0007] The object of the present invention is to provide a high strength cold rolled steel sheet and a method for manufacturing the same without performing any special manufacturing steps, the high strength cold rolled steel sheet having the TS of 340 to 400 MPa and the r value of 1.8 or more or having the TS of 400 to 590 MPa and the r value of 1.6 or more, preferably 1.7 or more.

[0008] The object can be attained by the high strength cold rolled steel sheet consisting of 0.015 % or less of C, 1.5 % or less of Si, 0.4 to 3 % of Mn, 0.15 % or less of P, 0.02 % or less of S, 0.1 to 1 % of sol.Al, 0.01 % or less of N, 0.2 % or less of Ti, by mass %, and the balance of Fe and inevitable impurities, in which the following equation (1) is satisfied.

$$1 \leqq ([Ti]/48)/([C]/12+[N]/14) \qquad (1),$$

where [M] represents the content (mass %) of the element M.

[0009] The high strength cold rolled steel sheet can be manufactured by the method for manufacturing a high strength cold rolled steel sheet comprising the steps of: heating a slab having the chemical composition described above at 1,080 to 1,350 °C; hot rolling the heated slab at a finishing temperature between (the Ar3 transformation temperature-20) °C and (the Ar3 transformation temperature+150) °C into a hot rolled steel sheet; coiling the hot rolled steel sheet at a coiling temperature CT which satisfies the following equation (5); cold rolling the hot rolled steel sheet with a reduction of 50 to 90 % into a cold rolled steel sheet; and continuously annealing the cold rolled steel sheet at a temperature of 750 to 870 °C or box annealing the cold rolled steel sheet at a temperature of 600 to 750 °C.

$$480 \leqq CT \leqq 580+0.17/\{([Ti]+0.08\times[sol.Al])\times[P]\} \qquad (5),$$

where [M] represents the content (mass %) of the element M.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

Fig. 1 is a graph showing the relationship between the content of sol.Al and the r value and the TS; and
Fig. 2 is a graph showing the relationship between [Si]+10×[P] and the r value.

DETAILED DESCRIPTION OF THE INVENTION

[0011] Through the detailed investigation by the inventors of the present invention on the influence of various alloy elements on the r value of the IF high strength cold rolled steel sheet, the following findings were obtained.

I) When the content of sol.Al is larger than that of the conventional high strength cold rolled steel sheet, the r value is significantly improved. In particular, the effect is significant when the content of Mn is set to 0.4 % or more.
II) The addition of Si and P is effective for improving the r value.
III) When the coiling temperature after hot rolling and the contents of P, sol.Al, and Ti are optimized in addition to the content of Nb when it is added, the high r value can be obtained.

[0012] The present invention is based on the findings described above, and hereinafter, the details thereof will be described.

1) Content of sol.Al and r value

[0013] In order to investigate the relation between the content of sol.Al and the r value, the following test was performed.

[0014] The slab containing 0.002 % of C, 0.25 % of Si, 0.08 % of P, 0.007 % of S, 0.015 % of Nb, 0.03 % of Ti, 0.002 % of N, and 0.001 % of B was heated to 1,250 °C, in which the contents of sol.Al and Mn were varied from 0.01 to 1.2 % and from 0.6 to 1.8 %, respectively. The slab was hot rolled to 3 mm thick, followed by soaking at 580 °C for one hour as the coiling simulation. The hot rolled steel sheet was cold rolled to 0.75 mm thick, continuously annealed at 820 °C for 60 seconds, and subjected to skin pass rolling with the elongation of 0.7 %. The r value and the TS were evaluated by the following methods.

[0015] The r value and the TS were measured using JIS No. 5 test pieces cut in the direction of 0° , 45° , and 90° to the rolling direction, respectively. The average value of the r value and the TS was calculated with the following equation, respectively.

$$\text{The average value} = ([T_0]+2[T_{45}]+[T_{90}])/4,$$

where $[T_0]$, $[T_{45}]$ and $[T_{90}]$ are the values of the r value or the TS measured in the direction of 0° , 45° , and 90° to the rolling direction, respectively.

[0016] Fig. 1 shows the relationship between the content of sol.Al and the r value and the TS. In the figure, black circles indicate the results obtained when the content of Mn is 1.8 %, and white circles indicate the results obtained when the total content of sol.Al and Mn is 1.8 %.

[0017] When the content of Mn is 1.8 %, the r value is 1.6 or more at the sol.Al content of 0.1 % or more, is 1.7 or more at the sol.Al content of 0.2 to 0.7 %, and decreases at the sol.Al content of more than 0.7 %. The TS exceeds 460 MPa at the sol.Al content of 0.1 % or more and increases with the increase in the sol.Al content.

[0018] The increase in TS is 35 MPa when the content of the sol.Al is increased by 1 %. Since it is approximately equivalent to solid solution hardenability of Mn, when the total content of sol.Al and Mn is set to 1.8 %, the relation between the TS and the r value, in which the TS is substantially constant, can be obtained as shown with the white circles. Therefore, it is understood that when the sol.Al is added and the content of Mn is decreased, the high r value can be obtained with the constant TS.

[0019] In addition, when the content of sol.Al is more than 1 %, the precipitation of fine AlN in the austenite grain boundaries at the continuous casting of slab and causes the deterioration of the grain boundary strength, which leads to the cracking in the surface of the slab by the plastic deformation at the casting or at the rough rolling. The surface defects with the scale tend to be caused by the cracking of the slab surface, so that the surface quality of the final product seriously deteriorates.

[0020] Therefore, even if the TS is more than 400 MPa, when the content of sol.Al is controlled in the range of 0.1 to 1 %, preferably 0.2 to 0.7 %, the high r value of 1.6 or more, preferably 1.7 or more can be obtained, respectively.

[0021] The reason why the high r value becomes high when the content of sol.Al is set in the range of 0.1 to 1 % is considered as follows. That is, since Al increases the Ar3 transformation temperature, the coarsening of the carbides and the decrease in the amount of solute C are caused by the precipitation of the at the high temperature below the Ar3 transformation temperature through the transformation from the austenite into the ferrite after the hot rolling; hence, the recrystallization texture preferable to the r value is developed at annealing. In addition, it may be also believed that the change in the cold rolling texture caused by the presence of Al contributes to the improvement in the r value.

2) Contents of Si and P, and r value

[0022] In order to investigate the relation between the contents of Si and P and the r value, using the slab containing 0.002 % of C, 1 % of Mn, 0.007 % of S, 0.25 % of sol.Al, 0.02 % of Nb, 0.01 % of Ti, 0.002 % of N, and 0.001 % of B in which the contents of Si and P were varied from 0.005 to 1.5 % and from 0.003 to 0.15 %, respectively, the same test as above-mentioned was performed.

[0023] In Fig. 2, the relationship between the r value and $[Si]+10\times[P]$ is shown. In the figure, the values represent the contents of Si in each steel.

[0024] In the steel containing 0.25 % of sol.Al, according to the present invention, when the following equation (2) is satisfied, the high r value of 1.7 or more can be obtained.

$$0.3 \leqq [Si]+10\times[P] \leqq 1.4 \qquad (2),$$

where [M] represents the content (mass %) of the element M.

[0025] However, when the content of Si and 10 times the content of P both exceed 1.5 %, the r value is very much decreased. Therefore, the contents of Si and P are set to 1.5 % or less and 0.15 % or less, respectively.

[0026] When the hot-dip galvannealing is applied to the high strength cold rolled steel sheet of the present invention, Si and P tend to cause the decrease in the adhesion of the coating, and hence the contents of Si and P are preferably set to 0.5 % or less and 0.08 % or less, respectively. In addition, since Si and P are effective elements for the solid solution hardening, the amounts of Si and P are preferably set to 0.003 % or more and 0.01 % or more, respectively.

3) Other elements

[0027] C: C is combined with Ti and Nb to form carbides. When the content of C is more than 0.015 %, the amount of carbides is increased, and the r value is extremely decreased. Hence, the content of C is set to 0.015 % or less, preferably 0.008 % or less, and more preferably less than 0.004 %. Since C has the effect of increasing the strength by the precipitation hardening when C precipitates as TiC and NbC, the content of C is preferably set to 0.004 % or more for the steel sheet having the TS of approximately 440 MPa. That is, when the content of C is set to 0.004 to 0.008 %, and the atomic ratio of Ti or Nb against C is 1.0 or more, the increase in the TS can be achieved without decreasing the r value. When the content of C is less than 0.0005 %, the ferrite grains coarsen at annealing, so that the surface defect which is called "orange peel" tends to occur at press forming. Therefore, the content of C is preferably set to 0.0005 % or more.

[0028] Mn: Mn is the effective element for the solid solution hardening which is essential to the IF high strength cold rolled steel sheet. In order to obtain the TS of 340 MPa or more, the content of Mn must be set to 0.4 % or more. When the content of Mn is more than 3 %, the r value is extremely decreased, and hence the content of Mn is set to 3 % or less, preferably 2 % or less, and more preferably 1.5 % or less.

[0029] The reason why the r value is decreased by the increment of Mn content is not clarified; however, it is considered that the decrease in the r value is caused by the interaction of Mn with solute C and by the suppression of the development in the recrystallization texture preferable to the r value at annealing, which is brought about by the fine carbides precipitation and the increase in the amount of solute C at hot rolling because of the decrease in the Ar3 transformation temperature by the addition of Mn.

[0030] S: S exists as sulfides in steel. When the content of S is more than 0.02 %, the ductility is decreased, and hence the content thereof is set to 0.02 % or less, preferably set to 0.01 % or less. In view of descaling, the content of S is preferably set to 0.004 % or more.

[0031] N: When the content of N is more than 0.01 %, fine AlN, NbN, and Nb(C,N) are precipitated in the austenite grain boundaries at slab continuous casting and causes the embrittlement of the grain boundaries, and as a result, the cracking tends to occur in the slab surface at the continuous casting or at the subsequent rough rolling. Hence, the content of N is set to 0.01 % or less. The content of N is preferably decreased as small as possible; however, it is too difficult to decrease the content of N below approximately 0.001 % by the smelting technique.

[0032] Ti: Ti has the effect of improving the r value by the grain refinement of the hot bands or by the decrease in the solute C and N with the formation of precipitates thereof. In order to fully obtain the effect of Ti described above, the content of Ti should be controlled to satisfy the following equation (1).

$$1 \leqq ([Ti]/48)/([C]/12+[N]/14) \qquad (1),$$

where [M] represents the content (mass %) of the element M.

[0033] However, even when the content of Ti is more than 0.2 %, the increase in the r value is small, and hence the content of Ti is set to 0.2 % or less. When the hot-dip galvannealing is performed on the high strength cold rolled steel sheet of the present invention, in order to prevent the non-uniform coating, the content of Ti is preferably set to 0.04 % or less. In addition, in order to obtain the high r value by the addition of Ti, the content of Ti is preferably set to 0.005 % or more.

[0034] The balance includes Fe and the inevitable impurities.

[0035] Besides the elements described above, 0.002 % or more of Nb is preferably further added in order to obtain the higher r value. The contents of Nb, Ti, C, and N must be controlled so as to satisfy the following equation (3).

$$1 \leqq ([Nb]/93+[Ti]/48)/([C]/12+[N]/14) \qquad (3),$$

where [M] represents the content (mass %) of the element M.

[0036] However, when the content of Nb is more than 0.02 %, fine NbN and Nb(C,N) precipitate in the austenite grain boundaries at slab continuous casting and lead to the embrittlement of the grain boundaries, and as a result, the cracking tends to occur in the slab surface at the casting or at the subsequent rough rolling. Hence, the content of Nb is set to 0.02 % or less.

[0037] Furthermore, when 0.0001 % or more of B is added, the resistance to the secondary work embrittlement is improved. However, when the content of B is more than 0.003 %, the effect of improving the anti-secondary work embrittlement is small, and the decrease in the r value and the increase in the rolling take place. Hence, the content of B is set to 0.003 % or less.

[0038] Besides the elements described above, in order to further improve the strength, the resistance to secondary work embrittlement, and the r value, at least one element selected from the group consisting of 0.03 to 0.5 % of Cu, 0.03 to 0.5 % of Ni, 0.03 to 0.5 % of Cr, 0.05 to 0.3 % of Mo, and 0.005 to 0.5 % of V may be added. Since Cu and Cr deteriorate the surface quality, the contents thereof are each set to 0.5 % or less. The addition of Ni causes the remarkable increase in cost, and hence the content thereof is set to 0.5 % or less. Although Mo has the less adverse influence on the resistance to the secondary work embrittlement and is effective for increasing the strength, the addition of Mo causes the increase in the yield strength which deteriorates the accuracy of the surface shape after press forming. Hence, the content of Mo is set to 0.3 % or less. Although V has also the less adverse influence on the resistance to the secondary work embrittlement and is effective for increasing the TS, the cost is largely increased when the content is more than 0.5 %. Hence, the content of V is set to 0.5 % or less. In addition, when Cu is added, Ni is preferably added with the content equivalent to that of Cu.

[0039] In order to improve the zinc coating appearance, the zinc coating adhesion, the resistance to the fatigue, the anti-secondary work embrittlement, or the like, it is effective that at least one element selected from the group consisting of 0.002 to 0.2 % of Sb and 0.002 to 0.2 % of Sn is contained, and that the following equation (4) is satisfied.

$$0.002 \leqq [Sb]+[Sn]/2 \leqq 0.2 \qquad (4),$$

where [M] represents the content (mass %) of the element M.

[0040] The addition of Sb and Sn prevents the surface nitridation and oxidation of the steel at slab heating, coiling, or annealing in a box annealing furnace (BAF), a continuous annealing line (CAL), a continuous hot-dip galvanizing line (CGL), and hence improves the non-uniform coating and the deterioration of the coating adhesion. In addition, the surface appearance can also be improved by the prevention of the adhesion of zinc oxides in a molten zinc bath. Furthermore, Sb and Sn reduce the surface oxidation and suppress the degradation in the resistance to the fatigue and the degradation in the toughness after press forming.

[0041] However, when the contents of Sb and Sn exceed 0.2 %, the zinc coating adhesion and the toughness deteriorate.

4) Manufacturing method

[0042] The high strength cold rolled steel sheet of the present invention can be manufactured by a method comprising the steps of: heating a slab having the chemical composition described above at 1,080 to 1,350 °C; hot rolling the heated slab at a finishing temperature between (the Ar3 transformation temperature-20) °C and (the Ar3 transformation temperature+150) °C into a hot rolled steel sheet; coiling the hot rolled steel sheet at a coiling temperature CT which satisfies the following equation (5) when Nb is not added or the following equation (6) when Nb is added; cold rolling the hot rolled steel sheet with a reduction of 50 to 90 % into a cold rolled steel sheet; and continuously annealing the cold rolled steel sheet at a temperature of 750 to 870 °C or box annealing the cold rolled steel sheet at a temperature of 600 to 750 °C.

$$480 \leqq CT \leqq 580+0.17/\{([Ti]+0.08\times[sol.Al])\times[P]\} \qquad (5),$$

and

$$480 \leqq CT \leqq 580+0.17/\{(0.6\times[Nb]+[Ti]+0.08\times[sol.Al])\times[P]\} \qquad (6),$$

where [M] represents the content (mass %) of the element M.

[0043] In order to sufficiently dissolve the phosphides such as Fe-Ti-P or Fe-Nb-P formed in the slab, the heating temperature SRT before hot rolling is set to 1,080 °C or more. However, when the temperature is more than 1,350 °C, the surface quality deteriorates. Therefore, the SRT is set to 1,350 °C or less.

[0044] In order to obtain the excellent surface appearance, not only the primary scale but also the secondary scale at hot rolling should be sufficiently removed. During the hot rolling, heating by using a bar heater may also be performed.

[0045] The finishing temperature FDT of hot rolling is set to the temperature between (the Ar3 transformation temperature-20) °C and (the Ar3 transformation temperature+150) °C for the grain refinement of hot bands.

[0046] The coiling temperature after hot rolling has the significant influence on the r value of the cold rolled steel sheet of the present invention which contains Al, P, and Ti and also contains Nb when it is necessary to be added. In the IF steel containing P, the phosphides such as Fe-Ti-P and Fe-Nb-P unfavorable for the r value tend to be precipitated. In general, the r value is significantly improved due to the coarsening of precipitates and the decrease in solute C by soaking at the high coiling temperature. However, when the coiling temperature is higher than the appropriate temperature, the phosphides as above mentioned are formed, and as a result, the r value is extremely decreased.

[0047] Through studies on the optimum coiling temperatures for various types of steel containing Al, P, and Ti and also containing Nb when it is necessary to be added, it is found that when the coiling temperature CT is more than $580+0.17/\{([Ti]+0.08\times[sol.Al])\times[P]\}$ in which Nb is not added or is more than $580+0.17/\{(0.6\times[Nb]+[Ti]+0.08\times [sol.Al])\times[P]\}$ in which Nb is added, the phosphides are formed, and which causes the remarkable decrease in the r value. When the coiling temperature CT is less than 480 °C, even when the phosphides are not formed, precipitation of carbides becomes insufficient at coiling, decreasing the r value. Hence, the coiling temperature CT must satisfy the equation (5) or (6).

[0048] The coiling temperature is preferably in the range between (the maximum value-40) °C and (the maximum value) °C in the equation (5) or (6).

[0049] In view of the improvement in the r value, the reduction of the cold rolling is set to 50 to 90 %, preferably to 65 to 80 %.

[0050] The annealing temperature AT is set to 750 to 870 °C when the continuous annealing is performed in CAL or CGL. When the annealing temperature AT is less than 750 °C, the ferrite recrystallization does not occur sufficiently, and hence the high r value cannot be obtained. In addition, the elongation becomes extremely small. When the annealing temperature AT is more than 870 °C and more than the Ar3 transformation temperature in case of the steel containing high Mn content, the strength is extremely increased, and the elongation and the n value are extremely decreased. In order to obtain the higher r value and the higher elongation, the annealing temperature is preferably 820 °C or more. In addition, since the annealing time is long in case of the box annealing, the annealing temperature is set in the range of 600 to 750 °C.

[0051] The coating containing zinc may be formed on the annealed steel sheet by the electrolytic coating or the hot-dip coating. The coating containing zinc may be, for example, zinc coating, alloy zinc coating, zinc-nickel alloy coating, or the like. In addition, after the coating, the organic film may be also coated.

Example

[0052] Various types of steel Nos. A to X shown in Table 1 were smelt and continuously cast into slabs having a thickness of 230 mm. After heating these slabs at the heating temperature SRT shown in Table 2, they were hot rolled to 3.2 mm thick at the finishing temperature FDT shown in Table 2, followed by the coiling at the coiling temperature CT shown in Table 2. The hot bands were cold to 0.8 mm thick and subsequently annealed at the annealing temperature AT shown in Table 2 in CAL, CGL, or BAF, followed by skin pass rolling with the elongation of 0.8 %, thereby producing steel sheet Nos. 1 to 34. In CGL, the annealed steel sheets were immersed in the molten zinc bath at the temperature of 460 °C, and heated at the temperature of 500 °C in the in-line alloying furnace. The amount of zinc on one side surface was 45 g/m^2.

[0053] The r value and the TS were measured by the methods described above. In addition, the surface defects were measured by eye inspection so as to evaluate the surface quality.

[0054] The results are shown in Table 2.

[0055] In both Tables 1 and 2, [Nb] of the equation in the topmost column is zero when Nb is not added.

[0056] In steel sheets Nos. 1 to 24 according to the examples of the present invention, the r value is 1.8 or more when the TS is 340 to 400 MPa, the r value is 1.6 or more when the TS is 400 to 590 MPa, and the surface quality is also superior. In addition, compared to steel sheets of comparative examples having equivalent strength to that of the examples, it is understood that the r value of the examples of the present invention is significantly high. In particular, when the content of Mn is more than 1 %, the effect described above becomes remarkable.

[0057] On the other hand, in steel sheets Nos. 25 to 34 according to the comparative examples, neither the r value of 1.8 or more at the TS of 340 to 400 MPa nor the r value of 1.6 or more at the TS of 400 to 590 MPa can be obtained. In steel sheets Nos. 27, 28, and 29 corresponding to the conventional high strength cold rolled steel sheet containing the large amount of Mn, the r value is small. In addition, in steel sheets Nos. 30, 31, 32, 33, and 34, at least one of the ratio (Nb+Ti)/(C+N), the content of C, that of Si, that of Mn, that of P, that of sol.Al, and that of Nb is out of the range of the present invention, and hence the r value is small. In particular, according to steel sheet No. 30 among those mentioned above corresponding to the conventional low carbon high strength cold rolled steel sheet, in which the content of C and the ratio (Nb+Ti)/(C+N) are not appropriately controlled and in which solute C and Mn coexist, even when the content of sol.Al is increased, the high r value cannot be obtained. According to steel sheets Nos. 31 and 34, in which the content of Nb and the contents of Nb and sol.Al are out of the range of the present invention, respectively, the surface quality is inferior.

[0058] In addition, it is understood that according to steel sheet No. 25 corresponding to the conventional mild cold rolled steel sheet SPC270F and steel sheet No. 26 which contains the large amount of sol.Al, the effect of the addition of sol.Al on the improvement in the r value is small when the contents of Mn and P are small.

TABLE 1

Mass %

Steel No.	C	Si	Mn	P	S	sol.Al	N	Nb	Ti	B	Others	[Si]+10×[P]	([Nb]/93+[Ti]/48)/([C]/12+[N]/14)	Remarks
A	0.0025	0.01	0.6	0.040	0.004	0.22	0.0026	-	0.032	0.0005	-	0.41	1.7	Invention
B	0.0018	0.01	0.9	0.070	0.004	0.28	0.0014	-	0.036	0.0008	-	0.71	3.0	Invention
C	0.0022	0.20	1.9	0.065	0.006	0.35	0.0016	0.009	0.035	0.0018	-	0.85	2.8	Invention
D	0.0013	0.20	2.2	0.064	0.006	0.15	0.0017	0.010	0.035	0.0012	-	0.84	3.6	Invention
E	0.0022	0.20	1.2	0.062	0.006	1.0	0.0016	0.009	0.035	0.0006	-	0.82	2.8	Invention
F	0.0019	0.20	2.1	0.010	0.006	0.35	0.0016	0.009	0.035	0.0014	-	0.30	3.0	Invention
G	0.0140	0.50	2.7	0.070	0.006	0.70	0.0018	-	0.070	0.0023	-	1.20	1.1	Invention
H	0.0014	0.01	0.6	0.030	0.006	0.35	0.0012	-	0.020	-	-	0.31	2.1	Invention
I	0.0013	0.21	2.0	0.064	0.006	0.32	0.0031	0.016	0.050	0.0009	-	0.85	3.7	Invention
J	0.0012	0.21	2.3	0.062	0.004	0.29	0.0022	-	0.102	0.0015	-	0.83	8.3	Invention
K	0.0070	0.01	1.8	0.061	0.004	0.25	0.0014	0.010	0.070	0.0005	-	0.62	2.3	Invention
L	0.0042	0.17	1.5	0.065	0.005	0.25	0.0021	-	0.060	0.0008	Cu:0.2,Ni:0.2	0.82	2.5	Invention
M	0.0041	0.18	1.4	0.068	0.004	0.27	0.0014	0.015	0.060	0.0011	Cr:0.2,Mo:0.27	0.86	3.2	Invention
N	0.0035	0.21	1.7	0.066	0.005	0.24	0.0012	-	0.065	0.0012	Sb:0.01	0.87	3.6	Invention
O	0.0020	0.01	0.15	0.008	0.006	0.03	0.0018	-	0.08	0.0002	-	0.09	5.6	Comparative
P	0.0019	0.01	0.10	0.008	0.008	0.25	0.0014	-	0.08	0.0002	-	0.09	6.5	Comparative
Q	0.0027	0.01	0.8	0.040	0.005	0.04	0.0024	-	0.033	0.0005	-	0.41	1.7	Comparative
R	0.0020	0.01	1.2	0.070	0.003	0.04	0.0015	-	0.036	0.0010	-	0.71	2.7	Comparative
S	0.0023	0.20	2.4	0.075	0.006	0.03	0.0016	0.010	0.035	0.0017	-	0.95	2.7	Comparative
T	0.017	0.01	0.4	0.050	0.003	0.29	0.0029	-	0.010	0.0005	-	0.51	0.1	Comparative
U	0.0018	1.80	0.3	0.010	0.006	0.20	0.0022	0.040	0.031	0.0005	-	1.90	3.5	Comparative
V	0.0016	0.20	3.2	0.050	0.005	0.21	0.0013	0.015	0.030	0.0006	-	0.70	3.5	Comparative
W	0.0025	0.01	0.7	0.18	0.004	0.20	0.0021	-	0.035	0.0004	-	1.81	2.0	Comparative
X	0.0036	0.01	0.7	0.060	0.001	1.80	0.0024	0.050	0.010	0.0007	-	0.61	1.6	Comparative

Underlined : Out of the range of the present invention

TABLE 2

Steel sheet No	Steel No	Hot rolling conditions			Annealing condition	Annealing line	Mechanical properties		Surface quality*2	580+0.17/{(0.6[Nb]+ [Ti] +0.08[sol.Al])[P]}*1	Remarks
.		SRT (°C)	FDT (°C)	CT (°C)	AT (°C)		r value	TS (MPa)			
1	A	1250	890	640	840	CGL	1.89	347	○	666	Example
2		1250	890	540	720	BAF	1.86	342	○	666	Example
3		1280	990	640	840	CGL	1.85	345	○	666	Example
4		1220	850	640	840	CGL	1.90	349	○	666	Example
5		1220	780	640	840	CGL	1.77	340	○	666	Example
6	B	1220	870	620	770	CGL	1.83	408	○	622	Example
7		1220	870	620	840	CGL	1.87	395	○	622	Example
8		1220	870	620	870	CGL	1.88	390	○	622	Example
9		1300	975	620	870	CGL	1.85	385	○	622	Example
10		1220	840	620	870	CGL	1.90	392	○	622	Example
11		1220	760	620	870	CGL	1.85	387	○	622	Example
12	C	1220	850	580	820	CGL	1.81	446	○	618	Example
13		1220	850	615	820	CGL	1.85	444	○	618	Example
14	D	1220	850	620	820	CGL	1.66	440	○	630	Example
15	E	1250	940	600	830	CGL	1.73	442	○	603	Example
16	F	1220	860	680	800	CGL	1.75	403	○	-	Example
17	G	1290	840	580	860	CAL	1.60	530	○	599	Example
18	H	1220	890	670	850	CGL	1.90	340	○	698	Example
19	I	1220	840	600	820	CGL	1.90	440	○	611	Example

*1 The value more than 800 °C is represented by -.

*2 ○: No surface defect or acceptable surface level

×: Surface degradation due to surface defect caused by scale

TABLE 2 (continued)

Steel sheet No	Steel No	Hot rolling conditions			Annealing condition	Annealing line	Mechanical properties		Surface quality*2	580+0.17/{(0.6[Nb]+ [Ti] +0.08[sol.Al]) [P]}*1	Remarks
.		SRT (°C)	FDT (°C)	CT (°C)	AT (°C)		r value	TS (MPa)			
20	J	1220	830	580	790	CAL	1.85	445	○	602	Example
21	K	1220	830	600	830	CGL	1.96	440	○	609	Example
22	L	1220	850	600	840	CGL	1.89	442	○	613	Example
23	M	1220	850	600	840	CGL	1.85	449	○	608	Example
24	N	1220	850	600	830	CGL	1.82	445	○	611	Example
25	O	1200	910	680	830	CGL	1.82	289	○	-	Comparative
26	P	1200	930	680	830	CGL	1.83	294	○	793	Comparative
27	Q	1230	880	640	830	CGL	1.69	340	○	697	Comparative
28	R	1220	880	640	820	CGL	1.62	392	○	642	Comparative
29	S	1220	840	640	800	CGL	1.46	440	○	632	Comparative
30	T	1220	890	680	770	CGL	1.12	405	○	682	Comparative
31	U	1270	950	640	820	CAL	1.40	480	×	-	Comparative
32	V	1270	840	640	800	CAL	1.43	450	○	641	Comparative
33	W	1270	950	600	820	CAL	1.49	475	○	599	Comparative
34	X	1290	1000	600	820	CAL	1.52	444	×	595	Comparative

*1 The value more than 800 °C is represented by -.

*2 ○: No surface defect or acceptable surface level
×: Surface degradation due to surface defect caused by scale

Claims

1. A high strength cold rolled steel sheet consisting of 0.015 % or less of C, 1.5 % or less of Si, 0.4 to 3 % of Mn, 0.15 % or less of P, 0.02 % or less of S, 0.1 to 1 % of sol.Al, 0.01 % or less of N, 0.2 % or less of Ti, by mass %, and the balance of Fe and inevitable impurities,
   wherein the following equation (1) is satisfied;

$$1 \leqq ([Ti]/48)/([C]/12+[N]/14) \qquad (1),$$

   where [M] represents the content (mass %) of the element M.

2. The high strength cold rolled steel sheet according to Claim 1, wherein the content of sol.Al is 0.2 to 0.7 %.

3. The high strength cold rolled steel sheet according to Claim 1, wherein the following equation (2) is satisfied;

$$0.3 \leqq [Si]+10\times[P] \leqq 1.4 \qquad (2),$$

   where [M] represents the content (mass %) of the element M.

4. The high strength cold rolled steel sheet according to Claim 2, wherein the following equation (2) is satisfied;

$$0.3 \leqq [Si]+10\times[P] \leqq 1.4 \qquad (2),$$

   where [M] represents the content (mass %) of the element M.

5. The high strength cold rolled steel sheet according to Claim 1, further comprising, by mass %, 0.002 to 0.02 % of Nb, wherein the following equation (3) is satisfied;

$$1 \leqq ([Nb]/93+[Ti]/48)/([C]/12+[N]/14) \qquad (3),$$

   where [M] represents the content (mass %) of the element M.

6. The high strength cold rolled steel sheet according to Claim 4, further comprising, by mass %, 0.002 to 0.02 % of Nb, wherein the following equation (3) is satisfied;

$$1 \leqq ([Nb]/93+[Ti]/48)/([C]/12+[N]/14) \qquad (3),$$

   where [M] represents the content (mass %) of the element M.

7. The high strength cold rolled steel sheet according to Claim 1, further comprising, by mass %, 0.0001 to 0.003 % of B.

8. The high strength cold rolled steel sheet according to Claim 6, further comprising, by mass %, 0.0001 to 0.003 % of B.

9. The high strength cold rolled steel sheet according to Claim 1, further comprising, by mass %, at least one element selected from the group consisting of 0.03 to 0.5 % of Cu, 0.03 to 0.5 % of Ni, 0.03 to 0.5 % of Cr, 0.05 to 0.3 % of Mo, and 0.005 to 0.5 % of V.

10. The high strength cold rolled steel sheet according to Claim 8, further comprising, by mass %, at least one element selected from the group consisting of 0.03 to 0.5 % of Cu, 0.03 to 0.5 % of Ni, 0.03 to 0.5 % of Cr, 0.05 to 0.3 % of Mo, and 0.005 to 0.5 % of V.

11. The high strength cold rolled steel sheet according to Claim 1, further comprising, by mass %, at least one element selected from the group consisting of 0.002 to 0.2 % of Sb and 0.002 to 0.2 % of Sn, wherein the following equation (4) is satisfied;

$$0.002 \leqq [Sb]+[Sn]/2 \leqq 0.2 \qquad (4),$$

where [M] represents the content (mass %) of the element M.

12. The high strength cold rolled steel sheet according to Claim 10, further comprising, by mass %, at least one element selected from the group consisting of 0.002 to 0.2 % of Sb and 0.002 to 0.2 % of Sn, wherein the following equation (4) is satisfied;

$$0.002 \leqq [Sb]+[Sn]/2 \leqq 0.2 \qquad (4),$$

where [M] represents the content (mass %) of the element M.

13. A method for manufacturing a high strength cold rolled steel sheet, comprising the steps of:

heating a slab having the chemical composition according to one of Claims 1 to 12 at 1,080 to 1,350 °C;
hot rolling the heated slab at a finishing temperature between (the Ar3 transformation temperature-20) °C and (the Ar3 transformation temperature+150) °C into a hot rolled steel sheet;
coiling the hot rolled steel sheet at a coiling temperature CT which satisfies the following equation (5) or (6) ;
cold rolling the hot rolled steel sheet with a reduction of 50 to 90 % into a cold rolled steel sheet; and
continuously annealing the cold rolled steel sheet at a temperature of 750 to 870 °C or box annealing the cold rolled steel sheet at a temperature of 600 to 750 °C;

$$480 \leqq CT \leqq 580+0.17/\{([Ti]+0.08\times[sol.Al])\times[P]\} \qquad (5),$$

and

$$480 \leqq CT \leqq 580+0.17/\{(0.6\times[Nb]+[Ti]+0.08\times[sol.Al])\times[P]\} \cdots (6), \qquad (6),$$

where [M] represents the content (mass %) of the element M.

FIG. 1

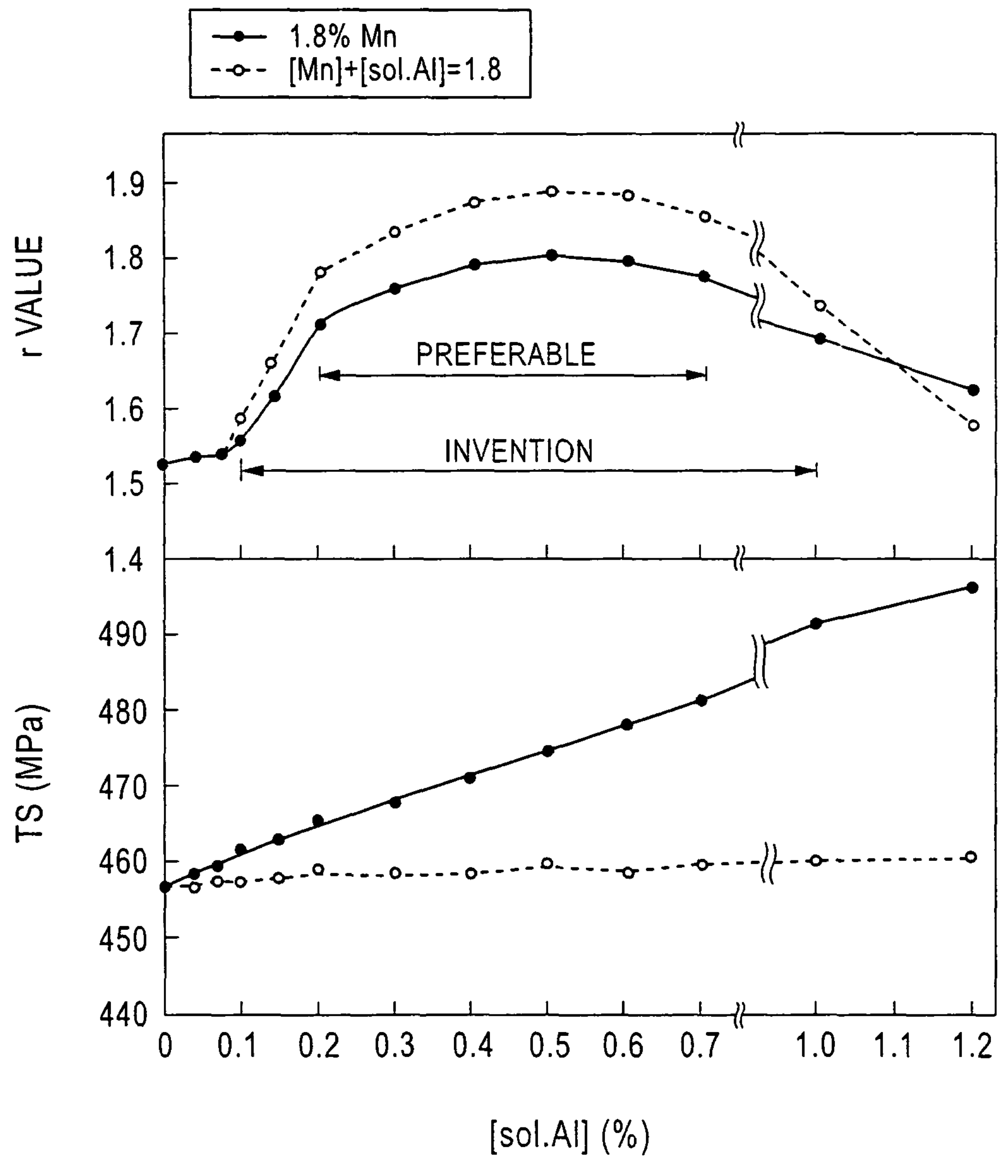
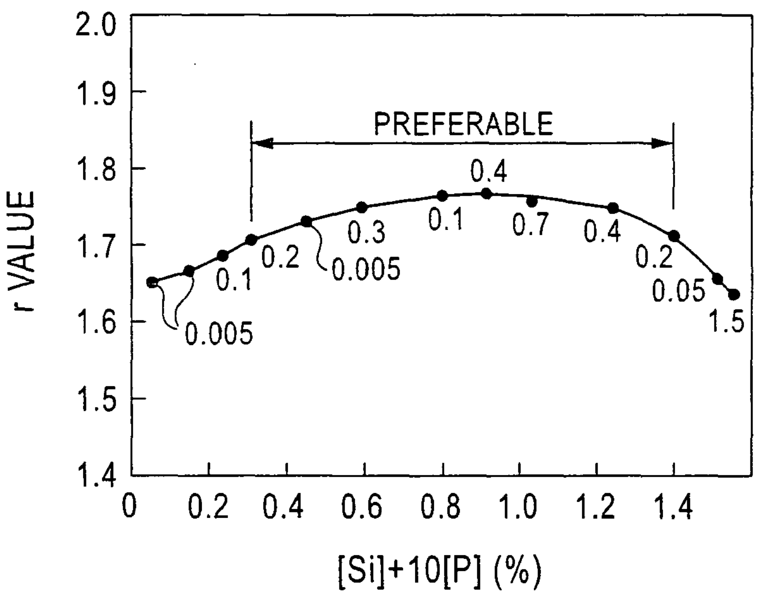

1.8% Mn
[Mn]+[sol.Al]=1.8
r VALUE
1.9
1.8
1.7
1.6
1.5
1.4
PREFERABLE
INVENTION
TS (MPa)
490
480
470
460
450
440
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1.0
1.1
1.2
[sol.Al] (%)

FIG. 2


2.0
1.9
1.8
1.7
1.6
1.5
1.4
r VALUE
PREFERABLE
0.4
0.1
0.7
0.4
0.3
0.2
0.1
0.005
0.005
0.2
0.05
1.5
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
[Si]+10[P] (%)

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EUROPEAN SEARCH REPORT

Application Number
EP 05 00 3676

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X A	US 2003/129444 A1 (MATSUOKA SAIJI ET AL) 10 July 2003 (2003-07-10) * paragraph [0091]; claims 1-24; tables 1a-8b *	1-6,9-13 7,8	C21D8/00 C21D9/46 C22C38/00
X A	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 10, 17 November 2000 (2000-11-17) & JP 2000 199030 A (KAWASAKI STEEL CORP), 18 July 2000 (2000-07-18) * abstract; tables 1,2 *	1-10,13 11,12	
X A	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 10, 17 November 2000 (2000-11-17) & JP 2000 199031 A (SUMITOMO METAL IND LTD), 18 July 2000 (2000-07-18) * abstract; tables 1-5 *	1-10,13 11,12	
X	KR 2001 061 575 A (POHANG IRON & STEEL CO., LTD) 7 July 2001 (2001-07-07) * abstract *	1-6,13	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
X	KR 2003 052 355 A (POSCO) 27 June 2003 (2003-06-27) * abstract *	1-6,13	C21D C22C
X	KR 2003 052 208 A (POSCO) 26 June 2003 (2003-06-26) * abstract *	1-6,13	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	14 June 2005	Chebeleu, A

CATEGORY OF CITED DOCUMENTS

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1

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14-06-2005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003129444 A1	10-07-2003	JP 2002226941 A	14-08-2002
		JP 2002226942 A	14-08-2002
		AU 776043 B2	26-08-2004
		AU 2411802 A	11-06-2002
		CA 2398126 A1	06-06-2002
		CN 1419607 A	21-05-2003
		EP 1338667 A1	27-08-2003
		WO 0244434 A1	06-06-2002
		TW 520398 B	11-02-2003
JP 2000199030 A	18-07-2000	NONE	
JP 2000199031 A	18-07-2000	NONE	
KR 2001061575 A	07-07-2001	NONE	
KR 2003052355 A	27-06-2003	NONE	
KR 2003052208 A	26-06-2003	NONE	

EPO FORM P0459

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