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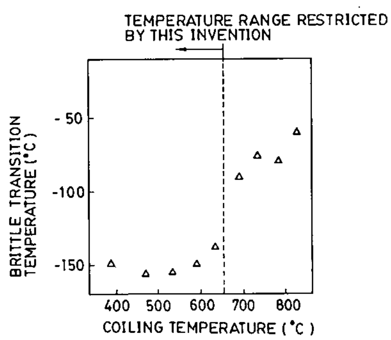
(54) Method of manufacturing a cold rolled steel sheet exhibiting an excellent resistance to cold-work embrittlement and a small planar anisotropy.

(57) A method of manufacturing a cold rolled steel sheet includes the steps of preparing, as a material, a steel whose composition consists of C : 0.004 wt% or less, Si : 0.10 wt% or less, Mn : 0.50 wt% or less, Ti : between 0.01 wt% and 0.10 wt%, Nb : between 0.003 wt% and 0.03 wt%, B : between 0.001 wt% and 0.004 wt%, Al : between 0.03 wt% and 0.10 wt%, P : 0.025 wt% or less, S :0.01 wt% or less, N : 0.006 wt% or less; performing a hot rolling on the material steel under the conditions of a finishing temperature between 800 °C and 900 °C; coiling the material at a temperature lower than 650 °C; performing a cold rolling; performing a continuous annealing at a temperature between 830 °C and Ac_3 transformation point; and performing a skin pass rolling.

FIG. 1 (a)



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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method of manufacturing a cold rolled steel sheet that exhibits excellent resistance to cold-work embrittlement and a small planar anisotropy by the continuous annealing method which is suitable as a pressed steel sheet for use in automobiles.

Description of the Related Art

When a cold rolled steel sheet is manufactured, a continuous annealing, including heating and cooling which last for a short period of time, is generally conducted subsequent to the cold rolling. In this continuous annealing process, the material quality of the product is greatly affected by the chemical composition of the material. Hence, to obtain a steel sheet exhibiting excellent deep drawing property and stretchability, it has been the practice to add a carbide/nitride producing component, such as Ti or Nb, to the extra low carbon steel.

However, the steel sheet in which Ti or Nb is present is characterized in that Ti is readily combined with C, S, N or O in the steel to form a precipitate. Consequently, the grain boundary is cleaned and the grain boundary strength is thus greatly reduced, increasing the possibility that a brittle fracture (the fracture due to cold-work embrittlement) will occur after deep drawing. Also, it has been a practice to obtain a high-strength steel sheet by adding Mn, Si or P to the steel material. In that case, however, since Si and P readily embrittle the steel sheet, the resistance to cold-work embrittlement greatly deteriorates. To improve such a drawback, B has been added to the steel in the form of a solid solution to increase the grain boundary strength, like C.

However, it is well known that adding B deteriorates the formability. Therefore, the proportion of B to be added is restricted to such a small value that sufficient resistance to cold-work embrittlement cannot be obtained.

Various other methods of improving the deep drawing property and stretchability of the steel sheet by controlling the conditions of hot rolling, cold rolling or annealing during the manufacturing process of the steel sheet have also been suggested. Generally, the hot rolling finishing temperature is set to an Ar_3 transformation point or above from the viewpoint of improving the deep drawing property. The coiling temperature is between 650 and 800°C from the viewpoint of improving the formability, especially deep drawing properties. The annealing temperature is set to a relatively low temperature which is equal to or higher than the recrystallization temperature and which is effective in terms of the energy.

Japanese Patent Laid-Open No. 62-278232 discloses a method of manufacturing a cold rolled steel sheet of the aforementioned type for use in non-aging deep drawing by the direct hot-rolling method. Japanese Patent Laid-Open No. 1-177321 discloses a method of manufacturing a cold rolled steel sheet of the aforementioned type which exhibits an excellent deep drawing property. Japanese Patent Laid-Open No. 2-200730 discloses a method of manufacturing a cold rolled steel sheet of the aforementioned type which exhibits an excellent press formability. In any of these methods, although B is added to improve the resistance to cold-work embrittlement, there is no concrete disclosure to exhibit brittle transition temperature. Also, coiling is performed at a high temperature of 640°C or above which impairs descaling ability in a pickling process. Therefore, in any of these methods, a sufficient improvement in the resistance to cold-work embrittlement cannot be expected.

Japanese Patent Laid-Open No. 63-241122 discloses a method of manufacturing a continuously galvanized steel sheet for use in a super deep drawing. In this method, the proportion of B contained is 0.0010 % or below, which is too small to improve the resistance to cold-work embrittlement.

Japanese Patent Laid-Open No. 62-40318 discloses a method of manufacturing a cold rolled steel sheet exhibiting an excellent deep drawing property. Japanese Patent Laid-Open No. 1-188630 discloses a method of manufacturing a cold rolled steel sheet exhibiting an excellent press formability. However, in any of these methods, there is no concrete description of the resistance to cold-work embrittlement, and annealing is conducted at a temperature ranging between the recrystallization temperature and 800°C. Therefore, a sufficient improvement of the resistance to cold-work embrittlement cannot be expected.

Japanese Patent Laid-Open No. 61-133323 discloses a method of manufacturing a steel sheet exhibiting an excellent formability. Japanese Patent Laid-Open No. 62-205231 discloses a method of manufacturing a high-strength steel sheet. Both of these methods are directed to the manufacture of a slab thinner than a normal one and to alleviation or simplification of the rolling process of steel sheet using such a thin slab. However, in the former method, there is no concrete description on the conditions of the annealing which is conducted subsequent to the cold rolling process. Although there is a concrete disclosure of the resistance to cold-work embrittlement, the effect thereof is insufficient. In the latter method, there is a concrete disclosure of the annealing which is conducted at a temperature of 775°C or below. However, sufficient improvement in the resistance to cold-work embrittlement cannot be expected under such conditions.

In any of the aforementioned conventional methods, it is thus difficult to readily obtain a cold rolled steel sheet exhibiting an excellent deep drawing property and an excellent resistance to cold-work embrittlement.

Planar anisotropy, known as one of barometers of the press formability, is generally evaluated by Δr. The closer to zero the planar anisotropy value is, the more uniform characteristics in each direction can be obtained, which is desirable in terms of press formability. Japanese Patent Laid-Open No. 61-64852 discloses a method of improving this planar anisotropy by adding a relative large amount of Nb in an extra low carbon steel. Although this method is effective in improving the planer anisotropy, it deteriorates elongation (El) or r value. No method of improving the resistance to cold-work embrittlement as well as the planar anisotropy has been disclosed.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method of manufacturing a cold rolled steel sheet for use in deep drawing which exhibits an excellent resistance to cold-work embrittlement and a small planar anisotropy while maintaining an excellent deep drawing property without the need for finely controlling the manufacturing conditions even when a continuous annealing process is employed.

The present inventors have made intensive studies on the composition to be added and the manufacturing method and discovered that it is possible to manufacture a cold rolled steel sheet for use in deep drawing which exhibits an excellent resistance to cold-work embrittlement and a small planar anisotropy from an extra low carbon steel in which Ti, Nb, B and Al are present each in an adequate amount by adequately setting the hot rolling and annealing conditions in the manufacturing process.

That is, the present invention provides a method of manufacturing a cold rolled steel sheet which exhibits an excellent resistance to cold-work embrittlement and a small planar anisotropy which comprises the steps of preparing, as a material, a steel whose composition consists of:

C :	0.004 wt% or less
Si :	0.10 wt% or less
Mn :	0.50 wt% or less
Ti :	between 0.01 wt% and 0.10 wt%
Nb :	between 0.003 wt% and 0.03 wt%
B :	between 0.001 wt% and 0.004 wt%
Al :	between 0.03 wt% and 0.10 wt%
P :	0.025 wt% or less
S :	0.01 wt% or less
N :	0.006 wt% or less

Ti and C satisfying the following equation:

$$3 \leqq Ti^*/C \leqq 12$$

where

$$Ti^* = Ti - (48/14)N - (48/32)S$$

balance : iron and unavoidable impurities, performing a hot rolling on the material steel under the conditions of a finish temperature between 800°C and 900°C, coiling the material at a temperature lower than 650°C, performing a cold rolling, performing a continuous annealing at a temperature between 830°C and an Ac_3 transformation point, and performing skin pass rolling.

Other features and variations of the present invention will be apparent from the following description taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1(a) is a graph showing the relationship between the coiling temperature and the brittle transition temperature;

Fig. 1(b) is a graph showing the coiling temperature and the planar anisotropy (Δr);

Fig. 2(a) is a graph showing the relation between the annealing temperature and the brittle transition temperature;

Fig. 2(b) is a graph showing the relation between the annealing temperature and the planar anisotropy (Δr); and

Fig. 3 is a graph showing the relation between the thickness of the steel and the brittle transition temperature regarding steels in which different amounts of B are present.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will be described below concretely.

First, the reason for the restrictions placed on the compositions will be explained.

C : 0.004 wt% or less

A smaller possible proportion of C is advantageous to improve the material quality. An increase in the amount of C contained increases the amount of Ti required to fix C, thus increasing the amount of precipitates produced and thereby deteriorating the material quality. More than 0.004 wt% of C greatly deteriorates the material quality. Therefore, up to 0.004 wt% of C is preferred.

Si : 0.10 wt% or less

Although the presence of Si is advantageous to obtain adequate steel strength, it promotes the cold-work embrittlement and degrades the phosphatability. Thus, the upper limit of the proportion of Si is set to 0.10 Wt%.

Mn : 0.50 wt% or less

Although the inclusion of Mn is effective to obtain an adequate strength of the steel, as in the case of Si, it increases the tendency for a solid solution to be produced and hence deteriorates the drawing property. The presence of Mn also increases the production cost. Hence, the upper limit of the proportion of Mn is set to 0.50 wt%.

Ti : 0.01 to 0.1 wt%

$3 \leqq Ti^*/C \leqq 12$

where $Ti^* = Ti - (48/14)N - (48/32)S$

The presence of Ti promotes precipitation of N and S and hence improves the deep drawing property. That is, in a cold rolled steel sheet on which the continuous annealing has been conducted, a reduction in the amounts of C, N and S contained alone is not enough to provide the press formability which is as good as that of a steel sheet which has been subjected to the box annealing process. In this invention, Ti promotes precipitation of N and S in the hot rolling process. Precipitation of C is promoted by a combination of Ti and Nb which will be described below. Precipitation of N by Ti enables B to be present in a solid solution which is effective to improve the resistance to cold-work embrittlement.

To stabilize C, N and S, at least 0.01 wt% of Ti must be added. More than 0.1 wt% of Ti does not increase the effect thereof.

Furthermore, it is necessary for Ti and C to be added in a range which satisfies the following equation (1):

$$3 \leqq Ti^*/C \leqq 12$$

where $Ti^* = Ti - (48/14)N - (48/32)S$.

The amount of Ti obtained by the above equation is the effective amount of Ti other than the amount which is consumed as nitride or sulfide. When $Ti^*/C < 3$, if coiling is performed at a low temperature of 650°C or less during the hot rolling process, as in the case of the present invention, part of C remains in the form of a solid solution, deteriorating the deep drawing property. When $Ti^*/C > 12$, although the deep drawing property does not deteriorate, the phosphatability deteriorates. As a result, $3 \leqq Ti^*/C \leqq 12$.

Nb : 0.003 to 0.03 wt%

The presence of Nb, which is a carbide forming component, improves the deep drawing property. The addition of Nb together with Ti increases the average r value and elongation. At least 0.003 wt% is required to obtain the effect of Nb. However, more than 0.03 wt% of Nb reduces the elongation. Thus, the desired proportion of Nb is between 0.003 wt% and 0.03 wt%.

B : 0.001 to 0.004 wt%

As mentioned above, the addition of B intensifies the grain boundary, like C, and hence improves the resistance to cold-work embrittlement. However, an excessive proportion of B increases the tendency for the average r value and elongation to deteriorate, and thus is not desirable in terms of the steel sheet for use in deep drawing. A preferred proportion of B is between 0.001 wt% and 0.004 wt%.

Al : 0.03 to 0.1 wt%

Al is a nitride forming component. The addition of Al together with Ti and Nb forms composite precipitates which are inferred as (Ti, Nb)C and (Ti, Al)N and hence promotes precipitation of C and N. It also improves the formability, particularly, the deep drawing property and reduces the planar anisotropy. At least 0.03 wt% of Al is necessary for the above-mentioned effects. More than 0.1 wt% of Al does not improve the effect of Al and increases the production cost. Therefore, a desired proportion of Al is between 0.03 wt% and 0.1 wt%.

P : 0.025 wt% or less

An excessive proportion of P increases the amount of grain boundary which is segregated and hence promotes the grain boundary embrittlement, and thus, deteriorates the resistance to cold-work embrittlement. Hence, the smaller the proportion of P, the better. 0.025 wt% or less of P is allowable.

S : 0.01 wt% or less

An excessive proportion of S, which is a hazardous component, readily promotes the grain boundary embrittlement and thus deteriorates the resistance to cold-work embrittlement. Thus, a smaller possible proportion of S is desired. 0.01 wt% or less of S is allowable.

N : 0.006 wt% or less

Like C, a smaller possible proportion of N is desirable from the viewpoint of improvement in the formability, particularly, deep drawing properties. The presence of N also deteriorates the resistance to strain aging. Thus, up to 0.006 wt% of N is allowable.

The reason for the restrictions placed on the manufacturing process conditions in the present invention will be described below.

Steel making process

Steel may be manufactured in a normal method which employs, for example, a converter. There is no restriction on the conditions of the steel making process.

Steel may be manufactured in a normally employed continuous casting or ingot casting method.

Hot rolled process

Finishing temperature : 800 to 900 °C

A finishing temperature lower than 800 °C deteriorates the average r value and the elongation due to residual strain. A finishing temperature higher than 900 °C increases the size of the grains and hence deteriorates the average r value. Thus, a desired finishing temperature range is from 800 °C and 900 °C.

Coiling temperature : lower than 650 °C

Conventionally, a high coiling temperature ranging from 650 °C to 800 °C has been employed because it has been considered that coiling conducted at such a high temperature further increases the size of the TiC precipitates and thus improves the elongation and average r value. It has also been considered that nuclei of TiC and (Ti, Al)N are not readily generated and the precipitation speed is thus slowed down or precipitation is made incomplete in the coiling conducted at a low temperature, making precipitation of C and N insufficient and deteriorating the elongation and average r value.

The present inventors made various experiments in which different coiling temperatures were employed, and discovered that coiling conducted at a low temperature provided a steel sheet which exhibited an excellent resistance to cold-work embrittlement and a small planar anisotropy.

The results of the experiments are shown in Fig. 1 (a) which is a graph showing the relation between the coiling temperature and the brittle transition temperature which is the index of the cold-work embrittlement. Fig. 1 (b) is a graph showing the relation between the coiling temperature and the planar anisotropy Δr. As shown in these figures, a reduction in the annealing temperature improves the resistance to cold-work embrittlement and reduces the planar anisotropy.

In the steel having the composition restricted by the present invention, it is considered that the planar anisotropy is reduced because precipitation of (Ti, Nb)C and (Ti, Al)N begins in the high-temperature range obtained before the hot rolling is finished and is promoted in the coiling conducted at a low temperature, precipitating C and N to a sufficient extent and reducing the size of the grains which have been subjected to the hot rolling process. It is also considered that the formation of such precipitates promotes segregation of B into the grain boundary, intensifies the grain boundary and thus improves the resistance to cold-work embrittlement.

Thus, the upper limit of the coiling temperature is set to 650 °C from the viewpoint of an improvement in the resistance to cold-work embrittlement and a reduction in the planar anisotropy. Although there is no restriction on the lower limit, a desirable lower limit is set to 300 °C with the cooling ability and cooling time or the coil shape obtained taken into consideration.

The samples used in the aforementioned experiments were manufactured under the following conditions using, as a material, a steel which contained 0.003 wt% of C, 0.01 wt% of Si, 0.15 wt% of Mn, 0.03 wt% of Ti, 0.005 wt% of Nb, 0.002 wt% of B, 0.06 wt% of Al, 0.015 wt% of P, 0.005 wt% of S and 0.004 wt% of N.

Hot rolling finishing temperature :	890 °C
Coiling temperature :	300 to 850 °C
Cold rolling reduction :	80%
Thickness of a cold rolled sheet :	0.7 mm
Continuous annealing conditions :	860 °C and 20 seconds
Skin pass reduction :	1%

The brittle transition temperature was measured by measuring the highest temperature at which the brittle fracture occurred in each of the conical cup samples each having a blank diameter of 50 mm, a diameter of a dice of 24.4 mm and a punch diameter of 20.64 mm in the crash tests by employing different testing temperatures.

The planar anisotropy Δr was calculated by the following equation (2) using the value in the L direction (the direction of rolling) r_L, the value in the D direction (the direction which is 45 degrees from the direction of rolling) r_D and the value in the C direction (the direction which is 90 degrees from the direction of rolling) r_C which were measured using the sample to which a tensile strain of 15% was applied beforehand:

$$\Delta r = (r_C + r_L - 2r_D)/2 \qquad (2)$$

As is clear from Fig. 1 (b), a desirable range of the planar anisotropy Δr is as follows:

$$0 \leqq \Delta r \leqq 0.25$$

A planar anisotropy Δr of more than 0.25 increases the inhomogeneous strain distribution and thus deteriorates the formability.

Continuous annealing temperature : 830 °C to Ac_3 transformation point

Conventionally, no restriction has been placed on the annealing temperature in the continuous annealing process because it has been considered that the material characteristics are determined by the hot rolling conditions. However, the present inventors have researched and found that the annealing temperature greatly affected cold-work embrittlement (the brittle transition temperature) and the planar anisotropy (Δr), as shown in Figs. 2 (a) and 2 (b).

Fig. 2 (a) shows the relation between the annealing temperature and the brittle transition temperature. Fig. 2 (b) shows the relation between the annealing temperature and the planar anisotropy (Δr).

It is considered that the resistance to cold-work embrittlement was not improved in the annealing conducted at a temperature less than 830 °C because segregation of B into the grain boundary was insufficient. It is also considered that the planar anisotropy was not reduced in the annealing conducted at a temperature less then 830 °C because the recrystallized grain orientation was affected by the cold-rolled grain orientation.

In an annealing conducted at a temperature higher than the Ac_3 transformation point, the size of the grains will increase, deteriorating the resistance to cold-work embrittlement and increasing the planar anisotropy due to the transformation.

Thus, a preferred continuous annealing temperature is from 830 °C and Ac_3 transformation point from the viewpoint of improvement in the resistance to cold-work embrittlement and reduction in the planar anisotropy.

The samples employed in the experiments were manufactured under the following conditions using, as a material, a steel which contained 0.004 wt% of C, 0.02 wt% of Si, 0.19 wt% of Mn, 0.025 wt% of Ti, 0.01 wt% of Nb, 0.0025 wt% of B, 0.08 wt% of Al, 0.02 wt% of P, 0.006 wt% of S and 0.003 wt% of N.

Hot rolling finishing temperature :	880 °C
Coiling temperature :	600 °C
Cold rolling reduction :	70%
Thickness of the cold rolled sheet :	1.2 mm
Continuous annealing conditions :	700 to 950 °C and 20 seconds
Skin pass reduction :	1%

The brittle transition temperature and Δr were measured in the same manner as the aforementioned one.

As stated above, the resistance to cold-work embrittlement is greatly affected by the chemical composition of the material and the hot rolling and continuous annealing temperatures. This resistance to cold-work embrittlement is also affected by the thickness of the steel sheet. In the case of the same material, the thicker the steel sheet, the higher the brittle transition temperature of the resistance to cold-work embrittlement (see Fig. 3).

The advantages of the present invention can be most readily obtained when the thickness is 1.0 mm or more at which deterioration in the resistance to cold-work embrittlement most readily occurs. The upper limit of the thickness is set to 5.0 mm because it is difficult to manufacture a cold rolled steel sheet having a thickness of more than 5.0 mm.

The samples employed in the experiments were manufactured under the following conditions using, as a material, a steel which contained 0.003 wt% of C, 0.01 wt% of Si, 0.15 wt% of Mn, 0.026 wt% of Ti, 0.008 wt% of Nb, 0.0026 wt% (26 ppm) or 0.0005 wt% (5 ppm) of B, 0.07 wt% of Al, 0.021 wt% of P, 0.005 wt% of S and 0.002 wt% of N and which had a thickness ranging from 0.6 mm to 3.1 mm.

Hot rolling finishing temperature :	880 °C
Coiling temperature :	600 °C
Continuous annealing conditions :	840 °C and 40 seconds
Cold rolling reduction :	65 to 73 %

(The brittle transition temperature was measured in the same manner as the aforementioned one.)

Other conditions

Although regarding the cold rolling and skin pass rolling processes, the normally employed conditions can be used, a preferred cold rolling reduction is between 50 and 95 % while a preferred skin pass rolling is between 0.5 and 2 %.

Examples

Table 1 shows the chemical composition of each of the slabs manufactured by the continuous casting method from a molten steel manufactured by a normal manufacturing process. After hot rolling was performed on the steels having the compositions shown in Table 1 under the conditions shown in Table 2 to obtain hot rolled sheet coils having a thickness of 3.5 mm, cold rolling was performed to obtain cold rolled sheets having a thickness of 1.2 mm. Thereafter, continuous annealing was conducted at various temperatures shown in Table 2, and then skin pass rolling was performed at a reduction of 1 %.

Table 1

SYMBOL	CHENICAL COMPOSITION (WT%)										Ti*/C	REMARKS
	C	Si	Mn	Ti	Nb	B	Al	P	S	N		
A	0.0025	0.01	0.17	0.028	0.005	0.0015	0.053	0.012	0.005	0.0035	3.4	SUITABLE EXAMPLE
B	0.0016	0.02	0.13	0.035	0.004	0.0025	0.071	0.011	0.006	0.0021	11.8	
C	0.0018	0.01	0.09	0.021	0.009	0.0018	0.058	0.009	0.005	0.0022	3.7	
D	0.0021	0.01	0.12	0.028	0.005	0.0022	0.065	0.009	0.004	0.0018	7.5	
E	0.0029	0.01	0.12	0.005	0.006	-	0.061	0.011	0.006	0.0033	-5.2	COMPARATIVE EXAMPLE
F	0.0022	0.02	0.10	-	0.009	0.0027	0.071	0.011	0.006	0.0021	-7.4	
G	0.0019	0.02	0.11	0.035	-	0.0005	0.053	0.012	0.006	0.0025	9.2	
H	0.0024	0.01	0.16	0.012	0.005	0.0016	0.057	0.013	0.005	0.0019	0.5	

Underlined figure is out of the range restricted by the present invention

Table 2

NO.	SYMBOL OF STEEL	MATERIAL CHARACTERISTICS						HOT ROLLING CONDITIONS		ANNEALING TEMPERATURE °C	REMARKS
		YS kgf/mm^2	TS kgf/mm^2	El %	AVERAGE r VALUE	Δr	Tcr *1 °C	FDT *2 °C	CT *3 °C		
1	A	16.8	30.5	52	2.2	0.18	-160	880	540	850	SUITABLE EXAMPLE
2	B	17.3	31.0	52	2.1	0.21	-150	890	580	850	
3	C	15.2	29.8	53	2.4	0.25	-140	885	610	870	
4	D	15.9	30.1	52	2.2	0.17	-155	890	510	880	
5	A	16.2	29.9	53	2.3	0.75	-70	880	680	870	COMPARISON EXAMPLE
6	B	18.3	32.3	48	1.7	0.69	-100	880	580	770	
7	E	20.3	34.7	46	1.6	1.03	-55	885	540	860	
8	F	19.6	33.5	47	1.7	0.85	-100	870	535	860	
9	G	20.1	33.9	44	1.6	0.77	-75	870	520	865	
10	H	18.9	33.0	48	1.8	0.58	-150	870	580	875	

Underlined figure is out of the range restricted by this invention
*1 Tcr: Brittle transition temperature
*2 FDT: Final finishing temperature
*3 CT : Coiling temperture

The tensile characteristics, the average r value, the planar anisotropy (Δr) and the cold-work embrittlement (brittle transition temperature) of the thus-obtained cold rolled steel sheets were examined. The results of the examinations are shown in Fig. 2.

The tensile test was conducted in conformity with JIS No. 5. The average r value was calculated from r_L, r_D and r_C by the following equation.

Average r value = $(r_L + 2r_D + r_C)/4$

Δr and the brittle transition temperature were obtained in the same manner as the aforementioned ones.

As is clear from Table 2, in the examples (sample Nos. 1 through 4) of the present invention, TS ≧ 29.5 Kgf/mm², El ≧ 50% and the average r value ≧ 2.0. Also, the brittle transition temperature ≦ −140 °C and Δr ≦ 0.25, that is, substantially no cold−work brittle fracture occurred and the planar anisotropy was very less.

In the comparative examples (sample Nos. 5 through 6) manufactured from the material having the composition restricted by the present invention under the manufacturing conditions which were out of the range restricted by the present invention, the brittle transition temperature was high and the planar anisotropy Δr ≧ 0.69. In the comparative examples (sample Nos. 7 through 10) manufactured from the material having the composition which was out of range restricted by the present invention under the manufacturing conditions restricted by the present invention, the brittle transition temperature ≧ −100 °C, and Δr ≧ 0.58.

Thus, the cold rolled steel sheets alone which satisfy both the composition and manufacturing conditions restricted by the present invention have excellent characteristics.

The present invention is directed to manufacture of a cold rolled steel sheet for use in deep drawing which exhibits an excellent resistance to cold−work embrittlement and a very small planar anisotropy using, as a material, an extra low carbon steel in which adequate amounts of Ti, Nb, B and Al are present under the appropriate hot rolling and continuous annealing conditions even when the continuous annealing process is used.

The cold rolled steel sheet obtained in this invention is suitable for use in, for example, automobiles, where excellent press formability is required.

Claims

1. A method of manufacturing a cold rolled steel sheet exhibiting an excellent resistance to cold−work embrittlement and a small planar anisotropy, comprising the steps of:

preparing, as a material, a steel whose composition consists of:

C : 0.004 wt% or less
Si : 0.10 wt% or less
Mn : 0.50 wt% or less
Ti : between 0.01 wt% and 0.10 wt%
Nb : between 0.003 wt% and 0.03 wt%
B : between 0.001 wt% and 0.004 wt%
Al : between 0.03 wt% and 0.10 wt%
P : 0.025 wt% or less
S : 0.01 wt% or less
N : 0.006 wt% or less

Ti and C satisfying the following equation:

$3 \leqq Ti^*/C \leqq 12$

where $Ti^* = Ti - (48/14)N - (48/32)S$

balance : iron and unavoidable impurities;

performing a hot rolling on the material steel under the conditions of a finishing temperature between 800 °C and 900 °C;

coiling the material at a temperature lower than 650 °C;

performing a cold rolling;

performing a continuous annealing at a temperature between 830 °C and Ac_3 transformation point; and

performing a skin pass rolling.

2. A method of manufacturing a cold rolled steel sheet exhibiting an excellent resistance to cold−work embrittlement and a small planar anisotropy according to claim 1, wherein the steel sheet has a thickness ranging from 1.0 mm and 5.0 mm.

3. A method of manufacturing a cold rolled steel sheet exhibiting an excellent resistance to cold−work embrittlement and a small planar anisotropy according to claim 1, wherein the planar anisotropy (Δr) satisfies the following equation:

$0 \leqq \Delta r \leqq 0.25$

where $\Delta r = (r_C + r_L - 2r_D)/2$

r_L : Lankford value in the direction of rolling

r_D : Lankford value in the direction which is 45 degrees with respect to the direction of rolling

r_C : Lankford value in the direction which is 90 degrees with respect to the direction of rolling.

FIG. 1 (a)

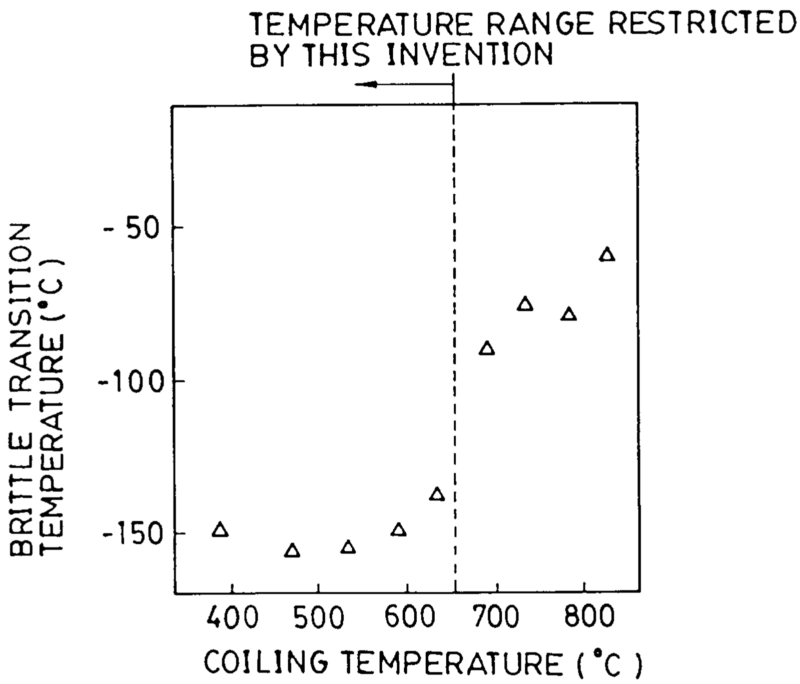

TEMPERATURE RANGE RESTRICTED
BY THIS INVENTION
BRITTLE TRANSITION
TEMPERATURE (°C)
- 50
-100
-150
400
500
600
700
800
COILING TEMPERATURE (°C)

FIG. 1 (b)

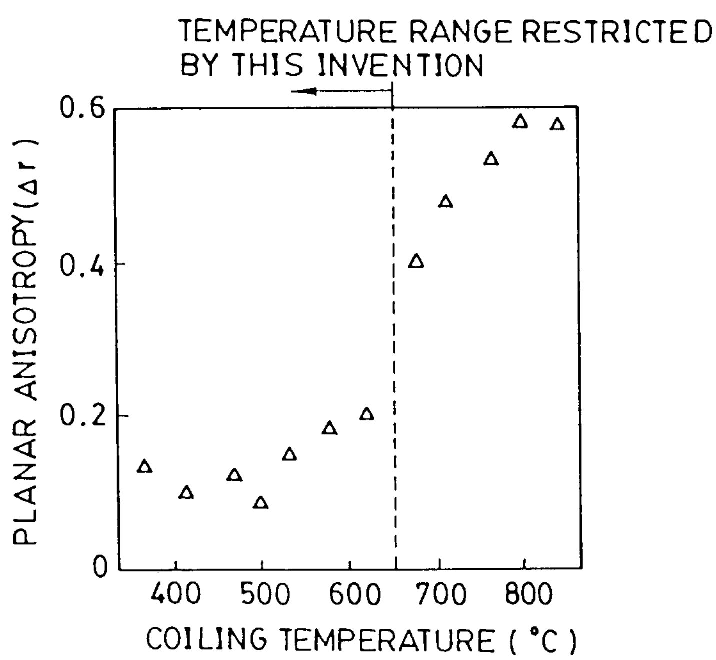

TEMPERATURE RANGE RESTRICTED
BY THIS INVENTION
PLANAR ANISOTROPY(Δr)
0.6
0.4
0.2
0
400
500
600
700
800
COILING TEMPERATURE (°C)

FIG. 2(a)

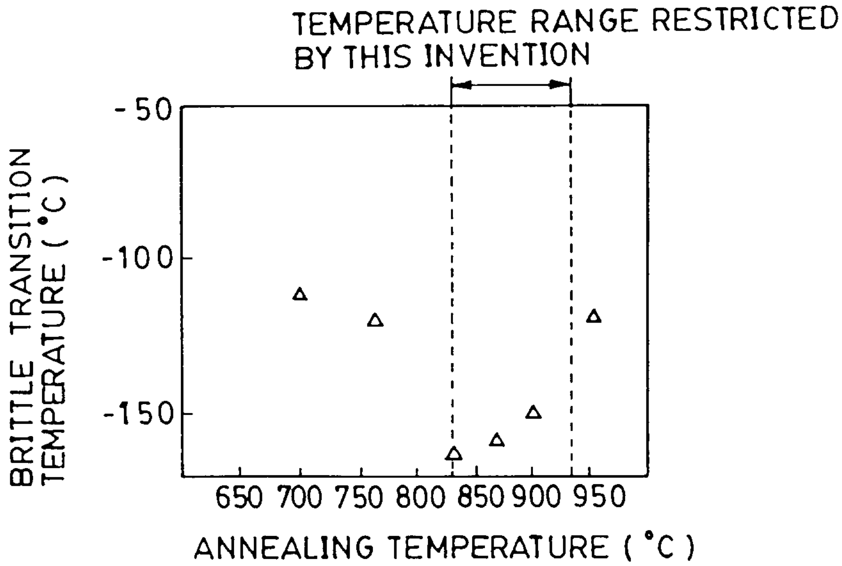

TEMPERATURE RANGE RESTRICTED
BY THIS INVENTION
-50
-100
-150
BRITTLE TRANSITION
TEMPERATURE (°C)
650 700 750 800 850 900 950
ANNEALING TEMPERATURE (°C)

FIG. 2(b)

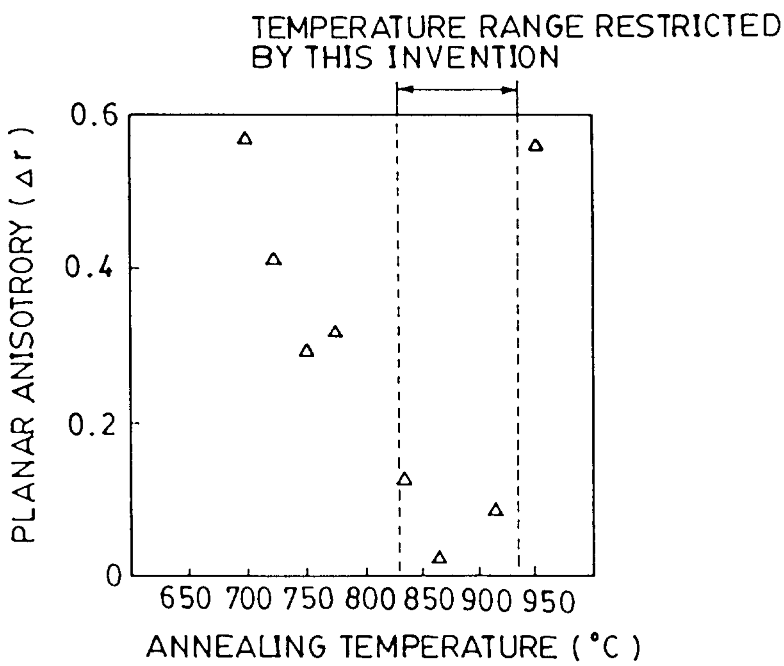
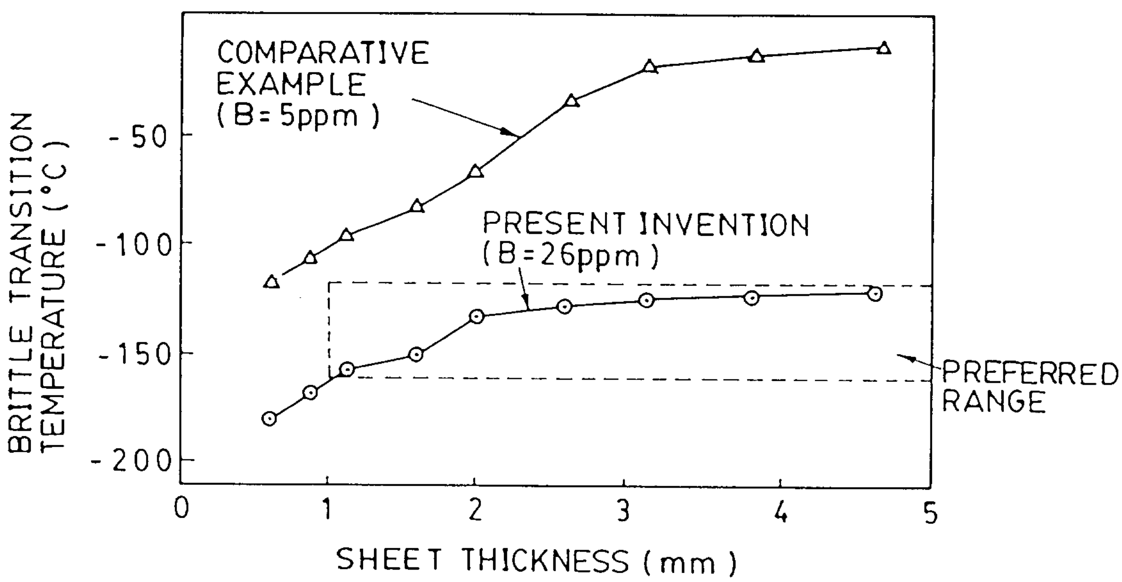

TEMPERATURE RANGE RESTRICTED
BY THIS INVENTION
0.6
0.4
0.2
0
PLANAR ANISOTRORY (Δr)
650 700 750 800 850 900 950
ANNEALING TEMPERATURE (°C)

FIG. 3


COMPARATIVE EXAMPLE (B=5ppm)
PRESENT INVENTION (B=26ppm)
PREFERRED RANGE
BRITTLE TRANSITION TEMPERATURE (°C)
-50
-100
-150
-200
0
1
2
3
4
5
SHEET THICKNESS (mm)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 92 11 8452

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.5)
X	EP-A-0 421 087 (KABUSHIKI KAISHA KOBE SEIKO SHO) 10 April 1991 * claims; examples *	1,2	C21D8/04 C22C38/12 C22C38/14
X	EP-A-0 108 268 (NIPPON STEEL CORPORATION) 16 May 1984 * claims; examples *	1	
A	EP-A-0 295 697 (KAWASAKI STEEL CORPORATION) 21 December 1988		
A	EP-A-0 203 809 (KAWASAKI STEEL CORPORATION) 3 December 1986		
A,D	PATENT ABSTRACTS OF JAPAN vol. 13, no. 479 (C-648)18 October 1989 & JP-A-11 88 630 (NIPPON STEEL CORPORATION) 27 July 1989 * abstract *		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
C21D C22C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	08 JANUARY 1993	MOLLET G.H.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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