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(54) **HIGH STRENGTH COLD ROLLED STEEL PLATE AND METHOD FOR PRODUCTION THEREOF**
HOCHFESTE KALTGEWALZTE STAHLPLATTE UND HERSTELLUNGSVERFAHREN DAFÜR
TOLE D'ACIER LAMINE A FROID A HAUTE RESISTANCE ET PROCEDE DE FABRICATION

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- **PATENT ABSTRACTS OF JAPAN vol. 1998, no. 11, 30 September 1998 (1998-09-30) -& JP 10 147838 A (KOBE STEEL LTD), 2 June 1998 (1998-06-02)**
- **PATENT ABSTRACTS OF JAPAN vol. 017, no. 176 (C-1045), 6 April 1993 (1993-04-06) & JP 04 333524 A (NIPPON STEEL CORP), 20 November 1992 (1992-11-20)**
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Description

TECHNICAL FIELD

[0001] The present invention relates to a high strength cold-rolled steel sheet, favorable for use in a structural member of machine, particularly in a structural member of automobile, which has a tensile strength of 780MPa or more, and a manufacturing method thereof.

BACKGROUND ART

[0002] From the point of view of achieving weight reduction of automobile for the purpose of reduction in fuel consumption and ensuring safety for occupants of automobile, application of a high strength cold-rolled steel sheet having a tensile strength of 780MPa or more to a structural member of automobile has been studied. However, since such a high strength cold-rolled steel sheet as described above is inferior in ductility and stretch-flangeability to a mild cold-rolled steel sheet, it is difficult to subject the high strength cold-rolled steel sheet to press-forming. The term "stretch-flangeability" as used herein means a property resisting to generation of cracks on a blank end face of steel sheet when it is press-formed and is evaluated, based on a hole-expanding ratio measured by means of hole-expanding test defined by the Japan Iron and Steel Federation Standard: JFST 1001-1996.

[0003] To date, various methods for improving stretch-flangeability of a high strength cold-rolled steel sheet have been disclosed as described below.

[0004] In JP-B No. 7-59726, JP-A Nos. 2001-226741, 10-60593 and 9-263838, high strength cold-rolled steel sheets which have each aimed for improving stretch-flangeability by controlling structure through optimizing steel compositions and manufacturing conditions, and manufacturing methods thereof are disclosed. More specifically, for example, in JP-A No. 9-263838, a cold-rolled steel sheet is slowly cooled from soaking temperature at the time of annealing to allow second phase to be uniformly dispersed in ferrite phase and, then, bainite phase is allowed to be uniformly dispersed in the ferrite phase as a main component by adjusting cooling rate and overaging temperature, thereby aiming for enhancing strength and improving stretch-flangeability.

[0005] In JP-A No. 2001-355044, a high strength cold-rolled steel sheet in which ferrite phase is allowed to have higher strength and from 2% to 20% of residual austenite phase is formed in the ferrite phase to aim for simultaneously achieving strength enhancement and stretch-flangeability improvement is disclosed.

[0006] In JP-A No. 11-350038, a method for producing a complex phase type high strength cold-rolled steel sheet which is excellent in ductility and stretch-flangeability and has a tensile strength of about 980MPa by controlling compositions and producing conditions is disclosed.

[0007] In JP-A No. 9-41040, a method for manufacturing a high strength cold-rolled steel sheet which is excellent in stretch-flangeability by subjecting a cold-rolled steel sheet to annealing in an $\alpha + \gamma$ region, cooling the resultant steel sheet by holding it in a temperature range of from 650°C to temperature to stop pearlite transformation for 10 seconds or more and, then, cooling the cooled steel sheet by holding it in a temperature range of from temperature to stop pearlite transformation to 450°C for 5 seconds or less is disclosed.

[0008] Further, prior arts as described below in regard to a high strength cold-rolled steel sheet which, though not referring to stretch-flangeability, aims for enhancement of formability and the like are also disclosed.

[0009] In JP-B No. 58-55219 and Japanese Patent No. 2545316, a method for producing a high strength cold-rolled steel sheet by more strictly defining compositions and performing annealing under specified continuous annealing conditions is disclosed.

[0010] In JP-B No. 7-68583, a method for manufacturing a dual phase type high strength cold-rolled steel sheet which is excellent in mechanical characteristics, spot-weldability and phosphatability by specifying content of C, Si, and Mn, reheating conditions before hot rolling, soaking conditions, atmosphere and the like in continuous annealing after cold rolling is disclosed.

[0011] In JP-B No. 8-30212, a method for manufacturing a high strength cold-rolled steel sheet having high ductility and excellent bending property by allowing structure after hot rolling to be uniformly finer such that band structure is not generated therein and, then, allowing the resultant structure after continuous annealing to be that in which ferrite phase and martensite phase are uniformly distributed is disclosed.

[0012] In JP-B No. 5-57332, a method for producing a high strength cold-rolled steel sheet which has a yield ratio of 0.65% or less and is excellent in both surface property and bending property by heating steel containing Si and a comparatively large amount of Mn to austenite single phase zone which is higher than Ac3 transformation temperature and, then, allowing complex phase structure comprising ferrite phase and second phase such as martensite phase to be formed in a cooling step is disclosed.

[0013] In JP-B Nos. 1-35051 and 1-35052, a method for manufacturing a high strength cold-rolled steel sheet which is excellent in ductility by controlling heating temperature in continuous annealing, water-quenching start temperature, and overaging treatment temperature is disclosed.

[0014] In JP-B Nos. 7-74412 and 3-68927, a method for producing a high strength cold-rolled steel sheet which is excellent in bending property, deep drawability, and resistance to seasoned crack by allowing condensation of C to be low to thereby set austenite phase to be 5% or less by means of performing annealing in a high temperature range after cold rolling is disclosed.

[0015] However, such conventional prior arts as described above have problems as described below.

[0016] In JP-B 7-59726, it is essential to perform overaging treatment at such a high temperature as 350°C or more and, in order to compensate decrease of tensile strength to be caused by such high temperature overaging treatment, a large amount of C which is a reinforcing element has been added (in steel Nos. 9, 10, and 13 according to the invention in Table 1, in order to have a tensile strength of 980MPa or more, 0.17% or more of C has been added.). For this reason, when the steel is spot-welded at the time of assembling an automobile, tenacity of spot-welded portion is deteriorated and, as a result, joint strength thereof is decreased. Further, since overaging treatment temperature is high, energy cost in production is increased, thereby deteriorating productivity. Still further, when the steel has a tensile strength of 980MPa or more, a hole-expanding ratio is as low as 56% (steel 9 or more, hole-expanding ratio is as low as 56% (steel according to the invention in Table 1), thereby allowing stretch-flangeability to be insufficient.

[0017] In JP-A No. 2001-226741, it is essential to perform austempering treatment after soaking in continuous annealing in order to generate bainite phase, but there is a problem in that consistent characteristics of steel sheet can not be obtained in this treatment.

[0018] In JP-A No. 2001-355044, since residual austenite phase is allowed to exist, it is essential to generate bainite phase, thereby decreasing strength. The tensile strength shown in an example is as low as from 600MPa to 800MPa, thereby being incapable of consistently obtaining a tensile strength of 780MPa or more. In order to enhance strength, it is necessary to add a large amount of C, Si, and Mn, thereby inviting deterioration of weldability and the like.

[0019] In JP-A No. 11-350038, since an amount of C is as large as from 0.10% to 0.15%, thereby deteriorating stretch-flangeability or tenacity of spot-welded portion.

[0020] In JP-A Nos. 9-41040 and 9-263838, since structure comprises ferrite phase and pearlite phase, or ferrite phase and bainite phase, tensile strength is as low as from 400MPa to 700MPa.

[0021] In JP-A No. 10-60593, JP-B Nos. 58-55219 and 7-68583, and Japanese Patent No. 2545316, tensile strength of from 400MPa to 700MPa can only be obtained.

[0022] In JP-B Nos. 1-35051, 1-35052, 3-68927, 8-30212, 5-57332 and 7-74412, consistent and excellent stretch-flangeability can not be obtained.

JP 10-147838 discloses a cold-rolled steel sheet with a tensile strength lower than 780 MPa and a martensite content of 5 to 30%.

DISCLOSURE OF THE INVENTION

[0023] An object of the present invention is to provide a high strength cold-rolled steel sheet having an elongation of 18% or more, a hole-expanding ratio of 60% or more, and a tensile strength of 780MPa or more and a manufacturing method thereof

[0024] This obj ect can be achieved by a high strength cold-rolled steel sheet comprising the features of claim 1.

[0025] Further, this high strength cold-rolled steel sheet can be realized by a method comprising the features of claim 2.

EMBODIMENTS OF THE INVENTION

[0026] In a high strength cold-rolled steel sheet having a tensile strength of 780MPa or more, it is necessary to allow structure to substantially be a dual-phase structure of ferrite phase and martensite phase. For such necessity, as described above, it is necessary to increase an amount of C, thereby deteriorating stretch-flangeability, spot-weldability and, further, phosphatability.

[0027] The present inventors have studied on a steel sheet which, even though an amount of C is reduced, has a tensile strength of 780MPa or more and, further, excellent ductility in which an elongation is 18% or more, and excellent stretch-flangeability in which a hole-expanding ratio is 60% or more, and found that the steel sheet can be realized by a steel sheet consisting essentially of, in terms of percentages by mass, 0.04 to 0.10% C, 0.5 to 1.5% Si, 1.8 to 3% Mn, 0.02% or less P, 0.01% or less S, 0.01 to 0.1% Sol. Al, 0.005% or less N, and the balance being iron and inevitable impurities and having a structure substantially comprising ferrite phase and martensite phase. Only components of 0.04 to 0.07 % are within the scope of the appending claims.

[0028] Hereinafter, the present invention will be described in detail.

1) Compositions

[0029] C: C is an important element for giving a great influence on tensile strength, and reinforcing martensite phase which is generated at quenching. When an amount of C is less than 0.04%, a tensile strength of 780MPa or more can not be obtained, while, when it is over 0.10%, stretch-flangeability and spot-weldability are remarkably deteriorated. Accordingly, the amount of C is set to be 0.04 to 0.10%. Further, in order to obtain a tensile strength of from 780MPa to less than 980MPa without deteriorating stretch-flangeability or spot-weldability, it is preferable to set the amount of C to be 0.04% to less than 0.070%.

[0030] Si: Si is effective in enhancing ductility of dual phase type steel sheet comprising ferrite phase and martensite phase. When an amount of Si is less than 0.5%, effectiveness thereof becomes insufficient, while, when it is over 1.5%, a large amount of Si oxide is formed on a surface of steel sheet in a hot rolling step, thereby generating surface defects. Accordingly, the amount of Si is set to be 0.5 to 1. 5%. Further, from the point of view of phosphatability, the amount of Si is desirably set to be 1.0% or less.

[0031] Mn: Mn is an important element for suppressing generation of ferrite phase in a cooling step of continuous annealing. When an amount of Mn is less than 1.8%, effectiveness thereof becomes insufficient, while, when it is over 3%, a slab crack is generated at the time of continuous casting. Accordingly, the amount of Mn is set to be 1.8 to 3%. Further, in order to consistently produce the steel sheet in a continuous annealing step, the amount of Mn is desirably set to be 2.0 to 2.5%.

[0032] P: when an amount of P is over 0.02%, spot-weldability is remarkably deteriorated and, accordingly, the amount of P is set to be 0.02% or less.

[0033] S: when an amount of S is over 0.01%, spot-weldability is remarkably deteriorated and, accordingly, the amount of S is set to be 0.01% or less.

[0034] Sol. Al: Al is added for performing deoxidization of steel or precipitating N as AlN. When an amount of Sol. Al is less than 0.01%, the deoxidization or the precipitation of AlN is not sufficiently performed, while, when it is over 0.1%, effectiveness thereof is saturated, thereby inviting a cost increase. Accordingly, the amount of Sol. Al is set to be 0.01 to 0.1%.

[0035] N: since N deteriorates formability of steel sheet, an amount of N is desirably as low as possible. However, when the amount thereof is reduced more than necessary, a refining cost is increased. Accordingly, the amount of N is set to be 0.005% or less such that it does not substantially deteriorate the formability.

[0036] Besides the aforementioned elements, when at least one element selected from 0.01 to 1.0% Cr, 0.01 to 0.5% Mo, 0.0001% to 0.0020% B, 0.001 to 0.05% Ti, 0.001 to 0.05% Nb, 0.001% to 0.05% V, and 0.001 to 0.05% Zr is allowed to be contained, there is an advantage in that structure adjustment at the time of continuous annealing is facilitated, or stretch-flangeability is enhanced by suppressing an occurrence in which a carbide or a nitride is formed in the steel sheet during casting or in a hot rolling step and, then, crystal grains come to be coarse. When a content of each element is less than the lower limit, the aforementioned effects are not sufficiently performed, while it is over the upper limit, the ductility is liable to be deteriorated.

2) Structure

[0037] Structure of steel sheet substantially comprises two phases of: ferrite phase and martensite phase. Besides these two phases, bainite phase in which iron is a main constitutional element or austenite phase may not deteriorate effectiveness of the present invention, so long as it is contained in an amount of less than 2% in terms of volume fraction. Further, compounds containing iron such as cementite may be contained in the ferrite phase, the martensite phase or an interface between ferrite and martensite phases. Still further, compounds such as AlN and MnS may not impair the effectiveness of the present invention, so long as each of the composition elements or impurity elements is within the scope of the invention.

[0038] When a volume fraction of martensite phase is 30 to 45%, in the range of from 780MPa to less than 980MPa of tensile strength, or when it is 45 to 60%, in the range of from 980MPa to 1180MPa of tensile strength, more excellent stretchflangeability can be obtained. Only a volume fraction of martensite phase from 30 to 45 % is within the scope of the appending claims

[0039] Further, in the range in which desired strength can be achieved, a tempering treatment can appropriately be performed on the martensite phase.

3) manufacturing method

[0040] Firstly, a slab having the aforementioned compositions is produced by continuous casting method or ingot making plus blooming method and, then, either after reheating or directly, the resultant slab is hot-rolled. A final rolling temperature (finishing temperature) at hot rolling is desirably from Ar3 transformation temperature to 870 DEG C, in order to allow structure to be finer to thereby enhance ductility or stretch-flangeability. The hot-rolled steel sheet is cooled and, then, coiled. A coiling temperature is desirably 620 DEG C or less for the purpose of enhancing ductility or stretch-flangeability.

[0041] Next, the resultant steel sheet is cold-rolled to be in a desired thickness. At this time, a cold-rolling reduction rate is desirably 55% or more for the purpose of enhancing ductility or stretch-flangeability by allowing structure to be finer.

[0042] Finally, the cold-rolled steel sheet is annealed under conditions as described below in a continuous annealing furnace.

i) Heating: from 750°C to 870°C for 10 seconds or more

[0043] When a heating temperature is less than 750°C, a sufficient amount of austenite phase is not generated and, accordingly, high strength can not be aimed for, while, when it is over 870°C, transformation into austenite single phase occurs allowing structure to be coarse, thereby deteriorating ductility or stretch-flangeability. Further, when a heating time is less than 10 seconds, austenite phase is not sufficiently generated and, accordingly, high strength can not be aimed for.

ii) Primary cooling (slow cooling); Cooling terminal temperature: from 550°C to 750°C

[0044] When a cooling terminal temperature is less than 550°C, a volume fraction of ferrite phase becomes unduly high, strength becomes insufficient, while, when it is over 750°C, not only ductility is deteriorated by subsequent rapid cooling, but also flatness of steel sheet is deteriorated. A cooling rate at this time is desirably set to be 20°C/sec in the range of from 550°C to 750°C depending on compositions such that a volume fraction of austenite phase can be adjusted to be from 30% to 45% or from 45% to 60%, namely, a volume fraction of martensite phase can ultimately be adjusted to be from 30% to 45% or from 45% to 60%.

iii) Secondary cooling (rapid cooling); Cooling rate: over 100°C/sec; Cooling terminal temperature: 300°C or less

[0045] When a cooling rate is 100°C/sec or less, quenching becomes insufficient and, accordingly, high strength can not be aimed for. In order to consistently aim for high strength, rapid cooling is desirably performed at a cooling rate of 500°C/sec or more. Further, when a cooling terminal temperature is over 300°C, either bainite phase is generated, or austenite phase remains, thereby deteriorating stretch-flangeability. In order to obtain consistent excellent stretch-flangeability, the cooling terminal temperature is preferably set to be 100°C or less.

[0046] After the rapid cooling, the resultant steel sheet may be held at the cooling terminal temperature for from 5 minutes to 20 minutes or subjected to tempering treatment at from 150°C to 390°C for from 5 minutes to 20 minutes. By performing the tempering treatment, the martensite phase which has been generated at the rapid cooling is tempered, thereby enhancing ductility and stretch-flangeability. Further, when a tempering temperature is less than 150°C, or a tempering time is less than 5 minutes, such effect as described above can not sufficiently be obtained. On the other hand, when the tempering temperature is over 390°C, or the tempering time is over 20 minutes, strength is remarkably decreased, thereby being sometimes incapable of obtaining a tensile strength of 780MPa or more.

[0047] Still further, it is preferable that the obtained steel sheet is subjected to temper rolling at a reduction rate of from 0.1% to 0.7% to thereby eliminate yield elongation completely.

[0048] Furthermore, the steel sheet according to the present invention can be electroplated, hot-dip galvanized or applied with solid lubricant.

Example 1

[0049] Steel Nos. 1 to 10 having respective compositions as shown in Table 1 were each cast into slab. The cast slab was reheated at 1250°C, hot-rolled at a finishing temperature of about 860°C, and slowly cooled at about 20°C/sec to produce a hot-rolled steel sheet having a thickness of 2.8mm by simulating coiling at 600°C for one hour. Next, the hot-rolled steel sheet was cold-rolled to produce a cold-rolled steel sheet having a thickness of 1.2 mm and, then, the cold-rolled steel sheet was subj ected to heating treatment which simulated continuous annealing. The continuous annealing was performed under conditions that a temperature of the steel sheet was elevated at a heating rate of about 20°C/sec and, then, the steel sheet was soaked at 830°C for 300 seconds, slowly cooled down to 700°C at about 10°C/sec and, thereafter, rapidly cooled in jet-flowing water having a temperature of 20°C. A cooling rate of such rapid cooling was about 2000°C/sec. Finally, the steel sheet was subjected to tempering treatment at 300°C for 15 minutes, cooled and, then, subjected to temper rolling of 0.3% to produce steel sheet Nos. 1 to 10. Thereafter, in regard to the steel sheet Nos. 1 to 10, respective tensile characteristics and hole-expanding ratios (λ) were measured.

[0050] In regard to the tensile characteristics, a JIS No. 5 test piece (JIS Z 2201) was obtained along each of a rolling direction and a direction at a right angle thereto and subjected to a test in accordance with JIS Z 2241 to determine yield strength (YP), tensile strength (TS), and elongation (El).

[0051] In regard to the hole-expanding ratio, a test was conducted in accordance with the evaluation method of stretch-flangeability defined by the Japan Iron and Steel Federation Standard (JFST 1001-1996), to determine the value thereof.

[0052] Values to be targeted according to the present invention are as follows:

TS≥780MPa; El≥18%; and λ≥60%.

[0053] The results are shown in Table 2.

[0054] It is found that each of steel sheet Nos. 2, 3, 9, and 10 which are examples according to the present invention satisfies the relations: TS≥780 MPa; El≥8%; and λ≥60%, and thus has high strength, and is excellent in ductility and stretch-flangeability.

[0055] On the other hand, as comparative examples, steel sheet No. 1 is low in TS, due to small amount of C; steel sheet No. 5 is remarkably low in λ, due to large amount of C and small amount of Mn; steel sheet No. 6 is low in λ, due to small amount of Si; steel sheet No. 7 is low in TS and λ, due to small amount of Mn; and steel sheet No. 8 is low in El, due to large amount of Mn.

Table 1

Steel No.	Chemical compositions (mass%)														Remark
	C	Sl	Mn	P	S	Sol. Al	N	B	Cr	Mo	Ti	Nb	V	Zr	
1	0.032	1.1	2.3	0.012	0.004	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Comparative Example
2	0.054	1.0	2.3	0.015	0.002	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Present invention
3	0.065	1.4	2.1	0.010	0.003	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Present Invention
4	0.081	0.8	2.0	0.006	0.001	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	not within the present invention
5	0.112	0.9	1.3	0.008	0.007	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Comparative Example
6	0.062	0.03	2.1	0.014	0.006	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Comparative Example
7	0.068	0.9	1.5	0.012	0.003	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Comparative Example
8	0.045	1.2	3.6	0.010	0.002	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Comparative Example
9	0.058	0.9	1.9	0.010	0.001	0.030	0.003	0.0010	0.020	<0.001	<0.001	<0.001	<0.001	<0.001	Present Invention
10	0045	0.8	2.0	0.010	0.003	0.030	0.003	<0.0001	<0.001	<0.001	0.02	0.02	<0.001	<0.001	Present Invention

Table 2

Steel sheet No.	Steel No.	Martensite volume fraction (%)	Tensile properties			Hole-expanding ratio λ (%)	Remark
			YP (MPa)	TS (MPa)	El(%)		
1	1	33	408	680	27.9	85	Comparative Example
2	2	42	498	830	22.9	88	Present Invention
3	3	38	510	850	22.4	80	Present Invention
4	4	35	630	1050	18.1	60	not within the present invention
5	5	25	492	820	23.2	30	Comparative Example
6	6	33	486	810	23.5	55	Comparative Example
7	7	26	432	720	26.4	40	Comparative Example
8	8	65	612	1020	13.2	85	Comparative Example
9	9	44	516	860	22.1	83	Present Invention
10	10	36	480	800	23.8	90	Present Invention

Example 2

[0056] By using the slab of steel No. 2 as shown in Table 1, the steps up to cold rolling were performed under same conditions as in Example 1 and, then, continuous annealing and tempering treatment were performed under conditions as shown in Table 3. Finally, temper rolling of 0.3% was performed in the same manner as in Example 1 to produce steel sheet Nos. A to H. Thereafter, in regard to steel sheet Nos. A to H, the same tests as in Example 1 were conducted.

[0057] The results are shown in Table 4.

[0058] It is found that each of steel sheet Nos. A, E, G, and H which are examples according to the present invention satisfies the relations: TS≥780 MPa; El≥18%; and λ≥60%, and thus has high strength, and is excellent in ductility and stretch-flangeability.

[0059] On the other hand, as comparative examples, steel sheet No. B is low in TS and λ, due to high heating temperature: this is considered to be caused by that structure having martensite phase as a main component has become coarse; steel sheet No. C is low in TS and λ, due to short heating time: this is considered to be caused by that a sufficient amount of austenite phase was not generated during heating and, after rapid cooling, a sufficient volume fraction of martensite phase was not obtained; steel sheet No. D is low in TS and λ, due to low slow cooling terminal temperature: this is considered to be caused by that ferrite phase was generated during the slow cooling and, after rapid cooling, a volume fraction of martensite phase was reduced; and steel sheet No. F is low in TS and λ, due to low rapid cooling speed and high rapid cooling terminal temperature.

Table 3

Steel sheet No.	Steel No.	Heating temperature (°C)	Heating time (sec)	Slow cooling rate (°C/sec)	Slow cooling terminal temperature (°C)	Rapid cooling rate (°C/sec)	Rapid cooling terminal temperature (°C)	Tempering temperature (°C)	Tempering time (sec)	Remark
A	2	830	150	5.0	680	2000	40	-	-	Present Invention
B	2	890	200	5.7	720	2000	40	-	-	Comparative Example
C	2	830	5	4.7	690	2000	40	-	-	Comparative Example
D	2	830	120	10.0	530	2000	40	-	-	Comparative Example
E	2	830	300	6.0	650	300	200	-	-	Present Invention
F	2	840	160	3.8	725	30	400	-	-	Comparative Example
G	2	850	60	5.7	680	2000	40	200	15	Present Invention
H	2	830	150	5.0	680	2000	40	300	15	Present Invention

Table 4

Steel sheet No.	Martensite volume fraction (%)	Tensile properties			Hole-expanding ratio λ (%)	Remark
		YP (MPa)	TS (MPa)	El (%)		
A	39	492	820	23.2	83	Present Invention
B	29	450	750	25.3	30	Comparative Example
C	25	438	730	26.0	45	Comparative Example
D	24	432	720	26.4	50	Comparative Example
E	44	510	850	22.4	99	Present Invention
F	20	390	650	29.2	55	Comparative Example
G	39	516	880	22.1	85	Present Invention
H	42	504	840	22.6	92	Present Invention

Example 3

[0060] Steel Nos. 1 to 9 having respective compositions as shown in Table 5 were each cast into slab. The cast slab was subjected, under the same conditions as in Example 1, to hot rolling, cold rolling, continuous annealing, and temper rolling to produce steel sheet Nos. 1 to 9. Thereafter, yield strength (YP), tensile strength (TS), elongation (El), and hole-expanding ratio (λ) were measured in the same manner as in Example 1.

[0061] The results are shown in Table 6.

[0062] It is found that each of steel sheet Nos. 1, 2, 3, 8, and 9 which are examples according to the present invention satisfies the relations: TS≥780 MPa; El≥18%; and λ≥60%, and thus has high strength, and is excellent in ductility and stretch-flangeability.

[0063] On the other hand, as comparative examples, steel sheet No. 4 is low in El and λ, due to large amount of C; steel sheet No. 5 is remarkably low in λ, due to large amount of C and small amount of Mn; steel sheet No. 6 is low in λ, due to small amount of Si; and steel sheet No. 7 is low in El and λ, due to large amount of Mn.

Table 5

Steel No.	Chemical compositions (mass%)														Remark
	C	Si	Mn	P	S	Sol. Al	N	B	Cr	Mo	TI	Nb	V	Zr	
1	0.065	1.1	2.3	0.012	0.004	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Present Invention
2	0.073	1.0	2.3	0.015	0.002	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	not within the present invention
3	0.095	1.4	2.1	0.010	0.003	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	not within the present invention
4	0.112	0.8	2.0	0.006	0.001	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Comparative Example
5	0.134	0.9	1.3	0.008	0.007	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Comparative Example
6	0.081	0.03	2.1	0.014	0.006	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Comparative Example
7	0.078	1.2	3.6	0.010	0.002	0.030	0.003	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	Comparative Example
8	0.083	0.9	1.9	0.010	0.001	0.030	0.003	0.0010	0.020	<0.001	<0.001	<0.001	<0.001	<0.001	not within the present invention
9	0.088	0.8	2.0	0.010	0.003	0.030	0.003	<0.0001	<0.001	<0.001	0.02	0.02	<0.001	<0.001	not within the present invention

Table 6

Steel sheet No.	Steel No.	Martensite volume fraction (%)	Tensile properties			Hole-expanding ratio λ (%)	Remark
			YP (MPa)	TS (MPa)	El (%)		
1	1	50	696	870	21.8	61	Present Invention
2	2	55	808	1010	18.8	70	not within the present invention
3	3	51	816	1020	18.6	65	not within the present invention
4	4	56	1000	1250	15.2	35	Comparative Example
5	5	32	792	990	19.2	30	Comparative Example
6	6	46	744	930	20.4	45	Comparative Example
7	7	80	1024	1280	13.2	55	Comparative Example
8	8	47	808	1010	18.8	73	not within the present invention
9	9	53	800	1000	19.0	71	not within the present invention

Claims

1. A high strength cold-rolled steel sheet, consisting of, in terms of percentages by mass, 0.04 to 0.070% C, 0.5 to 1.5% Si, 1.8 to 3% Mn, 0.02% or less P, 0.01% or less S, 0.01 to 0.1% Sol. Al, 0.005% or less N, optionally further comprising at least one element selected from the group consisting of: in terms of percentages by mass, 0.01 to 1.0% Cr, 0.01 to 0.5% Mo, 0.0001 to 0.0020% B, 0.001 to 0.05% Ti, 0.001 to 0.05% Nb, 0.001 to 0.05% V, and 0.001 to 0.05% Zr and the balance being iron and inevitable impurities, having a structure substantially consisting of ferrite phase and martensite phase, and having a tensile strength of from 780 MPa to less than 980 MPa wherein a volume fraction of martensite phase is from 30% to 45%.

2. A method for producing a high strength cold-rolled steel sheet, comprising the steps of:

   producing a steel sheet by hot rolling a steel slab consisting of compositions as set forth in any one of Claim 1, followed by cold rolling;
   heating the cold-rolled steel sheet at from 750°C to 870°C for 10 seconds or more;
   cooling the heated steel sheet down to from 550°C to 750°C;
   cooling the located steel sheet at a cooling rate of 20°C/sec. or less within the temperature range of from 550°C to 750°C so that a volume fraction of austenite phase is adjusted to be from 30% to 45%; and
   cooling the cooled steel sheet down to 300°C or less at a cooling rate of over 100°C/sec.

Patentansprüche

1. Hochfestes kaltgewalztes Stahlblech, das, bezogen auf die Massenprozentzahlen, aus 0,04 bis 0,070 % C, 0,5 bis

1,5 % Si, 1,8 bis 3 % Mn, 0,02 % oder weniger P, 0,01 % oder weniger S, 0,01 bis 0,1 % loslichem Al, 0,005 % oder weniger N besteht, gegebenenfalls ferner mindestens ein Element umfasst, das aus der Gruppe ausgewahlt wird, die aus folgendem besteht: bezogen auf die Massenprozentzahlen, 0,01 bis 1,0 % Cr, 0,01 bis 0,5 % Mo, 0,0001 bis 0,0020 % B, 0,001 bis 0,05 % Ti, 0,001 bis 0,05 % Nb, 0,001 bis 0,05 % V und 0,001 bis 0,05 % Zr und wobei der Rest Eisen und unvermeidbare Verunreinigungen sind, mit einer Struktur, die im wesentlichen aus einer Ferritphase und einer Martensitphase besteht, und mit einer Zugfestigkeit von 780 bis weniger als 980 MPa, worin ein Volumenanteil der Martensitphase 30 bis 45 % betragt.

2. Verfahren zur Herstellung eines hochfesten kaltgewalzten Stahlblechs, umfassend die folgenden Schritte:

Herstellen eines Stahlblechs durch Warmwalzen einer Stahlbramme, die aus der in Anspruch 1 dargelegten Zusammensetzung besteht, gefolgt von Kaltwalzen;
Erwarmen des kaltgewalzten Stahlblechs von 750 auf 870°C fur 10 Sekunden oder mehr;
Abkühlen des erwärmten Stahlblechs auf 550 bis 750°C;
Abkuhlen des erwärmten Stahlblechs bei einer Abkuhlgeschwindigkeit von 20°C/Sek oder weniger innerhalb des Temperaturbereichs von 550 bis 750°C, so dass ein Volumenanteil der Austenitphase auf 30 bis 45 % eingestellt wird, und
Abkuhlen des abgekuhlten Stahlblechs auf 300°C oder weniger bei einer Abkuhlgeschwindigkeit von mehr als 100°C/sek.

Revendications

1. Tôle d'acier à haute résistance laminée à froid, consistant en, en termes de pourcentages en masse, 0,04 à 0,070%des, 0,5 à 1,5 % de Si, 1,8 à 3 % de Mn, 0,02 % ou moins de P, 0,01 % ou moins de S, 0,01 à 0,1 % de Sol. Al, 0,005 % ou moins de N, comprenant en outre optionnellement au moins un élément sélectionné dans le groupe constitué de : en termes de pourcentages en masse, 0,01 à 1,0 % de Cr, 0,01 à 0,5 % de Mo, 0,0001 à 0,0020 % de B, 0,001 à 0,05 % de Ti, 0,001 à 0,05 % de Nb, 0,001 à 0,05 % de V et 0,001 à 0,05 % de Zr et le reste étant du fer et des impuretés inévitables, ayant une structure consistant sensiblement en une phase de ferrite et en une phase de martensite, et ayant une résistance à la traction de 780 MPa à moins de 980 MPa, dans laquelle une fraction volumique de phase de martensite est de 30 % à 45 %.

2. Procédé pour produire une tôle d'acier à haute résistance laminée à froid, comprenant les étapes consistant à :

produire une tôle d'acier par laminage à chaud d'une brame d'acier consistant en compositions telles qu'exposées dans la revendication 1, suivi par un laminage à froid ;
chauffer la tôle d'acier laminée à froid de 750 °C à 870 °C pendant 10 secondes ou plus ;
refroidir la tôle d'acier chauffée jusqu'a de 550 °C à 750 °C ;
refroidir la tôle d'acier chauffée à une vitesse de refroidissement de 20 °C/s ou moins à l'intérieur de la plage de températures allant de 550 °C à 750 °C de sorte qu'une fraction volumique de phase d'austénite est ajustée pour être comprise entre 30 % et 45 % ; et
refroidir la tôle d'acier refroidie jusqu'à 300 °C ou moins à une vitesse de refroidissement supérieure à 100 °C/s.

REFERENCES CITED IN THE DESCRIPTION

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