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(54) Cold-rolled steel strip having excellent combined press formability and method of producing same

Kaltgewalztes Stahlband mit hervorragender Pressverformbarkeit und Verfahren zur Herstellung

Tôles d'acier laminées à froid ayant une excellente formabilité à la presse et procédé de fabrication

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Description

[0001] This invention relates to a cold-rolled steel strip having excellent combined press-formability and also to a method of producing such a steel strip by continuous annealing.

[0002] Various techniques have been proposed for improving the press formability of a cold-rolled steel strip. For example. Japanese Patent Unexamined Publication No 63-210243 discloses a method in which a cold-rolled steel strip of super-formability having a total elongation of not less than 54% and r value of not less than 2.0 is subjected to box-annealing having stepped heating. Japarese Patent Unexamined Publication No. 61-275930 discloses a method in which a very low carbon-steel having Nb and Ti added thereto is cooled at a rate of 10°C/sec. within 0.5 seconds after the hot-rolling of the steel, thereby producing the cold-rolled very low carbon-steel strip having excellent elongation and deep-drawability. Japanese Patent Unexamined Publication Nos. 61-113724 and 63-76848 disclose methods of producing a steel strip having extremely high r value r_{45} and El.

[0003] Recently, there have been used many pressed products (e.g. a wheel house inner) of a complicated shape for an automobile, and the pressing of such product into a required shape has been getting very difficult. Steel strips. produced using a method of producing a steel strip having a very high r value, r_{45} and El which method was invented by the inventors of the present invention and is disclosed in Japanese Patent Unexamined Publication No. 61-113724. have been supplied to car manufacturers for forming such pressed products: however, the problem of defective pressing has now been encountered.

[0004] It is therefore an object of this invention to provide a cold-rolled steel strip having excellent combined press-formability.

[0005] Another object of the invention is to provide a method of producing such a cold-rolled steel strip by continuous annealing.

[0006] The inventors of the present invention have made an extensive study in an effort to develop a cold-rolled steel strip which exhibits excellent press formability (hereinafter referred to as "combined press formability") in an actual pressing for forming products or parts (hereinafter referred to as "combined pressed product") of a complicated shape. such as a wheel house inner having a deep-drawn portion, a stretched portion and a draw bead. The present inventors also have studied a method of producing such a steel strip by continuous annealing. As a result, the present inventors have found the following results. Subject matters of the prevent invention are as claimed:

(1) A cold-rolled steel strip having excellent combined press formability, consisting, by weight, of not more than 0.0025% C. not more than 0.05% Si. not more than 0.30% Mn, not less than 0.007% but not more than 0.030% P, not more than 0.020% S. not more than 0.080% sol Al, not more than 0.0030% N, not less than 0.025% but not more than 0.120% Ti. not less than 0.003% but not more than 0.020% Nb. not more than 0.0002% B, and the balance Fe and incidental impurities, said steel strip having tensile strength in 45° direction (expressed as $T.S_{45}$) of 28.5 to 31 0 kgf/mm^2 and r value in 45° direction (expressed as r_{45}) of not less than 1.90

(2) A method of producing a cold-rolled steel strip having excellent combined press formability comprising the steps of:

providing a steel slab consisting, by weight, of not more than 0.0025% C, not more than 0.05% Si, not more than 0.30% Mn. not less than 0.007% but not more than 0.030% P, not more than 0.020% S, not more than 0,080% sol Al. not more than 0.0030% N, not less than 0.025% but not more than 0.120% Ti, not less than 0.003% but not more than 0.020% Nb. not more than 0.0002% B, and the balance Fe and incidental impurities;
heating said steel slab and finishing hot finishing rolling at temperatures of 880 to 940°C to form a hot rolled steel strip:
subsequently starting cooling of said steel strip within 1.5 sec. from the end of said hot finishing rolling so as to cool said steel strip at a rate of 50 to 200°C/sec. at least until said steel strip is cocied to a temperature of 850°C. and coiling said hot-roiled steel strip at temperatures of 720 to 770°C:
subsequently cold-rolling said steel strip at a rolling rate of not less than 70% to produce steel strip: and
subsequently recrystallization-annealing said cold-rolled steel strip at temperatures of 750 to 900°C by continuous annealing.
said cold-rolled steel strip having $T\ S_{45}$ of 28 5 to 31.0 kgf/mm^2 and r value r_{45} of not less than 1.90

(3) In the cold-rolled steel strip as described in the above subject matter (1) a surface roughness (Ra) of said steel strip along a center axis thereof s preferably 0 2 to 1 0 μm. the combined press formability being still more excellent.

(4) In the method as described in the above subject matter (2) said steel strip is preferably subjected to skinpass roiling at a skinpass rolling rate of not less than 0.3% after said recrystallization-annealing to make said steel strip have a surface roughness (Ra) of 0 2 to 1.0 μm, the combined press formability being still more excellent.

[0007] The present invention will now be described in detail in connection with the drawings in which

Fig. 1 is a graph showing the relation between combined press formability and the characteristic values of steel material: and

Fig. 2 is a graph showing the relation between combined press formability (defective percentage) and the surface roughness of steel strips

[0008] First. reference is made to the above subject matters (1) and (3) of the present invention

[0009] In an attempt to develop a cold-rolled steel strip which exhibits excellent press formability (combined press formability) in the actual pressing for forming pressed products (combined pressed product) of a complicated shape such as a wheel house inner having a deep-drawn portion, a stretched portion and a draw bead. the inventors of the present invention first prepared combined pressed products using cold-rolled steel strips excellent in El. ṙ and r_{45}, including one of a quite excellent quality (as reported in Lecture Report of Japan Steel Association, Vol. 3. No. 6. 1990. p. 1771) having El of 51.0. r of 2.52 and r_{45} of 2.40. and their actual press-formability was examined. As a result, it turned out that despite the fact that the above cold-rolled steel strips (including the above steel strip of a quite excellent quality having El of 51.0. r of 2.52 and r_{45} of 2.40) were excellent in El. r and r_{45}, they were. in many cases. inferior in actual press formability. This is almost unbelievable in view of the findings heretofore obtained. Also, the inventors of the present invention prepared a cold-rolled steel of an ultra-high El($El_{45} \geq 55\%$: $r_{45} \geq 2.2$) using very low-phosphorous steel, and examined the combined pressed formability thereof. The result was that the formability was poor as was the case with the above cold-rolled strips.

[0010] Then, the inventors of the present invention studied the relation between the combined pressed formability and the characteristic values of the steel materials in further detail, and it has been found that the steel strip can have excellent combined press formability (1) if the steel strip has $T.S_{45}$ of 28.5 to 31.0 kgf/mm^2 and r_{45} of not less than 1.90 and (2) if the content of B is not more than 0.0002%. Further. it has been found that (3) if the steel strip is adjusted to have a surface roughness Ra of 0.2 to 1.0 µm, more excellent combined pressed formability can be obtained. The above coid-rolled steel strip (as reported in Lecture Report of Japan Steel Association, Vol. 3, No. 6 1990, p. 1771) was prepared for experimental use for an oil pan for an automobile. which steel strip contained 0.0008% B in order to prevent fabrication brittleness after it was formed into a square shell, and it is thought that this causes the above-mentioned poor combined press formability in the actual pressing.

[0011] Fig. 1 is a graph showing the relation between these combined press formabilities and the characteristic values of the materials in detail, and it will be appreciated that the steel strip can exhibit excellent combined press formability (1) if the steel strip has $T.S_{45}$ of 28.5 to 31.0 kgf/mm^2 and r_{45} of not less than 1.90 and (2) if the content of B is not more than 0.0002%.

[0012] Fig. 2 is a graph showing the results of examination of the combined press formability in the actual pressing with respect to steel strips which had $T.S_{45}$ of 29.5 kgf/mm^2. r_{45} of 2.14 and the B content of not more than 0.0002%, and were adjusted by skinpass rolling of 0.8% into a surface roughness Ra of 0.2 to 1.0 µm. From Fig. 2, it will be appreciated that the steel strip of the present invention adjusted to a surface roughness Ra of 0.2 to 0.1 µm exhibits more excellent combined press formability and. that the steel strip of the present invention exhibits excellent combined press formability in the actual pressing for forming a pressed product of a complicated shape, such for example as a wheel house inner, having a deep-drawn portion, a stretched portion and a draw bead. thus providing an excellent industrial value. Incidentally. when the cold-rolled steel strip of the present invention is used as a base plate (substrate) for a surface treated steel strip, such as an electrically Zn-plated steel strip. this surface treated steel strip can also exhibit excellent combined press formability, thus providing the advantages of the present invention.

[0013] Although it is difficult to clearly analyze the reasons why the excellent combined press formability can be achieved with the steel strip of the present invention as described above. these reasons are thought to be as follows:

(1) As regards the reason why it is indispensable for the steel strip to have T S_{45} of 28.5 to 31.0 kgf/mm^2, it is thought that the press formability limit in the actual pressing for a product of a complicated shape (e.g. a wheel house inner) having a deep-drawn portion, a stretched portion and a draw bead is generally determined by a frictional resistance force and a fracture resistance ($T.S_{45}$) of the steel strip both occurring when the steel strip flows at a die shoulder rounded portion of the the deep draw portion or the draw bead portion (In most deep drawn parts, that portion subjected to the severest drawing is in 45' direction of the steel strip). Therefore. it is thought that $T.S_{45}$ of not less than 28.5 kgf/mm^2 is indispensable to such combined pressed product for an automobile. The reason why the material of an ultra-high E_{45} as disclosed in the above Japanese Patent Unexamined Publication No 63-76848 is inferior in combined press formability is thought to be that $T.S_{45}$ of not less than 28 5 kgf/mm^2 required for the combined press formability can not be kept because El is too high Incidentally it is thought that when $T.S_{45}$ is above 31.0 kgf/mm^2, the combined press formability is lowered because the ductility of the steel

strip is lowered.

(2) The value of r_{45} must be not less than 1.90 in order to enhance the deep drawability in 45° direction. as described above For example with $r_{45} \leq 1.85$ as described in Japanese Patent Unexamined Publication No. 61-113724. good combined press formability can not be obtained.

(3) The reason why the content of B should be not more than 0.0002% is not clear: however various studies made by the inventors of the present invention indicated that in many cases. cold-rolled steel strips containing not less than 0 0005% B were lower in local elongation at tensile tests as compared with those having the same tensile strength (T.S) Therefore, such steel strip, having a low local elongation value for its tensile strength is subjected to severe bending and bending-back when the steel strip flows at the die shoulder rounded portion of the draw portion or the draw bead portion. so that the press formability is much deteriorated because of the low local elongation value. It is thought that this causes an easy fracture by pressing.

(4) Reference is made to the reason why the steel strip adjusted to a surface roughness Ra of 0.2 to 1.0 μm exhibits more excellent combined press formability. When the steel strip flows at the die shoulder rounded portion of the deep draw portion or the draw bead portion, the surface of the steel strip undergoes a high compressive stress by a tool while the steel strip is subjected to severe bending and bending-back, so that the rugged portion on the surface of the steel strip is plastically deformed into a smooth surface. It is thought that the energy required for this plastic deformation offers a resistance when the steel strip flows at the die shoulder rounded portion of the deep draw portion or the draw bead portion. Therefore, the steel strip adjusted to the surface roughness Ra of 0.2 to 1.0 μm is subjected to a less resistance when the steel strip flows at the die shoulder rounded portion of the deep draw portion or the draw bead portion. thereby achieving more excellent combined press formability. If the surface roughness Ra is less than 0.2 μm. the ruggedness of the steel strip surface is reduced, and the amount of oil residing on the steel strip surface is reduced, and therefore the oil is liable to be removed from the steel strip surface. As a result. it is thought that the frictional resistance is increased, so that the steel strip is less liable to flow, and the actual pressing ability can not be so improved as expected.

[0014] Although the effects mentioned in the above paragraphs (1). (2) and (3) can be effective independently of one another, the combination of these effects leads to the cold-rolled steel strip of the present invention having excellent combined press formability. Further when the requirement mentioned in the above paragraph (4) is satisfied, more excellent combined press formability can be achieved. Referring to the reason why the cold-rolled steel strip consists, by weight, of not more than 0.0025% C not more than 0.05% Si, not more than 0.30% Mn, not less than 0.007% but not more than 0.030% P not more than 0.020% S, not more than 0.080% sol Al, not more than 0.0030% N, not less than 0.025% but not more than 0.120% Ti, not less than 0.003% but not more than 0.020% Nb. not more than 0.0002% B, and the balance Fe and incidental impurities, these are the basic components for obtaining the cold-rolled steel strip having excellent combined press formability, satisfying the above characteristics, on an economical industrial basis.

[0015] Next, the invention described in the above subject matters (2) and (4) will now be explained. The invention described in the above subject matters (2) and (4) is directed to a method of producing the cold-rolled steel strip, described in the above subject matters (1) and (3), by continuous annealing. The features of the invention described in the above subject matters (2) and (4) are:

(a) to adjust the production conditions so as to bring the characteristic values of the cold-rolled steel strip to be obtained into agreement with the characteristic values of the invention in the above subject matters (1) and (3) so as to produce the cold-rolled steel strip satisfying the first condition of the invention, thereby providing the method of producing the cold-rolled steel strip having excellent combined press formability which has not heretofore been achieved: and

(b) to specify the composition of the steel, the hot rolling condition, the cold-rolling condition, the continuous annealing condition and the skinpass rolling condition so as to provide the method of producing the cold-rolled steel strip of excellent combined press formability which has T S_{45} of 28.5 to 31.0 kgf/mm^2 and r_{45} of not less than 1.90. and also a surface roughness Ra of 0 2 to 1.0 μm (the above subject matter (4)).

[0016] The production conditions will now be described in detail. C is a very important element for cbtaining the cold-rolled steel strip, having r_{45} of not less than 1.90, by continuous annealing, and if the C content exceeds 0 0025%, this characteristic value can not be obtained. Therefore, the upper limit of the C content should be not more than 0.0025%.

[0017] If the content of any of Si Mn S and N increases r_{45} is lowered and the characteristic value of r_{45} not less than 1 90 can not be obtained Therefore not more than 0.05% Si. not more than 0.30% Mn. not more than 0 020% S and not more than 0 0030% N are specified.

[0018] If the content of P is less than 0 007% it is difficult to obtain T.S_{45} of 28 5 kgf/mm^2. Also if this content exceeds 0 030%. the deterioration of deep drawing-induced brittleness becomes excessive and therefore this content is limited to not more than 0.0305.

[0019] Sol Al is usually used as an decxidizer, However, in the steel of the present invention, it is not undesirable at all to effect Ti deoxidation. and therefore there is no need to specify the lower limit of sol Al. r_{45} decreases with the increase of the content of sol Al. so that the characteristic value of not less than 1.90 is hardly obtained. Therefore, this content is limited to not more than O 080%.

[0020] Ti is a very important element for obtaining the r_{45} value of not less than 1 90, and if the Ti content is less than 0.025%, this characteristic value can not be obtained. Also. if the Ti content exceeds 0.120%. $T.S_{45}$ exceeds 31.0 kgf/mm^2. Therefore the Ti content is limited to 0.025% to 0 120%.

[0021] Nb is a more important element than Ti so as to obtain r_{45} of not less than 1 90 and if the Nb content is less than 0.003%, this characteristic value can not be obtained. Also. if the Nb content exceeds 0.020%. the recrystallization temperature becomes high, and the crystal grains become finer, so that $T.S_{45}$ exceeds 31.0 kgf/mm^2 Therefore. the Nb content is limited to 0.003% to 0.020%

[0022] B is an element which markedly improves the deep drawing-induced brittleness, and at the same time the cold-rolled steel strip containing more than 0.0005% B has a lower value of local elongation at a tensile test as compared with that having the same tensile strength (T.S), as described above, with the result that good combined press formability can not be obtained. Therefore the B content should be not more than 0.0002%.

[0023] The hot rolling with the particular condition serves to combine C with Ti to form TiC to thereby make C harmless, and also serves to make the crystal grains of the hot-rolled strip fine by the combined effects achieved by the addition of not less than 0.025% Ti and not less than 0.003% Nb.

[0024] The heating condition before the hot rolling is not particularly limited, and may be an ordinary heating condition. However. in order to obtain the softer steel strip, it is preferred to use the heating temperature (hereinafter referred to as "SRT") of not more than 1100°C.

[0025] If the finishing temperature of the hot rolling is less than 880°C. the crystal grains become coarse, so that the value of r_{45} is markedly decreased. Also. if this finishing temperature exceeds 940°C. the crystal grains become too coarse, so that r_{45} of not less than 1.90 can not be obtained. Therefore, the finishing temperature should be 880 to 940°C.

[0026] The coiling temperature (hereinafter referred to as "C.T") is a very important factor in promoting the precipitation of TiC and its coarse structure so as to obtain a very excellent r_{45} value. If this temperature is less than 680°C. the precipitation and coarse structure of TiC are insufficient, so that r_{45} value is low. If this temperature exceeds 680°C. the precipitation and coarse structure of TiC are promoted, so that the r_{45} value is improved. If this temperature exceeds 720°C the coarse precipitation of TiC occurs, so that the excellent r_{45} value can be obtained. If this temperature exceeds 770°C, the crystal grains become coarse, so that the r_{45} value of not less than 1.90 can not be obtained. Therefore, the coiling temperature should be 720 to 770°C. Thus. to coil out the strip at temperatures of not less than 720°C is an important feature of the production method of the present invention so as to obtain the excellent r_{45} value (not less than 1.90), and in this respect, the present method is greatly different from a method as disclosed in Japanese Patent Unexamined Publication No. 51 -275930 in which a strip is coiled out at temperatures of not more than 710°C.

[0027] In order to make the crystal grains of the hot-rolled strip fine, it is necessary to cool the strip down to at least 850°C at a rate of not less than 50°C/sec. and within at least 1.5 sec. after the finishing rolling. If the cooling is started later than the above time, or if the temperature range of the cooling, as well as the cooling rate (speed), do not satisfy the above conditions, the crystal grains become large, so that the r_{45} value of not less than 1.90 can not be obtained.

[0028] If the cold rolling rate is less than 70%, the r_{45} value is lowered, so that the intended cold-rolled steel strip of the present invention can not be obtained. Therefore, the cold rolling rate should be not less than 70%.

[0029] If the recrystallization annealing is carried out at temperatures of 750 to 900°C. the intended cold-rolled steel strip of the present invention can be obtained, and any other condition does not need to be satisfied. If the annealing temperature is less than 750°C. the r_{45} value of not less than 1.90 can not be obtained. Also, if the annealing temperature exceeds 900°C the crystal grains become unduly large, so that $T.S_{45}$ of 28.5 kgf/mm^2 can not be obtained. Therefore, the annealing temperature is limited to 750 to 900'C

[0030] Without particularly limiting the skinpass rolling (hereinafter referred to as "S.P"). excellent combined press formability can be obtained under an ordinary condition: however in order to obtain the steel strip having a surface roughness Ra of 0.2 to 1.0 µm required for obtaining more excellent combined press formability (as described in the above subject matter (4)). S P of not less than 0.3% is necessary. If the surface roughness of the steel strip produced by continuous annealing is too fine, the steel strip, when passing around a hearth roll during the continuous annealing, slips relative to the hearth roll because of a low friction between the steel strip and the hearth roll. and as a result the steel strip travels in a meandering manner in a continuous anealing furance so that the steel strip may rub or break the wall of the furnace. Therefore the surface roughness of the steel strip is made coarse during the cold rolling. Therefore in order to bring such a coarse surface of the steel strip subjected to the annealing to a surface roughness Ra of 0 2 to 1.0 µm by the skinpass rolling it is necessary to apply the skinpass rolling of not less than 0.3% to the steel strip Otherwise, the surface roughness Ra of not more than 1.0 µm would not be obtained even if the surface roughness of a temper rolling roll is made fine. Preferably the upper limit of the S.P amount should be about 1 5%

which is equal to the upper limit of the amount of S.P usually applied to ordinary cold-rolled steel strips. The surface roughness of the steel strip can be controlled by determining the surface roughness of the skinpass rolling roll and the rolling rate of the skinpass rolling.

[0031] The present invention can be applied not only to the method of producing the cold-rolling steel strip but also to a method of producing a base plate (substrate) for an electroplated (e.g. galvanized or tinned) steel strip and a base plate for a surface treated steel strip such for example as one coated with an organic film. Characteristic values of the properties of such a surface treated steel strip are influenced by characteristic values of the properties (e.g. hardness) of metal or alloy plated on the surface of the steel strip and the thickness of the plated film, so that usually Y.P. and T.S become high whereas El and the r value become low. However, the press formability of the surface-treated steel strip is determined not by the characteristic values of the plated steel strip including the plated film but by the properties of the substrate or base plate (i.e., steel strip perse). Namely, if the characteristic values (the properties and surface roughness) of the base plate of the surface treated steel strip satisfy the conditions of the present invention, excellent combined press formability can be obtained. Therefore, the surface treated steel strip having excellent combined press formability can be produced using the cold-rolled steel strip of the present invention as the base plate.

Example

[0032] The effects of the present invention will now be described by way of Examples.

[0033] Using compositions shown in Table 1 and hot-rolling conditions (finishing temperature: 910 to 930°C) shown in Table 2, hot-rolled steel strips (thickness: 4 mm) were prepared, and then were cold-rolled into a thickness of 0.8 mm. Then, each of the cold-rolled steel strips was recrystallization annealed at 820°C for 60 seconds by continuous annealing, and then was cooled to room temperature, and then was subjected to skinpass rolling to thereby obtain the cold-rolled steel strip.

[0034] The characteristic values of the mechanical properties ($T.S_{45}$, El_{45}, r_{45} value) and surface roughness Ra of the thus obtained cold-rolled steel strips were measured. Results obtained are shown in Table 2.

[0035] In order to examine the actual press formability of combined press products, actual pressing tests of wheel house inners were conducted, and their defective press percentage was examined. Results obtained are shown in Table 2.

[0036] Steels A, B and E are out of the range of the present invention in terms of the composition, and steels C, D and F are within the range of the present invention.

[0037] Sample Nos. 3, 4, 5, 6, 8 and 12 were prepared according to the above subject matters (1) and (2) of the present invention, and each of these samples had $T.S_{45}$ of 28.5 to 31.0 kgf/mm^2 and r_{45} of not less than 1.90 required for obtaining excellent combined press formability, and their press defective percentage was not more than 0.7%. Thus, these samples exhibited excellent values. Among these, sample Nos. 5, 6, 8 and 12 were prepared according to the method of the present invention as described in the above subject matters (3) and (4), and they had a surface roughness Ra of 0.2 to 1.0 µm, and their press defective percentage was not more than 0.2%, thus exhibiting more excellent results.

[0038] Sample Nos. 1, 2, 7, 9, 10, 11, 13 and 14 were conventional examples or comparative examples, and each of them could only achieve the press defective percentage of not less than 2.2%.

Table 1

Steel	Composition (%)										Note
	C	Si	Mn	P	S	solAl	N	Ti	Nb	B#	
A	0.0015	0.02	0.15	0.015	0.017	0.040	0.0025	0.033	Tr	4	out of invention
B	0.0012	0.01	0.12	0.003	0.004	0.045	0.0014	0.030	0.007	Tr	out of invention
C	0.0018	0.01	0.12	0.017	0.003	0.044	0.0012	0.038	0.007	Tr	within invention
D	0.0014	0.01	0.10	0.015	0.003	0.028	0.0016	0.037	0.007	2	within invention
E	0.0017	0.01	0.11	0.017	0.003	0.043	0.0013	0.036	0.007	8	out of invention
F	0.0015	0.01	0.12	0.019	0.002	0.005	0.0013	0.065	0.008	Tr	within invention

B#: B content (ppm)

Table 2

Sample No.	Steel	Hot				S.P	Ra	Mechanical Properties			Press defective percentage	Note
		SRT	tQ	α	C.T.			$T.S_{45}$	El_{45}	r_{45}		
		°C	sec	°C/s	C	%	μm	kgf/mm^2	%	-	%	
1	A	1050	0.7	80	730	0.8	1.0	28.9	52.8	1.53	100	Conventional example
2	B	1050	0.7	80	730	0.8	1.3	27.8	54.7	2.17	4.2	Conventional example
3	C	1050	0.7	80	730	0.1	1.8	29.0	51.9	2.15	0.7	Present invention
4	C	1050	0.7	80	730	1.0	0.1	29.5	50.6	2.16	0.6	Present invention
5	C	1050	0.7	80	730	1.0	0.6	29.5	50.6	2.17	0.1	Present invention
6	D	1050	0.7	120	730	0.8	0.4	29.6	50.2	2.03	0.2	Present invention
7	E	1150	1.2	80	730	0.8	1.2	30.5	48.8	1.94	3.8	Comparative example
8	F	1050	0.7	80	730	1.0	0.6	30.2	49.7	2.28	0.1	Present invention
9	C	1050	3.2	50	730	0.9	0.9	29.2	51.0	1.87	2.2	Comparative exmaple
10	C	1050	1.0	10	730	0.8	1.4	29.1	51.1	1.78	3.8	Comparative exmaple
11	C	1050	1.0	70	550	0.8	1.0	29.7	50.1	1.82	32.	Comparative example

- to be cont'd -

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12	C	1050	0.7	80	730	0.7	0.7	29.4	50.7	2.17	0.2	Present invention
13	B	1050	0.7	80	750	0.7	0.9	27.5	55.7	2.20	4.1	Conventional example
14	C	1150	0.4	40	620	0.8	1.0	29.8	50.0	1.83	3.1	Conventional example

tQ: the time from the end of the finishing rolling to the start of the cooling.

α: the cooling rate on ROT

1 kgf/mm^2 - 10 MPa

[0039] Sample No. 12 is the example of the present invention in which the cold-rolled steel strip of the present invention serving as a base plate was electrically plated with Zn-Ni (plating. 30 g/mm^2) and the characteristic values represent those of the base plate.

[0040] Sample No. 1 is the conventional example made of ordinary very low carbon steel containing Ti but no Nb The obtained characteristic values of this sample were insufficient in $T.S_{45}$ and r_{45}. and this sample could not be drawn at all. and exhibited the press defective percentage of 100%.

[0041] Sample No. 2 is the comparative example in which the P content (0.003%) does not fall within the range of the present invention. As regards the obtained characteristic values. El_{45} and r_{45} (mechanical properties) were the best among all the samples. However, the press defective percentage with respect to the actual pressing of the wheel house inner was as poor as 4 2%. From this fact. It will be appreciated that in the actual pressing of the wheel house inner or the like. It is indispensable to obtain $T.S_{45}$ of 28.5 to 31 0 kgf/mm^2 and r_{45} of not less than 1.90 as in the steel strip of the present invention

[0042] Sample Nos. 3. 4. 5. 6 and 8 are the examples of the present invention in which the composition and the hot rolling condition were varied within the range of the present invention, as shown in Tables 1 and 2. If the production conditions fall within the range of the present invention. the characteristic values necessary for obtaining excellent combined press formability. that is $T.S_{45}$ of 28.5 to 31.0 kgf/mm^2 and r_{45} of not less than 1.90, can be obtained, and the press defective percentage of the steel strip is excellently low. that is. not more than 0.7%. Further, as can be appreciated from Sample Nos. 5, 6 and 8. by limiting the surface roughness Ra of the steel strip to 0.2 to 1.0 μm. the press defective percentage of the steel strip can be further improved up to not more than 0.2%.

[0043] Sample No. 7 is the comparative example in which the B content is high (0.0003%), and although the values of $T.S_{45}$ and r_{45} of the obtained steel strip fall within the range of the present invention, the press defective percentage is quite poor (3.8%). This is thought to be due to the fact that the value of local elongation at the tensile test of the steel strip was lowered because the B content was as high as 0.0008%. Therefore. it will also be appreciated that it is important to limit the B content to not more than 0.0002 %.

[0044] Sample Nos. 9, 10 and 11 are the comparative examples in which the hot rolling condition is out of the range of the present invention, as shown in Table 2. That is, tQ of sample No. 9. α of Sample No. 10 and C.T of Sample No. 11 are out of the range of the present invention, and the r_{45} value of any of these samples is insufficient (that is, less than 1.90), and also the press defective percentage is poor (not less than 2.2).

[0045] Sample No. 12 is the example of the present invention in which the cold-rolled steel strip of the present invention serving as a base plate was electrically plated with Zn-Ni (plating: 30 g/mm^2). It will be appreciated that if the characteristic values of the base plate satisfy the required conditions of the steel strip of the present invention, excellent combined press formability can be obtained.

[0046] Sample No. 13 is the comparative example in which El_{45} is quite high (55.7%). but $T.S_{45}$ is low (27.5 kgf/mm^2) (These characteristic values are similar to those as disclosed in Japanese Patent Unexamined Publication No. 63-76848), and the press defective percentage is poor (4.1%), as shown in Table 2.

[0047] Sample No. 14 is the comparative example in which C.T is low (620°c) prepared generally according to the method of Japanese Patent Unexamined Publication No. 61-276930. and the r_{45} value is only 1.83. and the press defective percentage is poor (3.1%). as shown in Table 2.

[0048] As described above the cold-rolled steel strip according to the above subject matter (1) of the present invention achieves excellent combined press formability. According to the method as mentioned in the above subject matter (2) of the present invention, there can be produced the cold-rolled steel strip having excellent combined pressed formability. Further, according to the above subject matter (3) of the present invention. the cold-rolled steel strip can exhibit more excellent combined press formability. Further, according to the above subject matter (4). there can be produced the cold-rolled steel strip having more excellent combined press formability. Therefore, the present invention is of great industrial value.

Claims

1. A method of producing a cold-rolled steel strip having excellent combined press formability, comprising the steps of:

providing a steel slab consisting, by weight, of not more than 0.0025% C, not more than 0.05% Si, not more than 0.30% Mn, not less than 0.007% but not more than 0.030% P. not more than 0.020% S. not more than 0.080% sol Al, not more than 0.0030% N. not less than 0.025% but not more than 0.120% Ti, not less than 0.003% but not more than 0.020% Nb, not more than B. and the balance Fe and incidental impurities:

heating said steel slab and finishing hot-finishing-rolling at temperatures of 880 to 940°C to form a hot-rolled strip;

subsequently starting cooling of said steel strip down to at least 850°C within 1.5 sec from the end of said not finishing rolling so as to cool said steel strip at a rate of 50 to 200°C/sec, and coiling said hot-rolled steel strip

at temperatures of 720 to 770°C:
subsequently cold-rolling said steel strip at a rolling rate of not less than 70%; and
subsequently recrystallization-annealing said cold-rolled steel strip at temperatures of 750 to 900°C by continuous annealing,
said cold-rolled steel strip having tensile strength in 45° direction (expressed as $T.S_{45}$) of 28.5 to 31.0 kgf/mm^2 and r value in 45° direction (expressed as r_{45}) of not less than 1.90.

2. The method according to claim 1, in which said steel strip is subjected to skinpass rolling at a rolling rate of not less than 03% after said recrystallization-annealing to bring said steel strip into a surface roughness (Ra) of 0.2 to 1.0 μm.

3. A cold-rolled steel strip having excellent combined press formability, consisting, by weight, of not more than 0.0025% C, not more than 0.05% Si, not more than 0.30% Mn, not less than 0.007% but not more than 0.030% P, not more than 0.020% S, not more than 0.080% sol Al, not more than 0.0030% N, not less than 0.025% but not more than 0.120% Ti, not less than 0.003% but not more than 0.020% Nb, not more than B, and the balance Fe and incidental impurities, said steel strip having tensile strength in 45° direction (expressed as $T.S_{45}$) of 28.5 to 31.0 kgf/mm^2 and r value in 45° direction (expressed as r_{45}) of not less than 1.90, said cold-rolled steel strip being producible with the method according to claim 1 or 2

4. The cold-rolled steel strip according to claim 3, in which a surface roughness (Ra) of said steel strip along a center axis thereof is 0.2 to 1.0 μm.

Patentansprüche

1. Verfahren zur Herstellung eines Kaltgewalzten Stahlbandes mit hervorragender Preßverformbarkeit, mit den folgenden Schritten:
Bereitstellen einer Stahlbramme, bestehend aus höchstens 0,0025 Gew.-% C, höchstens 0,05 Gew.-% Si, höchstens 0,0030 Gew.-% Mn, mindestens 0,025 Gew.-% und höchstens 0,030 Gew.-% P, höchstens 0,020 Gew.-% S, höchstens 0,080 Gew.-% löslichem Al, höchstens 0,0030 Gew.-% N, mindestens 0,025 Gew.-% und höchstens 0,120 Gew.-% Ti, mindestens 0,003 Gew.-% und höchstens 0,020 Gew.-% Nb, höchstens 0,0002 Gew.-% B, wobei der Rest aus Fe und zufälligen Verunreinigungen besteht;

Erhitzen der Stahlbramme und Warmfertigwalzen bei Endtemperaturen von 880 bis 940°C zum Formen eines Warmbandes;
anschließender Beginn der Abkühlung des Stahlbandes auf mindestens 850°C innerhalb von 1,5 s nach Beendigung des Warmfertigwalzens, um das Stahlband mit einer Geschwindigkeit von 50 bis 200°C/s abzukühlen, und Aufwickeln des warmgewalzten Stahlbandes bei Temperaturen von 720 bis 770°C;
anschließendes Kaltwalzen des Stahlbandes mit einem Walzreduktionsgrad von mindestens 70%; und
anschließendes Rekristallisationsglühen des kaltgewalzten Stahlbandes bei Temperaturen von 750 bis 900°C mittels Durchlaufglühen,

wobei das kaltgewalzte Stahlband eine Zugfestigkeit in 45°-Richtung (ausgedrückt als TS_{45}) von 28,5 bis 31,0 kp/mm^2 und einen r-Wert in 45°-Richtung (ausgedrückt als r_{45}) von mindestens 1,90 aufweist.

2. Verfahren nach Anspruch 1, wobei das Stahlband nach dem Rekristallisationsglühen einem Nachwalzen mit einem Walzreduktionsgrad von mindestens 0,3% unterworfen wird, um die Oberflächenrauhigkeit (Ra) des Stahlbandes auf 0,2 bis 1,0 μm zu bringen.

3. Kaltgewalztes Stahlband mit hervorragender kombinierter Preßverformbarkeit, bestehend aus höchstens 0,0025 Gew.-% C, höchstens 0,05 Gew.-% Si, höchstens 0,30 Gew.-% Mn, mindestens 0,007 Gew.-% und höchstens 0,030 Gew.-% P, höchstens 0,020 Gew.-% S, höchstens 0,080 Gew.-% löslichem Al, höchstens 0,0030 Gew.-% N, mindestens 0,025 Gew.-% und höchstens 0,120 Gew.-% Ti, mindestens 0,003 Gew.-% und höchstens 0,020 Gew.-% Nb, höchstens 0,0002 Gew.-% B, wobei der Rest aus Fe und zufälligen Verunreinigungen besteht, wobei das Stahlband eine Zugfestigkeit in 45°-Richtung (ausgedrückt als TS_{45}) von 28,5 bis 31,0 kp/mm^2 und einen r-Wert in 45°-Richtung (ausgedrückt als r_{45}) von mindestens 1,90 aufweist,
wobei das kaltgewalzte Stahlband mit dem Verfahren nach Anspruch 1 oder 2 herstellbar ist.

4. Kaltgewalztes Stahlband nach Anspruch 3, wobei eine Oberflächenrauhigkeit (Ra) des Stahlbandes längs seiner Mittelachse 0,2 bis 1,0 µm beträgt.

Revendications

1. Procédé de fabrication d'un feuillard en acier laminé à froid possédant une excellente capacité de formage à la presse, comprenant les étapes consistant :

   à prévoir une plaque en acier se composant, exprimée en poids, d'une teneur non supérieure à 0,0025% en C, non supérieure à 0,05% en Si, non supérieure à 0,30% en Mn, non inférieure à 0,007% mais non supérieure à **0,030%** en P, non supérieure à 0,020% en S, non supérieure à 0,080% en Al en solution, non supérieure à 0,0030% en N, non inférieure à **0,025%** mais non supérieure à 0,120% en Ti, non inférieure à 0,003% mais non supérieure à 0,020% en Nb, non supérieure à 0,0002% en B, le reliquat étant constitué de Fe et d'impuretés insignifiantes,
   à chauffer ladite plaque en acier et à réaliser une finition par laminage à chaud à des températures comprises entre 880 et 940°C pour former un feuillard laminé à chaud ;
   à commencer consécutivement le refroidissement dudit feuillard en acier à une température pouvant descendre à au moins 850° en moins de 1,5 seconde à partir de l'achèvement de ladite finition par laminage à chaud en vue de refroidir ledit feuillard en acier à une vitesse de 50 à 200°C/sec., et à bobiner ledit feuillard en acier laminé à chaud à des températures comprises entre 720 et 770°C ;
   à laminer à froid consécutivement ledit feuillard en acier à une vitesse de laminage non inférieure à 70% ; et
   à recuire en présence de recristallisation consécutivement ledit feuillard en acier laminé à froid à des températures comprises entre 750 et 900°C grâce à une recuisson continue,
   ledit feuillard en acier laminé à froid ayant une résistance à la traction dans la direction à 45° (exprimée par $T.S_{45}$) de 28,5 à 31,0 kgf/mm2 et un facteur r dans la direction à 45° (exprimée par r_{45}) non inférieur à 1,90.

2. Le procédé selon la revendication 1, dans lequel ledit feuillard en acier est soumis, après ladite recuisson en présence de recristallisation, à une passe de laminage à froid à une vitesse de laminage non inférieure à 0,3% pour amener ledit feuillard en acier à une rugosité de surface (Ra) comprise entre 0,2 et 1,0 µm.

3. Feuillard en acier laminé à froid possèdant une excellente capacité de formage à la presse, se composant, exprimée en poids, d'une teneur non supérieure à 0,0025% en C, non supérieure à 0,05% en Si, non supérieure à 0,30% en Mn, non inférieure à 0,007% mais non supérieure à **0,030%** en P, non supérieure à 0,020% en S, non supérieure à 0,080% en Al en solution, non supérieure à 0,0030% en N,non inférieure à **0,025%** mais non supérieure à 0,120% en Ti, non inférieure à 0,003% mais non supérieure à 0,020% en Nb, non supérieure à 0,0002% en B, le reliquat étant constitué de Fe et d'impuretés insignifiantes, ledit feuillard en acier ayant une résistance à la traction dans la direction à 45° (exprimée par $T.S_{45}$) de 28,5 à 31,0 kgf/mm2 et un facteur r dans la direction à 45° (exprimée par r_{45}) non inférieur à 1,90, ledit feuillard en acier laminé à froid étant productible selon le procédé de la revendication 1 ou 2.

4. Le feuillard en acier laminé à froid selon la revendication 3, dans lequel une rugosité de surface (Ra) dudit feuillard en acier le long de son axe est comprise entre 0,2 et 1,0 µm.

FIG. 1

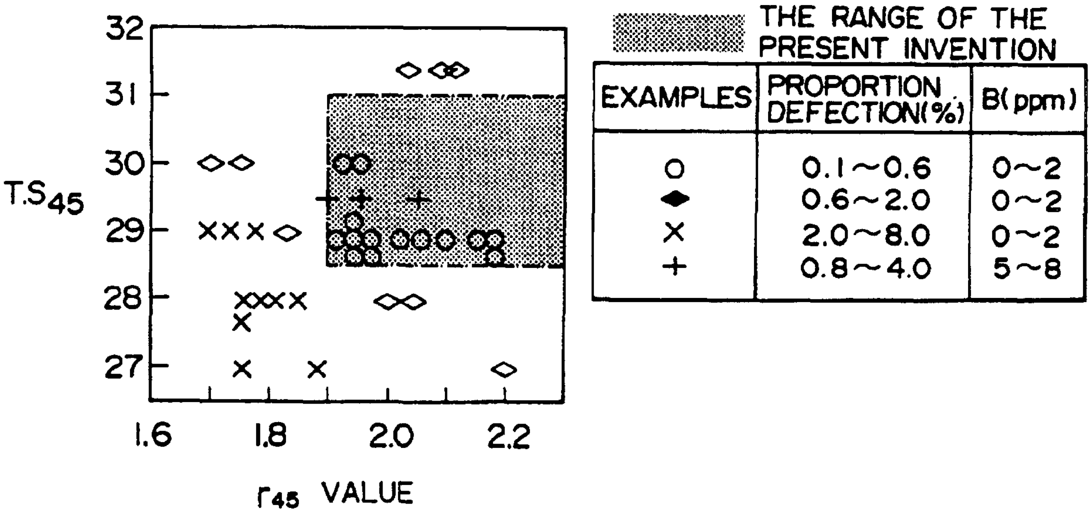
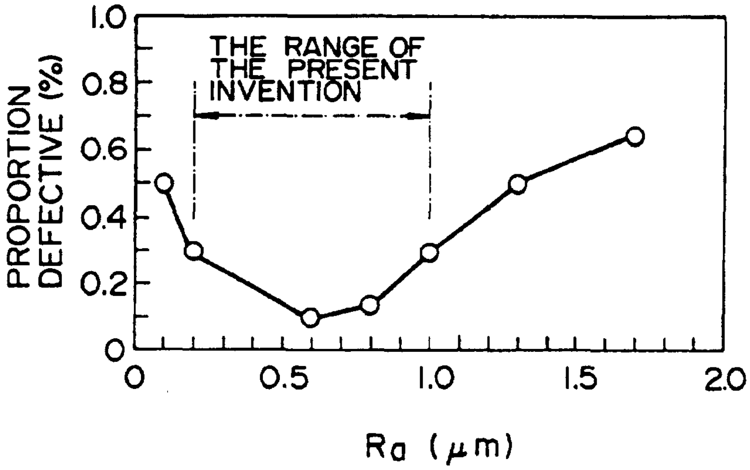

THE RANGE OF THE PRESENT INVENTION
EXAMPLES
PROPORTION DEFECTION(%)
B(ppm)
0.1~0.6
0~2
0.6~2.0
0~2
2.0~8.0
0~2
0.8~4.0
5~8
T.S45
32
31
30
29
28
27
1.6
1.8
2.0
2.2
r45 VALUE

FIG. 2


THE RANGE OF THE PRESENT INVENTION
PROPORTION DEFECTIVE (%)
1.0
0.8
0.6
0.4
0.2
0
0.5
1.0
1.5
2.0
Ra (μm)