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⑤④ **PROCESS FOR PRODUCING HIGH-STRENGTH COLD-ROLLED STEEL PLATE FOR PRESS WORKING.**

⑤⑦ A process for producing a high-strength cold-rolled steel plate for press working having a tensile strength of 35–45 kg/mm² and a yield ratio of 0.4–0.6, which comprises hot-rolling steel comprising 0.005–0.080% of C, not more than 0.30% of Si, 1.6–3.5% of Mn, 0.02–0.08% of sol. Al, 0.005–0.020% of N, and balance of Fe and unavoidable impurities, and, after cold-rolling, annealing at 660–750 °C for not shorter than 30 minutes.

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Specification

Title of the Invention:

Method of Producing High Strength Cold Rolled Steel
Sheet For Press Formation

5 Technical Field:

This invention relates to a method of producing a high strength cold rolled steel sheet having excellent press formability, comparable to the conventional cold rolled steel sheet for drawing.

10 Background Art:

The conventional cold rolled steel sheet for deep drawing has a tensile strength of 28 - 33 Kg/mm² and has been used as outer panels of automobile bodies after being press formed. However, with the recent trend in the auto industry to reduce the weight of automobiles in an attempt to improve mileage economy, more and more automobile bodies are using thinner outer panels. Thus, car manufactures demand cold rolled steel sheets whose formability is comparable to the conventional one and having a tensile strength higher than the latter.

20 The outer panels of automobile bodies assume various configurations depending on car models and their mounting locations, but since most of them undergo only a slight degree of press formation, form retention after pressing is a very important factor.

25 The conventional high tensile steel has a high yielding point and experiences considerable spring back and as a result, it is difficult to provide a press formed article with a desired configuration. In addition, since the steel permits only too small elongation, it can easily develop cracks during
30 press forming. The dual phase steel of recent development has

low yielding point, but since its tensile strength is 50 - 70 Kg/mm², it undergoes too rapid work hardening and provides high yielding point after slight press forming, making it difficult to produce a desired configuration free from the effect of spring back.

Disclosure of the Invention:

The inventors of this invention have found, after carrying out intensive study to solve these problems, that a cold rolled steel sheet having a tensile strength of 35 - 45 Kg/mm², a yield ratio (yield strength/tensile strength) of 0.4 - 0.6, an r-value of more than 1.2 is most suitable for providing the desired steel sheet for use as outer panels of an automobile body.

The primary purpose of this invention is to provide a method of producing a cold rolled steel sheet having the above defined characteristics.

In general, the higher the strength of steel, the less the press formability and form retention. However, according to this invention, a cold rolled steel sheet can be provided which has press formability and form retention comparable to the conventional cold rolled steel sheet and yet has high strength and dent resistance higher than the conventional one, thus making great contribution to making of lighter cars. The term "dent resistance" means the property of a cold rolled steel sheet that does not retain a depression (permanent deformation) resulting from an external force applied to a press formed article made of that sheet.

This invention resides in a method of producing a high strength cold rolled steel sheet for press formation which is characterized by hot rolling a steel consisting of 0.005 - 0.080% of C, less than 0.30% of Si, 1.6 - 3.5% of Mn, 0.02 - 0.08% of Sol. Al, 0.005 - 0.020% of N, the balance of Fe and incidental impurities, cold rolling the same with a reduction of at least 30%, and annealing the cold rolled steel by heating it at 660 - 750°C for a period longer than 30 minutes.

In carrying out the method of this invention a hot rolled steel is desirably coiled at a temperature lower than 600°C. Temper rolling is not necessarily performed, but if it is performed for a special purpose, a desired elongation

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ratio is 0.5% at maximum.

The characteristic feature of this invention consists in optimizing the Sol. Al content, N content, and optionally the coiling temperature after hot rolling in the production of a low yield ratio steel sheet from high-Mn steel for the purposes of limiting the number of recrystallizing nuclei to form large grains in the process of annealing after cold rolling as well as promoting the growth through recrystallization of grains having an orientation [111] parallel to the plate surface, thereby providing a cold rolled steel sheet having a yield ratio less than 0.60 and an r-value higher than 1.2.

Brief Description of the Drawings:

Fig. 1 is a photograph (x 500) showing a microstructure of a cold rolled steel sheet produced in accordance with this invention. Fig. 2 is a photograph (x 500) showing a microstructure of a cold rolled steel sheet produced in accordance with the prior art. Fig. 3 is diagrammatical view explaining the test of form retention, in which a steel sheet is bent in a U-shaped form. Fig. 4 is a perspective view showing the measuring of residual indentation in dent resistance test.

Figs. 1 and 2 are photomicrographs (x 500) showing, respectively, microstructures of our cold rolled steel sheet of Steel No. 1 and the conventional high strength and low yield ratio cold rolled steel sheet of Steel No. 10 in Table 1. The grain size of steel sheet produced in accordance with this invention as shown in Fig. 1 is larger than that in Fig. 2. This is because, as mentioned hereinbefore, the formation of recrystallization nuclei has been restricted by optimizing the proportions of Sol. Al and nitrogen as well as coiling temperature after hot rolling. The lower yield point and the higher r-value which are obtained in accordance with this invention are due to the microstructure shown in Fig. 1.

The reasons for limiting the chemical composition of the steel to which this invention is applied will be described in detail hereinafter.

Carbon (C): Carbon is effective for forming a dispersed phase of martensite in the cold rolled steel sheet to give a

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low yield ratio in the presence of manganese in an amount of more than 1.6%. A carbon content of less than 0.005% is not enough to give a thoroughly low yield ratio. On the other hand, more than 0.080% carbon raises tensile strength excessively and impairs spot weldability. The carbon content is restricted to from 0.005% to 0.080%.

Silicon (Si): Silicon may be used as a deoxidizer and is effective for making the formation of martensite easier. However, a large amount of Si increases yield point and tensile strength, impairing formability and surface flatness of the cold rolled steel sheet. Thus, the Si content is restricted to less than 0.30%. Si is not required if the addition of Al achieves thorough deoxidation.

Manganese (Mn): Manganese is effective for forming a dispersed phase of martensite in the presence of carbon. A manganese content of less than 1.6% is not enough to give a low yield ratio. A manganese content of more than 3.5% is not desirable, since such a large amount of manganese increases tensile strength excessively.

Acid soluble aluminium (Sol.Al): Sol.Al is effective for lowering yield ratio, optimizing crystal grain and improving recrystallization texture i.e. increasing an r-value in the presence of nitrogen in an amount of more than 0.005%. The Sol.Al content of 0.02 - 0.08% is desirable for obtaining desired mechanical properties.

Nitrogen (N): Nitrogen is necessary to optimize crystal grain and to improve recrystallization texture in the presence of a suitable amount of Sol.Al. For this purpose, a nitrogen content of 0.005 - 0.020% is necessary. A nitrogen content of less than 0.005% is not effective for this purpose.

The balance of the steel composition is Fe with incidental impurities, of which P and S are allowed to present in an amount of less than 0.05%, respectively.

A preferred composition of the steel to which this invention is applied is:

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C : 0.008 - 0.05%,
Si : 0 - 0.2%,
Mn : 1.8 - 2.5%,
Sol.Al : 0.02 - 0.08%,
5 N : 0.005 - 0.010%,
P : up to 0.05%,
S : up to 0.05%, and
Fe : balance.

Coiling temperature after hot rolling determines the
10 structure and arrangement of AlN and has an influence on the
r-value of the resulting steel sheet containing Sol.Al, N and
Mn in amounts specified in the above. In order to obtain a
steel sheet having an r-value of around 1.2, the coiling
temperature may be above 600°C. However, in order to obtain
15 an r-value of more than 1.2 constantly, it is necessary to
coil a hot rolled steel sheet at a temperature lower than
600°C. Annealing after cold rolling is necessary to obtain
a cold rolled steel sheet which is softened due to removal
of stress introduced during cold rolling and which has a dual
20 phase of ferrite plus martensite, giving a tensile strength
of 35 - 45 Kg/mm², a yield ratio of 0.4 - 0.6 and an r-value
of more than 1.2. For this purpose the desirable annealing
temperature is within the range of 660 - 750°C.

The soaking time during annealing is also important.
25 A soaking time of more than 30 minutes is necessary to effect
concentration of C and Mn in the steel, and to form martensite
during the period of cooling in annealing. A soaking time of
less than 30 minutes is sometimes insufficient to form
martensite.

30 Usually temper rolling with a reduction of more than
about 1% is applied to a cold rolled steel sheet so as to
avoid the formation of stretcher strains and to improve flat-
ness of the steel sheet. However, according to this invention,
such temper rolling is not necessarily required. This is
35 because the steel sheet produced in accordance with this inven-
tion does not show an elongation at yield point in the annealed
state. Thus, it is not necessary to effect temper rolling in
order to avoid the formation of stretcher strains. However,
even in this invention skin pass rolling may be applied to

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the cold rolled steel sheet in order to improve the surface flatness. However, since skin pass rolling (temper rolling) with a reduction of more than 0.5% results in increase in yield point with deterioration of formability, when temper
5 rolling is applied, it is advisable to restrict the reduction on temper rolling to not more than 0.5%.

Embodiments of the Invention:

Examples:

The working examples of this invention will be described
10 hereinafter.

Steels having chemical composition as shown in Table 1 were prepared with a converter to produce slabs 230 mm thick by a continuous casting method. Sulfur and phosphorous in each steel were restricted to 0.006 - 0.020% P and 0.002 -
15 0.020% S. These slabs were heated at a temperature of 1150 - 1270°C and then hot rolled to provide steel sheets 2.8 mm thick. Finishing temperature was 800 - 870°C. The hot rolled steel sheets were coiled at a temperature of 520 - 580°C. The thus obtained hot rolled steel sheets were, after pickling,
20 subjected to cold rolling with a reduction of about 70% to provide cold rolled steel sheets 0.8 mm thick. Annealing was applied to the cold steel sheets to finish the sheets. Some of the finished steel sheets were thereafter subjected to temper rolling. The conditions of annealing and temper rolling
25 are summarized in Table 2.

Table 1

Chemical Composition (%)

Steel No.	C	Si	Mn	Sol.Al	N
1	0.050	0.010	2.44	0.040	0.0074
2	0.070	0.020	1.80	0.035	0.0097
3	0.008	0.010	2.35	0.026	0.0063
4	0.045	0.250	1.65	0.065	0.0085
5	0.050	0.010	2.10	0.040	0.0068
6	0.030	0.040	2.45	0.033	0.0078
7	0.050	0.010	2.10	0.040	0.0068
8	0.050	0.010	2.10	0.040	0.0068
9	0.050	0.010	2.10	0.040	0.0068
10	0.045	0.020	2.15	0.010	0.0074
11	0.050	0.010	1.40	0.070	0.0045
12	0.070	0.010	1.80	0.055	0.0035
13	0.065	0.010	3.00	0.043	0.0040
14	0.060	0.500	1.80	0.042	0.0072
15	0.055	0.010	0.25	0.052	0.0045

Table 2

Annealing, Temper Rolling Conditions

Steel No.	annealing		temper rolling (reduction ratio)
	Soaking temp. (°C) -	soaking time (h)	
1	690	4	none
2	710	4	"
3	740	1	"
4	720	4	"
5	690	4	(0.4)
6	670	4	(0.3)
7	620	4	none
8	690	0.2	"
9	690	4	(1.5)
10	670	4	none
11	700	4	"
12	710	4	"
13	670	4	"
14	700	4	"
15	690	4	(0.8)

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A JIS No. 5 test piece was cut from each of the thus produced steel samples and used for a tensile test wherein it was stretched in the rolling direction. The results are given in Table 3 below, from which it can be seen that the cold rolled steel sheets having a yield ratio less than 0.60, an r-value more than 1.2 and a tensile strength of 35 - 45 Kg/mm² could only be produced by the method of this invention. It is also clear from the Table that excessive temper rolling resulted in an elevated yield point.

10 The press formability of each steel sample was determined by the conventional Erichsen test and hole widening test. The form retention was determined using a test piece 90 mm wide and 400 mm long cut from each steel sample and subjected to a U-shaping as illustrated in Fig. 3 followed by measurement of the amount of spring back ($\Delta L = L - 50$). A 700 mm ϕ dent resistance test piece in the form of a disc (2) was cut from each steel sample and subjected to shallow drawing to form a 400 mm ϕ dome (3) having a maximum depth of 45 mm as illustrated in Fig. 4. A loop tester (1) was forced against the center of the domed test piece under a load of 20 kg, and the residual deflection δ after removal of the load was measured. A greater residual deflection δ is not desired since it provides an outer panel of an automobile body that easily forms a dent if it is pressed with a finger or hit by a bouncing pebble.

Table 3 Test results

steel No.	tensile test				formability test		form retention test spring back ΔL (mm)	dent resistance test residual deflection δ (mm)
	yield point Kg/mm ²	tensile strength Kg/mm ²	yield ratio	elongation (%)	r-value	Erichsen value(mm)	hole winding ratio(%)	
1	19.8	43.7	0.44	34.0	1.30	11.2	88	0.02
2	19.5	40.5	0.48	38.5	1.35	11.0	80	0.02
3	19.3	36.8	0.52	45.2	1.35	11.5	85	0
4	21.0	43.5	0.48	35.5	1.35	10.8	68	0.02
5	20.5	39.2	0.52	40.5	1.30	11.2	77	0
6	19.8	44.5	0.44	37.5	1.30	10.8	65	0
7	32.5	44.3	0.73	32.0	1.30	10.2	65	0.02
8	30.6	40.8	0.75	40.0	1.25	10.5	80	0
9	28.8	40.5	0.71	32.0	1.25	10.5	77	0
10	24.8	47.4	0.52	30.5	0.85	9.8	52	0.02
11	29.7	38.8	0.77	40.0	1.05	10.5	66	0
12	24.4	48.3	0.51	31.5	0.95	9.6	44	0
13	25.5	53.3	0.40	31.0	0.80	9.4	40	0.02
14	26.4	47.8	0.55	34.5	0.95	10.2	53	0
15	18.9	32.0	0.59	47.5	1.80	12.3	110	0.16

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Thus, it is apparent from the foregoing that the cold rolled steel sheets produced in accordance with this invention are all satisfactory with respect to mechanical properties, formability, form retention and dent resistance.

Claims:

1. A method of producing high strength cold rolled steel sheet having improved press formability, the composition of which consists essentially of 0.005 - 0.080% of C, up to
5 0.30% of Si, 1.6 - 3.5% of Mn, 0.02 - 0.08% of Sol.Al, 0.005 - 0.020% of N and the balance iron and incidental impurities, which comprises, after hot rolling, cold rolling the steel sheet with a reduction of more than 30% and then annealing the cold rolled steel sheet at a temperature of
10 660 - 750°C for a period longer than 30 minutes.
2. The method of Claim 1, which further comprises coiling the hot rolled steel sheet after hot rolling at a temperature of lower than 600°C.
3. The method of Claim 1 or 2, which comprises temper-
15 rolling, after annealing, the annealed cold rolled steel sheet.
4. The method of Claim 3, in which the reduction on temper rolling is less than 0.5%.
5. The method of any of Claims 1 - 4, in which the composition of steel is 0.008 - 0.05% of C, 0 - 0.2% of Si, 1.8 - 2.5%
20 of Mn, 0.02 - 0.08% of Sol.Al, 0.005 - 0.010% of N, less than 0.05% of P, less than 0.05% of S and the balance substantially iron.

Fig. 1

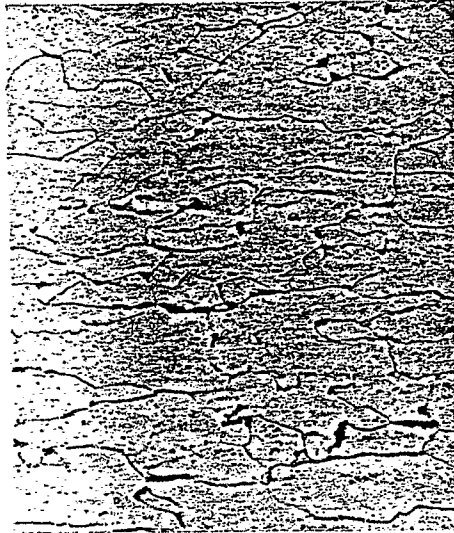


Fig. 2

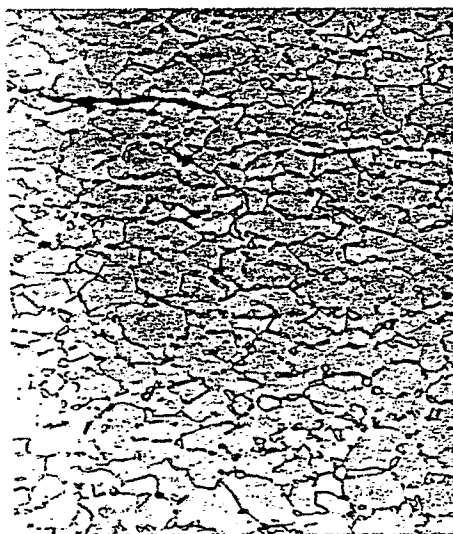
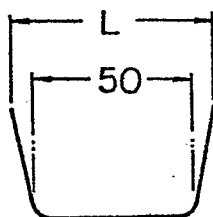
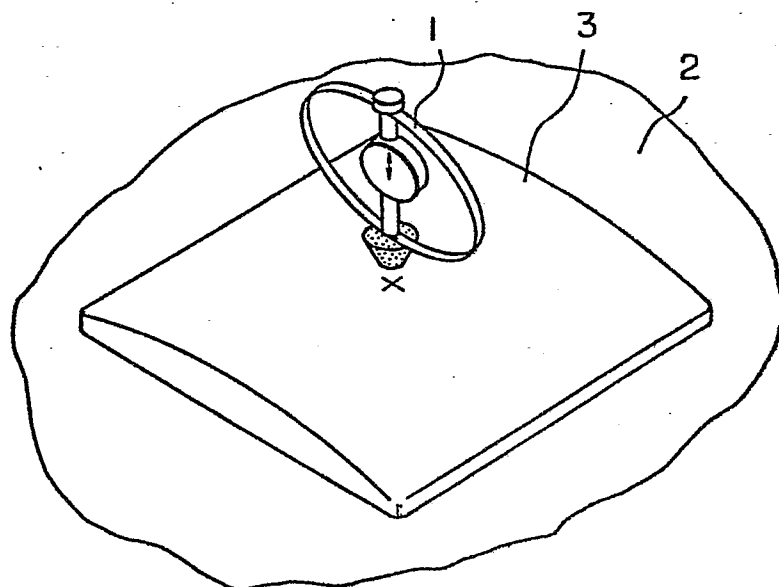


Fig. 3*Fig. 4*

INTERNATIONAL SEARCH REPORT

0016846

International Application No PCT/JP79/00227

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ²		
According to International Patent Classification (IPC) or to both National Classification and IPC		
C21D 9/46		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁴		
Classification System	Classification Symbols	
IPC	C21D 9/46, 9/48, C22C 38/04	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁴		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹¹		
Category ⁸	Citation of Document, ¹² with indication, where appropriate, of the relevant passages ¹³	Relevant to Claim No. ¹³
A	J. P. A, 49-18713 1974-2-19 See page 61, left column, claim and page 62, left column, line 32 to page 63, Table 2, Sumitomo Metal Industries, Ltd.	1 ~ 5
A	J. P. A, 51-107218 1976-9-22 See page 105, claim 1 and page 107, left column, line 33 to page 108, Table 2. Nippon Kokan K. K.	1 ~ 5
¹⁴ Special categories of cited documents: "A" document defining the general state of the art "E" earlier document but published on or after the international filing date "L" document cited for special reason other than those referred to in the other categories "O" document relating to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but on or after the priority date claimed "I" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention "X" document of particular relevance		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ²		Date of Mailing of this International Search Report ²
16 November 1979 (16.11.79)		26 November 1979 (26.11.79)
International Searching Authority ³		Signature of Authorized Officer ¹⁰
Japanese Patent Office		