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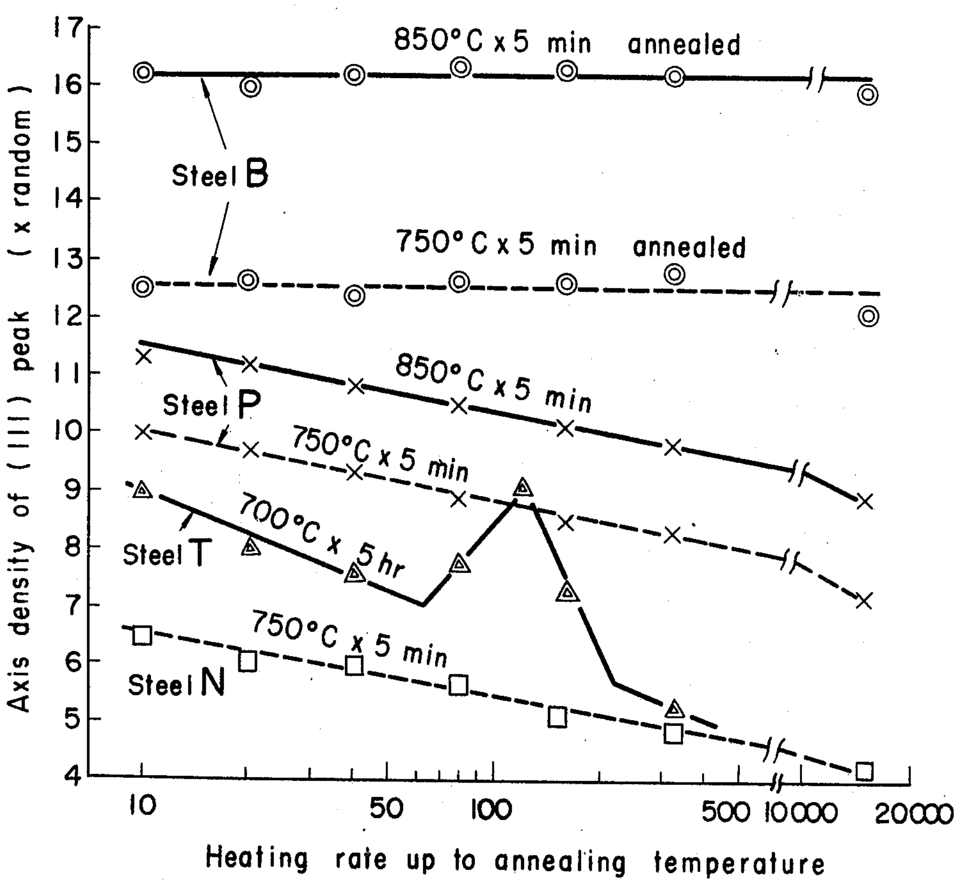
PROCESS FOR THE PRODUCTION OF COLD-ROLLED STEEL SHEETS HAVING EXCELLENT PRESS WORKABILITY

Filed Feb. 15, 1967 3 Sheets-Sheet 1

FIG. 1



INVENTORS.
Mineo Shimizu
Kamematsu Matsuda
Yuzo Sadamura
Nobuyuki Takahashi
Minoru Kawaharada

BY, Wenderoth, Lind and Ponack, Attorneys

FIG. 2

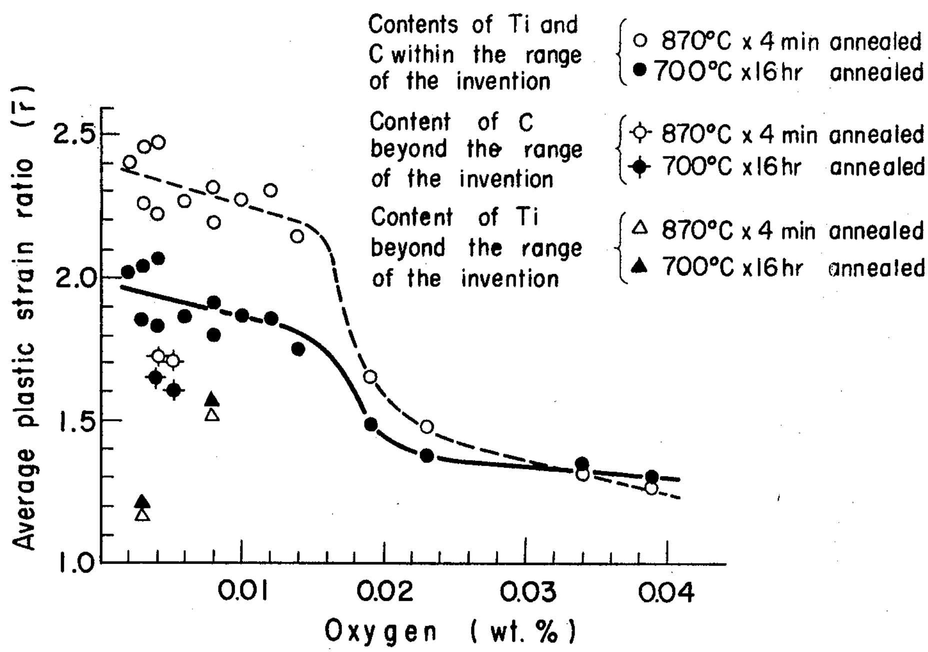
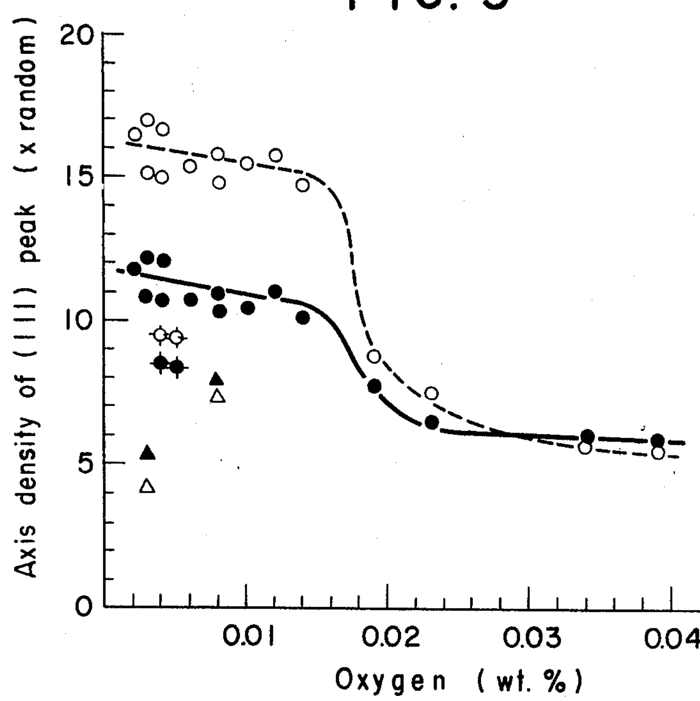


FIG. 3



INVENTORS.
Mineo Shimizu
Kamematsu Matsuda
Yuzo Sadamura
Nobuyuki Takahashi
Minoru Kawaharada
BY, Wenderoth, Lind and Ponack,
Attorneys

FIG. 4

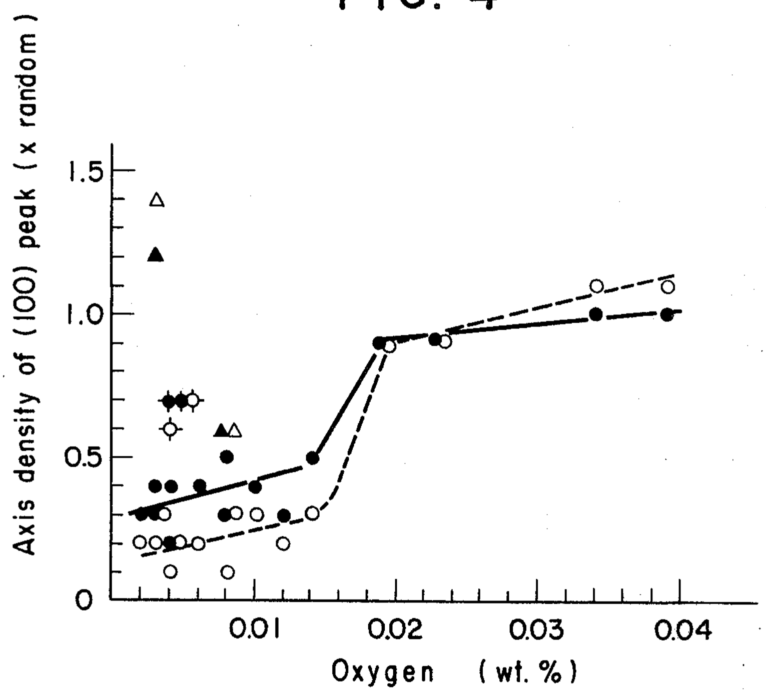
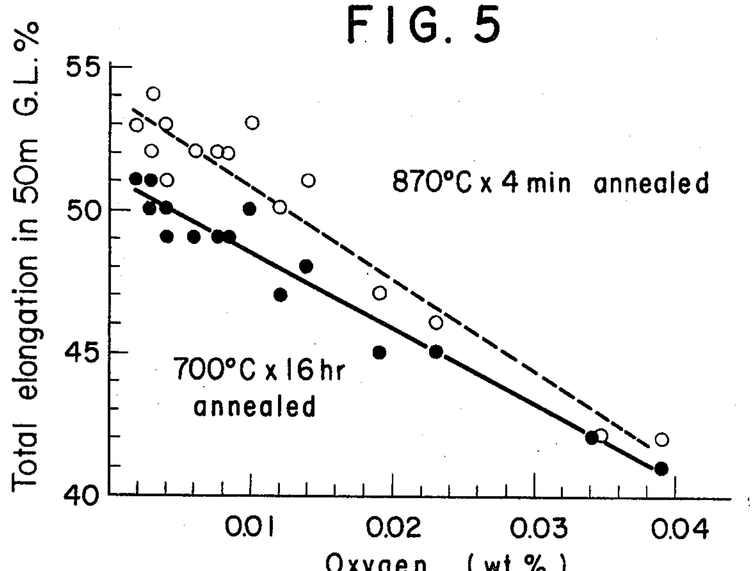


FIG. 5



INVENTORS.
Mineo Shimizu
Kamematsu Matsuda
Yuzo Sadamura
Nobuyuki Tahahashi
Minoru Kawaharada

BY, Wenderoth, Lind and Ponack,
Attorneys

United States Patent Office

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PROCESS FOR THE PRODUCTION OF COLD-ROLLED STEEL SHEETS HAVING EXCELLENT PRESS WORKABILITY

Mineo Shimizu, Kamematsu Matsuda, Yuzo Sadamura, Nobuyuki Takahashi, and Minoru Kawaharada, Kitakyushu, Japan, assignors to Nippon Steel Corporation, Chiyoda-ku, Tokyo, Japan

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U.S. Cl. 148—12 4 Claims

ABSTRACT OF THE DISCLOSURE

A process for producing cold-rolled steel plate durable to very severe press working, having excellent deep drawability and stretchability and non-aging property, comprising subjecting an extremely low carbon steel, which is characterized by oxygen content of less than 0.015% and titanium content of 0.02 to 0.5%, said titanium content being higher than 4 times of carbon content, to a hot-rolling at temperature above 780° C., a subsequent cold-rolling with a reduction rate of more than 30% and an annealing at 650 to 1000° C.

The present invention relates to a process for the production of cold-rolled steel sheets durable to severe press working.

In general, a severe press working for forming parts having complicated shapes from sheet metal by using a punch and a die is usually expressed by the term "deep drawing." However, the deformation of a material in "deep drawing" is not a simple deformation but a combination of various factors such as "drawing," "stretching" and "bending" in various rates.

Therefore, in the case of considering the problems about the press working of sheet metal, the press formability must be strictly separated into at least "drawability" and "stretchability" in accordance with the deforming mode to which the material is subjected. The drawing is characterized by letting the metal at the periphery of a blank (flange portion) flow into a die hole as in the case of forming a cylindrical cup from a circular blank and is called "die-drawing." On the other hand, the stretching forms a part having a desired shape by subjecting to a plastic deformation only a section contacted with a punch while preventing the metal at the flange portion of a blank from being let flow into a die hole by applying a sufficient blank-holding pressure or providing beads at the flange portion, and is called "punch-stretching."

Various steel sheets for deep drawing have been known at present but in the case of treating the formability of the steel sheet, it is not always classified into drawability and stretchability strictly speaking.

However, there is no direct relation between drawability and stretchability and hence in order to improve the workability of materials for press working, it is reasonable to consider the production factors about both drawability and stretchability. In fact, among various factors there are ones which improve the one property but reduce the other property. As a material for press working mainly consisting of drawing, a material having an excellent drawability may be employed while as a material for press working mainly consisting of stretching, a material having

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an excellent stretchability may be employed. However, if it is possible to find a material having an excellent drawability and an excellent stretchability simultaneously, such a material will be widely utilized as a material for severe press working.

The drawability is evaluated by the ratio of width strain, ϵ_w, and thickness strain, ϵ_t, at tension test, that is a so-called plastic strain ratio, $r=\epsilon_w/\epsilon_t$, and if an average value of the plastic strain ratio, $\bar{r}$, obtained by subjecting the samples cut into each direction in the plane of the sheet to a tension test, that is, an average plastic strain ratio is larger, the drawability is better. The average plastic strain ratio relates to the preferred crystallographic orientation of a material and in the case of steel sheet, if the density of (111) crystal plane and crystal planes near (111) plane accumulated in the rolling plane of the steel sheet is larger and if the density of (100) plane and planes near (100) plane is smaller, the average plastic strain ratio becomes larger. Also it is considered that the stretchability is better if an Erichsen value (or Olsen cup value), an elongation by tension test, and a work-hardening exponent are larger, and if an yield point and an yield-tensile ratio are low.

Thus, the drawability and the stretchability relate fundamentally to the chemical composition of steel, the size, shape, and distribution of inclusions contained in the steel, or the crystal grain size and the textures of the steel.

At present, a cold-rolled aluminum-killed low-carbon steel sheet for extra deep drawing quality has widely used in practice. Furthermore, there is a low-carbon steel wherein the drawability is improved by adding a specific element such as phosphorus, antimony and molybdenum whereby more (111)-texture preferable for deep drawability is developed at annealing for recrystallization after cold rolling, but such a steel is inferior to the aluminum-killed steel about stretchability.

Moreover, by decarburizing low-carbon steel by open-coil anneal process, a steel sheet having a drawability same as that of the aluminum-killed steel and a stretchability better than that of the aluminum-killed steel, but if the steel sheet is not subjected to a denitriding treatment at the same time, it is impossible to avoid the deterioration of the stretchability owing to strain aging and the recovery of yield point elongation which cause the formation of stretcher strain at press working. Further, by the decarburization annealing, the crystal grains tend to be coarsened and hence by the press working a defect so-called orange peel tends to occur.

Furthermore, in the case where a speed for heating a material to an annealing temperature is high as in an open-coil annealing or a continuous annealing, the development of the (111) texture preferable for deep drawability becomes generally difficult. Further, in particular, in a continuous annealing, if the annealing temperature becomes higher than A_{c3}, the crystal orientation becomes random, the drawability is extremely deteriorated, and the high cooling speed after annealing causes the increase of strain aging. Therefore, it is difficult to produce a sheet having both excellent drawability and stretchability by these processes.

A principal object of the present invention is to provide a steel sheet having excellent drawability as well as excellent stretchability and non-aging property by defining the oxygen content to the below-stating range of an extremely low carbon steel containing titanium.

Other object of this invention is to provide a process for the production of a steel sheet having excellent drawability, stretchability and non-aging property even by conducting high speed heating in annealing, for example continuous annealing in the treating process.

Other objects of this invention will become apparent from the following descriptions and the accompanying drawings, in which:

FIG. 1 is a graph showing the influences of heating rates up to annealing temperature on the textures of the cold-rolled steel sheet containing titanium of the present invention, a Ti-containing cold-rolled steel sheet beyond the range of this invention, and an aluminum-killed steel sheet for extra deep drawing quality after annealing,

FIG. 2 is a graph showing the influences of the concentration of oxygen in steel on the average plastic strain ratio ($\bar{r}$) in the case of subjecting the steel to a continuous annealing of 870° C. for 4 min. and to a box annealing of 700° C. for 16 hrs.,

FIG. 3 is a graph showing the influences of the concentration of oxygen in steel on the axis density of (111) diffraction peak in the case of subjecting the steel to a continuous annealing of 870° C. for 4 min. and to a box annealing of 700° C. for 16 hrs.,

FIG. 4 is a graph showing the influences of the concentration of oxygen in steel on the axis density of (100) diffraction peak in the case of subjecting the steel to a continuous annealing of 870° C. for 4 min. and to a box annealing of 700° C. for 16 hrs., and

FIG. 5 is a graph showing the influences of the concentration of oxygen in steel on the total elongation in the case of subjecting the steel to a continuous annealing of 870° C. for 4 min. and to a box annealing of 700° C. for 16 hrs.

The chemical composition of the steel of this invention comprises more than 0.001% (by weight) and less than 0.020% C, less than 0.15% O, more than 0.02% Ti (except Ti as Ti-oxides), said titanium content being more than 4 times larger than carbon content and less than 0.5%, and less than 0.45% Mn, the balance Fe and unavoidable impurities.

If the content of carbon is above 0.02% by weight, there occur the increase of tensile strength and the reduction of ductility (stretchability) and further owing to the weak development of (111) texture, the average plastic strain ratio is reduced. Moreover, depending upon the combination of sheet manufacturing conditions, for example, in the practice of 900° C. in hot-roll finishing temperature, 550° C., in coiling temperature and 850° C. for 5 min. in continuous annealing, yield point elongation is developed in the annealed steel sheet. Thus, since in the case of containing more than 0.02% of carbon the press formability of the steel is generally deteriorated, the content of carbon is preferably less but it is generally impossible in a steel making furnace of an economical scale to reduce the content of carbon less than 0.001%.

In general, if the content of carbon in steel is reduced by refining in a steel making furnace, the content of oxygen in the molten steel is increased in reverse proportion to the content of carbon, but if the content of oxygen in the steel of this invention is more than 0.015%, the press formability (in particular drawability) is remarkably reduced as will be mentioned below, and in particular, in the case where the steel is heated rapidly to the recrystallizing temperature at annealing, the press formability (in particular drawability) is very remarkably reduced. Accordingly, the content of oxygen in the steel must be reduced below 0.015% by a suitable means.

Since titanium is caused to react with carbon, oxygen, nitrogen, sulfur and the like, the content thereof is influenced by the amounts of these ingredients but if the contents of carbon and oxygen are defined as mentioned above and if the steel contains nitrogen and sulfur as impurities in steel obtained conventionally employed various steel manufacturing furnaces ($S<0.05\%$, $N<0.007\%$), it is necessary that the content of titanium

except Ti as Ti-oxides thereof be more than 0.020%. If the content of Ti as Ti-oxides is high, (111) texture preferable for deep drawing is not sufficiently developed at annealing for recrystallization even though the steel contains titanium in amount higher than that necessary for stabilizing carbon in the steel, and hence the drawability of the steel is not improved. Further, if the content of titanium is larger than 0.5%, the production cost for steel is increased in vain without providing further effects.

The addition of manganese is not always necessary in the steel of this invention or the addition of it is undesirable since the average plastic strain ratio tends to be deteriorated by the addition thereof, but if it is necessary to add manganese for making ingots of the steel of this invention, it may be added in an amount of without remarkably deteriorating the average plastic strain ratio or of about 0.45%.

The steel of this invention may be produced by any furnace such as a converter, an open-hearth furnace, and an electric furnace, but since the steel containing less than 0.020% of carbon and less than 0.015% of oxygen must be produced, it is profitable in the points of facilitating the practice and improving the titanium yield to conduct a vacuum degassing treatment before ingot making. At the vacuum degassing treatment a deoxydizing agent such as aluminum may be used supplemenetally for adjusting the content of oxygen. The residual aluminum in steel does not influence the properties of the steel of this invention. The steel is formed into ingot, rolled into slabs, if necessary subjected to slab condition, and hot-rolled in which the hot-roll finishing temperature is preferably above 780° C. The steel is then, after pickling, subjected to cold rolling and the cold reduction is desirably, in particular, above 30% for drawability. As annealing may be employed box annealing, open-coil annealing or continuous annealing to provide a material having an excellent press workability but by employing a continuous annealing, a particularly excellent steel sheet can be obtained, which is a feature of this invention.

Therefore, the invention is applied to the production of various surface treated steel sheets such as zinc-coated (galvanized) steel sheets, tin plates, aluminized steel sheets, etc., produced by a process including the continuous annealing step, of coarse materials having very excellent press formability.

The annealing temperature is from 650° C. to 1000 C., but a preferably annealing temperature is 650–950° C. in the case of box annealing or open-coil annealing and 750–980° C. in the case of continuous annealing.

Temper rolling is generally omitted in this invention in the case of employing continuous annealing since the steel of this invention does not have yield point elongation in the as-annealed state but in the case of adjusting the flatness of the sheet or providing a specific surface roughness to the sheet, the temper rolling is conducted with the minimum reduction.

In Table 1 are shown the chemical compositions of materials used in various examples for explaining the present invention. These materials were hot-rolled into 2.7 mm. in thickness and then cold-rolled into 0.8 mm. in thickness in the conventional process for the production of steel sheet for deep drawing. Two types of annealing were employed in the examples, one of which tight-coil batch annealing under the conditions of 700° C. for 16 hrs. and the other of which was continuous annealing under the conditions of 870° C. for 4 min.

The mechanical properties of thus batch annealed sheet are shown in Table 2 and the mechanical properties of thus continuously annealed sheet are shown in Table 3.

As shown in Tables 2 and 3, thus annealed sheets having the chemical compositions in the range of this invention have very high average plastic strain ratio ($\bar{r}$), high intensity of (111) difraction peak, low intensity of (100) diffraction peak, high Erichsen value, and high work-hardening exponent (n) from the view points of both drawability and stretchability and on comparing with the properties of aluminum-killed steel of extra-deep-drawing quality (hereinafter it is simply designated E.D.D.Q.) shown as steel T and steel U, the excellency of thus obtained steel of this invention will become more remarkable.

However, the drawability and the stretchability of the steel in which the carbon content is in the range of this invention are remarkably better than those of steel P and steel Q. Further, these differences in the properties are more remarkable in the case of conducting a high-temperature annealing such as continuous annealing. That

TABLE 1.—CHEMICAL COMPOSITION OF MATERIALS USED IN EXAMPLES

	Sample No.	C	Mn	Si	S	P	Sol Al	Total Ti	Ti as Ti-oxide	O	N
Ti-containing cold-rolled steel plate within the range of the present invention	A	0.007	0.05	0.03	0.02	0.02	0.00	0.112	0.010	0.008	0.0041
	B	0.005	0.06	0.04	0.01	0.02	0.00	0.119	0.004	0.004	0.0040
	C	0.009	0.13	0.02	0.02	0.01	0.00	0.130	0.002	0.002	0.0045
	D	0.008	0.15	0.03	0.01	0.02	0.00	0.115	0.007	0.006	0.0042
	E	0.006	0.06	0.04	0.01	0.02	0.00	0.096	0.012	0.010	0.0040
	F	0.013	0.12	0.02	0.02	0.02	0.00	0.110	0.018	0.014	0.0043
	G	0.004	0.20	0.02	0.01	0.01	0.00	0.080	0.003	0.003	0.0044
	H	0.003	0.06	0.01	0.02	0.02	0.00	0.098	0.016	0.012	0.0044
	I	0.011	0.08	0.03	0.02	0.01	0.00	0.105	0.004	0.004	0.0073
	J	0.017	0.14	0.02	0.02	0.01	0.00	0.101	0.004	0.003	0.0042
	K	0.009	0.13	0.02	0.02	0.02	0.00	0.063	0.009	0.008	0.0049
Ti-containing cold-rolled steel plate outside the range of the present invention.	L	0.008	0.05	0.02	0.02	0.01	0.00	0.093	0.025	0.019	0.0057
	M	0.005	0.08	0.03	0.01	0.02	0.00	0.112	0.025	0.023	0.0040
	N	0.011	0.05	0.01	0.02	0.02	0.00	0.108	0.046	0.034	0.0043
	O	0.012	0.06	0.04	0.02	0.01	0.00	0.121	0.050	0.039	0.0045
	P	0.025	0.20	0.02	0.02	0.02	0.01	0.172	0.006	0.004	0.0043
	Q	0.035	0.10	0.03	0.01	0.02	0.00	0.229	0.006	0.005	0.0050
	R	0.008	0.15	0.03	0.02	0.02	0.00	0.023	0.004	0.003	0.0035
	S	0.004	0.05	0.03	0.03	0.02	0.00	0.027	0.010	0.008	0.0041
E.D.D.Q. Al killed steel.	T	0.039	0.34	0.02	0.02	0.01	0.04			0.018	0.0052
	U	0.046	0.33	0.01	0.02	0.01	0.03			0.016	0.0045

TABLE 2.—MECHANICAL PROPERTIES OF BATCH-ANNEALED MATERIALS

Sample No.	Yield point (kg./mm.)	Tensile strength (kg./mm.)	Total elongation (percent in 50 mm. G.L.)	Work-hardening exponent (−n)	$\bar{r}$	Erichsen value (mm.)	Luder's strain	Aging index (kg./mm.)	Axis Density of (111) peak	Axis Density of (100) peak	A.S.T.M. grain size No.
A	12.5	32.1	49	0.278	1.91	12.1	0	0.1	11.0	0.3	9.5
B	11.8	31.2	50	0.281	2.06	12.1	0	0.0	12.1	0.2	8.8
C	12.7	32.3	51	0.274	2.02	12.4	0	0.0	11.8	0.3	9.0
D	12.5	32.3	49	0.265	1.87	12.0	0	0.1	10.8	0.4	8.9
E	12.0	32.0	50	0.271	1.87	12.3	0	0.0	10.5	0.4	9.1
F	13.2	32.9	48	0.268	1.75	11.8	0	0.2	10.2	0.5	10.0
G	11.6	31.5	51	0.283	2.04	12.4	0	0.0	12.2	0.3	8.6
H	12.1	32.4	47	0.272	1.86	11.6	0	0.0	11.0	0.3	9.0
I	13.1	33.0	49	0.261	1.83	12.0	0	0.0	10.7	0.4	9.8
J	13.8	33.2	50	0.273	1.85	12.3	0	0.0	10.8	0.4	10.3
K	12.6	32.2	49	0.265	1.80	11.6	0	0.2	10.4	0.5	9.3
L	13.5	33.1	45	0.245	1.49	11.0	0	0.0	7.8	0.9	10.5
M	12.9	32.7	45	0.236	1.38	10.7	0	0.0	6.5	0.9	10.4
N	14.0	33.2	42	0.217	1.35	10.3	0	0.1	6.0	1.0	10.7
O	14.0	33.5	41	0.215	1.30	9.9	0	0.0	5.8	1.0	10.8
P	17.0	34.0	44	0.233	1.65	10.8	0	0.0	8.6	0.7	10.4
Q	18.5	34.2	43	0.232	1.61	10.8	0	0.2	8.4	0.7	10.6
R	[1] 23.2	37.2	42	0.203	1.22	10.0	3.9	2.2	5.4	1.2	10.7
S	[1] 17.6	35.0	46	0.237	1.57	11.0	2.0	1.1	8.1	0.8	9.3
T	[1] 21.5	30.6	47	0.250	1.65	11.3	4.2	0.0	8.5	0.6	7.8
U	[1] 18.6	30.2	47	0.253	1.79	11.2	4.4	0.0	9.5	0.5	7.1

Remarks: [1] Indicates "lower yield strength" and the others in the column "yield point" indicate "flow stress at 0.2% strain."

TABLE 3.—MECHANICAL PROPERTIES OF CONTINUOUS-ANNEALED MATERIALS

Sample No.	Yield point (kg./mm.)	Tensile strength (kg./mm.)	Total elongation (percent in 50 mm. G.L.)	Work-hardening exponent (−n)	$\bar{r}$	Erichsen value (mm.)	Luder's strain	Aging index (kg./mm.)	Axis Density of (111) peak	Axis Density of (100) peak	A.S.T.M. grain size No.
A	12.3	31.8	52	0.295	2.31	12.8	0	0.0	15.8	0.1	8.5
B	11.2	30.9	53	0.299	2.47	12.8	0	0.0	16.7	0.1	8.0
C	12.8	31.8	53	0.301	2.40	13.0	0	0.0	16.5	0.2	8.1
D	12.4	31.7	52	0.288	2.27	12.7	0	0.2	15.4	0.2	8.0
E	12.2	31.6	53	0.296	2.27	12.9	0	0.1	15.5	0.3	8.5
F	12.8	32.3	51	0.283	2.15	12.5	0	0.0	14.8	0.3	8.8
G	11.6	31.0	54	0.304	2.45	13.2	0	0.3	17.0	0.2	7.5
H	12.0	32.1	50	0.279	2.30	12.4	0	0.0	15.8	0.2	8.0
I	12.7	32.7	51	0.289	2.22	12.6	0	0.0	15.0	0.2	8.4
J	13.1	32.9	52	0.294	2.26	12.6	0	0.2	15.1	0.3	8.9
K	12.7	31.6	52	0.284	2.19	12.7	0	0.0	14.9	0.3	8.1
L	13.2	33.0	47	0.256	1.65	11.5	0	0.1	8.8	0.9	10.0
M	12.5	32.5	46	0.252	1.52	11.3	0	0.0	7.5	0.9	9.9
N	14.0	33.6	42	0.211	1.32	9.8	0	0.0	5.8	1.1	10.3
O	14.0	33.6	42	0.204	1.27	9.8	0	0.0	5.5	1.1	10.6
P	[1] 25.2	36.1	44	0.240	1.72	10.9	3.7	0.2	9.5	0.6	10.2
Q	[1] 26.0	36.5	43	0.234	1.71	10.7	4.3	0.0	9.4	0.7	10.6
R	[1] 25.2	38.7	42	0.201	1.18	10.0	5.2	2.7	4.2	1.4	10.8
S	[1] 20.4	35.8	46	0.240	1.51	11.2	2.5	1.1	7.5	0.8	9.0

Remarks: [1] The same as in Table 2.

The invention will now be explained by the following examples.

Steel P and steel Q in which only the content of carbon is higher than that of the range of this invention have almost same drawability and stretchability as those of aluminum-killed steel of E.DD.Q. in mechanical properties.

is, on comparing Table 2 with Table 3 it can be understood that the differences of the properties of the steel of this invention from those of various steels, in which not only the content of carbon but also the content of other ingredients are different from those of the steel of this invention, become more remarkable in continous annealing than in batch annealing.

Therefore, the contents of carbon and other elements are defined in this invention for obtaining very excellent materials even by continuous annealing.

The profitability of the continuous annealing consists of two factors. In general, the factors in annealing process which control the development of annealed texture are a heating rate up to annealing temperature, an annealing temperature, and a holding time at the annealing temperature. In general low carbon steel, the development of (111) texture preferable for deep drawability is more remarkable as the heating rate is lower, and hence continuous annealing by rapid heating is unsuitable as an annealing procedure for steel sheet for deep drawing.

However, the development of (111) annealed texture of the cold-rolled steel containing titanium in an amount in the range of this invention is not influenced by the heating rate. Also, the cold-rolled steel containing titanium in an amount of the range of this invention has a keen susceptibility of the development of (111) texture for annealing conditions and hence the development of (111) texture of the cold-rolled steel sheet of this invention is remarkable as compared with that of a cold-rolled steel sheet containing titanium in an amount beyond the range of this invention. These relations are shown in FIG. 1.

The cold-rolled steel containing titanium in the amount of the range of this invention strongly developes (111) texture in the plane of the sheet even if it is continuous-annealed, while a cold-rolled steel containing titanium in an amount beyond the range of this invention and a general cold-rolled low carbon steel do not develop the (111) texture by the reason to be rapidly heated to continuous-annealing temperature.

Furthermore, in the steel sheet of this invention, the higher concentrating of (111) planes in the plane of the sheet are developed if the steel is continuous-annealed at higher temperatures which can be attained in only continuous annealing line than in conventional batch-type annealer.

However, the most important factor in this invention is the content of oxygen. As mentioned above, if the oxygen content in steel is higher than 0.015% by weight, the press formability (in particular drawability) is markedly deteriorated. For clearly showing this point about the examples, the relations of the oxygen content with the *r* value, the intensity of (111) diffraction peak, and the intensity of (100) diffraction peak as the most suitable criterions for drawability are detected from Table 2 and Table 3 and they are shown in FIG. 2, FIG. 3, and FIG. 4 respectively. In the relation of the $\bar{r}$ value and the oxygen content shown in FIG. 2, there is a general tendency that the $\bar{r}$ value is reduced as the increase of the oxygen content but in particular the change is remarkable at the oxygen content of about 0.015%. Further, this tendency becomes more remarkable in the case of a high-temperature annealing such as the continuous annealing. This is a similar tendency as in the case of the $\bar{r}$ value about the relation of the oxygen content and the intensity of (111) diffraction peak shown in FIG. 3 and the relation of the oxygen content and the intensity of (100) diffraction peak, and the proportions of (111) orientation which is preferable for drawability and (100) orientation which is unpreferable for drawability are changed suddenly at the oxygen content of about 0.015%. This is considered to be caused by that the greater part of oxygen in the Ti-containing steel sheet is converted into a titanium oxide. As the titanium oxide, there are various ones such as TiO, Ti_2O_3, TiO_2, etc., and these oxides have different crystal structures by the kind thereof.

For developing an aimed texture, a base for generating it and growing it is necessary .In general, non-metallic inclusions such as oxides are considered to give influences on the mechanism for growing the texture rather than on the action of generating the nucleus of the texture.

It is well known that as an inhibitor of migration of both sub-boundary and grain boundary, the crystal structure and the habit plane of the inhibitor (nitrides, carbides, oxides, etc.) as well as the size and the distribution play an important role. It is commonly considered that when only the influences of the size and the distribution appear as relation as shown in FIG. 2 to FIG. 4, the relation is in linear. Accordingly, the drastic change in the cold rolled sheet steel containing titanium in the amount of the range of this invention at the oxygen content of about 0.015% by weight is not caused by the size and the distribution of the oxides defined by the oxygen content but is assumed to be caused by the change in the composition of titanium oxides in steel. Therefore, it is considered that the oxides existing in an amount of oxygen less than 0.015% does not hinder the growth of the crystal grains (including recrystallizing nuclei) having (111) planes in the plane of the sheet.

Such influences by the change of the compositions of the oxides do not appear in the mechanical properties such as stretchability. For example, in regard to the relation of elongation and the oxygen content shown in FIG. 5, the elongation is decreased almost linearly as the increase in the oxygen content. This may be due to the reason why the movement of dislocation in plastic deformation and the work-hardening occuring therefrom are most strongly influenced by the size and the distribution of oxides but are scarcely influenced by the oxide composition and the like.

As clearly shown from the examples about steel R and steel S, it is necessary that the content of titanium except the Ti as Ti-oxides be above 0.02% by weight.

In the case where the titanium content is less than 4 times of the content of carbon (e.g., steel R), the quality of the steel is inferior to that of commercial quality rimmed steel. The lower limit of the titanium content is based on the fundamental concept that the presence of a proper amount of free titanium in steel is a factor for keeping the excellent qualities of the steel of this invention, which is supported by the examples.

As mentioned above about the constitutional factors of the present invention, the cold rolled steel containing titanium in the amount of the range of this invention is a very excellent sheet and has the properties markedly superior to those of conventional steel sheet for deep drawing. Further, when a conventional steel sheet is in an annealed state although it is aging steel or non-aging steel, the yield point elongation always appears and hence for removing it temper rolling must be applied. However, in the Ti-containing cold rolled steel sheet of this invention, no yield point phenomena occurs even if it is annealed by any annealing process (for example, by a batch annealing or continuous annealing) and hence the temper rolling process for preventing the occurrence of stretcher strains is essentially unnecessary. Furthermore, no strain aging of this steel, of course, is observed by applying any aging treatment and the yield stress is little influenced by the grain size.

As mentioned above practically about the examples of this invention, the Ti-containing cold rolled steel by the present invention has very excellent properties as compared with conventional steel as the sheet for severe press forming.

Having thus described the invention, what is claimed is:

1. A process for the production of a cold rolled steel sheet which comprises hot rolling at a temperature higher than 780° C. steel comprising 0.001–0.020% (by weight) C, less than 0.45% Mn, less than 0.015% O, and 0.02–0.5% Ti except Ti as Ti-oxides, said titanium content being higher than four times of the carbon content, the balance Fe and unavoidable impurities, cold rolling it with a reduction of more than 30%, and then annealing it at a temperature of from 650° C. to 1000° C.

2. The process as claimed in claim **1** wherein said cold rolled steel sheet is subjected to box annealing or open-coil annealing at a temperature lower than 900° C.

3. The process as claimed in claim **1** wherein said cold rolled steel sheet is subjected to continuous annealing at a temperature of from 750° C. to 1000° C.

4. The process as claimed in claim **1** wherein said steel sheet comprises 0.001–0.020% (by weight) C, less than 0.015% O, and 0.02–0.5% Ti except Ti as Ti-oxides, said titanium content being higher than four times of the carbon content, the balance Fe and unavoidable impurities.

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L. DEWAYNE RUTLEDGE, Primary Examiner

W. W. STALLARD, Assistant Examiner

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INVENTOR(S) : Mineo Shimizu, Kamematsu Matsuda, Yuzo Sadamura, Nobuyuki Takahashi, and Minoru Kawaharada

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 1, line 9, insert --Claims priority of Japanese Application No. 9115 filed February 17, 1966.--

Signed and Sealed this

Twenty-eighth **Day of** *January 1986*

[SEAL]

Attest:

DONALD J. QUIGG

Attesting Officer *Commissioner of Patents and Trademarks*