

19



Europäisches Patentamt
European Patent Office
Office européen des brevets



11 Publication number: **0 496 423 A1**

12

EUROPEAN PATENT APPLICATION

21 Application number: **92101186.2**

51 Int. Cl.⁵: **C23C 28/00**

22 Date of filing: **24.01.92**

30 Priority: **25.01.91 JP 25695/91**

43 Date of publication of application:
29.07.92 Bulletin 92/31

84 Designated Contracting States:
DE FR GB IT

71 Applicant: **NKK CORPORATION**
1-2 Marunouchi 1-chome, Chiyoda-ku
Tokyo(JP)

72 Inventor: **Watanabe, Toyofumi, c/o NKK Corporation**
1-2, Marunouchi 1-chome, Chiyoda-ku
Tokyo(JP)
Inventor: **Furuta, Akihiko, c/o NKK Corporation**
1-2, Marunouchi 1-chome, Chiyoda-ku

Tokyo(JP)
Inventor: **Ono, Tadashi, c/o NKK Corporation**
1-2, Marunouchi 1-chome, Chiyoda-ku
Tokyo(JP)
Inventor: **Yomura, Yoshinori, c/o NKK Corporation**
1-2, Marunouchi 1-chome, Chiyoda-ku
Tokyo(JP)
Inventor: **Iwado, Shuuichi, c/o NKK Corporation**
1-2, Marunouchi 1-chome, Chiyoda-ku
Tokyo(JP)

74 Representative: **Henkel, Feiler, Hänzel & Partner**
Möhlstrasse 37
W-8000 München 80(DE)

54 **Nickel electroplated cold-rolled steel sheet excellent in press-formability and phosphating-treatability and method for manufacturing same.**

57 A nickel electroplated cold-rolled steel sheet excellent in press-formability and phosphating-treatability, which comprises:

- a cold-rolled steel sheet consisting of:
- carbon (C) : up to 0.06 wt.%,
- silicon (Si) : up to 0.5 wt.%,
- manganese (Mn) : up to 2.5 wt.%,
- phosphorus (P) : up to 0.1 wt.%,
- sulfur (S) : up to 0.025 wt.%,
- soluble aluminum (Sol.Al) : up to 0.10 wt.%,
- nitrogen (N) : up to 0.005 wt.%,

and
the balance being iron (Fe) and incidental-impurities;

a nickel electroplating layer, formed on at least one surface of the cold-rolled steel sheet, in which layer nickel particles are precipitated at a distribution density of at least $1 \times 10^{12}/m^2$, the plating weight of the nickel electroplating layer being within a range of from 5 to 60 mg/m² per surface of the cold-rolled steel sheet; and

a nickel oxide film, formed on the surface of the nickel electroplating layer, having an average thickness within a range of from 0.0005 to 0.003 μm.

The above-mentioned cold-rolled steel sheet may additionally contain at least one of up to 0.15 wt.% titanium (Ti) and up to 0.15 wt.% niobium (Nb). In the case where titanium and/or niobium are added, up to 0.003 wt.% boron (B) may also be additionally added.

EP 0 496 423 A1

REFERENCE OF PATENTS, APPLICATIONS AND PUBLICATIONS PERTINENT TO THE INVENTION

As far as we know, there are available the following prior art documents pertinent to the present invention:

- 5 (1) Japanese Patent Provisional Publication No. 56-116,883 dated September 12, 1981;
(2) Japanese Patent Provisional Publication No. 56-116,887 dated September 12, 1981; and
(3) Japanese Patent Provisional Publication No. 2-101,200 dated April 12, 1990.

The contents of the prior art disclosed in the above-mentioned prior art documents will be discussed hereafter under the heading of the "BACKGROUND OF THE INVENTION."

10

BACKGROUND OF THE INVENTION

(FIELD OF THE INVENTION)

- 15 The present invention relates to a nickel electroplated cold-rolled steel sheet excellent in press-formability and phosphating-treatability, and a method for manufacturing same.

(PRIOR ART STATEMENT)

- 20 In general, a cold-rolled steel sheet for automobile or electric appliances is formed into a prescribed shape by means of a large-capacity press. With a view to achieving a larger automobile body, reducing air resistance during running of a car, and achieving an exterior view of a better style, it is the present practice to form fenders, doors and rear quarter portions into rounded shapes.

- From the point of view of economic merits and environmental protection, on the other hand, efforts are
25 being made to reduce the weight of an automobile body so as to reduce the fuel consumption. In order to reduce the weight of the automobile body, it is necessary to decrease the thickness of a steel sheet which forms the automobile body, and this is also the case with a steel sheet such as an exposed panel that should be subjected to a deep drawing. The steel sheet for an exposed panel requires a satisfactory dent resistance and shape freezability. It is therefore necessary to use a high-strength steel having a thin
30 thickness for the exposed panel. In order to form a thin and high-strength cold-rolled steel sheet by deep drawing, it is necessary to previously increase the wrinkle inhibiting force of the steel sheet by means of a powerful press so as to prevent wrinkles from producing on the cold-rolled steel sheet during press forming.

- Annealing applied to the cold-rolled steel sheet for the purpose of recrystallization of crystal grains subjected to a serious strain during the cold rolling thereof, is applicable either by a continuous annealing or
35 a box annealing.

- An ordinary low-carbon aluminum-killed steel has been used as a material for a mild cold-rolled steel sheet for deep drawing. A low-carbon aluminum-killed steel containing silicon, manganese and phosphorus has been used as a material for a high-strength steel sheet for deep drawing. The box annealing has been applied for the purpose of annealing the above-mentioned mild cold-rolled steel sheet for deep drawing and
40 high-strength steel sheet for deep drawing. The box annealing is characterized by a long heating time, a long cooling time, easy growth of crystal grains, and the availability of a cold-rolled steel sheet having a high Lankford value.

- A box-annealed steel sheet is exposed to a high temperature for a longer period of time than a continuous-annealed steel sheet. As a result, silicon, manganese and phosphorus contained in the box-annealed steel sheet are concentrated onto the surface of the steel sheet in the form of oxides. These
45 oxides concentrated onto the surface of the steel sheet serve as a lubricant film during press forming. In addition, the box-annealed steel sheet has a high Lankford value than that of the continuous-annealed steel sheet. Therefore, troubles such as press cracks hardly occur in the box-annealed steel sheet.

- When the box-annealed steel sheet is press-formed and then subjected to a phosphating treatment, the
50 elements contained in the steel sheet and the elements such as manganese concentrated onto the surface of steel sheet activate a phosphate film forming reaction, so that a dense and thin phosphate film is formed on the surface of the steel sheet. The phosphate film has a function of improving paint adhesivity and corrosion resistance after painting of the steel sheet.

- Recently, however, it is becoming increasingly usual practice to anneal a steel sheet by the continuous
55 annealing for such reasons as the reduction of manufacturing processes, the improvement of production yield and labor saving. The known cold-rolled steel sheets suitable for the application of the continuous annealing treatment, comprise an extra-low-carbon steel or a steel known as the inter-stitial free steel (hereinafter referred to as "IF steel").

In order to improve Lankford value serving as an indicator of press-formability of an extra-low-carbon steel sheet, the following measure is taken: degassing the steel during the steelmaking step to reduce the carbon content to up to 100 ppm, and minimizing the contents of other impurity elements, thereby permitting rapid growth of crystal grains of steel.

5 An if steel is produced by adding at least one of titanium and niobium to an extra-low-carbon steel, and fixing carbon and nitrogen acting as solid-solution elements by means of these added elements, thereby making it possible to obtain a higher Lankford value with a short continuous annealing.

10 Since the development of the above-mentioned extra-low carbon steel and IF steel, it is now possible to manufacture a cold-rolled steel sheet having a high Lankford value even by applying the continuous annealing.

15 However, the Lankford value of a cold-rolled steel sheet for deep drawing subjected to the continuous annealing (hereinafter referred to as the "continuous-annealed cold-rolled steel sheet") is equal or even superior to the Lankford value of a cold-rolled steel sheet for deep drawing subjected to the conventional box annealing (hereinafter referred to as the "box-annealed cold-rolled steel sheet"). However, the continuous-annealed cold-rolled steel sheet is easily susceptible to cracks during the press forming, and when worked into a complicated shape, more susceptible to the galling than the box-annealed cold-rolled steel sheet. As a result of various studies on causes thereof, it was revealed that, as shown in Table 1, there was a substantial difference in the value of frictional coefficient of the steel sheet surface between the continuous-annealed cold-rolled steel sheet and the box-annealed cold-rolled steel sheet. Table 1 shows values of frictional coefficient (μ) of the surface, Lankford values (r -value) and limiting drawing ratios (LDR) for the conventional continuous-annealed and box-annealed cold-rolled steel sheets, and Table 2 shows chemical compositions of the continuous-annealed and box-annealed cold-rolled steel sheets used in these studies.

25

30

35

40

45

50

55

Table 1

Box-annealed cold-rolled steel sheet (conventional; without plating)								Continuous-annealed cold-rolled steel sheet (conventional; without plating)							
Steel grade	Reduction ratio (%)	Heating temperature (°C)	n - value	Frictional coefficient (μ)	LDR	Remarks	Steel grade	Reduction ratio (%)	Heating temperature (°C)	n - value	Frictional coefficient (μ)	LDR	Remarks		
A	60	600	1.55	0.13	2.04		B	75	750	1.45	0.16	2.01			
A	65	600	1.60	0.12	2.03		B	80	750	1.50	0.17	2.01			
A	70	600	1.65	0.12	2.06		C	80	830	1.75	0.16	2.05			
A	75	650	1.75	0.11	2.06		C	85	830	1.75	0.17	2.04			
A	80	650	1.80	0.13	2.08		D	75	830	1.95	0.19	2.07			
A	85	650	1.80	0.14	2.07		D	80	830	2.05	0.17	2.08			
A	75	750	1.95	0.12	2.11	OCA decarburized	D	80	830	2.00	0.18	2.06			
A	80	750	2.05	0.12	2.13	OCA decarburized	D	85	830	2.00	0.19	2.08			
A	85	750	2.05	0.11	2.11	OCA decarburized	E	75	830	2.05	0.17	2.07			
F	75	700	1.65	0.12	2.05	40 Kg High-strength steel	E	80	830	2.20	0.18	2.10			
							E	80	830	2.25	0.18	2.10			
							E	85	830	2.25	0.19	2.08			
							G*	80	830	1.10	0.17	1.94	45 Kg High-strength steel		

(OCA decarburized: open coil annealing decarburized) (*Only steel G hot-rolled and coiled at a low temperature)

Table 2
(wt. %)

Steel grade	C	Si	Mn	P	S	Sol. Al	N	Nb	Ti	Remarks
A	0.050	0.020	0.250	0.015	0.010	0.050	0.0030	—	—	Low carbon A0-K CC steel
B	0.025	0.015	0.200	0.014	0.009	0.045	0.0031	—	—	Medium carbon A0-K CC steel
C	0.003	0.012	0.150	0.014	0.010	0.038	0.0020	—	—	Extra-low-carbon A0-K CC steel
D	0.003	0.012	0.130	0.015	0.008	0.037	0.0020	0.010	0.040	Extra-low-carbon Ni-Ti IF steel
E	0.003	0.012	0.140	0.014	0.009	0.040	0.0020	—	0.070	Extra-low-carbon Ti IF steel
F	0.080	0.050	0.500	0.011	0.008	0.047	0.0035	—	—	Box-annealed 40 Kg high-strength steel
G	0.032	0.350	2.200	0.040	0.005	0.030	0.0030	0.010	0.080	Continuous-annealed 45 Kg high-strength steel

(A0-K: aluminum killed; CC steel: continuously cast steel)

5
10
15
20
25
30
35
40
45
50

Fig. 1 is a graph illustrating the relationship between a Lankford value and a limiting drawing ratio for a continuous-annealed cold-rolled steel sheet and a box-annealed cold-rolled steel sheet. In Fig. 1, the mark "o" represents the box-annealed cold-rolled steel sheet, and the mark "Δ" represents the continuous-annealed cold-rolled steel sheet. As shown in Fig. 1, the differences in the Lankford value and the limiting drawing ratio between the continuous-annealed and the box-annealed cold-rolled steel sheets are consid-

ered to be caused by the fact that a high frictional coefficient of the steel sheet surface as in the continuous-annealed cold-rolled steel sheet reduces lubricity between the steel sheet surface and the wrinkle inhibiting jig or the die, thus impairing smooth flow of the material in the press die.

Now, the phosphating-treatability of the continuous-annealed cold-rolled steel sheet is described.

5 Application of a phosphating treatment to the press-formed continuous-annealed cold-rolled steel sheet forms a phosphate film on the surface of the continuous-annealed cold-rolled steel sheet. Because the continuous-annealed cold-rolled steel sheet has only low contents of impurity elements, and the time of exposure of the steel sheet surface to high temperatures during annealing is far shorter than that in the box-annealed steel sheet, there is almost no concentration of the elements contained in the steel sheet onto the
10 steel sheet surface. Consequently, there are only a very few cathodes to form precipitation nuclei of phosphate crystal grains on the surface of the continuous-annealed cold-rolled steel sheet, so that a phosphate film formed on the steel sheet surface comprises rough and coarse crystal grains.

Fig. 5 is an SEM (scanning electron microscope) micrograph showing the metallurgical structure of crystals of the phosphate film formed on the surface of the box-annealed cold-rolled steel sheet, and Fig. 6
15 is an SEM micrograph showing the metallurgical structure of crystals of the phosphate film formed on the surface of the continuous-annealed cold-rolled steel sheet. As shown in Fig. 6, the phosphate film formed on the surface of the continuous-annealed cold-rolled steel sheet has coarse and larger crystal grains than those formed on the surface of the box-annealed cold-rolled steel sheet shown in Fig. 5. The continuous-annealed cold-rolled steel sheet is therefore inferior in phosphating-treatability, paint adhesivity and
20 corrosion resistance after painting to the box-annealed cold-rolled steel sheet.

The above-mentioned inferiority of the continuous-annealed cold-rolled steel sheet in phosphating-treatability is observed when pickling the steel sheet surface with an inorganic acid not only in the case of an extra-low-carbon steel but also in the case of an ordinary low-carbon aluminum-killed steel and a capped steel.

25 As a means to solve the problem regarding the inferior phosphating-treatability of the pickled continuous-annealed cold-rolled steel sheet, technologies of forming a plating layer of a metal such as nickel in a slight amount on the surface of the cold-rolled steel sheet have been proposed as follows:

(1) A method for improving phosphating-treatability of a cold-rolled steel sheet, as disclosed in Japanese Patent Provisional Publication No. 56-116,883 dated September 12, 1981, which comprises forming a
30 nickel plating layer having a plating weight within a range of from 0.3 to 10 mg/dm² on the surface of a cold-rolled steel sheet (hereinafter referred to as the "prior art 1").

(2) A metal plated cold-rolled steel sheet excellent in phosphating-treatability, as disclosed in Japanese Patent Provisional Publication No. 56-116,887 dated September 12, 1981, which comprises:

35 a cold-rolled steel sheet; and a plating layer of at least one metal selected from the group consisting of titanium (Ti), manganese (Mn), nickel (Ni), cobalt (Co), copper (Cu), molybdenum (Mo) and tungsten (W), having a plating weight within a range of from 1 to 500 mg/m², formed on the surface of said cold-rolled steel sheet (hereinafter referred to as the "Prior art 2").

40 According to the above-mentioned prior arts 1 and 2, it is possible to obtain a nickel electroplated cold-rolled steel sheet excellent in phosphating-treatability. This is attributable to the fact that, because of the metal plating layer of nickel and the like formed on the surface of the cold-rolled steel sheet, cathodes activating the phosphate film forming reaction are formed on the portion where the metal such as nickel is precipitated.

However, the prior arts 1 and 2 have the following problems.

45 In order to improve phosphating-treatability of the cold-rolled steel sheet, it is particularly important to adjust the number of precipitation nuclei of phosphate to a certain distribution density. According to the prior arts 1 and 2, however, the range of the plating weight of the plating layer of nickel and the like is so wide as from 1 to 500 mg/m². When the plating weight of the plating layer of nickel and the like is large beyond the necessary level, or when particles of nickel and the like are not distributed at a certain distribution density, a crystal grain size suitable for forming a thin and dense phosphate film is not available,
50 thus making it impossible to obtain an excellent paint adhesivity and an excellent corrosion resistance after painting. When the plating weight of the plating layer of nickel and the like is too slight, on the contrary, the number of precipitation nuclei of phosphate is insufficient with a coarse and thick phosphate film, and a sufficient reducing effect of frictional coefficient of the steel sheet surface is not available.

55 Even when the plating weight of the plating layer of nickel and the like is within a prescribed range, if the oxide film of nickel and the like is not existent on the plating layer., or when the oxide film, if any, is very thin, the frictional coefficient of the surface of the cold-rolled steel sheet increases, this causing decrease in press-formability of the steel sheet. In order to prevent press-formability from decreasing, it is required to bring the plating weight of the metal plating layer closer to the upper limit of the amount

disclosed in the prior arts 1 and 2. This however in turn causes deterioration of phosphating-treatability of the steel sheet.

As a technology for improving phosphating-treatability and corrosion resistance of the cold-rolled steel sheet, the following cold-rolled steel sheet is proposed;

5 A nickel plated cold-rolled steel sheet excellent in phosphating-treatability and corrosion resistance, disclosed in Japanese Patent Provisional Publication No. 2-101,200 dated April 12, 1990, which comprises: a cold-rolled steel sheet; and a nickel plating layer, formed on the surface of said cold-rolled steel sheet, in which layer nickel particles are precipitated at a distribution density within a range of from 1×10^{12} to $5 \times 10^{14}/m^2$, the plating weight of said nickel plating layer being within a range of from 1 to 50 mg/m² per
10 surface of said cold-rolled steel sheet, each of said nickel particles comprising metallic nickel and non-metallic nickel, having a thickness within a range of from 0.0009 to 0.03 μm , adhering to the surface of said metallic nickel, and said nickel particles having particle size within a range of from 0.001 to 0.3 μm (hereinafter referred to as the "prior art 3").

According to the above-mentioned prior art 3, it is possible to form a dense and uniform phosphate film
15 having a crystal grain size within a certain range, thereby making it possible to obtain a cold-rolled steel sheet excellent in phosphating-treatability and corrosion resistance. In addition, the prior art 3 permits reduction of frictional coefficient of the surface of the continuous-annealed cold-rolled steel sheet.

However, our detailed studies revealed that the prior art 3 had the following problems.

In the prior art 3, when the plating weight of the nickel plating layer is under 5 mg/m², a cold-rolled steel
20 sheet excellent in phosphating-treatability is unavailable. The reason is as follows. More specifically, the number of initially precipitated nuclei of phosphate, which is required for forming a dense and uniform phosphate film and giving a crystal grain size within a certain range by means of the phosphating treatment, is within a range of from 1×10^{10} to $5 \times 10^{11}/m^2$ in terms of the distribution density.

In order to limit the distribution density of nickel particles in the nickel plating layer within the range of
25 from 1×10^{12} to $5 \times 10^{14}/m^2$ as described above, however, the plating weight of the nickel plating layer must be at least 5 mg/m². According to the prior art 3, however, the plating weight of the nickel plating layer is disclosed to be within a range of from 1 to 50 mg/m². Accordingly, when the plating weight of the nickel plating layer is under 5 mg/m², it is impossible to achieve a distribution density of the nickel particles of at least $1 \times 10^{12}/m^2$. Therefore, the number of initially precipitated nuclei of phosphate cannot in some cases
30 be kept within a desired range described above by the prior art 3, in which case an excellent phosphating-treatability of the steel sheet is unavailable.

In the prior art, 3 furthermore, improvement of phosphating-treatability and reduction of frictional
coefficient of the surface of the cold-rolled steel sheet are attempted by forming a non-metallic nickel film on the surface of the nickel plating layer. However, non-metallic nickel is basically a metal oxide, and as
35 disclosed in the examples of the prior art 3, when forming a non-metallic nickel oxide film having an average thickness of at least 0.005 μm on the steel sheet surface by subjecting the steel sheet to an anodic electrolytic treatment in an alkaline bath, non-metallic nickel oxide film having an average thickness larger than the above is formed on a portion of the steel sheet surface not having a nickel plating layer. Consequently, although press-formability is improved, the phosphate film contains more portions with a
40 small deposited weight, thus resulting in a lower paint adhesivity and a poorer corrosion resistance after painting.

When manufacturing a cold-rolled steel sheet for deep drawing by using a mild steel sheet as the material and subjecting same to a continuous annealing treatment, it is necessary to solve simultaneously the two problems of a decrease in phosphating-treatability as well as in press-formability.

45 Under such circumstances, there is a strong demand for the development of a nickel electroplated cold-rolled steel sheet for deep drawing excellent in press-formability and phosphating-treatability, suitable for the application of the continuous annealing treatment, but such a cold-rolled steel sheet and a method for manufacturing same have not as yet been proposed.

50 SUMMARY OF THE INVENTION

An object of the present invention is therefore to provide a nickel electroplated cold-rolled steel sheet for deep drawing excellent in press-formability and phosphating-treatability, suitable for the application of the continuous annealing treatment.

55 In accordance with one of the features of the present invention, there is provided a nickel electroplated cold-rolled steel sheet excellent in press-formability and phosphating-treatability, which comprises:

a cold-rolled steel sheet consisting essentially of:
carbon (C) : up to 0.06 wt.%,

silicon (Si) : up to 0.5 wt.%,
 manganese (Mn) : up to 2.5 wt.%,
 phosphorus (P) : up to 0.1 wt.%,
 sulfur (S) : up to 0.025 wt.%,
 5 soluble aluminum (Sol.Al) : up to 0.10 wt.%,
 nitrogen (N) : up to 0.005 wt.%,

and
 the balance being iron (Fe) and incidental impurities;

10 a nickel electroplating layer, formed on at least one surface of said cold-rolled steel sheet, in which layer nickel particles are precipitated at a distribution density of at least $1 \times 10^{12}/m^2$, the plating weight of said nickel electroplating layer being within a range of from 5 to 60 mg/m² per surface of said cold-rolled steel sheet; and

a nickel oxide film, formed on the surface of said nickel electroplating layer, having an average thickness within a range of from 0.0005 to 0.003 μm .

15 In accordance with another one of the features of the present invention, there is provided a method for manufacturing a nickel electroplated cold-rolled steel sheet excellent in press-formability and phosphating-treatability, which comprises the steps of:

preparing a steel ingot consisting essentially of:

20 carbon (C) : up to 0.06 wt.%,
 silicon (Si) : up to 0.5 wt.%,
 manganese (Mn) : up to 2.5 wt.%,
 phosphorus (P) : up to 0.1 wt.%,
 sulfur (S) : up to 0.025 wt.%,
 soluble aluminum (Sol.Al) : up to 0.10 wt.%,
 25 nitrogen (N) : up to 0.005 wt.%,

and
 the balance being iron (Fe) and incidental impurities; then

hot-rolling said steel ingot to prepare a hot-rolled steel sheet; then

30 cold-rolling said hot-rolled steel sheet at a reduction ratio within a range of from 60 to 85% to prepare a cold-rolled steel sheet; then

subjecting said cold-rolled steel sheet to a continuous annealing treatment which comprises heating said cold-rolled steel sheet to a recrystallization temperature and then slowly cooling same; then

35 subjecting said continuously annealed cold-rolled steel sheet to a continuous nickel electroplating treatment in an acidic electroplating bath to form a nickel electroplating layer, in which layer nickel particles are precipitated at a distribution density of at least $1 \times 10^{12}/m^2$, on at least one surface of said cold-rolled steel sheet, said nickel electroplating layer having a plating weight within a range of from 5 to 60 mg/m² per surface of said cold-rolled steel sheet; and then

40 immersing said cold-rolled steel sheet having said nickel electroplating layer on said at least one surface thereof into a neutral bath or an alkaline bath to form a nickel oxide film having an average thickness within a range of from 0.0005 to 0.003 μm on said nickel electroplating layer.

In the above-mentioned nickel electroplated cold-rolled steel sheet and manufacturing method therefor, said cold-rolled steel sheet may additionally contain any one of the following element(s):

- (1) Titanium (Ti) in an amount of up to 0.15 wt.%;
- (2) Niobium (Nb) in an amount of up to 0.15 wt.%;
- 45 (3) Titanium (Ti) in an amount of up to 0.15 wt.% and niobium (Nb) in an amount of up to 0.15 wt.%;
- (4) Titanium (Ti) in an amount of up to 0.15 wt.% and boron (B) in an amount of up to 0.003 wt.%;
- (5) Niobium (Nb) in an amount of up to 0.15 wt.%
- 50 and boron (B) in an amount of up to 0.003 wt.%; or
- (6) Titanium (Ti) in an amount of up to 0.15 wt.%, niobium (Nb) in an amount of up to 0.15 wt.% and boron (B) in an amount of up to 0.003 wt.%.

55 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph illustrating the relationship between the Lankford value and the limiting drawing ratio, for the conventional continuous-annealed cold-rolled steel sheet and the conventional box-annealed cold-

rolled steel sheet, both without plating;

Fig. 2 is a graph illustrating the effect of the plating weight of the nickel electroplating layer on the number of initially precipitated nuclei of phosphate, the distribution density of nickel particles, frictional coefficient and the grain size of crystals of the phosphate, film, for the examples of the present invention and the examples for comparison outside the scope of the present invention;

Fig. 3 is a graph illustrating the relationship between the Lankford value and the limiting drawing ratio, for the examples of the present invention and the examples for comparison outside the scope of the present invention;

Fig. 4 is a graph illustrating the effect of the average thickness of the nickel oxide film on the grain size of crystals of the phosphate film and the frictional coefficient, for the examples of the present invention and the examples for comparison outside the scope of the present invention;

Fig. 5 is an SEM micrograph showing the metallurgical structure of crystals of the phosphate film formed on the surface of the box-annealed cold-rolled steel sheet;

Fig. 6 is an SEM micrograph showing the metallurgical structure of crystals of the phosphate film formed on the surface of the continuous-annealed cold-rolled steel sheet;

Fig. 7 is an SEM micrograph showing the metallurgical structure of crystals of the phosphate film formed on the surface of the sample of the invention No. 7, which has a nickel electroplating layer having a plating weight of 23 mg/m² and a nickel oxide film having an average thickness of 17 Å; and

Fig. 8 is an SEM micrograph showing the metallurgical structure of crystals of the phosphate film formed on the surface of the sample for comparison No. 10 outside the scope of the present invention, which has a nickel plating layer having a plating weight of 23 mg/m² and a nickel oxide film having an average thickness of 75 Å.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

From the above-mentioned point of view, extensive studies were carried out to develop a nickel electroplated cold-rolled steel sheet excellent in press-formability and phosphating-treatability and a method for manufacturing same. As a result, the following findings were obtained:

By forming a nickel electroplating layer having a prescribed plating weight, in which layer nickel particles are precipitated at a prescribed distribution density, on the surface of a continuous-annealed cold-rolled steel sheet having a specific chemical composition, then forming a nickel oxide film having a prescribed average thickness on the surface of the nickel electroplating layer, and then subjecting the cold-rolled steel sheet to a phosphating treatment to form a phosphate film on the surface of the nickel oxide film, the phosphate film becomes denser, and paint adhesivity and corrosion resistance after painting are further improved.

The present invention was made on the basis of the above-mentioned findings. Now, the nickel electroplated cold-rolled steel sheet excellent in press-formability and phosphating-treatability of the present invention and the method for manufacturing same are described further in detail.

The chemical composition of the cold-rolled steel sheet of the present invention is limited within the above-mentioned range for the following reasons.

(1) Carbon:

A carbon content of over 0.06 wt.% seriously impairs ductility of the cold-rolled steel sheet, thus leading to a poorer workability. A carbon content of under 0.0005 wt.% results, on the other hand, in a longer refining time of steel, which is economically unfavorable.

(2) Silicon and manganese:

Silicon and manganese are added to a high-strength steel sheet required to have a high press-formability. Silicon and manganese are elements which strengthen the solid-solution. Addition of silicon and manganese improves strength of the cold-rolled steel sheet without seriously impairing workability thereof. However, because of the easy oxidation of these elements, a silicon content of over 0.5 wt.% or a manganese content of over 2.5 wt.% causes oxidation of the steel sheet surface, thus impairing the surface appearance unique to the cold-rolled steel sheet. A silicon content of under 0.005 wt.% or a manganese content of under 0.05 wt.% results on the other hand in a longer refining time of steel, which is economically unfavorable.

(3) Phosphorus:

Phosphorus has a function of improving strength of the cold-rolled steel sheet. A phosphorus content of over 0.1 wt.% causes however, longitudinal cracks during the deep drawing of the cold-rolled steel sheet. A phosphorus content of under 0.001 wt.% results on the other hand in a longer refining time of steel, which is economically unfavorable.

(4) Sulfur and nitrogen:

A lower sulfur content or a lower nitrogen content brings about an improved press-formability of the cold-rolled steel sheet. A sulfur content of over 0.025 wt.% or a nitrogen content of over 0.005 wt.% is however economically unfavorable. A sulfur content of under 0.005 wt.% or a nitrogen content of under 0.0005 wt.% results on the other hand in a longer refining time of steel, which is economically unfavorable.

(5) Soluble aluminum:

Soluble aluminum is contained in steel as a residue of aluminum (Al) used as a deoxidizing agent. When a hot-rolled coil is prepared in the hot-rolling process at a coiling temperature of at least 640 °C, soluble aluminum has functions of fixing nitrogen and improving formability. By adjusting a soluble aluminum content to at least 0.01 wt.%, it is possible to obtain a stably deoxidized aluminum-killed steel. With a soluble aluminum content of over 0.1 wt.%, however, the above-mentioned effects are saturated.

(6) Titanium and niobium:

Titanium and niobium are additionally added as required in cases where a very high formability is required to the cold-rolled steel sheet. Titanium and niobium have a function of fixing carbon and nitrogen, thus making it possible to manufacture IF steel by adding titanium and/or niobium to steel. The contents of titanium and niobium are dependent on the contents of carbon and nitrogen. With the contents of titanium and nitrogen of over 0.15 wt.%, respectively, a desired effect of fixing carbon and nitrogen is unavailable and economic demerits are encountered. When the contents of titanium and niobium are under 0.001 wt.%, respectively, the effect as described above is unavailable.

(7) Boron:

Boron has a function of preventing longitudinal cracks inevitably occurring in a cold-rolled steel sheet which comprises IF steel containing titanium and/or niobium. Addition of boron improves deep-drawability of the cold-rolled steel sheet. Therefore, boron is additionally added as required together with titanium and/or niobium. A boron content of over 0.003 wt.% leads however to a lower ductility of the cold-rolled steel sheet. With a boron content of under 0.0002 wt.%, on the other hand, a desired effect as described above is unavailable.

In the present invention, a nickel electroplating layer is formed on the surface of the continuous-annealed cold-rolled steel sheet having the above-mentioned chemical composition. Nickel particles are precipitated in the nickel electroplating layer at a distribution density of at least $1 \times 10^{12}/\text{m}^2$, and the nickel electroplating layer has a plating weight within a range of from 5 to 60 mg/m². The reason is as follows.

In order to improve phosphating-treatability of the continuous-annealed cold-rolled steel sheet, it is necessary that cathodes serving as precipitation nuclei for the precipitation of hopeite ($\text{Zn}_3(\text{PO}_4)_2$) and phosphophyllite ($\text{Zn}_2\text{Fe}(\text{PO}_4)_2$), which are phosphate crystals, are distributed at a certain density on the surface of the continuous-annealed cold-rolled steel sheet to form initially precipitated nuclei of phosphate known as local cells. The number of cathodes distributed on the surface of the steel sheet is equal to the number of local cells formed under the effect of the difference in potential which is produced by elements concentrated on the steel sheet surface and nickel particles precipitated in the nickel electroplating layer formed on the steel sheet surface.

In order to ensure an excellent paint adhesivity and, an excellent corrosion resistance after painting, the crystal grains of the phosphate film should have a grain size within a certain range, and for this purpose, the number of initially precipitated nuclei of phosphate should have a distribution density within a range of from 1×10^{10} to $5 \times 10^{11}/\text{m}^2$. In order for the number of initially precipitated nuclei of phosphate to achieve a distribution density within the above-mentioned range, the nickel particles precipitated in the nickel electroplating layer should have a distribution density within a range of from 1×10^{12} to $5 \times 10^{14}/\text{m}^2$.

Furthermore, to achieve a distribution density of the precipitated nickel particles within the above-mentioned range, it is necessary to limit the plating weight of the nickel electroplating layer within a range of from 5 mg/m² to 60 mg/m² per surface of the cold-rolled steel sheet. By limiting the plating weight of the nickel electroplating layer within the above-mentioned range, it is possible to adjust the distribution density of the nickel particles precipitated in the nickel electroplating layer to at least $1 \times 10^{12}/\text{m}^2$, and hence, to ensure the number of initially precipitated nuclei of phosphate necessary for the phosphating treatment, thereby reducing frictional coefficient.

The average grain size of phosphate crystals thus made available by limiting the plating weight of the nickel electroplating layer and the distribution density of the precipitated nickel particles is within a range of from 1 to 3 μm , which is equal to that of the phosphate crystals formed on the surface of the box-annealed cold-rolled steel sheet. This permits achievement of satisfactory paint adhesivity and corrosion resistance after painting.

With a plating weight of the nickel electroplating layer of under 5 mg/m² per surface of the cold-rolled steel sheet, however, it is impossible to adjust the distribution density of the nickel particles to at least $1 \times 10^{12}/\text{m}^2$, thus making it impossible to ensure the number of initially precipitated nuclei necessary for the phosphating treatment. In addition, a desired effect of reducing frictional coefficient of the steel sheet surface is unavailable. With a plating weight of the nickel electroplating layer of over 60 mg/m², on the other hand, the above-mentioned effect reaches saturation, and the resultant consumption is only uneconomical. A plating weight of the nickel electroplating layer of over 60 mg/m², furthermore, leads to a decreasing tendency of the number of initially precipitated nuclei of phosphate, which is an adverse effect.

In the present invention, a nickel oxide film having an average thickness within a range of from 0.0005 to 0.003 μm is formed on the surface of the nickel electroplating layer. The reason is as follows.

When forming the nickel electroplating layer on the surface of the continuous-annealed cold-rolled steel sheet, hardness of the steel sheet surface becomes relatively low. In order to increase hardness of the steel sheet surface, it is necessary to increase the plating weight of the nickel electroplating layer. However, when increasing the plating weight of the nickel electroplating layer, it becomes impossible to keep the distribution density of the nickel particles precipitated therein within an appropriate range. In the present invention, therefore, the plating weight of the nickel electroplating layer is not increased, but a nickel oxide film having an average thickness within a range of from 0.0005 to 0.003 μm , or more preferably, within a range of from 0.001 to 0.002 μm is formed on the surface of the nickel electroplating layer so as to increase lubricity of the steel sheet surface. This permits reduction of frictional coefficient of the steel sheet surface. An average thickness of the nickel oxide film of under 0.0005 μm cannot provide a desired effect of reducing frictional coefficient.

On the other hand, because the nickel oxide film is an electric insulator, an average thickness thereof of over 0.003 μm hinders smooth flow of electric current for causing precipitation of phosphate crystals. Therefore, when a nickel oxide film is formed through an anodic electrolytic treatment in a neutral or alkaline bath, if a bath concentration is high or an electric current is large, a thick nickel oxide film is formed, not only on the surface of the nickel electroplating layer, but also on the surface portions of the steel sheet not covered with the nickel electroplating layer. This reduces the number of initially precipitated nuclei of phosphate, leading to coarser crystal grains of phosphate, thus preventing formation of a dense phosphate film. For this reason, the average thickness of the nickel oxide film should be limited within a range of from 0.0005 to 0.003 μm , or more preferably, from 0.001 to 0.002 μm .

The above-mentioned nickel electroplated cold-rolled steel sheet of the present invention is manufactured as follows.

A steel ingot having a chemical composition within the above-mentioned range of the present invention is prepared. Then, the steel ingot is hot-rolled to prepare a hot-rolled steel sheet.

Then the hot-rolled steel sheet is cold-rolled at a reduction ratio within a range of from 60 to 85% to prepare a cold-rolled steel sheet. The reduction ratio in the cold-rolling should be limited within the range of from 60 to 85%. With a reduction ratio of under 60% or over 85% in the cold-rolling, a sufficient deep-drawability of the cold-rolled steel sheet is unavailable.

Then, the thus prepared cold-rolled steel sheet is subjected to a continuous annealing treatment which comprises heating the cold-rolled steel sheet to a recrystallization temperature and then slowly cooling same.

An exemplification of the continuous annealing treatment in the present invention is described. More specifically, the cold-rolled steel sheet is heated to a recrystallization temperature, and held at this temperature for a period of time within a range of from three to ten minutes. Then, the thus heated cold-rolled steel sheet is slowly cooled to a temperature of about 50°C at a cooling rate of up to 5°C/sec appropriately selected depending upon the grade of steel.

Another exemplification of the continuous annealing treatment in the present invention is as follows. The cold-rolled steel sheet is heated to a recrystallization temperature, and held at this temperature for a period of time within a range of from three to ten minutes. Then, thus heated cold-rolled steel sheet is rapidly cooled to a temperature of up to 450 °C at a cooling rate of at least 10 °C/sec. Then, the steel sheet is subjected to an overaging treatment at a temperature within a range of from 250 to 400 °C for a period of time within a range of from one to three minutes. Then, the steel sheet is cooled to a temperature of up to 50 °C.

The cold-rolled steel sheet is thus subjected to the continuous annealing treatment because of the possibility of reducing the operation time, the availability of uniformity in quality, and the potential improvement of product yield and productivity.

Subsequently, the thus continuous-annealed cold-rolled steel sheet is subjected to a continuous nickel electroplating treatment in an acidic electroplating bath to form, on at least one surface of the cold-rolled steel sheet, a nickel electroplating layer having a plating weight within a range of from 5 to 60 mg/m² per surface of the cold-rolled steel sheet, in which layer nickel particles are precipitated at a distribution density of at least $1 \times 10^{12}/\text{m}^2$.

The nickel particles may be precipitated on the surface of the cold-rolled steel sheet by a substitution method which comprises immersing the cold-rolled steel sheet in an acidic plating bath, but in order to cause stable precipitation of the nickel particles at a constant distribution density, the electroplating treatment should be employed.

Then, the cold-rolled steel sheet on at least one surface of which the nickel electroplating layer has thus been formed, is immersed into a neutral bath or an alkaline bath, or is subjected to an anodic electrolytic treatment in the neutral bath or the alkaline bath. A nickel oxide film having an average thickness within a range of from 0.0005 to 0.003 μm is thus formed on the surface of the nickel electroplating layer. An aqueous solution of 10 g/l sodium carbonate (Na₂CO₃) is applicable as an alkaline bath.

Prior to the continuous nickel electroplating treatment, the surface of the cold-rolled steel sheet is cleaned by a pickling as required. The pickling is applied because a continuous annealing equipment is in many cases provided with a direct heating furnace on the entry side and a rapid cooling apparatus such as a water coiling device and an air/water cooling device in a rapid cooling zone in the middle so that the increase in the dew point of the atmospheric gas during the heating produces an iron oxide film on the steel sheet surface, and this may prevent the nickel particles from being precipitated in a desirable state. While the immersion method in a hydrochloric acid bath is adopted for pickling in these exemplifications, use of the immersion method in a sulfuric acid bath or an electrolytic treatment in a diluted sulfuric acid bath for the pickling does not impair the essence of the present invention.

Now, the present invention is described further in detail by means of examples while comparing with examples for comparison.

EXAMPLE

Steels B to G each having a chemical composition as shown in Table 2 were refined, and then slabs were prepared from the respective steels B to G by the continuous casting method. Then, the thus prepared slabs were hot-rolled to prepare respective hot-rolled steel sheets having a prescribed thickness. The finishing temperature of each of the hot-rolled steel sheets was a temperature of at least the Ar₃ transformation point of each of the steels, and the coiling temperature in the hot-rolling was 730 °C for the steels B to E and G, and 560 °C for the steel F. Then, the hot-rolled steel sheets were subjected to the pickling by the hydrochloric acid pickling method to remove scale from the surfaces of the hot-rolled steel sheets.

Then, the pickled hot-rolled steel sheets were cold-rolled under the conditions as shown in Table 4 to prepare respective cold-rolled steel sheets having a thickness within a range of from 0.8 to 1.0 mm. Then, the cold-rolled steel sheets were subjected to a continuous annealing treatment under the conditions as shown in Table 4. Then, the thus continuous-annealed cold-rolled steel sheets were immersed in an acidic bath comprising hydrochloric acid as shown in Table 3 to apply a pickling under the conditions as shown in Table 3.

Then, each of the pickled cold-rolled steel sheets was subjected to a continuous nickel electroplating treatment in a nickel electroplating bath as shown in Table 3 under the conditions as shown also in Table 3. Then, the cold-rolled steel sheet having the nickel electroplating layer formed thereon was subjected to an anodic electrolytic treatment in an aqueous solution of sodium hydrogencarbonate (NaHCO₃) under the conditions as shown in Table 3 to form a nickel oxide film on the surface of the nickel electroplating layer. The cold-rolled steel sheets on each of which the nickel electroplating layer and the nickel oxide film had

been formed, were subjected to a temper rolling with an elongation ratio of about 1.0% to prepare samples of the nickel electroplated cold-rolled steel sheet within the scope of the present invention (hereinafter referred to as the "samples of the invention") Nos. 1 to 12.

5 For comparison purposes, samples of the nickel electroplated steel sheet outside the scope of the present invention (hereinafter referred to as the "samples for comparison") Nos. 1 to 13 were prepared by the use of the steels D and E each having a chemical composition within the scope of the present invention as shown in Table 2. The samples for comparison Nos. 1 to 13 had a plating weight of the nickel electroplating layer outside the scope of the present invention or an average thickness of the nickel oxide film outside the scope of the present invention as shown in Table 5.

10 For each of the thus prepared samples of the invention Nos. 1 to 12 and the samples for comparison Nos. 1 to 13, a frictional coefficient (μ) of the steel sheet surface, a limiting drawing ratio (LDR), a Lankford value (\bar{r} -value), phosphating-treatability, a distribution density of the nickel particles in the nickel electroplating layer, and an average thickness of the nickel oxide film were investigated. The results are shown in Tables 4 and 5.

15 Test method of frictional coefficient of steel sheet surface:

A test piece having a size of 30 mm x 200 mm was cut out from each of the samples of the invention Nos. 1 to 12 and the samples for comparison Nos. 1 to 13. The test piece was placed on guide rollers, and then a pressing member having a size of 3 mm x 10 mm was pressed under a pressure of 400 kg·F from above onto the surface of the test piece. Then, in this state, the test piece was withdrawn at a speed of 1,000 m/minute to determine the withdrawing force F (kg·f) at this moment, and the frictional coefficient $\mu = 400/F$ was calculated from the thus determined withdrawing force F. The surface roughness was imparted to the bottom surface of the pressing member in the direction at right angles to the sliding direction by means of diamond particles having a particle size of about 3 μm .

Test method of limiting drawing ratio:

A plurality of disks having various diameters were cut out from each of the samples of the invention Nos. 1 to 12 and the samples for comparison Nos. 1 to 13. Then, these disks were drawn by means of a punch having a diameter of 50 mm. The ratio of the maximum disks diameter, in which cracks had not been produced on the disk, to the punch diameter was determined as a limiting drawing ratio. When measuring the limiting drawing ratio, a commercially available anticorrosive oil was smeared as a lubricant on the disk and the punch.

35 Test method of Lankford value:

For each of the samples of the invention Nos. 1 to 12 and the samples for comparison Nos. 1 to 13, a Lankford value was measured by a known method prior to forming the nickel electroplating layer.

40 Test method of phosphating-treatability:

Each of the samples of the invention Nos. 1 to 12 and the samples for comparison Nos. 1 to 13 was immersed for 15 seconds in a phosphating treatment solution (manufactured by Japan Perkerizing Co., Ltd.; PB-3030), then rinsed and dried. The surface of each of the samples of the invention and the samples for comparison thus immersed in the phosphating treatment solution was observed by means of a scanning type electron microscope to measure the number of initially precipitated nuclei of phosphate. In addition, each of the samples of the invention and the samples for comparison was immersed in the above-mentioned phosphating treatment solution for 120 seconds to form a phosphate film completely on the surface of the steel sheet, and was observed by means of a scanning type electron microscope to measure the grain size of phosphate crystal grains and the appearance of the phosphate film. The appearance of the phosphate film was evaluated in accordance with the following criteria:

- ⊙ : the phosphate crystal grain has a grain size within a range of from 1.5 to 2.5 μm , and the deposited amount of the phosphate film is sufficient;
- : the phosphate crystal grain has a grain size within a range of from 1.0 to under 1.5 μm or from over 2.5 μm to 3.0 μm , and the deposited amount of the phosphate film is sufficient;
- △ : the phosphate crystal grain has a grain size of over 3.0 μm , and the deposited amount of the phosphate film is sufficient,

x : the phosphate crystal grain has a grain size of over 3.0 μm, and the deposited amount of the phosphate film is insufficient.

The phosphate film was peeled off by the reverse electrolysis to determine the deposited amount of the phosphate film from the difference in weight between before and after peeloff.

5

Measuring methods of the distribution density of nickel particles in the nickel electroplating layer and the average thickness of the nickel oxide film:

10 The distribution density of nickel particles was measured by extracting nickel precipitated on the steel sheet surface by the application of the extraction replica method, and then observing by means of a transmission type electron microscope. Measurement of the average thickness of the nickel oxide film was conducted by the application of the Anger electron spectroscopic method.

15

Table 3

Process	Bath composition	Temperature	Electric current density
Pickling	HCl 50 g/l	50±5°C	—
Ni plating	NiSO ₄ ·6H ₂ O 240 g/l NiCl ₂ ·6H ₂ O 45 g/l H ₃ BO ₃ 30 g/l pH 2.5-3.5	40±5°C	-1.0-3.0 A/dm ²
Ni oxide film forming	NaHCO ₃ 20 g/l	25±5°C	0.1-1.0 A/dm ²

45

50

55

Table 4

No	Continuous-annealed cold-rolled steel sheet				Nickel plating			Press-formability		Phosphating-treatability			
	Steel grade	Reduction ratio (%)	Heating temperature (°C)	r _n - value	Plating weight (mg/m ²)	Distribution density of Ni particles (per m ²)	Oxide film (Å)	Frictional coefficient (μ)	LDR	Deposited amount (mg/m ²)	Number of initially precipitated nuclei (per m ²)	Crystal grain size (μm)	Appearance
1	B	75	750	1.55	15	3 × 10 ¹³	16	0.13	2.04	2.2	2 × 10 ¹¹	2.0	◎
2	B	80	750	1.60	45	3 × 10 ¹⁴	10	0.13	2.04	2.0	4 × 10 ¹¹	2.0	◎
3	C	75	830	1.80	5	1 × 10 ¹²	16	0.14	2.08	3.5	2 × 10 ¹⁰	2.7	◎
4	C	80	830	1.85	32	2 × 10 ¹³	12	0.13	2.08	2.3	4 × 10 ¹¹	1.8	◎
5	C	85	830	1.85	55	3 × 10 ¹³	18	0.13	2.09	2.1	3 × 10 ¹¹	1.5	◎
6	D	75	830	2.00	13	1 × 10 ¹³	15	0.14	2.12	2.5	7 × 10 ¹⁰	2.5	◎
7	D	80	830	2.10	23	3 × 10 ¹³	17	0.13	2.11	2.5	4 × 10 ¹¹	2.0	◎
8	D	85	830	2.15	40	6 × 10 ¹³	19	0.12	2.12	2.3	7 × 10 ¹¹	2.0	◎
9	E	75	830	2.15	7	1 × 10 ¹²	15	0.15	2.14	2.7	1 × 10 ¹⁰	2.8	◎
10	E	80	830	2.25	28	3 × 10 ¹³	18	0.13	2.15	2.2	2 × 10 ¹¹	2.2	◎
11	G	80	830	1.10	45	7 × 10 ¹³	13	0.12	1.98	2.3	6 × 10 ¹¹	2.0	◎
12	E	80	830	2.25	5	2 × 10 ¹²	7	0.17	2.10	2.9	1 × 10 ¹⁰	3.3	○

Sample of the invention

Table 5

NO	Continuous-annealed cold-rolled steel sheet				Nickel plating			Press-formability		Phosphating-treatability			
	Steel grade	Reduction ratio (%)	Heating temperature (°C)	r - value	Plating weight (mg/m ²)	Distribution density of Ni particles (per m ²)	Oxide film thickness (Å)	Frictional coefficient (μ)	LDR	Deposited amount (mg/m ²)	Number of initially precipitated nuclei (per m ²)	Crystal grain size (μm)	Appearance
1	D	80	830	2.10	2	9 × 10 ¹⁰	5	0.17	2.10	3.1	2 × 10 ⁹	3.8	△
2	D	80	830	2.10	12	7 × 10 ¹²	2	0.16	2.10	2.5	4 × 10 ¹⁰	2.5	◎
3	E	80	830	2.25	25	3 × 10 ¹³	3	0.15	2.12	2.7	2 × 10 ¹¹	2.2	◎
4	D	80	830	2.10	38	1 × 10 ¹⁴	4	0.15	2.08	2.3	3 × 10 ¹¹	2.3	◎
5	E	80	830	2.25	48	1 × 10 ¹⁴	8	0.14	2.13	2.3	5 × 10 ¹¹	2.0	◎
6	D	80	830	2.10	18	3 × 10 ¹³	42	0.12	2.13	3.5	2 × 10 ¹⁰	3.6	×
7	E	80	830	2.25	25	4 × 10 ¹³	53	0.12	2.14	3.7	1 × 10 ¹⁰	4.8	×
8	D	80	830	2.10	27	3 × 10 ¹³	35	0.12	2.12	3.2	3 × 10 ¹⁰	2.9	△
9	E	80	830	2.25	32	6 × 10 ¹³	45	0.13	2.15	3.6	2 × 10 ¹⁰	4.3	×
10	D	80	830	2.10	23	4 × 10 ¹³	75	0.12	2.11	2.2	7 × 10 ⁹	5.5	×
11	E	80	830	2.25	25	5 × 10 ¹³	250	0.11	2.12	2.0	2 × 10 ⁹	7.3	×
12	D	80	830	2.10	150	9 × 10 ¹¹	14	0.13	2.12	3.5	1 × 10 ¹⁰	3.8	△
13	E	80	830	2.25	230	2 × 10 ¹¹	17	0.13	2.13	3.7	7 × 10 ⁹	4.5	△

Sample of the invention

As shown in Tables 4 and 5, the samples of the invention Nos. 1 to 12, of which the plating weight of the nickel electroplating layer, the distribution density of nickel particles and the average thickness of the nickel oxide film were within the scope of the present invention, showed satisfactory results of tests and were excellent in press-formability and phosphating-treatability.

The sample for comparison No. 1, in contrast, having a low plating weight of the nickel electroplating

layer outside the scope of the present invention and a low distribution density of nickel particles outside the scope of the present invention, showed a high frictional coefficient and a large grain size of phosphate crystal grains resulting in inferior press-formability and phosphating-treatability.

The samples for comparison Nos. 2 to 5, of which the average thickness of the nickel oxide film was low outside the scope of the present invention, showed a high frictional coefficient and an insufficient limiting drawing ratio, thus resulting in an inferior press-formability.

In the samples for comparison Nos. 6 to 11, of which the average thickness of the nickel oxide film was large outside the scope of the present invention, the grain size of phosphate crystal grains was large, with an insufficient deposited amount of the phosphate film, resulting in an inferior phosphating-treatability.

The samples for comparison Nos. 12 and 13, having a large plating weight of the nickel electroplating layer outside the scope of the present invention and a low distribution density of nickel particles outside the scope of the present invention, showed a large grain size of phosphate crystal grains, hence an inferior phosphating-treatability.

Fig. 2 is a graph illustrating the effect of the plating weight of the nickel electroplating layer on the number of initially precipitated nuclei of phosphate, the distribution density of nickel particles, frictional coefficient and the grain size of crystals of the phosphate film, for the examples of the present invention and the examples for comparison outside the scope of the present invention. In Fig. 2, the mark "o" represents the sample of the invention, and the mark "●" represents the sample for comparison. In Fig. 2, the range of the grain size of crystals of the phosphate film formed on the surface of the nickel electroplated cold-rolled steel sheet prepared from the steel H and the range of the frictional coefficient are indicated by the arrows. It is understood from fig. 2, that, with a plating weight of the nickel electroplating layer within the scope of the present invention, the number of initially precipitated nuclei of phosphate, the distribution density of nickel particles, the frictional coefficient and the grain size of phosphate crystal grains are as satisfactory as the results available in the box-annealed cold-rolled steel sheet.

Fig. 3 is a graph illustrating the relationship between the Lankford value and the limiting drawing ratio, for the examples of the present invention and the examples for comparison outside the scope of the present invention. In Fig. 3, the mark "o" represents the sample of the invention, the mark "●" represents the sample for comparison, and the mark "△" represents a continuous-annealed cold-rolled steel sheet not nickel-electroplated. It is understood from Fig. 3 that there are differences in the Lankford value and the limiting drawing ratio between the examples of the invention and the examples for comparison.

Fig. 4 is a graph illustrating the effect of the average thickness of the nickel oxide film on the grain size of crystals of the phosphate film and the frictional coefficient, for the examples of the present invention and the examples for comparison outside the scope of the present invention. In Fig. 4, the mark "o" represents the sample of the invention, and the mark "●" represents the sample for comparison. In Fig. 4, the range of the grain size of crystals of the phosphate film formed on the surface of the nickel electroplated cold-rolled steel prepared from the steel F and the range of the frictional coefficient are indicated by the arrows. It is understood from fig. 4 that, even with a plating weight of the nickel electroplating layer within the scope of the present invention, if the average thickness of the nickel oxide film is low outside the scope of the present invention, the frictional coefficient becomes higher. With a low average thickness of the nickel oxide film outside the scope of the present invention, on the other hand, the grain size of phosphate crystal grains becomes larger, thus resulting in an inferior phosphating-treatability.

According to the present invention, as described above in detail, it is possible to obtain a nickel electroplated cold-rolled steel sheet for deep drawing excellent in press-formability and phosphating-treatability, suitable for the application of the continuous annealing treatment and a method for manufacturing same, thus providing industrially useful effects.

Claims

1. A nickel electroplated cold-rolled steel sheet excellent in press-formability and phosphating-treatability, which comprises:

a cold-rolled steel sheet consisting essentially of:

carbon (C)	: up to 0.06 wt.%,
silicon (Si)	: up to 0.5 wt.%,
manganese (Mn)	: up to 2.5 wt.%,
phosphorus (P)	: up to 0.1 wt.%,
sulfur (S)	: up to 0.025 wt.%,
soluble aluminum (Sol.Al)	: up to 0.10 wt.%,

nitrogen (N) : up to 0.005 wt.%,
and
the balance being iron (Fe) and incidental impurities;

5 a nickel electroplating layer, formed on at least one surface of said cold-rolled steel sheet, in which layer nickel particles are precipitated at a distribution density of at least $1 \times 10^{12}/\text{m}^2$, the plating weight of said nickel electroplating layer being within a range of from 5 to 60 mg/m² per surface of said cold-rolled steel sheet; and

10 a nickel oxide film, formed on the surface of said nickel electroplating layer, having an average thickness within a range of from 0.0005 to 0.003 μm .

2. A nickel electroplated cold-rolled steel sheet as claimed in Claim 1, wherein:

said cold-rolled steel sheet additionally contains titanium (Ti) in an amount of up to 0.15 wt.%.
15

3. A nickel electroplated cold-rolled steel sheet as claimed in Claim 1, wherein:

said cold-rolled steel sheet additionally contains niobium (Nb) in an amount of up to 0.15 wt.%.
20

4. A nickel electroplated cold-rolled steel sheet as claimed in Claim 2, wherein:

said cold-rolled steel sheet additionally contains niobium (Nb) in an amount of up to 0.15 wt.%.
25

5. A nickel electroplated cold-rolled steel sheet as claimed in Claim 2, wherein:

said cold-rolled steel sheet additionally contains boron (B) in an amount of up to 0.003 wt.%.
30

6. A nickel electroplated cold-rolled steel sheet as claimed in Claim 3, wherein:

said cold-rolled steel sheet additionally contains boron (B) in an amount of up to 0.003 wt.%.
35

7. A nickel electroplated cold-rolled steel sheet as claimed in Claim 4, wherein:

said cold-rolled steel sheet additionally contains boron (B) in an amount of up to 0.003 wt.%.
40

8. A nickel electroplated cold-rolled steel sheet as claimed in Claim 1, wherein:

said nickel oxide film has an average thickness within a range of from 0.001 to 0.002 μm .

9. A method for manufacturing a nickel electroplated cold-rolled steel sheet excellent in press-formability and phosphating-treatability, which comprises the steps of:

preparing a steel ingot consisting essentially of:

45 carbon (C) : up to 0.06 wt.%,

silicon (Si) : up to 0.5 wt.%,

manganese (Mn) : up to 2.5 wt.%,

phosphorus (P) : up to 0.1 wt.%,

sulfur (S) : up to 0.025 wt.%,

soluble aluminum (Sol.Al) : up to 0.10 wt.%,

50 nitrogen (N) : up to 0.005 wt.%,

and

the balance being iron (Fe) and incidental impurities; then

hot-rolling said steel ingot to prepare a hot-rolled steel sheet; then

55

cold-rolling said hot-rolled steel sheet at a reduction ratio within a range of from 60 to 85% to prepare a cold-rolled steel sheet; then

subjecting said cold-rolled steel sheet to a continuous annealing treatment which comprises heating said cold-rolled steel sheet to a recrystallization temperature and then slowly cooling same; then

5 subjecting said continuously annealed cold-rolled steel sheet to a continuous nickel electroplating treatment in an acidic electroplating bath to form a nickel electroplating layer, in which layer nickel particles are precipitated at a distribution density of at least $1 \times 10^{12}/\text{m}^2$, on at least one surface of said cold-rolled steel sheet, said nickel electroplating layer having a plating weight within a range of from 5 to 60 mg/m² per surface of said cold-rolled steel sheet; and then

10 immersing said cold-rolled steel sheet having said nickel electroplating layer on said at least one surface thereof into a neutral bath or an alkaline bath to form a nickel oxide film having an average thickness within a range of from 0.0005 to 0.003 μm on said nickel electroplating layer.

15 **10.** A method as claimed in Claim 9, wherein:

said cold-rolled steel sheet additionally contains titanium (Ti) in an amount of up to 0.15 wt.%.

11. A method as claimed in Claim 9, wherein:

20 said cold-rolled steel sheet additionally contains niobium (Nb) in an amount of up to 0.15 wt.%.

12. A method as claimed in Claim 10, wherein:

25 said cold-rolled steel sheet additionally contains niobium (Nb) in an amount of up to 0.15 wt.%.

13. A method as claimed in Claim 10, wherein:

said cold-rolled steel sheet additionally contains boron (B) in an amount of up to 0.003 wt.%.

30 **14.** A method as claimed in Claim 11, wherein:

said cold-rolled steel sheet additionally contains boron (B) in an amount of up to 0.003 wt.%.

15. A method as claimed in Claim 12, wherein:

35 said cold-rolled steel sheet additionally contains boron (B) in an amount of up to 0.003 wt.%.

16. A method as claimed in Claim 9, wherein:

40 said cold-rolled steel sheet having said nickel electroplating layer is subjected to an anodic electrolytic treatment in said neutral bath or said alkaline bath.

17. A method as claimed in Claim 9, wherein:

45 the surface of said cold-rolled steel sheet is cleaned by a pickling prior to said continuous nickel electroplating treatment.

18. A method as claimed in Claim 9, wherein:

50 said nickel oxide film has an average thickness within a range of from 0.001 to 0.002 μm .

55

FIG. 1

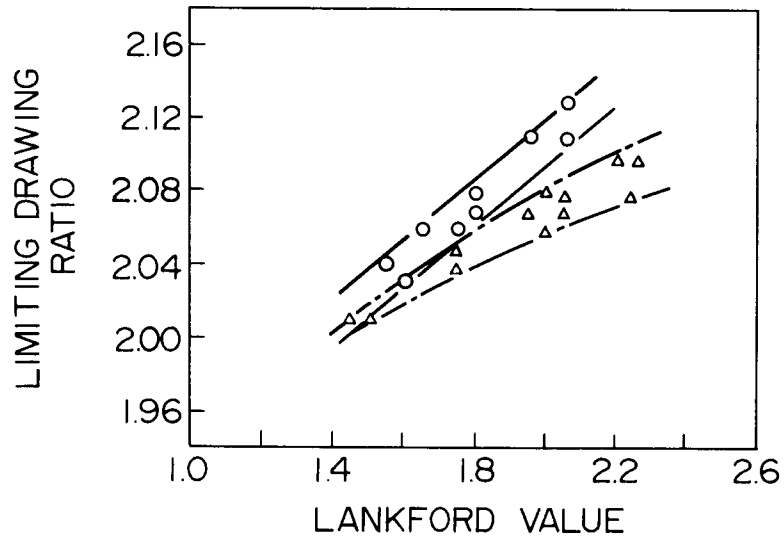


FIG. 3

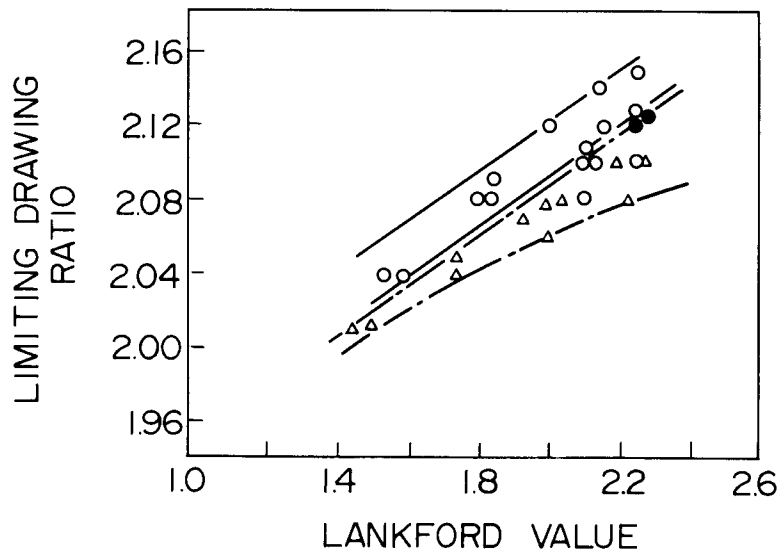


FIG. 2

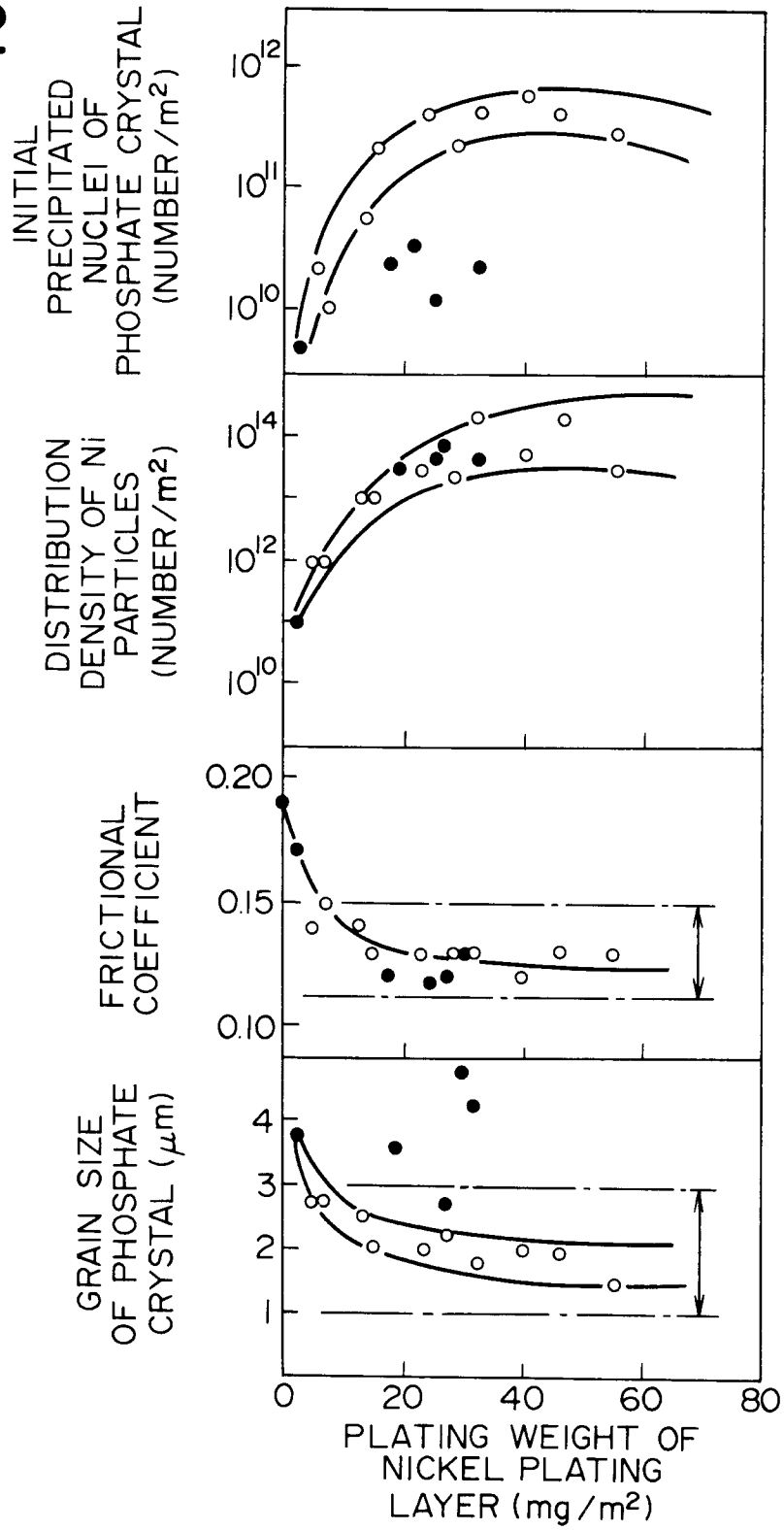


FIG. 4

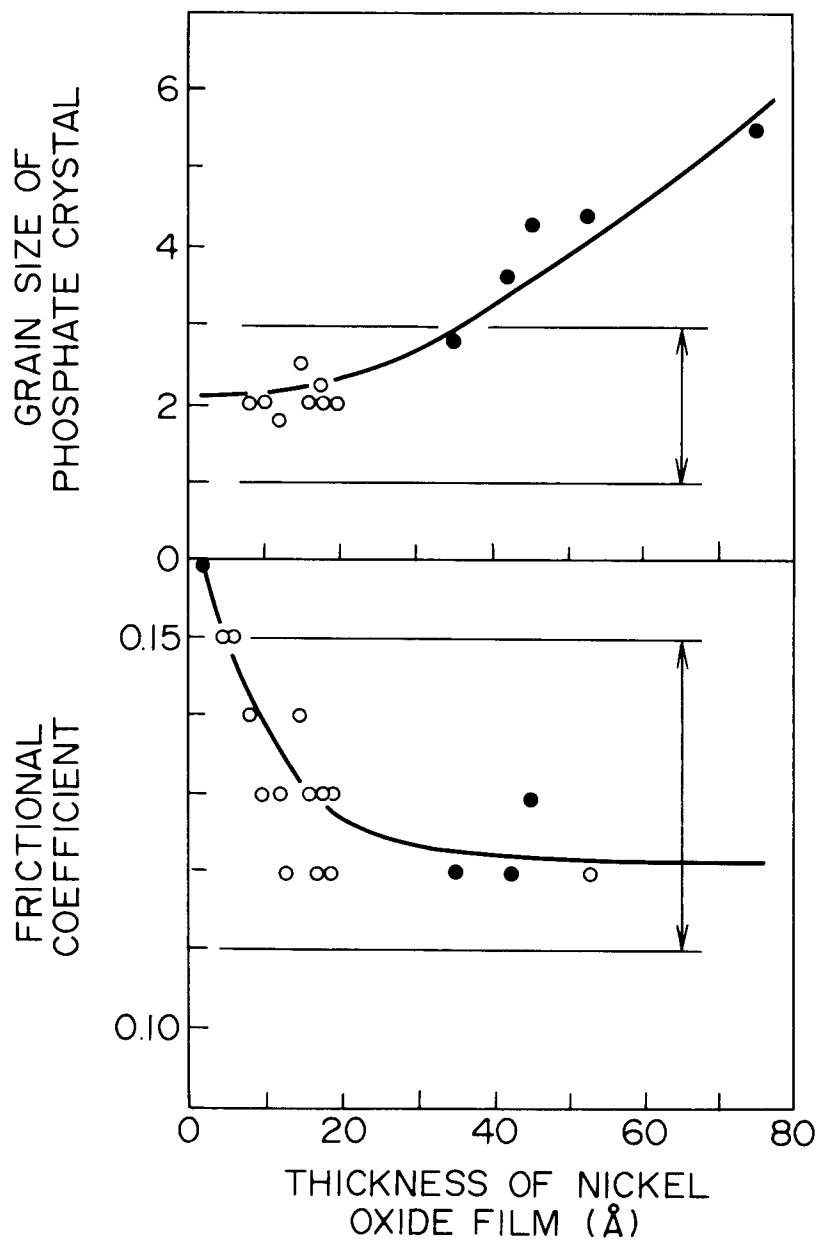


FIG. 5

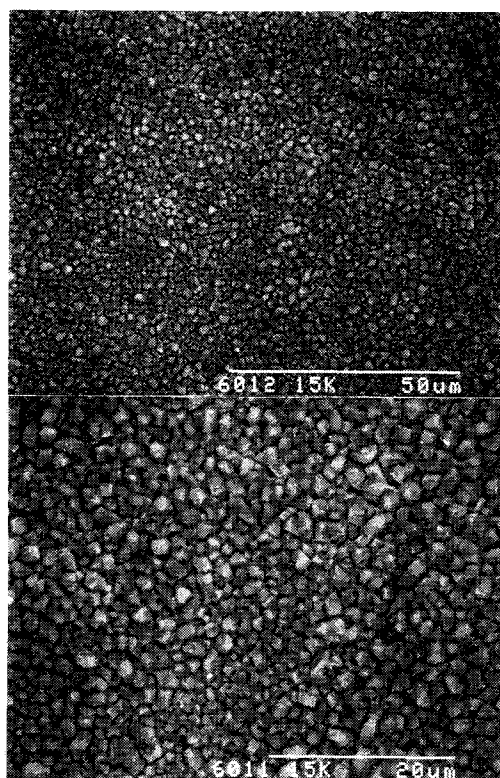


FIG. 6

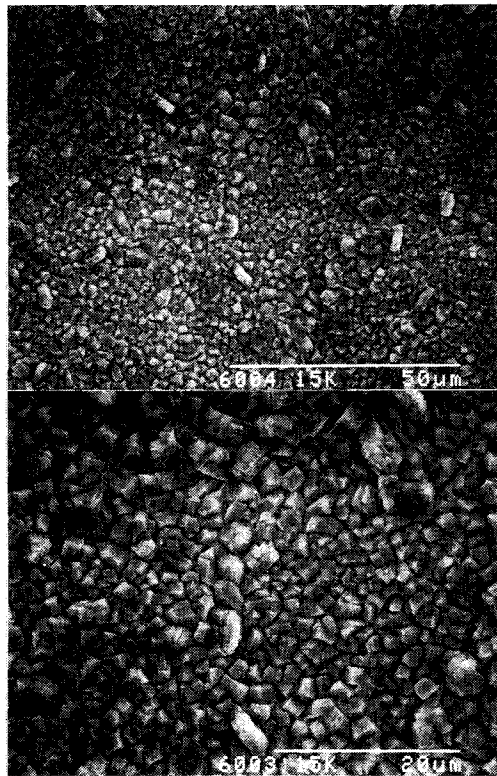


FIG. 7

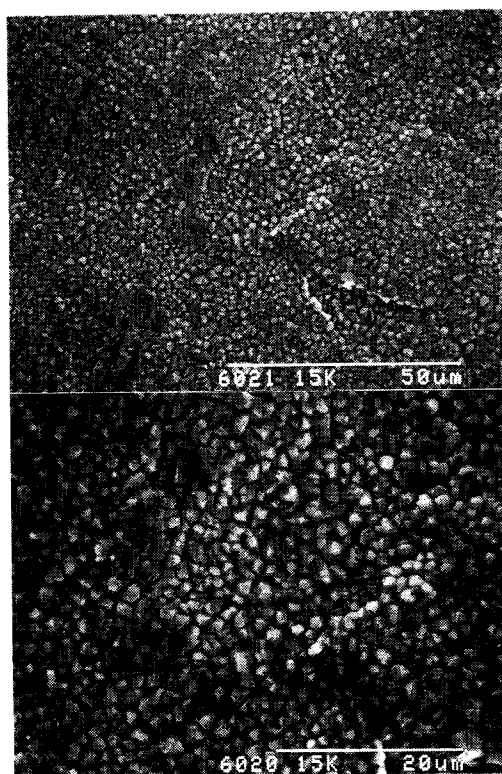
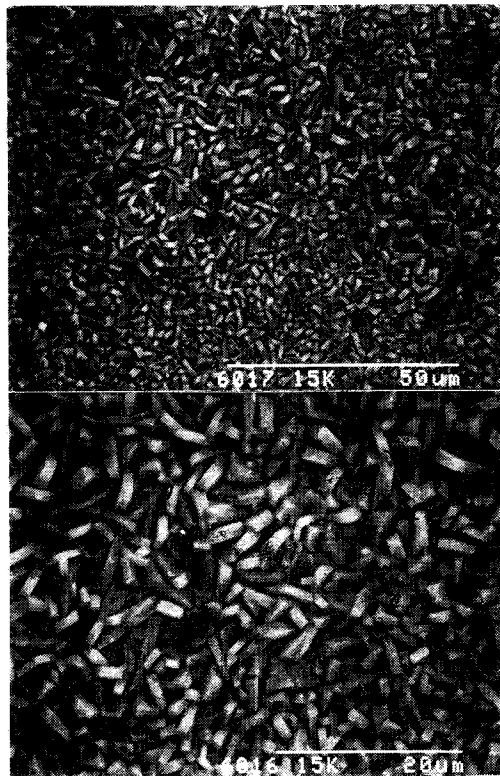


FIG. 8





DOCUMENTS CONSIDERED TO BE RELEVANT			EP 92101186.2
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D,A	PATENT ABSTRACTS OF JAPAN, unexamined applications, C field, vol. 5, no. 195, December 11, 1981, THE PATENT OFFICE JAPANESE GOVERNMENT page 28 C 83 * Kokai-no. 56-116 883 (SHIN NIPPON SEITETSU) *	1-18	C 23 C 28/00
D,A	PATENT ABSTRACTS OF JAPAN, unexamined applications, C field, vol. 5, no. 195, December 11, 1981, THE PATENT OFFICE JAPANESE GOVERNMENT page 29 C 83 * Kokai-no. 56-116 887 (SHIN NIPPON SEITETSU) *	1-18	
D,A	PATENT ABSTRACTS OF JAPAN, unexamined applications, C field, vol. 14, no. 304, June 29, 1990, THE PATENT OFFICE JAPANESE GOVERNMENT page 167 C 734 * Kokai-no. 2-101 200 (NKK CORP) *	1-18	TECHNICAL FIELDS SEARCHED (Int. Cl.5) C 23 C C 23 F C 25 D
A	PATENT ABSTRACTS OF JAPAN, unexamined applications, C field, vol. 13, no. 362, August 14, 1989, THE PATENT OFFICE JAPANESE GOVERNMENT page 67 C 625 * Kokai-no. 1-119 651 (NIPPON STEEL CORP) *	1-18	
The present search report has been drawn up for all claims			
Place of search VIENNA		Date of completion of the search 02-05-1992	Examiner HAUK
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document



DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
A	<p>US - A - 4 035 248 (HIDEJIRO ASANO et al.) * Abstract; claims 1-8 *</p> <p>-----</p>	1-18
		CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
		TECHNICAL FIELDS SEARCHED (Int. Cl.5)
The present search report has been drawn up for all claims		
Place of search	Date of completion of the search	Examiner
VIENNA	02-05-1992	HAUK
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>..... & : member of the same patent family, corresponding document</p>		