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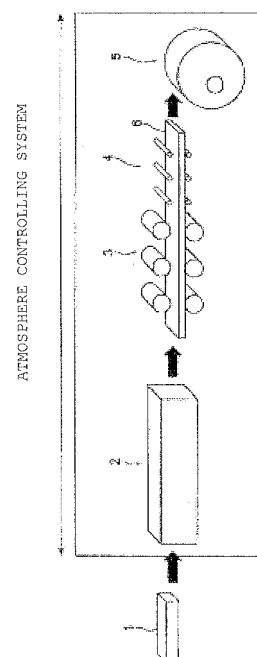
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(54) **PROCESS FOR PRODUCING HOT-ROLLED STEEL SHEET AND PROCESS FOR PRODUCING HOT-DIP GALVANIZED STEEL SHEET**

(57) A method for producing a hot rolled steel sheet includes a slab heating step of heating a steel slab in a slab heating furnace, a step of hot-rolling the heated steel slab in a rough rolling mill to form a strip and a finish rolling mill, and a coiling step of coiling the strip around a coiler. The atmosphere in steps from the slab heating step to the coiling step is a non-oxidizing atmosphere. The slab steel contains C: 0.01-0.15%, Si: 0.1-1.8%, Mn: 1.0-2.7%, Al: 0.01-1.5%, P: 0.005-0.025%, and S: 0.01% or less, by mass. A hot-dip galvanized steel sheet is produced by pickling the hot rolled steel sheet to remove mill scale, or by pickling the sheet and further cold-rolling the sheet, and subsequently by subjecting the resultant to hot-dip galvanizing.

Fig. 1



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Description

Field of the Invention

[0001] The present invention relates to a method for producing a hot rolled steel sheet having a good external appearance by restraining the generation of mill scale on a steel surface at the time of hot-rolling a steel slab. The present invention also relates to a method for producing a Si-containing hot rolled steel sheet suitable for hot-dip galvanizing. Furthermore, the present invention relates to a method for producing a hot-dip galvanized steel sheet by use of a high-strength Si-containing steel sheet as a base material.

Description of the Related Arts

[0002] In general, a hot rolled steel sheet is produced by hot-rolling a steel slab and then coiling the resultant by a coiler. On the surfaces of the hot rolled steel sheet coiled by the coiler, there exists mill scale generated in the hot rolling process from the slab heating step to the coiling step.

[0003] Hot rolled steel sheets are classified into steel sheets shipped in the state that oxide scale generated in the hot rolling process are present (so-called steel sheets as hot rolled), and sheets shipped in the state that oxide scale are removed (so-called hot rolled steel sheets as pickled). The hot rolled steel sheets as pickled are shipped after hot rolled steel sheets are pickled to remove mill scale on their surfaces.

[0004] If the generation of the mill scale is restrained in the hot rolling process, any pickling step for removing the mill scale becomes unnecessary. However, a suggestion has not been made so far about technique for restraining the generation of the mill scale in the hot rolling process.

[0005] In recent years, from the viewpoint of the preservation of the global environment, an improvement in the fuel-efficiency of cars has become an important theme. Thus, there becomes a trend to try to make the strength of the material of car body higher to reduce the wall thickness and thereby to try to reduce the car body weight. When Si is added to steel, a high-strength steel sheet excellent in workability may be produced. However, the use of a steel slab wherein Si is added to steel causes a problem that in a hot rolling process there frequently generated surface defects called red scale (hereinafter referred to as red scale defects). The problem causes deterioration in the quality of the external appearance of hot rolled steel sheets.

[0006] In recent years, in the fields of cars, household electrical appliances, building materials and others, surface-treated steel sheets to which rust-prevention is given, in particular, hot-dip galvanized steel sheets excellent in rust prevention, have been used. Hot rolled steel sheets are also used for application of hot-dip galvanizing. When a hot rolled steel sheet is used for application of hot-dip galvanizing, a thin steel sheet having the surfaces from which mill scale are removed by pickling the hot rolled steel sheet, or a thin steel sheet further subjected to cold rolling after the pickling is used as a base steel sheet for galvanizing. This base steel sheet is degreased in a pre-treatment step, recrystallization-annealed, and then subjected to hot-dip galvanizing, or the resultant sheet is further subjected to alloying treatment in a CGL (continuous galvanizing line), thereby to produce a hot-dip galvanized steel sheet.

[0007] When a high-strength Si-containing steel sheet is subjected to hot-dip galvanizing, there is a problem not only causing external appearance defects attributable to red scale defects but also hindering the galvanizability due to a Si oxide generating on a surface layer of the steel sheet.

[0008] Examples of the type of a heating furnace in the CGL include a DFF (direct firing type), an NOF (non-oxidizing type), and an all-radiant-tube type, and the like. In recent years, the construction of all-radiant-tube type CGLs has been increasing since this type furnace is easily operated and pickups are hardly generated in a roll inside this furnace. All-radiant-tube type CGLs are different from DFF (direct firing type) and NOF (non-oxidizing type) and do not require any oxidizing step in advance. For this reason, in high-strength steel sheets containing an easily oxidizable element such as Si or Mn, a Si oxide or a Mn oxide is generated on the surface layers of the steel sheets. Thus, the all-radiant-tube type CGLs have disadvantage for securing a good galvanizing performance.

[0009] Patent Document 1 relates to a technique of using a high-strength steel sheet containing easily oxidizable elements such as Si and Mn in a large amount as a base steel sheet for galvanizing, to keep a good galvanizing performance surely in an all-radiant-tube type CGL. This Patent Document 1 discloses a technique that at the time of producing a hot-dip galvanized steel sheet (GI) having a galvanization layer in which hot-dip galvanizing is performed but no subsequent treatment is conducted, the temperature for heating in a reducing furnace is specified by a relationship with the partial pressure of water vapor in the atmosphere and further the dew point is raised to enhance the potential of oxygen, thereby Si, Mn and others are internally oxidized.

Patent Document 2 discloses a technique that at the time of producing a hot-dip galvanized steel sheet (GA) by performing hot-dip galvanizing and then subjecting the resultant galvanization layer to alloying treatment, the temperature for heating in a reducing furnace is specified by a relationship with the partial pressure of water vapor in the atmosphere, and further the dew point is raised to enhance the potential of oxygen, thereby Si, Mn and others are internally oxidized. However,

according to these techniques, the furnace body is violently damaged to make it impossible to produce a high-strength Si-containing hot-dip galvanized steel sheet having a good external appearance.

[0010] Patent Document 3 discloses a technique of specifying, for the atmosphere of a reducing zone, the concentrations of H₂O and O₂, which are oxidizing gases and further specifying the concentration of CO₂ to enhance the potential of oxygen, thereby Si, Mn and others are internally oxidized so as to restrain external oxidation to improve the external appearance of a galvanization. However, this technique has fears, such as deterioration in the galvanization-external-appearance by in-furnace pollution attributable to CO₂, and a change in mechanical properties by carburization into the steel sheet surface layer.

[0011] For this reason, in the case of using, as a base steel sheet for galvanizing, a high-strength steel sheet containing easily oxidizable elements such as Si and Mn in a large amount, any all-radiant-tube type CGL makes it impossible to produce a hot-dip galvanized steel sheet having a good galvanizing property.

Prior Art Documents

Patent Documents

[0012]

[Patent Document 1] Japanese Patent Application Laid-Open No. 2004-323970

[Patent Document 2] Japanese Patent Application Laid-Open No. 2004-315960

[Patent Document 3] Japanese Patent Application Laid-Open No. 2006-233333

Summary of the Invention

Problems to be solved by the Invention

[0013] In light of this situation, the present invention has been made. It is an object of the present invention to provide a production method for producing a hot rolled steel sheet which makes it possible to restrain the generation of mill scale on steel sheet surfaces in a hot rolling process. It is another object of the present invention to provide a method for producing a hot rolled steel sheet having a beautiful external appearance by preventing, for a Si-containing hot rolled steel sheet, the generation of red scale defects.

[0014] It is still another object of the present invention to provide a method for producing a hot rolled steel sheet which prevents the generation of external appearance defects resulting from a galvanization omission or red scale defects and is suitable for producing a hot-dip galvanized steel sheet having a beautiful external appearance. It is a further object of the present invention to provide a method for producing a hot-dip galvanized steel sheet having a beautiful external appearance which generates no external appearance defects resulting from galvanization omission or red scale defects regardless of the type of a heating furnace in a CGL.

[0015] The subject matter of the present invention for attaining the objects above is as follows:

[0016] [1] A method for producing a hot rolled steel sheet, comprising:

a slab heating step of heating a steel slab in a slab heating furnace,
a step of hot-rolling the heated steel slab in a rough rolling mill and a finishing rolling machine to form a strip, and
a coiling step of coiling the strip in a coiler,
characterized by performing the steps from the slab heating step to the coiling step in a non-oxidizing atmosphere.

[0017] [2] The method for producing a hot rolled steel sheet according to [1], wherein the non-oxidizing atmosphere is a N₂ atmosphere.

[0018] [3] The method for producing a hot rolled steel sheet according to [2], wherein the non-oxidizing atmosphere is the N₂ atmosphere containing H₂ in an amount of 1 to 10% by volume, and further has a dew point of -40°C to +20°C.

[0019] [4] The method for producing a hot rolled steel sheet according to [1], [2] or [3], wherein the steel slab contains: C: 0.01-0.15%, Si: 0.1-1.8%, Mn: 1.0-2.7%, Al: 0.01-1.5%, P: 0.005-0.025%, and S: 0.01% or less, by mass.

[0020] [5] The method for producing a hot rolled steel sheet according to [4], wherein the steel slab further contains at least one element selected from the group consisting of: Cr: 0.05-1.0%, Mo: 0.05-1.0%, Nb: 0.005-0.05%, Ti: 0.005-0.05%, Cu: 0.05-1.0%, Ni: 0.05-1.0%, and B: 0.001-0.005%, by mass.

[0021] [6] A method for producing a hot-dip galvanized steel sheet, comprising:

removing mill scale by pickling the hot rolled steel sheet produced by the method according to [4] or [5],
or

removing mill scale by pickling the hot rolled steel sheet and further cold-rolling the hot rolled steel sheet; and subsequently hot-dip galvanizing the hot rolled steel sheet.

[0022] [7] A method for producing a hot-dip galvanized steel sheet, further comprising subjecting alloying treatment to the hot-dip galvanized steel sheet produced by the method according to [6].

Effects of the Invention

[0023] According to the present invention, the atmosphere in steps of from the slab heating through the hot rolling to the coiling is controlled to a non-oxidizing atmosphere, thereby making it possible to restrain the generation of mill scale on the steel sheet surfaces. Thus, a hot rolled steel sheet having no scale on the surfaces can be produced. This hot rolled steel sheet can be shipped as a hot rolled steel sheet of a "hot rolled steel sheets as pickled" without performing any pickling step for removing mill scale. In addition, according to the present invention, any pickling is omitted and a material-reduction with an acid is not caused, so that the yield can be improved.

[0024] In a Si-containing hot rolled steel sheet, easily oxidizable elements such as Si, Mn and Al are internally oxidized. Thus, the generation of red scale defects and the generation of a temper color are prevented, so that a hot rolled steel sheet having a beautiful external appearance can be produced. In a case where this Si-containing hot rolled steel sheet is used as a base steel sheet for a hot-dip galvanized steel sheet, the easily oxidizable elements such as Si, Mn and Al do not undergo any selective external oxidation when the base steel sheet is annealed in a CGL. Thus, the generation of galvanization omission caused by selective external oxidation of the easily oxidizable elements such as Si, Mn and Al can be prevented. Additionally, external appearance defects attributable to red scale defects are not generated, either. Thus, a hot-dip galvanized steel sheet having a beautiful external appearance can be yielded.

Brief Description of the Drawing

[0025] Fig. 1 is a schematic perspective view for describing an atmosphere controlling system.

Embodiments for Carrying Out the Invention

[0026] Hereinafter, the present invention will be specifically described.

[0027] Fig. 1 is a schematic perspective view for describing an embodiment of an atmosphere controlling system used at the time of carrying out the present invention. In Fig. 1, reference number 1 represents a steel slab; 2, a slab heating furnace; 3, a rough rolling mill; 4, a finish rolling mill; 5, a coiler; and 6, a hot rolled steel sheet (strip). The steel slab 1 is heated to a predetermined temperature in the slab heating furnace 2, and then hot-rolled in the rough rolling mill 3 and the finish rolling mill 4 so as to be made to the hot rolled steel sheet 6 having a predetermined thickness. The sheet 6 is then coiled by the coiler 5.

[0028] In the conventional art, in steps of from the slab heating to the coiling by a coiler, oxide scales are inevitably generated on the surfaces of the steel sheet by atmospheric oxidation. Moreover, when a Si-containing steel slab is used, there arises a problem that red scale defects are generated. Red scale defects are surface defects peculiar to Si-containing steel sheets, and are surface defects which are a scale pattern, in the form of stripes, that is generated by a matter that when a slab is heated, regions where Fe oxide scale are locally generated for some causes, and a region where Fe_2SiO_4 (fayalite) is generated on an interface of the base iron so as to restrain the generation of Fe oxide scale and then the Fe oxide scale are extended by hot rolling.

[0029] As illustrated in Fig. 1, in the present invention, an enclosure is placed from the slab heating furnace 2 to the coiler 5 for blocking the outside air to inhibit the incorporation of oxygen therein. The atmosphere in the enclosure is controlled into a non-oxidizing atmosphere in which iron is not oxidized.

[0030] The non-oxidizing atmosphere, in which iron is not oxidized, is a N_2 atmosphere, a He atmosphere or an Ar atmosphere. Considering costs, a N_2 atmosphere is preferred.

[0031] Furthermore, it is preferred to incorporate H_2 into a N_2 atmosphere in an amount of 1 to 10% by volume and to set the dew point in the range of -40 to $+20^\circ\text{C}$. Even when the outside air is incorporated into the atmosphere to oxidize steel surfaces, the produced iron oxide can be reduced in a case where H_2 is incorporated in an amount of 1% or more by volume and further the dew point is set to $+20^\circ\text{C}$ or lower. Thus, a beautiful external appearance having no temper color can be obtained. If the dew point is higher than 20°C , iron is oxidized. If the dew point is lower than -40°C , the control is difficult and the costs increase. Thus, the dew point is preferably from -40 to 20°C . If the amount of H_2 is less than 1% volume, the iron oxide generated in the steel surfaces cannot be reduced. As the content by percentage of H_2 is higher, a more advantageous result can be obtained from the viewpoint of the reduction of the iron oxide. However, if the content by percentage is more than 10%, the costs increase. Accordingly, the H_2 content by percentage is preferably from 1 to 10% by volume. When the dew point of the atmosphere is raised, the control of the dew point can

be attained by blowing humidified gas. When the dew point is lowered, the control can be attained by introducing dry N_2 , wherein the water content is decreased, or by absorbing and removing water in the atmosphere.

[0032] Expect that the atmosphere is controlled as described above, conditions for production from the step of heating a slab to the step for coiling may be ordinary manners.

[0033] Mill scale formed in the step of producing the slab need to be removed by a technique such as polishing before the slab is put into a slab heating furnace.

[0034] In the present invention, the atmosphere from a slab heating step to a coiling step is controlled to a non-oxidizing atmosphere, in which iron is not oxidized, thereby the generation of mill scale on the surfaces of the steel sheet is restrained. Since no mill scale are present on the surfaces of the steel sheet coiled by the coiler, a surface state possible to ship the steel sheet as it is, is obtained as a hot rolled steel sheets as pickled without conducting pickling for removing any mill scale. The composition of components of the steel slab that produces an effect of restraining the generation of any mill scale is not particularly limited.

[0035] In Si-containing steel, to which Si is added, no Fe_2SiO_4 (fayalite) is generated on any interface of the base iron by controlling the heating atmosphere at the time of heating a slab to a non-oxidizing atmosphere not to generate any Fe oxidized scale, at the same time, by internally oxidizing Si which creates a solid solution in surface layers of the slab. Therefore, red scale defects are not generated in the (resultant) hot rolled steel sheet. In a case where easily oxidizable elements such as Mn and Al are added, the easily oxidizable elements such as Mn and Al are internally oxidized when the slab is heated.

[0036] In the case where the hot rolled steel sheet in which the easily oxidizable elements such as Si, Mn and Al are internally oxidized, is pickled, or is further cold-rolled after the pickling, and then using the hot rolled steel sheet which has been pickled, or the cold rolled steel sheet which has been cold-rolled, as a base steel sheet for galvanizing, the internally oxidized easily oxidizable elements such as Si, Mn and Al do not shift onto the steel sheet surfaces in an annealing step in a CGL. Therefore, a galvanization defect attributable to the external oxidation of the easily oxidizable elements such as Si, Mn and Al is not generated, and further a poor external appearance resulting from red scale defects is not generated, either.

[0037] In order to prevent the generation of red scale defects and a temper color, and also prevent the galvanizability from being hindered by the easily oxidizable elements such as Si which are externally oxidized in a CGL, it is preferred that the steel slab in which Si is added into steel has a composition described below. Any symbol "%" in connection with each component denotes % by mass as far as the symbol is not particularly otherwise specified.

C: 0.01-0.15%

[0038] C is preferably incorporated in an amount of 0.01% or more in order to make the strength of the steel high. When the amount is 0.15% or less, the steel can surely keep weldability.

Si: 0.1-1.8%

[0039] Si is an element effective for making the strength of the steel high. If the Si amount is less than 0.1%, red scale defects are not generated even when the present invention is even not used. If the Si amount is more than 1.8%, Si cannot be sufficiently internally oxidized in the slab heating step even according to the present invention. Thus, Si remains in the form of a solid solution so that Si is selectively oxidized on the surface layers to generate a temper color. Moreover, the solid-solution-form Si remaining in the annealing step in a CGL is externally oxidized with selectivity, so that a galvanization defect is caused. Thus, the amount thereof is preferably 1.8% or less.

Mn: 1.0-2.7%

[0040] In order to make the strength of the steel high, adding Mn is more effective. If the Mn amount is less than 1.0%, a poor external appearance is not generated when the present invention is even not used. If the Mn amount is more than 2.7%, Mn cannot be internally oxidized sufficiently in the slab heating step so that Mn dissolved in a solid form remains. As a result, Mn is selectively oxidized on the surface layers to generate a temper color. Moreover, the solid-form-dissolved Mn remaining in the annealing step in a CGL is externally oxidized selectively, so that a galvanization defect is caused. Thus, the amount thereof is preferably 2.7% or less.

Al: 0.01-1.5%

[0041] The lower limit is an amount at which Al is inevitably incorporated. Al has a remaining- γ -phase-stabilizing effect. Thus, Al may be added to improve the mechanical properties. For the purpose, it is preferred to incorporate Al in an amount of 0.1% or more. If the Al amount is more than 1.5%, Al is not sufficiently internally oxidized in the slab heating

step so that Al dissolved in a solid form remains so that Al is selectively oxidized on the surface layers to generate a temper color. Moreover, the solid-form-dissolved Al remained in the annealing step in a CGL is externally oxidized selectively, so that a galvanization defect is caused. Thus, the amount thereof is preferably 1.5% or less.

5 P: 0.005-0.025%

[0042] P is an element which is inevitably incorporated. In order to make the precipitation of cementite delay to retard the advance of the transformation, P is incorporated in an amount of 0.005% or more. If the amount is more than 0.025%, the weldability deteriorates and further the steel is not sufficiently internally oxidized in the slab heating step. Thus, the steel is oxidized in the annealing step in a CGL so that the surface quality deteriorates. Thus, the amount thereof is preferably 0.025% or less.

S: 0.01% or less

15 [0043] S is an element which is inevitably incorporated. The lower limit is not specified. However, when S is incorporated in a large amount, the weldability deteriorates. Further, when the steel is annealed, S precipitates on the surfaces so that the external appearance deteriorates. Thus, the amount thereof is preferably 0.01% or less.

[0044] The balance is Fe and inevitable impurities. Besides these elements, one or more elements selected from the following may be optionally added in order to raise mechanical properties of the steel sheet: Cr: 0.05-1.0%, Mo: 0.05-1.0%, Nb: 0.005-0.05%, Ti: 0.005-0.05%, Cu: 0.05-1.0%, Ni: 0.05-1.0%, and B: 0.001-0.0050. Cr, Mo, Nb, Cu and Ni have an advantageous effect of promoting the internal oxidation of Si and restraining selective external oxidation when these elements are added alone or in a multiple form of two or more thereof. These elements may be added not to improve the mechanical properties but to promote the internal oxidation of Si.

[0045] When the above-mentioned elements are added, desired ranges of the components will be described herein-after.

[0046] Cr does not easily give an effect of promoting the hardenability, or the internal oxidation of Si if the amount thereof is less than 0.05%. If the amount is more than 1.0%, Cr is externally oxidized selectively so that the galvanizability deteriorates. Thus, the Cr amount is desirably from 0.05 to 1.0%.

[0047] Mo does not easily gives an effect of adjusting the strength nor an effect of promoting the internal oxidation of Si at the time of adding Mo together with Nb, Ni or Cu if the Mo amount is less than 0.05%. If the amount is more than 1.0%, the cost increases. Thus, the Mo amount is desirably from 0.05 to 1.0%.

[0048] Nb does not easily give an effect of adjusting the strength nor an effect of promoting the internal oxidation of Si at the time of adding Nb together with Mo if the Nb amount is less than 0.005%. If the amount is more than 0.05%, the cost increases. Thus, the Nb amount is desirably from 0.005 to 0.05%.

35 [0049] Ti does not give an effect of adjusting the strength if the Ti amount is less than 0.005%. If the amount is more than 0.05%, the galvanizability deteriorates. Thus, the Ti amount is desirably from 0.005 to 0.05%.

[0050] If the amount of Cu is less than 0.05%, the following effect is not easily obtained: the effect of promoting the formation of a remaining γ -phase, or the effect of promoting the internal oxidation of Si when Cu is added together with Ni or Mo. If the amount is more than 1.0%, the cost increases. Thus, the Cu amount is desirably from 0.05 to 1.0%.

40 [0051] If the amount of Ni is less than 0.05%, the following effect is not easily obtained: the effect of promoting the formation of a remaining γ -phase, or the effect of promoting the internal oxidation of Si when Ni is added together with Cu or Mo. If the amount is more than 1.0%, the cost increases. Thus, the Ni amount is desirably from 0.05 to 1.0%.

[0052] If the B amount is less than 0.001%, the effect of promoting the hardenability is not easily obtained. If the amount is more than 0.005%, the galvanizability deteriorates. Thus, the B amount is desirably from 0.001 to 0.005%.

45 It goes without saying that B does not need to be added when the addition thereof is unnecessary for an improvement in mechanical properties.

[0053] When the steel slab having the above-mentioned component composition is used to produce a hot rolled steel sheet, the easily oxidizable elements such as Si, Mn and Al on the steel sheet surface layers can be internally oxidized by shutting out the outside air and by keeping the steps from the slab heating step to the coiling step in a non-oxidizing controlled atmosphere which does not incorporate oxygen. In other words, when oxygen is incorporated, the easily oxidizable elements such as Si, Mn and Al which are more easily oxidized than Fe, are externally oxidized with selectivity but not internally oxidized. However, in the non-oxidizing atmosphere which does not incorporate oxygen, O supplied from H₂O in the atmosphere becomes an oxygen-supplying source, so that the easily oxidizable elements such as Si, Mn and Al that are dissolved in a solid form in the steel are internally oxidized though Fe is not oxidized. As a result, the generation of red scale defects and a temper color can be prevented.

55 [0054] On the surface of the hot rolled steel sheet wound around the coiler, there exists a very thin oxidized coat generated during the hot rolling process. Thus, when the hot rolled steel sheet is used as a base steel sheet for galvanizing, the rolled steel sheet is pickled by an ordinary pickling treatment after the hot rolling process, so that the oxidized coat

on the surface is completely removed. The pickled hot rolled steel sheet, or a cold rolled steel sheet obtained by cold-rolling the pickled hot rolled steel sheet in the usual way is used as a base steel sheet for galvanizing. This base steel sheet is charged into a CGL.

[0055] In the base steel sheet (high-strength Si-containing steel sheet), the easily oxidizable elements such as Si, Mn and Al are internally oxidized in the hot rolling process, and red scale defects are not generated. Accordingly, even when the steel sheet is heated in a heating furnace of any one of the types selected from a DFF (direct firing type), an NOF (non-oxidizing type) and an all-radiant-tube type in the CGL, oxides of the easily oxidizable elements such as Si, Mn and Al do not diffuse onto the steel sheet surfaces, regardless of the heating furnace type. Thus, a good galvanizability is surely kept and further a poor external appearance attributable to red scale defects is not generated, so that a good external appearance is obtained. Conditions for the heating furnace in a CGL may be ordinary conditions.

[0056] The galvanization coating weight is preferably from 20 to 120 g/m² for each of the surfaces. If the weight is less than 20 g/m², it is difficult to surely keep the corrosion resistance. If the weight is more than 120 g/m², the galvanization peeling resistance deteriorates. In the hot-dip galvanized steel sheet that has been alloyed, the Fe content by percentage of the galvanization layer is preferably from 7 to 15%. If the content by percentage is less than 7%, alloying unevenness is generated and the flaking resistance deteriorates. If the content by percentage is more than 15%, the galvanization peeling resistance deteriorates.

[0057] Conditions for the hot-dip galvanizing and conditions for the alloying treatment may be ordinary manners.

Example 1

[0058] Soft steel slabs containing chemical composition shown in Table 1 and the balance being Fe and inevitable impurities were prepared with a thickness of 200 mm, and then a laboratory test was performed for the production of hot rolled steel sheets from a slab heating step to a coiling step under the following condition: The slab was heated in a heating furnace, and then the slab was rolled into a strip with a thickness of 3 mm by a rough rolling mill and a finish rolling mill. The strip was coiled around a coiler. The slab heating temperature of the heating furnace was set to 1250°C, and the finishing temperature in the finishing rolling and the coiling temperature were set to 900°C and 550°C, respectively. The atmosphere from the heating furnace to the coiler was controlled into an atmosphere shown in Table 2. The resultant coil was cooled and then uncoiled to be evaluated about the external appearance. For the external appearance, the color tone thereof was observed with the naked eyes. The uncoiled steel in which no temper color was generated to give an external appearance equivalent to that of a conventional hot rolled steel sheet as pickled was judged to be "white", the uncoiled steel sheet having a black external appearance equivalent to that of a conventional steel sheet as hot rolled was judged to be "black", and the uncoiled steel sheet in which a temper color was generated to give an external appearance discolored into a light brown color was judged to be "light brown". Any hot rolled steel sheet that is judged to be "white" has an external appearance possible to be shipped the steel sheet without the pickling for removing scale. For any steel sheet that is judged to be "light brown" or "black", performing the pickling is necessary for removing scale in order to ship the steel sheet as a hot rolled steel sheet as pickled.

[0059]

[Table 1]

(% by mass)						
C	Si	Mn	Al	P	S	Ti
0.002	0.01	0.1	0.03	0.01	0.004	0.02

[0060]

[Table 2]

No	Hot rolling atmosphere				External appearance	
	Controlling	Atmosphere	Dew point (°C)	Atmosphere type		
1	Not made	Atmospheric air	Not controlled	Oxidizing	Black	Comparative example
2	Made	N ₂	Not controlled	Non-oxidizing	White	Inventive example

(continued)

No	Hot rolling atmosphere				External appearance	
	Controlling	Atmosphere	Dew point (°C)	Atmosphere type		
3	Made	N ₂ +3%H ₂	-40	Non-oxidizing	White	Inventive example
4	Made	N ₂ +3%H ₂	0	Non-oxidizing	White	Inventive example
5	Made	N ₂ +3%H ₂	20	Non-oxidizing	White	Inventive example
6	Made	N ₂ +3%H ₂	60	Oxidizing	Light Brown	Comparative example

[0061] The results are shown in Table 2. As is evident from Table 2, the hot rolled steel sheets of the inventive examples in which of each the atmosphere is controlled within the scope of the present invention, give the beautiful external appearances possible to be shipped as they are, as hot rolled steel sheet as pickled. By contrast, the hot rolled steel sheets of the comparative examples in which the atmosphere is out of the scope of the present invention, do not give the beautiful external appearances possible to be shipped as they are, as hot rolled steel sheets as pickled.

Example 2

[0062] The results obtained by performing an experiment for producing a hot rolled steel sheet by use of a Si-containing steel slab is explained.

A steel slab with a thickness of 300 mm containing chemical composition shown in Table 3 and the balance being Fe and inevitable impurities, was prepared.

Steels B, C and D were each a steel slab containing the following: C: 0.01-0.15%, Si: 0.1-1.8%, Mn: 1.0-2.7%, Al: 0.01-1.5%, P: 0.005-0.025%, and S: 0.01% or less, and each of these percentages (%) represents % by mass.

Steels E, F, G, H, I and J were each a steel slab further containing one or more elements selected from the following: Cr: 0.05-1.0%, Mo: 0.05-1.0%, Nb: 0.005-0.05%, Ti: 0.005-0.05%, Cu: 0.05-1.0%, Ni: 0.05-1.0%, and B: 0.001-0.005%, and each of these percentages (%) represents % by mass.

Steel K was a steel slab in which the amount of Si was out of the range of 0.1-1.8%.

Steel L was a steel slab in which the amount of Mn was out of the range of 1.0-2.7%.

Steel M was a steel slab in which the amount of P was out of the range of 0.005-0.025%.

Steel N was a steel slab in which the amount of S was out of the range of 0.01% or less.

A laboratory test of the production of hot rolled steel sheets from a slab heating step to a coiling step was performed under the following condition: The slab was heated in a heating furnace, and then the slab was rolled into a strip with a thickness of 3 mm by a rough rolling mill and a finish rolling mill. The strip was coiled around a coiler. The slab heating temperature of the heating furnace was set to 1250°C, and the finishing temperature in the finish rolling and the coiling temperature were set to 900°C and 550°C, respectively. The atmosphere from the heating furnace to the coiler was controlled into an atmosphere shown in Table 4. The resultant coil was cooled and then uncoiled, and the external appearance was observed with the naked eyes to be evaluated about the color tone thereof and as to whether or not red scale defects were generated. The color tone was judged in the same way as in Example 1. The criterion for judging whether or not any one of the uncoiled steel sheets had an external appearance possible to be shipped as a hot rolled steel sheet as pickled was the same as in Example 1.

[0063]

[Table 3]

(% by mass)														
Steel symbol	C	Si	Mn	Al	P	s	Cr	Mo	B	Nb	Cu	Ni	Ti	Classification
B	0.03	1.0	2.0	0.03	0.010	0.004	-	-	-	-	-	-	-	Inventive steel
C	0.08	0.1	2.0	0.03	0.010	0.004	-	-	-	-	-	-	-	Inventive steel
D	0.10	0.1	1.6	1.20	0.010	0.004	-	-	-	-	-	-	-	Inventive steel
E	0.05	1.6	1.9	0.02	0.010	0.004	0.3	-	-	-	-	-	-	Inventive steel
F	0.05	1.5	1.9	0.03	0.010	0.004	-	0.1	-	-	-	-	-	Inventive steel
G	0.05	1.6	2.2	0.03	0.010	0.004	-	-	0.003	-	-	-	-	Inventive steel
H	0.05	1.5	2.0	0.05	0.010	0.004	-	-	0.001	0.03	-	-	-	Inventive steel
I	0.05	1.7	1.9	0.03	0.010	0.004	-	0.1	-	-	0.1	0.2	-	Inventive steel
J	0.05	1.6	1.9	0.04	0.010	0.004	-	-	0.001	-	-	-	0.02	Inventive steel
K	0.14	1.9	1.9	0.03	0.010	0.004	-	-	-	-	-	-	0.05	Comparative steel
L	0.14	1.2	3.2	0.03	0.010	0.004	-	-	-	-	-	-	-	Comparative steel
M	0.14	1.5	1.6	0.03	0.035	0.004	-	-	-	-	-	-	-	Comparative steel
N	0.14	1.5	1.6	0.03	0.010	0.02	-	-	-	-	-	-	-	Comparative steel

[0064]

[Table 4]

Hot rolled steel sheet No.	Steel	Hot rolling atmosphere				External appearance		Notes
		Controlling	Atmosphere	Dew point (°C)	Atmosphere type	Color tone	Red scale defects	
1	B	Not made	Atmospheric air	Not controlled	Oxidizing	Black	Generated	Comparative example
2	B	Made	N ₂	Not controlled	Non-oxidizing	White	Not generated	Inventive example
3	B	Made	N ₂ +3%H ₂	-40	Non-oxidizing	White	Not generated	Inventive example
4	B	Made	N ₂ +3%H ₂	0	Non-oxidizing	White	Not generated	Inventive example
5	B	Made	N ₂ +3%H ₂	20	Non-oxidizing	White	Not generated	Inventive example
6	B	Made	N ₂ +3%H ₂	60	Oxidizing	Light Brown	Not generated	Comparative example
7	C	Made	N ₂ +3%H ₂	20	Non-oxidizing	White	Not generated	Inventive example
8	D	Made	N ₂ +3%H ₂	20	Non-oxidizing	White	Not generated	Inventive example
9	E	Made	N ₂ +3%H ₂	20	Non-oxidizing	White	Not generated	Inventive example
10	F	Made	N ₂ +3%H ₂	20	Non-oxidizing	White	Not generated	Inventive example
11	G	Made	N ₂ +3%H ₂	20	Non-oxidizing	White	Not generated	Inventive example
12	H	Made	N ₂ +3%H ₂	20	Non-oxidizing	White	Not generated	Inventive example
13	I	Made	N ₂ +3%H ₂	20	Non-oxidizing	White	Not generated	Inventive example
14	J	Made	N ₂ +3%H ₂	20	Non-oxidizing	White	Not generated	Inventive example
15	K	Made	N ₂ +3%H ₂	20	Non-oxidizing	Light Brown	Not generated	Comparative example
16	L	Made	N ₂ +3%H ₂	20	Non-oxidizing	Light Brown	Not generated	Comparative example
17	M	Made	N ₂ +3%H ₂	20	Non-oxidizing	Light Brown	Not generated	Comparative example
18	N	Made	N ₂ +3%H ₂	20	Non-oxidizing	Light Brown	Not generated	Comparative example

[0065] The results are shown in Table 4. As is evident from Table 4, the hot rolled steel sheets of the inventive examples in which a steel slab having components described below is used and further the atmosphere is controlled to produce the hot rolled steel sheet, give such a beautiful external appearance possible to be shipped as they are, as a hot rolled steel sheet as pickled is obtained. Further, red scale defects are not generated.

Steel slabs containing the following: C: 0.01-0.15%, Si: 0.1-1.8%, Mn: 1.0-2.7%, Al: 0.01-1.5%, P: 0.005-0.025%, and S: 0.01% or less, and each of these percentages (%) represents % by mass.

Steel slabs containing the following: C: 0.01-0.15%, Si: 0.1-1.8%, Mn: 1.0-2.7%, Al: 0.01-1.5%, P: 0.005-0.025%, and S: 0.01% or less, and further containing one or more elements selected from the following: Cr: 0.05-1.0%, Mo: 0.05-1.0%, Nb: 0.005-0.05%, Ti: 0.005-0.05%, Cu: 0.05-1.0%, Ni: 0.05-1.0%, and B: 0.001-0.005%, and each of these percentages (%) represents % by mass.

By contrast, the hot rolled steel sheets of the comparative examples, in which the atmosphere is out of the scope of the present invention, do not give such a beautiful external appearance possible to be shipped as they are, as a hot rolled steel sheet as pickled.

Example 3

[0066] The hot rolled steel sheets produced in Example 2 were pickled to remove the oxide film generated by the hot rolling. Some of the hot rolled steel sheets were used as pickled hot rolled steel sheets without being subjected to any other treatment, and some of the others were subjected further to cold rolling at a rolling reduction ratio of 50% after the pickling so as to be made to cold rolled steel sheets. The thus-produced hot rolled steel sheets and cold rolled steel sheets were each annealed at 850°C and then subjected to hot-dip galvanizing in an all-radiant type CGL simulator. Some thereof were further subjected to alloying treatment. For the hot-dip galvanized steel sheets (GA) subjected to the alloying treatment after the hot-dip galvanizing, a 0.14% Al-containing Zn bath was used. For the hot-dip galvanized steel sheet (GI) subjected to no alloying treatment after the hot-dip galvanizing, a 0.18% Al-containing Zn bath was used. The galvanization adhesion amount was adjusted to 50 g/m² for each of the surfaces (of each of the steel sheets) by gas-wiping. The method for the hot-dip galvanizing and the method for the alloying treatment were used with the usual methods.

[0067] The external appearances of the thus-produced galvanized steel sheets were observed, and the following were observed: whether or not the defects attributable to red scale defects were generated; and whether or not a galvanization omission was generated. Any steel sheet in which at least one of the defect attributable to the red scale defects and the galvanization omission was recognized was judged to be poor in external appearance, and any steel sheet in which any one of the defect attributable to the red scale defects and the galvanization omission was not recognized was judged to be beautiful in external appearance.

[0068]

[Table 5]

Hot-dip galvanized steel sheet No	Hot rolled steel sheet No. in Table 4	Steel	Hot rolling atmosphere			Base steel sheet	Hot-dip galvanized steel sheet species	External appearance	Notes
			Controlling	Atmosphere	Dew point (°C)				
1	1	B	Not made	Atmospheric air	Not controlled	Hot rolled steel sheet	GA	Poor external appearance (defects attributable to red scale defects)	Comparative example
2	1	B	Not made	Atmospheric air	Not controlled	Cold rolled steel sheet	GA	Poor external appearance (defects attributable to red scale defects)	Comparative example
3	3	B	Made	$N_2+3\%H_2$	-40	Cold rolled steel sheet	GA	Beautiful external appearance	Inventive example
4	4	B	Made	$N_2+3\%H_2$	0	Cold rolled steel sheet	GA	Beautiful external appearance	Inventive example
5	5	B	Made	$N_2+3\%H_2$	20	Cold rolled steel sheet	GA	Beautiful external appearance	Inventive example
6	5	B	Made	$N_2+3\%H_2$	20	Hot rolled steel sheet	GA	Beautiful external appearance	Inventive example
7	5	B	Made	$N_2+3\%H_2$	20	Hot rolled steel sheet	GI	Beautiful external appearance	Inventive example

(continued)

Hot-dip galvanized steel sheet No	Hot rolled steel sheet No. in Table 4	Steel	Hot rolling atmosphere			Base steel sheet	Hot-dip galvanized steel sheet species	External appearance	Notes
			Controlling	Atmosphere	Dew point (°C)				
8	6	B	Made	N ₂ +3%H ₂	60	Cold rolled steel sheet	GA	Poor external appearance (galvanization omission)	Comparative example
9	7	C	Made	N ₂ +3%H ₂	20	Cold rolled steel sheet	GA	Beautiful external appearance	Inventive example
10	8	D	Made	N ₂ +3%H ₂	20	Cold rolled steel sheet	GA	Beautiful external appearance	Inventive example
11	9	E	Made	N ₂ +3%H ₂	20	Cold rolled steel sheet	GA	Beautiful external appearance	Inventive example
12	10	F	Made	N ₂ +3%H ₂	20	Cold rolled steel sheet	GA	Beautiful external appearance	Inventive example
13	11	G	Made	N ₂ +3%H ₂	20	Cold rolled steel sheet	GA	Beautiful external appearance	Inventive example
14	12	H	Made	N ₂ +3%H ₂	20	Cold rolled steel sheet	GA	Beautiful external appearance	Inventive example
15	13	I	Made	N ₂ +3%H ₂	20	Cold rolled steel sheet	GA	Beautiful external appearance	Inventive example
16	14	J	Made	N ₂ +3%H ₂	20	Cold rolled steel sheet	GA	Beautiful external appearance	Inventive example

(continued)

Hot-dip galvanized steel sheet No	Hot rolled steel sheet No. in Table 4	Steel	Hot rolling atmosphere			Base steel sheet	Hot-dip galvanized steel sheet species	External appearance	Notes
			Controlling	Atmosphere	Dew point (°C)				
17	15	K	Made	$N_2+3\%H_2$	20	Cold rolled steel sheet	GA	Poor external appearance (galvanization omission)	Comparative example
18	16	L	Made	$N_2+3\%H_2$	20	Cold rolled steel sheet	GA	Poor external appearance (galvanization omission)	Comparative example
19	17	M	Made	$N_2+3\%H_2$	20	Cold rolled steel sheet	GA	Poor external appearance (galvanization omission)	Comparative example
20	18	N	Made	$N_2+3\%H_2$	20	Cold rolled steel sheet	GA	Poor external appearance (galvanization omission)	Comparative example

[0069] The examination results are shown in Table 5. As is evident from Table 5, the hot-dip galvanized steel sheets of the inventive examples produced by the method of the present invention using the steel slab B, C or D wherein the amounts of C, Si, Mn, Al, P and S are within the specified ranges, give a galvanized steel sheet good in external appearance even when the hot-dip galvanized steel sheet is a steel to which Si, Mn and Al are added. The hot-dip galvanized steel sheets of the inventive examples produced by the method of the present invention using the steel slab E, F, G, H, I or J wherein at least one of Cr, Mo, Nb, Ti, Cu, Ni and B is contained in the specified amount(s), also give a galvanized steel sheet good in external appearance. By contrast, for the hot-dip galvanized steel sheets produced by use of the steel slab wherein the amount of C, Si, Mn, Al, P and S are out of the specified range, or the amount of Cr, Mo, Nb, Ti, Cu, Ni and B are out of the specified range, or the hot-dip galvanized steel sheets produced in the atmosphere out of the scope of the method of the present invention, red scale defects or a galvanization omission is generated so that the external appearance is poor.

Industrial Applicability

[0070] According to the present invention, a hot rolled steel sheet possible to be shipped as a "hot rolled steel sheet as pickled" can be produced even when a pickling step for removing mill scale is not conducted. For a Si-containing hot rolled steel sheet, easily oxidizable elements such as Si, Mn and Al are internally oxidized so that a Si-containing hot rolled steel sheet beautiful in the external appearance can be produced in which red scale defects are not generated and a temper color is not generated. When this Si-containing hot rolled steel sheet is used as a base steel sheet for a hot-dip galvanized steel sheet, easily oxidizable elements such as Si, Mn and Al are not externally oxidized with selectivity at the time of annealing in a CGL. Therefore, the generation of a galvanization omission caused by the selective, external oxidation of the easily oxidizable elements such as Si, Mn and Al is prevented, and further a poor external appearance attributable to red scale defects is not generated, thus a hot-dip galvanized steel sheet beautiful in external appearance can be produced.

Description of Reference Numerals

[0071] 1: slab, 2: slab heating furnace, 3: rough rolling mill, 4: finish rolling mill, 5: coiler, and 6: hot rolled steel sheet

Claims

1. A method for producing a hot rolled steel sheet, comprising:

a slab heating step of heating a steel slab in a slab heating furnace,
a step of hot-rolling the heated steel slab in a rough rolling mill and a finish rolling mill to form a strip,
and
a coiling step of coiling the strip in a coiler, comprising:

characterized by performing the steps from the slab heating step to the coiling step in a non-oxidizing atmosphere.

2. The method for producing a hot rolled steel sheet according to claim 1, wherein the non-oxidizing atmosphere is a N₂ atmosphere.

3. The method for producing a hot rolled steel sheet according to claim 2, wherein the non-oxidizing atmosphere is the N₂ atmosphere containing H₂ in an amount of 1 to 10% by volume, and further has a dew point of -40°C to +20°C.

4. The method for producing a hot rolled steel sheet according to claim 1, 2 or 3, wherein the steel slab contains: C: 0.01-0.15%, Si: 0.1-1.8%, Mn: 1.0-2.7%, Al: 0.01-1.5%, P: 0.005-0.025%, and S: 0.01% or less, by mass.

5. The method for producing a hot rolled steel sheet according to claim 4, wherein the steel slab further contains at least one element selected from the group consisting of Cr: 0.05-1.0%, Mo: 0.05-1.0%, Nb: 0.005-0.05%, Ti: 0.005-0.05%, Cu: 0.05-1.0%, Ni: 0.05-1.0%, and B: 0.001-0.005%, by mass.

6. A method for producing a hot-dip galvanized steel sheet, comprising:

removing mill scale by pickling the hot rolled steel sheet produced by the method according to claim 4 or 5,

or

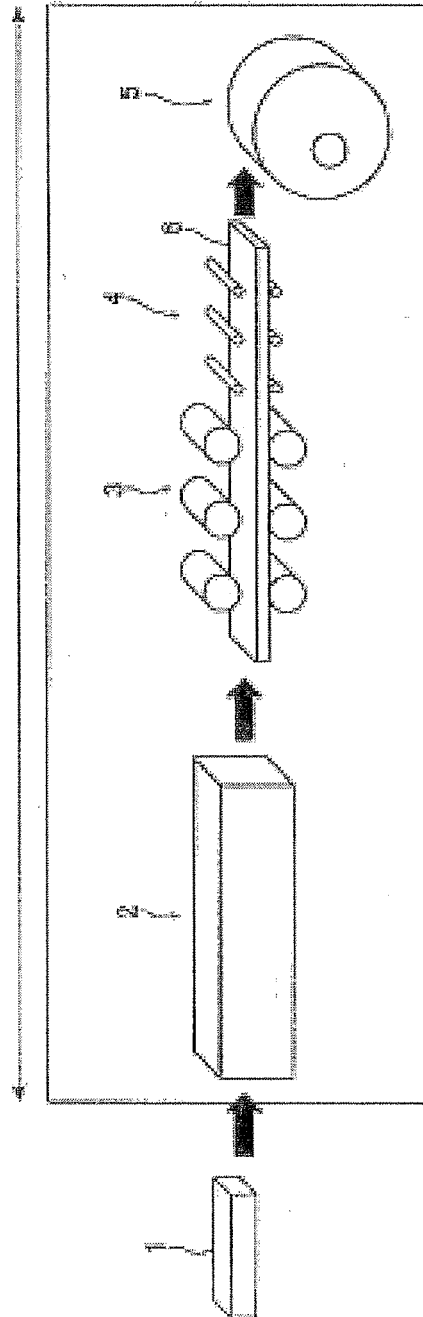
removing mill scale by pickling the hot rolled steel sheet and further cold-rolling the hot rolled steel sheet; and
subsequently

hot-dip galvanizing the hot rolled steel sheet.

- 5
7. A method for producing a hot-dip galvanized steel sheet, further comprising: subjecting an alloying treatment to the hot-dip galvanized steel sheet produced by the method according to claim 6.
- 10
- 15
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- 50
- 55

Fig. 1

ATMOSPHERE CONTROLLING SYSTEM



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/059768

A. CLASSIFICATION OF SUBJECT MATTER

B21B9/00(2006.01)i, B21B1/26(2006.01)i, B21B3/00(2006.01)i, C21D1/70(2006.01)i, C21D1/76(2006.01)i, C21D9/00(2006.01)i, C21D9/46(2006.01)i, C22C38/00(2006.01)i, C22C38/06(2006.01)i, C22C38/58(2006.01)i,

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B21B9/00, B21B1/26, B21B3/00, C21D1/70, C21D1/76, C21D9/00, C21D9/46, C22C38/00, C22C38/06, C22C38/58, C23C2/06, C23C2/28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 59-97710 A (Kawasaki Steel Corp.), 05 June 1984 (05.06.1984), claim 1; examples; fig. 4 (Family: none)	1-7
Y	JP 58-32506 A (Kawasaki Steel Corp.), 25 February 1983 (25.02.1983), claim 1 (Family: none)	1-7
Y	JP 7-126747 A (Sumitomo Metal Industries, Ltd.), 16 May 1995 (16.05.1995), paragraph [0052] (Family: none)	3-7

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search
16 May, 2011 (16.05.11)

Date of mailing of the international search report
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Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/059768

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 2002-192309 A (Ishikawajima-Harima Heavy Industries Co., Ltd.), 10 July 2002 (10.07.2002), fig. 1, 3 to 5 (Family: none)	1-7
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Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/059768

Continuation of A. CLASSIFICATION OF SUBJECT MATTER
(International Patent Classification (IPC))

C23C2/06(2006.01)i, C23C2/28(2006.01)i

(According to International Patent Classification (IPC) or to both national classification and IPC)

REFERENCES CITED IN THE DESCRIPTION

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