

NON-PICKLED HOT-ROLLED STEEL SHEET AND METHOD FOR MANUFACTURING SAME

TECHNICAL FIELD

5 **[0001]** The present disclosure relates to a non-pickled hot-rolled steel sheet, and in particular to a non-pickled hot-rolled steel sheet suitable for structural parts such as building materials, piping and agricultural tools, which are used with scale left unremoved therefrom. The present disclosure also relates to a method for manufacturing the non-pickled hot-rolled steel sheet.

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BACKGROUND

[0002] Removing scale, i.e., oxide scale, from a non-pickled hot-rolled steel sheet requires pickling with hydrochloric acid, shot blasting and the like. A bare material where the scale has been removed is therefore highly expensive.

15 For such a reason, and for the purpose of cost reduction, there has been so far a great demand for inexpensive non-pickled hot-rolled steel sheets having favorable scale adhesion. In addition, a new need of seeking for the non-pickled hot-rolled steel sheets having a design characterized by its blackness is increasing in recent years.

20 **[0003]** Examples of the non-pickled hot-rolled steel sheets excellent in the scale adhesion include, for example, steel sheets described in PTL 1 and PTL 2.

[0004] JP H9-067649 A (PTL 1) offers a hot-rolled steel sheet containing C: 0.001 to 0.20 %, Si: 0.01 to 0.50 %, Mn: 0.05 to 2.0 %, P: 0.05 % or less, S: 0.05 % or less, sol. Al: 0.01 to 0.10 %, and N: 0.020 % or less, having scale of 4 μ m or less in thickness on its surface, and having a surface roughness of 0.8 μ m or less.

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[0005] JP 2014-031537 A (PTL 2) offers a hot-rolled steel sheet containing C: 0.01 to 0.4 %, Si: 0.001 to 2.0 %, Mn: 0.01 to 3.0 %, P: 0.05 % or less, S: 0.05 % or less, Al: 0.3 % or less, and N: 0.01 % or less, and having scale of 20 μ m or less in thickness. In such a hot-rolled steel sheet, a percentage of a contact length between a steel substrate of the steel sheet and magnetite is 80 % or more with respect to a contact length between the steel substrate of the steel sheet and scale in a rolling direction, and an average grain size of the

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magnetite is 3 μm or less.

[0006] On the other hand, examples of the non-pickled hot-rolled steel sheets excellent in the scale adhesion as well as in the blackness include, for example, hot-rolled steel sheets described in PTL 3 to PTL 5.

5 [0007] JP 2004-043888 A (PTL 3) offers a hot-rolled steel sheet having scale of more than 4 μm in thickness, the scale containing 50 % by volume or more of Fe_3O_4 . The scale of the hot-rolled steel sheet does not contain precipitated Fe in a region up to 2 μm deep from a surface in a thickness direction.

10 [0008] JP H7-048622 A (PTL 4) offers a method for manufacturing a hot-rolled steel sheet in which rolling is performed while water cooling with high-pressure water immediately after each rolling reduction or immediately after every two rolling reductions, and a rolling finish temperature is set to 850 $^{\circ}\text{C}$ or less.

15 [0009] JP H7-048623 A (PTL 5) offers a method for manufacturing a hot-rolled steel sheet in which rolling is performed while water cooling with high-pressure water immediately after each rolling reduction, and water cooling to a temperature of 800 $^{\circ}\text{C}$ or less and 700 $^{\circ}\text{C}$ or more immediately after completion of the rolling.

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CITATION LIST

Patent Literature

[0010] PTL 1: JP H9-067649 A

PTL 2: JP 2014-031537 A

25 PTL 3: JP 2004-043888 A

PTL 4: JP H7-048622 A

PTL 5: JP H7-048623 A

SUMMARY

30 (Technical Problem)

[0011] There was a problem, however, that sufficient blackness cannot be obtained in the techniques described in PTLs 1 and 2. Moreover, the technique described in PTL 3 had a problem that only a certain direction gives a black appearance while other directions cannot give the black appearance

because degree of blackness varies largely depending on light directions. Furthermore, obtained scale was in bluish black in the techniques described in PTLs 4 and 5, which was insufficient from the perspective of the degree of blackness.

5 **[0012]** In view of the aforementioned circumstances, it could be helpful to provide a non-pickled hot-rolled steel sheet demonstrating sufficient blackness seen from any direction and excellent scale adhesion, as well as a method for manufacturing such a non-pickled hot-rolled steel sheet.

(Solution to Problem)

10 **[0013]** We thus provide the followings.

1. A non-pickled hot-rolled steel sheet including:

a base hot-rolled steel sheet; and

scale on a surface of the base hot-rolled steel sheet, the scale consisting of Fe_3O_4 and Fe and having a thickness of 3.0 μm to 20 μm ,

15 wherein an average grain size on a surface layer of the scale is 3.0 μm or less, and

 wherein an area ratio of Fe in a cross-section of the scale is less than 1.0 % in a region of 0 to 1.0 μm in a thickness direction of the scale from an outermost surface layer of the scale, while 1.0 % or more in a region of 0 to 1.0 μm in the thickness direction of the scale from an interface between the
20 scale and the base hot-rolled steel sheet.

[0014] 2. The non-pickled hot-rolled steel sheet according to the foregoing 1, wherein the base hot-rolled steel sheet has a chemical composition containing (consisting of), in mass%,

25 C in an amount of 0.20 % or less,

 Si in an amount of 1.5 % or less,

 Mn in an amount of 0.1 % to 3.0 %,

 P in an amount of 0.10 % or less,

 S in an amount of 0.10 % or less,

30 Al in an amount of 1.0 % or less, and

 N in an amount of 0.020 % or less, with the balance being Fe and inevitable impurities.

[0015] 3. A method for manufacturing a non-pickled hot-rolled steel sheet, the method comprising:

hot rolling a steel slab having the chemical composition according to the foregoing 2 to obtain a hot-rolled steel sheet, the hot rolling including rough rolling and finish rolling;

5 cooling the hot-rolled steel sheet at an average cooling rate of 10 °C/s or more; and

 coiling the cooled hot-rolled steel sheet at a coiling temperature of 400 °C or more and less than 600 °C,

 wherein descaling is performed at a temperature of 1100 °C or less using high-pressure water with an impingement pressure of 1.0 MPa or more, 10 after completion of the rough rolling,

 wherein the finish rolling is started within 10 seconds after completion of the descaling,

 wherein a finisher delivery temperature of the finish rolling is set in a range of 800 °C to 950 °C, and

15 wherein the cooling is started within 2.0 seconds from completion of the finish rolling.

(Advantageous Effect)

[0016] The present disclosure allows obtaining a non-pickled hot-rolled steel sheet demonstrating sufficient blackness seen from any direction as well as 20 excellent scale adhesion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] In the accompanying drawings:

 FIG. 1 is a graph illustrating a relationship between impingement 25 pressures in descaling and average grain sizes on surface layers of the scale; and

 FIG. 2 is a graph illustrating a relationship between average grain sizes on surface layers of the scale and L*.

30 DETAILED DESCRIPTION

[0018] Methods for carrying out the present disclosure will now be described in detail. The description below is for the purpose of providing preferred embodiments of the disclosure, and the disclosure will not be limited in any way by the following description.

[0019] The non-pickled hot-rolled steel sheet of the present disclosure has a hot-rolled steel sheet as a base metal and scale (non-pickled surface) formed on a surface of the hot-rolled steel sheet. The scale has the thickness, the composition, and the area ratio of Fe as described above. Reasons for these
5 limitations will be described below.

[0020] Thickness: 3.0 to 20 μm

With the scale having a thickness of less than 3.0 μm , transformation of FeO into Fe_3O_4 at the interface of scale/base metal, so-called a magnetite seam, is not formed, resulting in reduction in the scale adhesion. The
10 thickness of the scale, therefore, should be 3.0 μm or more. On the other hand, when the scale is excessively thick, the scale becomes easy to be fractured inside to cause reduction in the adhesion. The thickness of the scale, therefore, should be 20 μm or less. And the thickness of the scale is preferably 15 μm or less, more preferably 10 μm or less. The thickness of
15 the scale can be measured by a method described in Examples.

[0021] Composition: Fe_3O_4 and Fe

Fe_3O_4 (magnetite) is the most excellent in blackness among iron oxides that can be components of the oxide scale. In addition, Fe is a component produced along with a reaction where FeO (wustite) undergoes a
20 eutectoid transformation into Fe_3O_4 . This makes the scale of the present disclosure to consist only of Fe_3O_4 and Fe. The composition of the scale can be evaluated by a method described in Examples.

[0022] Average grain size on surface layer: 3.0 μm or less

Degree of blackness, when seen from all directions, can be enhanced
25 by reducing grain sizes of the scale on a surface layer. The average grain size on the surface layer of the scale therefore should be 3.0 μm or less. And the average grain size is preferably 2.0 μm or less. On the other hand, the lower limit of the average grain size can be of any value without being particularly limited. However, the average grain size of 0.5 μm or more
30 enables to further prevent the scale fracture. The average grain size is therefore preferably 0.5 μm or more. As used herein, "surface layer" refers to a region up to 0.5 μm in a thickness direction of the scale from an outermost surface layer of the scale. The average grain size can be measured by a method described in Examples.

[0023] Area ratio of Fe in surface layer: less than 1.0 %

The blackness reduces when a large amount of Fe precipitates in the surface layer part of the scale. An area ratio of Fe in a cross-section of the scale in a region of 0 to 1.0 μm in a thickness direction of the scale from the outmost surface layer of the scale (hereinafter referred to as “Area ratio of Fe in surface layer”) therefore should be less than 1.0 %. The lower limit of the area ratio of Fe in surface layer may be, although without particularly being limited to, 0 %. The area ratio of Fe in surface layer is preferably less than 0.5 %, and more preferably 0 %. The area ratio of Fe in surface layer can be measured by a method described in Examples.

[0024] Area ratio of Fe at interface: 1.0 % or more

At an interface between the scale and the base hot-rolled steel sheet, it is possible to improve the scale adhesion by precipitating Fe along with formation of the magnetite seam. An area ratio of Fe in a cross-section of the scale in a region of 0 to 1.0 μm in the thickness direction of the scale from the interface between the scale and the base hot-rolled steel sheet (hereinafter referred to as “Area ratio of Fe at interface”) therefore should be 1.0 % or more. And the area ratio of Fe at interface is preferably 2.0 % or more, and more preferably 3.0 % or more. On the other hand, although no particular limitations are placed on the upper limit of the area ratio of Fe at interface, it is possible to further prevent the scale from fracturing if the area ratio of Fe at interface is 10 % or less. The area ratio of Fe at interface is therefore preferably 10 % or less.

[0025] The base hot-rolled steel sheet preferably has a chemical composition as described below. The expression “%” in the following description is intended to mean “mass%”, unless otherwise specified.

[0026] C: 0.20 % or less

C, as carbon, combines with O at an interface between the scale and the base hot-rolled steel sheet to generate CO gas, causing reduction in the scale adhesion. An amount of C is therefore preferably 0.20 % or less. On the other hand, while the lower limit of the amount of C is not particularly limited and may be 0 %, C is still allowed to be contained as an inevitable impurity. The amount of C, however, is preferably 0.0010 % or more as excessive reduction in the amount of C causes a cost increase.

[0027] Si: 1.5 % or less

Si, as silicon, greatly reduces generation of the scale, as well as segregates to the interface between the scale and the base metal to cause reduction in the scale adhesion. In addition, Si is an element that contributes
5 for generating ferrite, leading to increase in the grain size of the scale in association with increase in the grain size of the base metal. Moreover, Si causes red scale, and generation of the red scale greatly deteriorates the degree of blackness as well as the design property. An amount of Si is therefore preferably 1.5 % or less. And the amount of Si is more preferably
10 1.0 % or less, and even more preferably 0.5 % or less. On the other hand, while the lower limit of the amount of Si is not particularly limited and may be 0 %, Si is still allowed to be contained as an inevitable impurity. The amount of Si, however, is preferably 0.005 % or more as excessive reduction in the amount of Si causes a cost increase.

[0028] Mn: 0.1 to 3.0 %

Mn, as manganese, contributes to grain refinement of the scale with reducing the grain size of the base metal. In order to obtain such an effect, an amount of Mn is preferably 0.1 % or more. On the other hand, Mn is an element that contributes for generating austenite. Therefore transformation
20 temperature of the base metal reduces during cooling performed after hot rolling when a large amount of Mn is contained. The reduction in the transformation temperature induces generation of transformation strain at low temperature, initiating cracks in the scale, and resulting in a possible reduction in the scale adhesion. The amount of Mn is therefore preferably
25 3.0 % or less. And the amount of Mn is more preferably 2.0 % or less.

[0029] P: 0.10 % or less

P, as phosphorus, segregates to the interface between the scale and the base metal to cause reduction in the scale adhesion. An amount of P is therefore preferably 0.10 % or less. And the amount of P is more preferably
30 0.03 % or less, and even more preferably 0.01 % or less. On the other hand, while the lower limit of the amount of P is not particularly limited and may be 0 %, P is still allowed to be contained as an inevitable impurity. The amount of P, however, is preferably 0.005 % or more as excessive reduction in the amount of P causes a cost increase.

[0030] S: 0.10 % or less

S, as sulfur, significantly reduces ductility of the steel during hot processing, consequently inducing hot cracking, and resulting in significantly deteriorated surface characteristics in the steel sheet. An amount of S is therefore preferably 0.10 % or less. And the amount of S is more preferably 0.03 % or less. On the other hand, while the lower limit of the amount of S is not particularly limited and may be 0 %, S is still allowed to be contained as an inevitable impurity. The amount of S, however, is preferably 0.0001 % or more as excessive reduction in the amount of S causes a cost increase.

10 **[0031]** Al: 1.0 % or less

Al, as aluminum, is an element that contributes for generating ferrite, leading to increase in the grain size of the scale in association with increase in the grain size of the base metal. An amount of Al is therefore preferably 1.0 % or less. And the amount of Al is more preferably 0.5 % or less. On the other hand, while the lower limit of the amount of Al is not particularly limited and may be 0 %, Al is still allowed to be contained as an inevitable impurity. The amount of Al, however, is preferably 0.01 % or more as excessive reduction in the amount of Al causes a cost increase.

[0032] N: 0.020 % or less

20 N, as nitrogen, significantly reduces ductility of the steel during hot processing, consequently inducing hot cracking, and resulting in significantly deteriorated surface characteristics in the steel sheet. An amount of N is therefore preferably 0.020 % or less. And the amount of N is more preferably 0.010 % or less. On the other hand, while the lower limit of the amount of N is not particularly limited and may be 0 %, N is still allowed to be contained as an inevitable impurity. The amount of N, however, is preferably 0.001 % or more as excessive reduction in the amount of N causes a cost increase.

30 **[0033]** A chemical composition in the base hot-rolled steel sheet according to one embodiment of the present disclosure may contain the aforementioned elements and a balance, the balance being Fe and inevitable impurities. As used herein, "balance being Fe and inevitable impurities" means that cases where other trace elements are contained will fall within the scope of the present disclosure as long as actions and effects of the present disclosure are

not impaired. For example, in one embodiment of the disclosure, the chemical composition may optionally further contain one or more selected from the group consisting of Ti, Nb, V, Mo, Ta, W, Cr, Ni, Cu, Ca, REM (rare earth metal), Sb, B, Sn, Mg, Co, As, Pb, Zn and O, in a total content of 1.0 % or less.

[0034] A method for manufacturing a non-pickled hot-rolled steel sheet according to one embodiment of the present disclosure will now be described.

[0035] The non-pickled hot-rolled steel sheet according to the present disclosure can be manufactured by subjecting a steel slab having the aforementioned chemical composition to the following treatments in the following order:

- (1) Hot rolling that includes rough rolling and finish rolling;
- (2) Cooling; and
- (3) Coiling,

as well as descaling, using high-pressure water, performed between the rough rolling and the finish rolling.

[0036] Reasons for limitations on conditions in each aforementioned process will be described below.

[0037] Descaling temperature: 1100 °C or less

High descaling temperature leads to increase in the grain size of the scale newly generating after the descaling, in association with increase in the grain size of the base metal. The descaling temperature is therefore required to be 1100 °C or less. And the descaling temperature is preferably 1050 °C or less. On the other hand, while the lower limit of the descaling temperature is not particularly limited, the descaling temperature is preferably 950 °C or more from the perspective of securing a temperature of the steel sheet during the finish rolling. As used herein, “descaling temperature” indicates a surface temperature of the steel sheet at the time of starting the descaling.

[0038] Impingement pressure: 1.0 MPa or more

Increasing an impingement pressure of high-pressure water used for the descaling helps cool a surface layer of the base metal to reduce the grain size of the scale at the time of scale generation after the descaling. The impingement pressure is therefore required to be 1.0 MPa or more. And the

impingement pressure is preferably 2.0 MPa or more, and more preferably 3.0 MPa or more. On the other hand, while the upper limit of the impingement pressure is not particularly limited, the impingement pressure is preferably 10 MPa or less from the perspective of securing the temperature of the steel sheet during the finish rolling.

[0039] Period of time from completion of descaling until start of finish rolling: within 10 seconds

Finish rolling is performed after completion of the descaling. At such timing, as the thickness of the scale increases, the grain size of the scale increases as well if a period of time from completion of the descaling until a start of the finish rolling is long. It is therefore required to start the finish rolling within 10 seconds after completion of the descaling. And it is preferred to start the finish rolling within 5 seconds after completion of the descaling.

[0040] Finisher delivery temperature: 800 °C to 950 °C

The thickness of the scale as well as the grain size of the scale increase when a finisher delivery temperature of the finish rolling is high. The finisher delivery temperature is therefore required to be 950 °C or less, and preferably 900 °C or less. On the other hand, when the finisher delivery temperature of the finish rolling is excessively low, the scale cracks upon rolled while the scale becomes excessively thin. The finisher delivery temperature is therefore required to be 800 °C or more, and preferably 830 °C or more.

[0041] Period of time from completion of finish rolling until start of cooling: 2.0 seconds or less

The thickness of the scale as well as the grain size of the scale increase when a period of time from completion of the finish rolling until a start of a cooling is long. The period of time from the completion of the finish rolling until the start of the cooling is required to be 2.0 seconds or less, and preferably 1.0 second or less. On the other hand, while the lower limit of the period of time from the completion of the finish rolling until the start of the cooling is not particularly limited and may be 0 seconds, the period of time from the completion of the finish rolling until the start of the cooling is preferably 0.1 seconds or more.

[0042] Average cooling rate: 10 °C/s or more

The obtained hot-rolled steel sheet is cooled after the completion of the finish rolling. At such timing, the thickness of the scale as well as the grain size of the scale increase if a cooling rate is low. An average cooling
5 rate from a start of the cooling until a start of a subsequent coiling is therefore required to be 10 °C/s or more. And the average cooling rate is preferably 20 °C/s or more. While the upper limit of the average cooling rate is not particularly limited, the average cooling rate is preferably 100 °C/s or less as the scale becomes easier to crack when the average cooling rate is excessively
10 high.

[0043] Any method for the cooling can be employed without being particularly limited, so long as the method satisfies the aforementioned conditions. And the cooling can be performed preferably by water cooling.

[0044] Coiling temperature: 400 °C or more and less than 600 °C

15 Fe_3O_4 on the surface layer of the scale transforms into FeO when a coiling temperature is high, and then transforms again, in turn, into Fe_3O_4 and Fe upon cooled to result in Fe precipitation onto the surface layer. This leads to reduction in the degree of blackness. The coiling temperature is therefore required to be less than 600 °C. And the coiling temperature is
20 preferably less than 580 °C. On the other hand, when the coiling temperature is excessively low, Fe precipitation at the interface between the base hot-rolled steel sheet and the scale is suppressed to reduce the scale adhesion, while FeO remains in the scale. This leads to reduction in the blackness. The coiling temperature is therefore required to be 400 °C or
25 more, and preferably 450 °C or more.

EXAMPLES

[0045] Examples of the present disclosure will now be described.

[0046] A steel slab having a chemical composition presented in Table 1 was
30 subjected to rough rolling, descaling, finish rolling, cooling, and coiling, in above order, to manufacture a non-pickled hot-rolled steel sheet having a sheet thickness of 3 mm. The cooling was performed through water cooling. Manufacturing conditions in each process were as presented in Table 2.

[0047] Each of the obtained non-pickled hot-rolled steel sheets was then

evaluated in terms of thickness, composition, average grain size on surface layer, area ratio of Fe in surface layer, area ratio of Fe at interface, degree of blackness, and adhesion of the scale. Evaluation results are reported in Table 3.

5 **[0048] (Scale thickness)**

Thickness of the scale was measured in the following procedure. A cross-section along a rolling direction-thickness direction of the non-pickled hot-rolled steel sheet was embed-polished. A reflected electron image of the polished cross-section was captured using a scanning electron microscope (SEM). In the capturing, three images of a region having a width of 100 μm in the rolling direction were taken at a magnification of 1,000 times such that total thickness of the scale can be observed in a field of view. An average thickness of the scale was then calculated by obtaining an area of the scale portion through image processing the captured reflected electron image, and dividing the area by 300 μm which is a total width of the observation range.

15 **[0049] (Composition)**

A component (phase) making up the scale was identified by means of an X-ray diffractometer with a Co tube. Fe peaks from the base hot-rolled steel sheet are also detected in the X-ray analysis. Therefore, Fe was distinguished based on presence or absence of a light gray part, the color similar to the base metal, in the reflected electron SEM image.

20 **[0050] (Average grain size on surface layer)**

An average grain size of the scale on its surface layer was evaluated by electron backscatter diffraction (EBSD) using the same sample as in the measurement of the scale thickness. The EBSD measurement was conducted for three regions with a width of 100 μm in the rolling direction at a measurement step of 0.1 μm such that the surface layer of the scale can be included. The average grain size on a surface layer was calculated by counting the number of grain boundaries present across an overall width of the measurement area, the measurement area being positioned at a side of the base hot-rolled steel sheet by 0.5 μm in the thickness direction of the scale from the outermost surface layer of the scale; and by dividing 300 μm , which corresponds to the observation range, by the number of the grain boundaries. For the measurement, the grain boundaries were determined where an

orientation difference is 15° or more.

[0051] (Area ratio of Fe)

An area ratio of Fe in surface layer as well as an area ratio of Fe at interface were obtained through image processing the same SEM images as in the aforementioned scale thickness measurement. A region of 0 to 1.0 μm from an interface reference was measured regardless of possible cases where the interface between the scale and the base hot-rolled steel sheet has a roughness.

[0052] (Degree of blackness)

A value of L* provided by JIS Z 8729 (CIE1976) was used for quantification of degree of blackness. Smaller in the L* indicates closer to black. The L* was measured under the condition of geometric condition c (de: 8°) according to JIS Z 8722 so that the degree of blackness from all directions can be taken into account. An illuminant D65 was used for the measurement.

[0053] (Adhesion)

Scale adhesion was evaluated by bending the non-pickled hot-rolled steel sheet, and then by conducting a tape peeling test. The bending was carried out in accordance with a pressing bend method of JIS Z 2248 with an inner punch of 2t (t: sheet thickness) and a bending angle of 170°. The tape peeling test was carried out on a periphery of the bending test piece. A state of the periphery after the peeling test was visually evaluated. Evaluation criteria were as follows.

- Good: Almost no peeling is recognized,
- Fair: Peeling is partly recognized, and
- Poor: Peeling is recognized over an entire surface.

[0054]

Table 1

No.	Chemical composition (mass%)*						
	C	Si	Mn	P	S	Al	N
1	0.20	1.5	0.10	0.02	0.03	0.05	0.005
2	0.06	0.01	0.35	0.02	0.01	0.03	0.004
3	0.15	0.1	0.75	0.02	0.02	1.0	0.007
4	0.06	0.05	0.35	0.01	0.03	0.05	0.005
5	0.05	0.01	0.25	0.01	0.01	0.06	0.003
6	0.04	0.02	0.25	0.03	0.02	0.04	0.005
7	0.09	0.02	<u>0.04</u>	0.02	0.02	0.05	0.005
8	0.02	0.03	0.55	0.02	0.02	0.02	0.004
9	0.11	0.8	1.1	0.01	0.01	0.04	0.006
10	0.02	1.0	3.0	0.01	0.03	0.5	0.005
11	0.15	0.2	1.1	0.01	0.03	0.04	0.006
12	0.18	0.01	0.45	0.01	0.01	<u>1.1</u>	0.005
13	0.08	<u>1.6</u>	0.50	0.03	0.01	0.04	0.006
14	0.002	0.2	1.5	0.03	0.05	0.03	0.012
15	0.05	0.02	0.25	0.01	0.02	0.05	0.005
16	0.08	0.02	0.25	0.03	0.02	0.3	0.005
17	0.05	0.03	0.25	0.02	0.01	0.06	0.004
18	0.03	0.01	0.45	0.01	0.01	0.08	0.005

* Balance being Fe and inevitable impurities

[0055]

Table 2

No.	Manufacturing conditions						
	Descaling temperature (°C)	Impingement pressure (MPa)	Time until start of finish rolling *1 (s)	Finisher delivery temperature (°C)	Time until start of cooling *2 (s)	Average cooling rate (°C/s)	Coiling temperature (°C)
1	950	1.0	3	900	0.5	10	590
2	1040	<u>0.9</u>	4	860	0.8	40	540
3	1100	3.1	10	800	0.8	20	500
4	1020	1.6	6	<u>960</u>	1.7	20	510
5	1050	1.2	5	860	1.0	30	550
6	1000	3.5	4	850	1.5	<u>9</u>	540
7	930	1.4	6	870	1.1	30	570
8	950	1.4	5	880	0.8	50	<u>390</u>
9	1030	2.2	6	840	1.2	80	460
10	1080	9.8	8	950	0.7	50	530
11	1020	2.1	<u>11</u>	900	1.2	50	450
12	1050	1.1	8	880	1.2	50	520
13	940	1.5	4	880	1.5	40	560
14	990	5.0	4	930	2.0	60	400
15	<u>1110</u>	1.5	5	850	1.1	30	560
16	1060	1.2	5	<u>790</u>	1.5	30	500
17	980	2.3	5	920	<u>2.1</u>	10	520
18	1010	2.2	8	860	1.1	80	<u>605</u>

*1 Period of time from completion of descaling until start of finish rolling

*2 Period of time from completion of finish rolling until start of cooling

[0056]

Table 3

No.	Scale					L*	Adhesion	Remarks
	Thickness (μm)	Composition *1	Average grain size of surface layer (μm)	An area ratio of Fe in surface layer (%)	Area ratio of Fe at interface (%)			
1	6.8	M, Fe	3.0	0.9	5.5	39	Good	Example
2	4.5	M, Fe	3.5	0.2	3.2	48	Good	Comparative example
3	3.0	M, Fe	2.2	0	3.1	33	Good	Example
4	2.1	M, Fe	2.1	0	2.6	33	Poor	Comparative example
5	5.5	M, Fe	2.5	0.3	3.5	34	Good	Example
6	5.2	M, Fe	3.2	0.1	2.5	42	Good	Comparative example
7	5.3	M, Fe	3.5	0.5	3.5	45	Good	Comparative example
8	5.9	M, W, Fe	2.3	0	0.9	27	Poor	Comparative example
9	4.5	M, Fe	2.6	0	2.2	32	Good	Example
10	20	M, Fe	0.8	0.1	2.5	27	Good	Example
11	5.5	M, Fe	3.2	0	1.5	42	Good	Comparative example
12	5.4	M, Fe	3.2	0	3.4	44	Good	Comparative example
13	5.2	M, Fe	3.3	0.2	3.6	43	Good	Comparative example
14	10	M, Fe	1.5	0	1.0	30	Good	Example
15	4.4	M, Fe	3.3	0.6	3.3	45	Good	Comparative example
16	2.8	M, Fe	2.3	0	2.4	35	Fair	Comparative example
17	8.2	M, Fe	3.1	0	2.3	41	Good	Comparative example
18	5.3	M, Fe	2.2	1.0	6.8	46	Good	Comparative example

*1 M: magnetite, W: wustite

[0057] As found from results reported in Tables 1 to 3, the non-pickled hot-rolled steel sheets that meet the conditions of the present disclosure offered a combination of sufficient blackness, seen from any direction, and excellent scale adhesion. Obtained results were further arranged into FIGs. 1 and 2.

[0058] FIG. 1 is a plotted graph illustrating a relationship between the impingement pressure during the descaling and the average grain size on surface layer of the scale. In FIG. 1, the plotting includes only the results from the cases where all the manufacturing conditions other than the impingement pressure satisfy the conditions of the present disclosure. From the result presented in FIG. 1, it was found that setting the impingement pressure during the descaling within the scope of the present disclosure enables the average grain size on surface layer of the scale to fall within the scope of the present disclosure.

[0059] FIG. 2 is a plotted graph illustrating a relationship between the average grain size on surface layer of the scale and the L^* . In FIG. 2, the plotting includes only the results from the cases where all the parameters other than the average grain size on surface layer of the scale satisfy the conditions of the present disclosure. From the result presented in FIG. 2, it was found that the L^* can be 40 or less by setting the average grain size on surface layer of the scale within the scope of the disclosure.

CLAIMS

1. A non-pickled hot-rolled steel sheet comprising:
a base hot-rolled steel sheet; and
5 scale on a surface of the base hot-rolled steel sheet, the scale consisting of Fe_3O_4 and Fe and having a thickness of 3.0 μm to 20 μm , wherein
an average grain size on a surface layer of the scale is 3.0 μm or less,
and
10 an area ratio of Fe in a cross-section of the scale is less than 1.0 % in a region of 0 to 1.0 μm in a thickness direction of the scale from an outermost surface layer of the scale, while 1.0 % or more in a region of 0 to 1.0 μm in the thickness direction of the scale from an interface between the scale and the base hot-rolled steel sheet.
15
2. The non-pickled hot-rolled steel sheet according to claim 1,
wherein the base hot-rolled steel sheet comprises a chemical composition comprising, in mass%,
C in an amount of 0.20 % or less,
20 Si in an amount of 1.5 % or less,
Mn in an amount of 0.1 % to 3.0 %,
P in an amount of 0.10 % or less,
S in an amount of 0.10 % or less,
Al in an amount of 1.0 % or less, and
25 N in an amount of 0.020 % or less, with the balance being Fe and inevitable impurities.
3. A method for manufacturing a non-pickled hot-rolled steel sheet, the method comprising:
30 hot rolling a steel slab comprising the chemical composition according to claim 2 to obtain a hot-rolled steel sheet, the hot rolling comprising rough rolling and finish rolling;
cooling the hot-rolled steel sheet at an average cooling rate of 10 $^{\circ}\text{C/s}$ or more; and

coiling the cooled hot-rolled steel sheet at a coiling temperature of 400 °C or more and less than 600 °C, wherein

5 descaling is performed at a temperature of 1100 °C or less using high-pressure water with an impingement pressure of 1.0 MPa or more, after completion of the rough rolling,

 the finish rolling is started within 10 seconds after completion of the descaling,

 a finisher delivery temperature of the finish rolling is set in a range of 800 °C to 950 °C, and

10 the cooling is started within 2.0 seconds from completion of the finish rolling.