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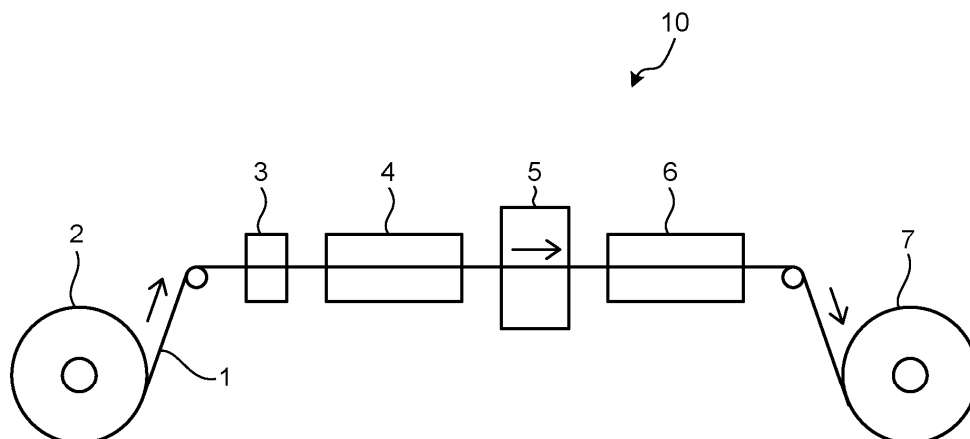
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(54) **SCALE REMOVAL FACILITY FOR STEEL SHEET, PRODUCTION FACILITY FOR STEEL SHEET, METHOD FOR REMOVING SCALES FROM STEEL SHEET, AND METHOD FOR PRODUCING STEEL SHEET**

(57) A scale removal facility of the present invention is a steel sheet scale removal facility that removes a scale of a steel sheet to be conveyed, in which a first pickling device that performs first pickling on the steel sheet using a first acid liquid, a breaking device that mechanically

breaks the scale, and a second pickling device that performs second pickling on the steel sheet using a second acid liquid are disposed in this order from an upstream side in a conveyance direction of the steel sheet.

**FIG.1**



**EP 4 772 675 A1**

## Description

## Field

- 5 **[0001]** The present invention relates to a steel sheet scale removal facility, a steel sheet manufacturing facility, a steel sheet scale removal method, and a steel sheet manufacturing method.

## Background

- 10 **[0002]** Electromagnetic steel sheets mainly used as an iron core material of an electric device are roughly classified into a non-oriented electromagnetic steel sheet and an oriented electromagnetic steel sheet, and in order to reduce iron loss, the electromagnetic steel sheets usually contain a large amount of Si or Al that increases a specific resistance of steel. The non-oriented electromagnetic steel sheet is generally manufactured by melting steel adjusted to have a predetermined component composition, forming a slab as a steel material by a continuous casting method or the like, and then subjecting  
15 the slab to hot rolling, hot rolled sheet annealing as necessary, pickling, cold rolling, and finish annealing for recrystallization. The oriented electromagnetic steel sheet is generally manufactured by melting steel adjusted to have a predetermined component composition, forming a steel material (slab) by a continuous casting method or the like, then subjecting the slab to hot rolling, hot rolled sheet annealing as necessary, pickling, cold rolling, recrystallization annealing and second cold rolling as necessary, primary recrystallization annealing also serving as decarburization annealing, application of an  
20 annealing separator, and finish annealing for secondary recrystallization.

- [0003]** The hot rolled sheet annealing is a step of performing a uniformizing heat treatment on a steel sheet after hot rolling (hot rolled steel sheet). By performing the uniformizing heat treatment, recrystallization shortage of the hot rolled sheet can be eliminated, crystal grains before cold rolling can be coarsened and size-regulated, a texture of the steel sheet before cold rolling can be improved to be advantageous for magnetic characteristics, and ridging can be suppressed.  
25 Therefore, a high-grade electromagnetic steel sheet with a large amount of Si added is often subjected to hot rolled sheet annealing.

- [0004]** The pickling is a step of removing an oxidized scale (descaling) from a surface of the steel sheet before cold rolling. When a steel sheet in which an oxidized scale formed on a surface of the steel sheet by hot rolling or hot rolled sheet annealing remains is subjected to cold rolling without being pickled, the following problems may occur. That is, the oxidized  
30 scale is pushed into the surface of the steel sheet by a rolling roll, or the exfoliated oxidized scale adheres to a surface of the roll and is transferred thereto to cause surface defects, thereby significantly impairing surface quality of a final product. As an acid liquid used in the pickling, any acid of hydrochloric acid, sulfuric acid, hydrofluoric acid, and a mixed acid obtained by mixing these acids is used.

- [0005]** An oxidized scale of a hot rolled steel sheet for an electromagnetic steel sheet containing a large amount of Si or Al includes an external scale and a subscale. The external scale is made of FeO, Fe<sub>3</sub>O<sub>4</sub>, Fe<sub>2</sub>O<sub>3</sub>, or the like formed by diffusion of Fe from the inside to the outside of the steel sheet. The subscale is made of a Si oxide such as SiO<sub>2</sub> or Fe<sub>2</sub>SiO<sub>4</sub>, Al<sub>2</sub>O<sub>3</sub>, or the like formed by diffusion of oxygen from the outside to the inside of the steel sheet. In particular, it is known that a subscale containing SiO<sub>2</sub> or Al<sub>2</sub>O<sub>3</sub> has a significantly poor descaling property. Therefore, in descaling of a hot rolled steel sheet for an electromagnetic steel sheet, a descaling property is improved by performing a mechanical descaling  
40 treatment for mechanically breaking a scale, such as shot blasting, before pickling.

- [0006]** However, when a high-grade electromagnetic steel sheet having a large Si content is subjected to hot rolled sheet annealing in order to ensure magnetic characteristics, there is a problem that a crystal grain size increases and the steel sheet becomes brittle. In particular, when the Si content is more than 2.5 [mass%], there is a problem that a surface of the steel sheet undergoes twinning deformation by shot blasting performed in order to improve a descaling property, and a  
45 trouble such as sheet fracture easily occurs during cold rolling using this twinning deformation as a starting point.

- [0007]** Patent Literature 1 discloses a technique of reducing the amount of strain introduced to a surface of a steel sheet and suppressing twinning deformation by reducing the size of a shot particle projected by shot blasting to less than 0.35 [mm] and reducing energy of particles colliding with the surface of the steel sheet. In addition, Patent Literature 2 discloses a technique of suppressing twinning deformation that easily occurs under a low temperature and high strain rate condition  
50 by raising a steel sheet temperature Ts so as to satisfy a relational expression of  $T_s[^\circ\text{C}] \geq 80 \times \text{Si}[\text{mass}\%] - 180$  according to the Si content when an electromagnetic steel sheet containing 2.5 to 3.5 [mass%] of Si is subjected to shot blasting.

## Citation List

- 55 Patent Literature

**[0008]**

Patent Literature 1: JP S61-126919 A

Patent Literature 2: JP S62-048463 A

## Summary

## Technical Problem

**[0009]** However, in the technique disclosed in Patent Literature 1, twinning deformation can be suppressed by reducing a shot particle size and collision energy, but conversely, there is a problem that a descaling property deteriorates. In the technique disclosed in Patent Literature 2, twinning deformation can be suppressed by raising the steel sheet temperature  $T_s$ . However, the higher the Si content, the higher the necessary steel sheet temperature, and therefore in a steel sheet containing 4.0 [mass%] of Si, which is said to be a rollable limit, the steel sheet temperature  $T_s$  obtained from the above relational expression is 140[°C]. As a result, there is a problem that a risk of dust explosion due to shot particles increases. Therefore, it is actually difficult to apply the techniques disclosed in Patent Literatures 1 and 2 to actual production.

**[0010]** The present invention has been made in view of the above problems, and an object of the present invention is to provide a steel sheet scale removal facility, a steel sheet manufacturing facility, a steel sheet scale removal method, and a steel sheet manufacturing method capable of achieving both a descaling property of a steel sheet and suppression of fracture occurrence in cold rolling. Solution to Problem

**[0011]** To solve the problem and achieve the object, (1) a steel sheet scale removal facility according to the present invention is the facility that removes a scale of a steel sheet to be conveyed, wherein a first pickling device that performs first pickling on the steel sheet using a first acid liquid, a breaking device that mechanically breaks the scale, and a second pickling device that performs second pickling on the steel sheet using a second acid liquid are disposed in this order from an upstream side in a conveyance direction of the steel sheet.

(2) Moreover, in the steel sheet scale removal facility according to above (1), a pickling inhibitor may be added to the second acid liquid.

(3) Moreover, in the steel sheet scale removal facility according to above (1) or (2), a pickling accelerator may be added to the first acid liquid, and a pickling time in the first pickling may be 10 to 30 [s].

(4) Moreover, in the steel sheet scale removal facility according to any one of above (1) to (3), a preliminary breaking device that mechanically breaks the scale may be disposed on an upstream side of the first pickling device in the conveyance direction of the steel sheet.

(5) Moreover, a steel sheet manufacturing facility according to the present invention includes: a hot rolling facility that performs hot rolling on a steel material to obtain a hot rolled sheet; a hot rolled sheet annealing facility that performs hot rolled sheet annealing on the hot rolled sheet as necessary; a scale removal facility that removes a scale of the hot rolled sheet or the hot rolled sheet that has been subjected to the hot rolled sheet annealing; a cold rolling facility that performs cold rolling on the hot rolled sheet from which the scale has been removed to obtain a cold rolled sheet; and a finish annealing facility that performs annealing on the cold rolled sheet to obtain a cold rolled annealed sheet, wherein the steel sheet scale removal facility according to any one of above (1) to (4) is used as the scale removal facility.

(6) Moreover, a steel sheet scale removal method according to the present invention includes: pickling a steel sheet that has been subjected to hot rolling with a first pickling device that performs pickling using a first acid liquid; mechanically breaking a scale on a surface of the steel sheet pickled with the first pickling device with a breaking device; and pickling the steel sheet treated by the breaking device with a second pickling device using a second acid liquid.

(7) Moreover, in the steel sheet scale removal method according to above (6), a pickling inhibitor may be added to the second acid liquid.

(8) Moreover, in the steel sheet scale removal method according to above (6) or (7), a pickling accelerator may be added to the first acid liquid, and a pickling time with the first pickling device may be 10 to 30 [s].

(9) Moreover, in the steel sheet scale removal method according to any one of above (6) to (8), a preliminary breaking device may be disposed on an upstream side of the first pickling device in a conveyance direction of the steel sheet to mechanically break the scale.

(10) Moreover, a steel sheet manufacturing method according to the present invention includes: a hot rolling step of performing hot rolling on a steel material to obtain a hot rolled sheet; a hot rolled sheet annealing step of performing hot rolled sheet annealing on the hot rolled sheet as necessary; a scale removal step of removing a scale of the hot rolled sheet or the hot rolled sheet that has been subjected to the hot rolled sheet annealing; a cold rolling step of performing cold rolling on the hot rolled sheet from which the scale has been removed to obtain a cold rolled sheet; and a finish annealing step of performing annealing on the cold rolled sheet to obtain a cold rolled annealed sheet, wherein the steel sheet scale removal method according to any one of above (6) to (9) is used as the scale removal step.

## Advantageous Effects of Invention

**[0012]** The steel sheet scale removal facility, the steel sheet manufacturing facility, the steel sheet scale removal method, and the steel sheet manufacturing method according to the present invention have an effect of being able to achieve both a descaling property of a steel sheet and suppression of fracture occurrence in cold rolling.

## Brief Description of Drawings

**[0013]**

FIG. 1 is a diagram illustrating a schematic configuration of a steel strip scale removal facility according to an embodiment.

FIG. 2 is a schematic view illustrating an external scale and an internal scale of a scale present on a surface of a steel strip.

## Description of Embodiments

**[0014]** Hereinafter, an embodiment of a steel sheet scale removal facility, a steel sheet manufacturing facility, a steel sheet scale removal method, and a steel sheet manufacturing method according to the present invention will be described. Note that the present invention is not limited by the present embodiment. The "steel sheet" includes a "steel strip".

**[0015]** FIG. 1 is a diagram illustrating a schematic configuration of a scale removal facility 10 for a steel strip 1 according to an embodiment. The scale removal facility 10 removes a scale of the steel strip 1 conveyed in a conveyance direction indicated by an arrow in FIG. 1. The scale removal facility 10 is configured by disposing a pay-off reel 2, a welding machine 3, a first pickling device 4, a breaking device 5, a second pickling device 6, and a tension reel 7 in this order from an upstream side in the conveyance direction of the steel strip 1. The pay-off reel 2 unwinds a coil of a hot rolled steel strip on an entry side to dispense the steel strip 1. The welding machine 3 welds the preceding steel strip 1 to the following steel strip 1. The first pickling device 4 performs first pickling on the steel strip 1 using an acid liquid (first acid liquid) to remove an easily pickled scale on a surface of the steel strip. The breaking device 5 mechanically breaks a film-like hardly pickled scale on the surface of the steel strip. The second pickling device 6 performs second pickling on the steel strip 1 using an acid liquid (second acid liquid) to remove a broken hardly pickled scale remaining on the surface of the steel strip together with dissolution of base metal. The tension reel 7 winds the steel strip 1 that has been subjected to the second pickling around a coil.

**[0016]** Note that, in the scale removal facility 10 according to the embodiment, a preliminary breaking device that mechanically breaks a scale on the surface of the steel strip may be disposed on an upstream side of the first pickling device 4 and a downstream side of the welding machine 3 in the conveyance direction of the steel strip 1. As the preliminary breaking device and the breaking device 5, for example, any one of shot blasting, a tension leveler, a grinding brush, and a laser cleaning device can be used.

**[0017]** In FIG. 1, the steel strip 1 obtained by winding a steel sheet which is a metal flat sheet as a steel material in a coil shape is a product (scale removal target), but the product (scale removal target) is not limited to the steel strip 1. For example, the product (scale removal target) may be a metal flat steel sheet as a steel material. That is, the scale removal facility 10 can be used in a steel sheet scale removal method in a broad sense.

**[0018]** Generally, in a steel sheet scale removal facility, a mechanical descaling treatment for mechanically breaking a scale on a surface of a steel sheet by a breaking device is performed, and then the scale is removed by pickling with a pickling device.

**[0019]** As a result of intensive studies, the inventors of the present application have found that a scale 20 on a surface of a steel sheet has a layered structure including an external scale 21 and an internal scale 22, and a film-like internal scale 222 included in the internal scale 22 is present so as to cover a base metal 23 as illustrated in FIG. 2.

**[0020]** Here, the external scale 21 is an iron-based scale generated on a surface of a base metal generally called a black scale, and is a scale which is generated mainly by external oxidation during hot rolling or hot rolled sheet annealing, mainly contains  $\text{FeO}$ ,  $\text{Fe}_3\text{O}_4$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{Fe}_2\text{SiO}_4$ , or the like, and is soluble in an acid. On an inner layer side of the external scale 21, the internal scale 22 whose generation behavior is rate-controlled by diffusion of oxygen is generated. Scales generated by internal oxidation during hot rolling or hot rolled sheet annealing are an island-like internal scale 221 and the film-like internal scale 222. The island-like internal scale 221 is present in an island shape in a metal iron 223, and mainly contains  $\text{FeO}$ ,  $\text{Fe}_2\text{SiO}_4$ ,  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{FeAl}_2\text{O}_3$ , and the like. In the island-like internal scale 221, an oxide soluble in an acid and an oxide insoluble in an acid are mixed, but since the metal iron 223 itself is soluble in an acid, the oxide insoluble in an acid is also peeled off by an acid treatment and can be removed. The film-like internal scale 222 is made of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{FeAl}_2\text{O}_4$ , an amorphous oxide of Si and Al, and the like. These oxides generated on the innermost layer side having a low oxygen potential are insoluble in an acid because they are oxides having a very strong bonding force to oxygen. In addition, the

film-like internal scale 222 is generated in a film shape so as to cover the base metal 23, and therefore cannot be peeled off by dissolving the base metal 23 by an acid treatment.

**[0021]** First, by first pickling by the first pickling device 4, a scale other than the film-like internal scale 222 (the island-like internal scale 221 and the metal iron 223) in the external scale 21 and the internal scale 22 that are easily soluble in an acid is removed. Subsequently, the film-like internal scale 222 is broken by a mechanical descaling treatment by the breaking device 5 such as shot blasting. Then, by second pickling by the second pickling device 6, the remaining film-like internal scale 222 is removed together with dissolution of the base metal 23. As a result, the inventors of the present application have found that removal of the scale 20 on the surface of the steel sheet can be effectively completed while sheet fracture in cold rolling is suppressed.

**[0022]** Therefore, in the scale removal facility 10 according to the embodiment, the first pickling device 4 and the second pickling device 6 are disposed on an upstream side and a downstream side of the breaking device 5 in a conveyance direction of the steel strip 1, respectively. In the scale removal facility 10 according to the embodiment, a scale of the steel strip 1 is removed by pickling (first pickling and second pickling) by the first pickling device 4 and the second pickling device 6.

**[0023]** Next, an example of a method for manufacturing the steel strip 1 according to the embodiment will be described. Schematically, the method for manufacturing the steel strip 1 according to the embodiment is a method for manufacturing the steel strip 1 by sequentially performing a hot rolling step, a hot rolled sheet annealing step as necessary, a scale removal step, a cold rolling step, and a finish annealing step on a steel material.

<Steel material>

**[0024]** A composition of the steel material is not particularly limited. A scale removal method according to the embodiment is particularly useful for descaling a steel strip (electromagnetic steel sheet) having a large Si content (for example, Si is contained in an amount of 1.0 [mass%] or more) in which a film-like strong scale is easily generated, but is also suitably applicable to a steel strip having a small Si content. A method for melting the steel material is not particularly limited, and a known melting method using a converter, an electric furnace, or the like can be adopted. Note that a slab (steel material) is preferably formed by a continuous casting method after melting from a viewpoint of productivity and the like, but the slab (steel material) may be formed by a known casting method such as an agglomeration-ingot rolling method or a thin slab continuous casting method.

<Hot rolling step>

**[0025]** The hot rolling step is a step of performing hot rolling on a steel material to obtain a hot rolled sheet. The hot rolling step is not particularly limited as long as it is a step of heating a steel material performing hot rolling thereon to obtain a hot rolled sheet having a predetermined dimension, and a normal hot rolling step can be applied. As the normal hot rolling step, for example, a steel material is heated to a temperature of 1000[°C] or higher and 1200[°C] or lower. Then, a hot rolling step of performing hot rolling on the heated steel material at a finish rolling outlet temperature of 800[°C] or higher and 950[°C] or lower, cooling the steel material after completion of the hot rolling, and winding the steel material at a winding temperature of 400[°C] or higher and 700[°C] or lower to form a hot rolled sheet having a predetermined dimensional shape can be exemplified.

<Hot rolled sheet annealing step>

**[0026]** The hot rolled sheet annealing step is a step of annealing a hot rolled sheet by heating and holding the hot rolled sheet at a high temperature. The hot rolled sheet annealing step is not particularly limited, and a normal hot rolled sheet annealing step can be applied. Note that this step is not essential and can be omitted.

<Pickling step>

**[0027]** The pickling step is a step of performing various treatments including a pickling treatment on a steel sheet after the hot rolled sheet annealing step or a hot rolled sheet when the hot rolled sheet annealing step is omitted. The pickling step is performed using the scale removal facility 10 according to the embodiment.

<Cold rolling step>

**[0028]** The cold rolling step is a step of performing cold rolling on a pickled sheet that has undergone the pickling step. The cold rolling step is not particularly limited as long as a steel sheet after pickling can be reduced to a desired sheet thickness, and a normal cold rolling step can be applied. For example, a cold rolling step of performing one-pass or multi-

pass rolling under conditions that a rolling reduction ratio of each pass is 10 to 40[%] and a strain rate is 10 to 1000 [s<sup>-1</sup>] to form a cold rolled sheet having a predetermined dimensional shape can be exemplified. In addition, a cold rolled sheet having a predetermined dimensional shape may be formed by two or more times of cold rolling including an intermediate annealing step as necessary, and conditions of the intermediate annealing step in this case are not particularly limited, and a normal intermediate annealing step can be applied.

<Finish annealing step>

**[0029]** The finish annealing step is a step of performing annealing on a cold rolled sheet that has undergone the cold rolling step. The finish annealing step is not particularly limited, and a normal finish annealing step can be applied. For example, a finish annealing step of heating a cold rolled sheet that has undergone the cold rolling step to an annealing temperature of 700[°C] or higher and 1050[°C] or lower and cooling the cold rolled sheet to obtain a cold rolled annealed sheet can be exemplified. Although insulating coating is applied to a surface of the cold rolled annealed sheet after the finish annealing step, this method and the type of coating are not particularly limited, and a normal insulating coating step can be applied.

**[0030]** The scale removal facility 10 according to the embodiment can be applied to, for example, a facility for manufacturing the steel strip 1 using the above-described method for manufacturing the steel strip 1. In the facility for manufacturing the steel strip 1, the scale removal facility 10 removes a scale of the steel strip 1 to manufacture the steel strip 1. As a result, it is possible to manufacture the steel strip 1 by suppressing fracture due to twinning deformation in cold rolling without causing dust explosion in shot blasting and without deteriorating a descaling property.

[Examples]

**[0031]** Hereinafter, the present invention will be specifically described with reference to Examples. Note that the present invention is not limited thereto. For example, driving conditions of a breaking device that mechanically breaks a film-like hardly pickled scale on a surface of a steel strip are reference values, and do not limit the present invention. Although detailed driving conditions differ depending on the type of a breaking device, the type of a steel strip to be a target, and a preliminary heat treatment, the present invention is characterized by performing a scale breaking treatment with a breaking device after removal of an external scale by primary pickling, and optimum values of various conditions of the primary pickling, secondary pickling, and the breaking device 5 only need to be found by appropriate adjustment.

<Manufacture of steel strip>

**[0032]** First, a hot rolled steel sheet containing C: 0.002 [mass%], Si: 3.7 [mass%], and Mn: 0.5 [mass%] and having a sheet thickness of 2.2 [mm] was subjected to hot rolled sheet annealing under a soaking condition of 1000[°C] × 30 [s]. In this way, the steel strip 1 for an evaluation experiment of a descaling property and a cold rolling property was manufactured.

(Evaluation Experiment 1)

**[0033]** In Evaluation Experiment 1, shot blasting is used as the breaking device 5, and an effect of application of first pickling by the first pickling device 4 disposed on an upstream side of the breaking device 5 in a conveyance direction of the steel strip 1 is confirmed. For this purpose, as in Examples 1 to 12 and Comparative Examples 1 to 12, an evaluation experiment of a descaling property and a cold rolling property was performed by changing the presence or absence of the first pickling by the first pickling device 4, conditions of shot blasting in the breaking device 5, and the like.

**[0034]** Table 1 presents conditions and results of pickling and a rolling experiment in Examples 1 to 12 and Comparative Examples 1 and 2. Note that "scale removal" in Table 1 indicates, as a descaling property, "○" if scale removal was completed after second pickling was performed, and "×" if scale removal was not completed. In addition, "fracture occurrence ratio in cold rolling" in Table 1 indicates, as the cold rolling property, a fracture occurrence ratio when cold rolling is performed after second pickling is performed to form a cold rolled sheet.

Table 1

| No.                   | First pickling    |                  |          | Shot blasting           |                                         | Second pickling   |                  |          | Scale removal | Fracture occurrence ratio in cold rolling [%] |
|-----------------------|-------------------|------------------|----------|-------------------------|-----------------------------------------|-------------------|------------------|----------|---------------|-----------------------------------------------|
|                       | Acid liquid       | Temperature [°C] | Time [s] | Particle velocity [m/s] | Projection density [kg/m <sup>2</sup> ] | Acid liquid       | Temperature [°C] | Time [s] |               |                                               |
| Example 1             | Hydrochloric acid | 80               | 20       | 10                      | 12.5                                    | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 2             | Hydrochloric acid | 80               | 20       | 20                      | 12.5                                    | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 3             | Hydrochloric acid | 80               | 20       | 30                      | 12.5                                    | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 4             | Hydrochloric acid | 80               | 20       | 40                      | 12.5                                    | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 5             | Hydrochloric acid | 80               | 20       | 50                      | 12.5                                    | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 6             | Hydrochloric acid | 80               | 20       | 60                      | 12.5                                    | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Comparative Example 1 | Hydrochloric acid | 80               | 20       | 100                     | 12.5                                    | Hydrochloric acid | 80               | 20       | ○             | 25                                            |
| Example 7             | Hydrochloric acid | 80               | 20       | 10                      | 25                                      | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 8             | Hydrochloric acid | 80               | 20       | 20                      | 25                                      | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 9             | Hydrochloric acid | 80               | 20       | 30                      | 25                                      | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 10            | Hydrochloric acid | 80               | 20       | 40                      | 25                                      | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 11            | Hydrochloric acid | 80               | 20       | 50                      | 25                                      | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 12            | Hydrochloric acid | 80               | 20       | 60                      | 25                                      | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Comparative Example 2 | Hydrochloric acid | 80               | 20       | 100                     | 25                                      | Hydrochloric acid | 80               | 20       | ○             | 27                                            |

[Example 1]

**[0035]** In Example 1, first pickling by the first pickling device 4 was performed, and as conditions of the first pickling, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], and a pickling time was 20 [s]. In Example 1, as conditions of shot blasting in the breaking device 5, a particle velocity was 10 [m/s], and a projection density was 12.5 [kg/m<sup>2</sup>]. In Example 1, as conditions of second pickling by the second pickling device 6, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], and a pickling time was 20 [s]. As a result, in Example 1, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 2]

**[0036]** In Example 2, the same conditions as in Example 1 were used except that the particle velocity was 20 [m/s] as the condition of shot blasting in the breaking device 5. As a result, in Example 2, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 3]

**[0037]** In Example 3, the same conditions as in Example 1 were used except that the particle velocity was 30 [m/s] as the condition of shot blasting in the breaking device 5. As a result, in Example 3, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 4]

**[0038]** In Example 4, the same conditions as in Example 1 were used except that the particle velocity was 40 [m/s] as the condition of shot blasting in the breaking device 5. As a result, in Example 4, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 5]

**[0039]** In Example 5, the same conditions as in Example 1 were used except that the particle velocity was 50 [m/s] as the condition of shot blasting in the breaking device 5. As a result, in Example 5, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 6]

**[0040]** In Example 6, the same conditions as in Example 1 were used except that the particle velocity was 60 [m/s] as the condition of shot blasting in the breaking device 5. As a result, in Example 6, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Comparative Example 1]

**[0041]** In Comparative Example 1, the same conditions as in Example 1 were used except that the particle velocity was 100 [m/s] as the condition of shot blasting in the breaking device 5. As a result, in Comparative Example 1, scale removal was completed, and a fracture occurrence ratio in cold rolling was 25[%].

[Example 7]

**[0042]** In Example 7, the same conditions as in Example 1 were used except that the projection density was 25 [kg/m<sup>2</sup>] as the condition of shot blasting in the breaking device 5. As a result, in Example 7, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 8]

**[0043]** In Example 8, the same conditions as in Example 2 were used except that the projection density was 25 [kg/m<sup>2</sup>] as the condition of shot blasting in the breaking device 5. As a result, in Example 8, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 9]

**[0044]** In Example 9, the same conditions as in Example 3 were used except that the projection density was 25 [kg/m<sup>2</sup>] as the condition of shot blasting in the breaking device 5. As a result, in Example 9, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 10]

**[0045]** In Example 10, the same conditions as in Example 4 were used except that the projection density was 25 [kg/m<sup>2</sup>] as the condition of shot blasting in the breaking device 5. As a result, in Example 10, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 11]

**[0046]** In Example 11, the same conditions as in Example 5 were used except that the projection density was 25 [kg/m<sup>2</sup>] as the condition of shot blasting in the breaking device 5. As a result, in Example 11, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 12]

**[0047]** In Example 12, the same conditions as in Example 6 were used except that the projection density was 25 [kg/m<sup>2</sup>] as the condition of shot blasting in the breaking device 5. As a result, in Example 12, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Comparative Example 2]

**[0048]** In Comparative Example 2, the same conditions as in Comparative Example 1 were used except that the projection density was 25 [kg/m<sup>2</sup>] as the condition of shot blasting in the breaking device 5. As a result, in Comparative Example 2, scale removal was completed, and a fracture occurrence ratio in cold rolling was 27[%].

**[0049]** Table 1 indicates that, as in Comparative Examples 1 and 2, under the conditions that the first pickling by the first pickling device 4 is performed and the particle velocity of shot blasting in the breaking device 5 is as extremely high as 100 [m/s], scale removal is completed, but the fracture occurrence ratio in cold rolling increases.

**[0050]** On the other hand, as in Examples 1 to 12, under the conditions that the first pickling by the first pickling device 4 is performed and the particle velocity of shot blasting in the breaking device 5 is low, it is found that both scale removal and suppression of fracture occurrence in cold rolling can be achieved.

**[0051]** That is, in Examples 1 to 12, the external scale 21 and the internal scale 22, which are easily pickled on a surface of the steel strip, are removed by the first pickling by the first pickling device 4, and the film-like internal scale 222, which is hardly pickled, is exposed on the surface. Then, since a mechanical scale breaking treatment is directly performed on the exposed film-like internal scale 222, the film-like internal scale 222 can be broken even if the particle velocity of shot blasting in the breaking device 5 is low. Therefore, even when the particle velocity of shot blasting in the breaking device 5 is low, scale removal is completed by performing the second pickling by the second pickling device 6. As described above, in Examples 1 to 12, even when the mechanical scale breaking treatment by the breaking device 5 is weak, scale removal is completed, and therefore processing damage to the base metal 23 can be suppressed, and a fracture occurrence ratio in cold rolling can be reduced.

(Evaluation Experiment 2)

**[0052]** In Evaluation Experiment 2, for the purpose of confirming an effect of an additive on an acid liquid of the second pickling by the second pickling device 6, as in Examples 13 to 24, an evaluation experiment of a descaling property and a cold rolling property was performed by changing conditions such as a time of the second pickling and the presence or absence of the additive. Table 2 presents conditions and evaluation results of Examples 13 to 24 in Evaluation Experiment 2.

Table 2

| No.        | First pickling    |                  |          | Shot blasting |                         | Second pickling                         |                   |                  |          | Scale removal      | Fracture occurrence ratio in cold rolling [%] |
|------------|-------------------|------------------|----------|---------------|-------------------------|-----------------------------------------|-------------------|------------------|----------|--------------------|-----------------------------------------------|
|            | Acid liquid       | Temperature [°C] | Time [s] | Additive      | Particle velocity [m/s] | Projection density [kg/m <sup>2</sup> ] | Acid liquid       | Temperature [°C] | Time [s] | Additive           |                                               |
| Example 13 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 10       | -                  | 0                                             |
| Example 14 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 20       | -                  | 0                                             |
| Example 15 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 30       | -                  | 0                                             |
| Example 16 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 40       | -                  | 0                                             |
| Example 17 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 50       | -                  | 0                                             |
| Example 18 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 60       | -                  | 0                                             |
| Example 19 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 10       | Pickling inhibitor | 0                                             |
| Example 20 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 20       | Pickling inhibitor | 0                                             |
| Example 21 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 30       | Pickling inhibitor | 0                                             |
| Example 22 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 40       | Pickling inhibitor | 0                                             |
| Example 23 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 50       | Pickling inhibitor | 0                                             |
| Example 24 | Hydrochloric acid | 80               | 20       | -             | 30                      | 15                                      | Hydrochloric acid | 80               | 60       | Pickling inhibitor | 0                                             |

[Example 13]

**[0053]** In Example 13, as conditions of the first pickling by the first pickling device 4, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], a pickling time was 20 [s], and no additive was used. In Example 13, as conditions of shot blasting in the breaking device 5, a particle velocity was 30 [m/s], and a projection density was 15 [kg/m<sup>2</sup>]. In Example 13, as conditions of the second pickling by the second pickling device 6, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], a pickling time was 10 [s], and no additive was used. As a result, in Example 13, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 14]

**[0054]** In Example 14, the same conditions as in Example 13 were used except that a pickling time was 20 [s] as a condition of the second pickling by the second pickling device 6. As a result, in Example 14, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 15]

**[0055]** In Example 15, the same conditions as in Example 13 were used except that a pickling time was 30 [s] as a condition of the second pickling by the second pickling device 6. As a result, in Example 15, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 16]

**[0056]** In Example 16, the same conditions as in Example 13 were used except that a pickling time was 40 [s] as a condition of the second pickling by the second pickling device 6. As a result, in Example 16, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 17]

**[0057]** In Example 17, the same conditions as in Example 13 were used except that a pickling time was 50 [s] as a condition of the second pickling by the second pickling device 6. As a result, in Example 17, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 18]

**[0058]** In Example 18, the same conditions as in Example 13 were used except that a pickling time was 60 [s] as a condition of the second pickling by the second pickling device 6. As a result, in Example 18, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 19]

**[0059]** In Example 19, the same conditions as in Example 13 were used except that a pickling inhibitor was added to the acid liquid as a condition of the second pickling by the second pickling device 6. As a result, in Example 19, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 20]

**[0060]** In Example 20, the same conditions as in Example 14 were used except that a pickling inhibitor was added to the acid liquid as a condition of the second pickling by the second pickling device 6. As a result, in Example 20, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 21]

**[0061]** In Example 21, the same conditions as in Example 15 were used except that a pickling inhibitor was added to the acid liquid as a condition of the second pickling by the second pickling device 6. As a result, in Example 21, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 22]

**[0062]** In Example 22, the same conditions as in Example 16 were used except that a pickling inhibitor was added to the acid liquid as a condition of the second pickling by the second pickling device 6. As a result, in Example 22, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 23]

**[0063]** In Example 23, the same conditions as in Example 17 were used except that a pickling inhibitor was added to the acid liquid as a condition of the second pickling by the second pickling device 6. As a result, in Example 23, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 24]

**[0064]** In Example 24, the same conditions as in Example 18 were used except that a pickling inhibitor was added to the acid liquid as a condition of the second pickling by the second pickling device 6. As a result, in Example 24, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

**[0065]** Table 2 indicates that, as in Examples 13 to 24, both scale removal and suppression of fracture occurrence in cold rolling can be achieved even when the time of the second pickling increases regardless of the presence or absence of addition of the pickling inhibitor to the acid liquid as a condition of the second pickling by the second pickling device 6.

(Evaluation Experiment 3)

**[0066]** In Evaluation Experiment 3, as in Examples 25 to 41 and Comparative Example 3, an effect of an additive on an acid liquid of the first pickling and an application effect of preliminary breakage for mechanically breaking a scale on a surface of a steel strip before the first pickling is performed are confirmed. For this purpose, an evaluation experiment of a descaling property and a cold rolling property was performed by changing conditions such as a time of the first pickling, the presence or absence of an additive, and the presence or absence of preliminary breakage. Table 3 presents conditions and evaluation results of Examples 25 to 41 and Comparative Example 3 in Evaluation Experiment 3. Note that no preliminary breakage was performed except for Evaluation Experiment 3 among the five Evaluation Experiments.

Table 3

| No.                      | Shot blasting<br>(preliminary<br>breakage) |                                               | First pickling       |                     |             |                           | Shot blasting                 |                                               | Second pickling      |                     |             |                       | Scale<br>removal | Fracture<br>occurrence<br>ratio in cold<br>rolling [%] |
|--------------------------|--------------------------------------------|-----------------------------------------------|----------------------|---------------------|-------------|---------------------------|-------------------------------|-----------------------------------------------|----------------------|---------------------|-------------|-----------------------|------------------|--------------------------------------------------------|
|                          | Particle<br>velocity<br>[m/s]              | Projection<br>density<br>[kg/m <sup>2</sup> ] | Acid liquid          | Temperature<br>[°C] | Time<br>[s] | Additive                  | Particle<br>velocity<br>[m/s] | Projection<br>density<br>[kg/m <sup>2</sup> ] | Acid liquid          | Temperature<br>[°C] | Time<br>[s] | Additive              |                  |                                                        |
| Comparative<br>Example 3 | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 5           | -                         | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ×                | 0                                                      |
| Example 25               | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 10          | -                         | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 26               | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 15          | -                         | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 27               | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 20          | -                         | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 28               | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 25          | -                         | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 29               | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 30          | -                         | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 30               | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 5           | Pickling ac-<br>celerator | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 31               | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 10          | Pickling ac-<br>celerator | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 32               | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 15          | Pickling ac-<br>celerator | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 33               | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 20          | Pickling ac-<br>celerator | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 34               | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 25          | Pickling ac-<br>celerator | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 35               | -                                          | -                                             | Hydrochloric<br>acid | 80                  | 30          | Pickling ac-<br>celerator | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 36               | 30                                         | 10                                            | Hydrochloric<br>acid | 80                  | 5           | -                         | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example                  | 30                                         | 10                                            | Hydrochloric         | 80                  | 10          | -                         | 30                            | 10                                            | Hydrochloric         | 80                  | 20          | Pickling              | ○                | 0                                                      |

(continued)

| No.        | Shot blasting<br>(preliminary<br>breakage) |                                               | First pickling       |                     |             |          | Shot blasting                 |                                               | Second pickling      |                     |             |                       | Scale<br>removal | Fracture<br>occurrence<br>ratio in cold<br>rolling [%] |
|------------|--------------------------------------------|-----------------------------------------------|----------------------|---------------------|-------------|----------|-------------------------------|-----------------------------------------------|----------------------|---------------------|-------------|-----------------------|------------------|--------------------------------------------------------|
|            | Particle<br>velocity<br>[m/s]              | Projection<br>density<br>[kg/m <sup>2</sup> ] | Acid liquid          | Temperature<br>[°C] | Time<br>[s] | Additive | Particle<br>velocity<br>[m/s] | Projection<br>density<br>[kg/m <sup>2</sup> ] | Acid liquid          | Temperature<br>[°C] | Time<br>[s] | Additive              |                  |                                                        |
| 37         |                                            |                                               | acid                 |                     |             |          |                               |                                               | acid                 |                     |             | inhibitor             |                  |                                                        |
| Example 38 | 30                                         | 10                                            | Hydrochloric<br>acid | 80                  | 15          | -        | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 39 | 30                                         | 10                                            | Hydrochloric<br>acid | 80                  | 20          | -        | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 40 | 30                                         | 10                                            | Hydrochloric<br>acid | 80                  | 25          | -        | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |
| Example 41 | 30                                         | 10                                            | Hydrochloric<br>acid | 80                  | 30          | -        | 30                            | 10                                            | Hydrochloric<br>acid | 80                  | 20          | Pickling<br>inhibitor | ○                | 0                                                      |

[Comparative Example 3]

**[0067]** In Comparative Example 3, a preliminary breakage treatment was not performed before the first pickling by the first pickling device 4, and as conditions of the first pickling by the first pickling device 4, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], a pickling time was 5 [s], and no additive was used. In Comparative Example 3, as conditions of shot blasting in the breaking device 5, a particle velocity was 30 [m/s], and a projection density was 10 [kg/m<sup>2</sup>]. In Comparative Example 3, as conditions of the second pickling by the second pickling device 6, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], a pickling time was 20 [s], and a pickling inhibitor was added as an additive. As a result, in Comparative Example 3, scale removal was not completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 25]

**[0068]** In Example 25, a preliminary breakage treatment was not performed before the first pickling by the first pickling device 4, and as conditions of the first pickling by the first pickling device 4, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], a pickling time was 10 [s], and no additive was used. In Example 25, as conditions of shot blasting in the breaking device 5, a particle velocity was 30 [m/s], and a projection density was 10 [kg/m<sup>2</sup>]. In Example 25, as conditions of the second pickling by the second pickling device 6, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], a pickling time was 20 [s], and a pickling inhibitor was added as an additive. As a result, in Example 25, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 26]

**[0069]** In Example 26, the same conditions as in Example 25 were used except that a pickling time was 15 [s] as a condition of the first pickling by the first pickling device 4. As a result, in Example 26, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 27]

**[0070]** In Example 27, the same conditions as in Example 25 were used except that a pickling time was 20 [s] as a condition of the first pickling by the first pickling device 4. As a result, in Example 27, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 28]

**[0071]** In Example 28, the same conditions as in Example 25 were used except that a pickling time was 25 [s] as a condition of the first pickling by the first pickling device 4. As a result, in Example 28, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 29]

**[0072]** In Example 29, the same conditions as in Example 25 were used except that a pickling time was 30 [s] as a condition of the first pickling by the first pickling device 4. As a result, in Example 29, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 30]

**[0073]** In Example 30, the same conditions as in Example 25 were used except that a pickling time was 10 [s], and a pickling accelerator as an additive was added to the acid liquid as conditions of the first pickling by the first pickling device 4. As a result, in Example 30, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 31]

**[0074]** In Example 31, the same conditions as in Example 25 were used except that a pickling accelerator as an additive was added to the acid liquid as a condition of the first pickling by the first pickling device 4. As a result, in Example 31, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 32]

**[0075]** In Example 32, the same conditions as in Example 26 were used except that a pickling accelerator was added to the acid liquid as a condition of the first pickling by the first pickling device 4. As a result, in Example 32, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 33]

**[0076]** In Example 33, the same conditions as in Example 27 were used except that a pickling accelerator was added to the acid liquid as a condition of the first pickling by the first pickling device 4. As a result, in Example 33, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 34]

**[0077]** In Example 34, the same conditions as in Example 28 were used except that a pickling accelerator was added to the acid liquid as a condition of the first pickling by the first pickling device 4. As a result, in Example 34, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 35]

**[0078]** In Example 35, the same conditions as in Example 29 were used except that a pickling accelerator was added to the acid liquid as a condition of the first pickling by the first pickling device 4. As a result, in Example 35, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 36]

**[0079]** In Example 36, shot blasting as a preliminary breakage treatment was performed before the first pickling by the first pickling device 4, and as conditions of shot blasting, a particle velocity was 30 [m/s], and a projection density was 10 [kg/m<sup>2</sup>]. In Example 36, as conditions of the first pickling by the first pickling device 4, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], a pickling time was 5 [s], and no additive was used. In Example 36, as conditions of shot blasting in the breaking device 5, a particle velocity was 30 [m/s], and a projection density was 10 [kg/m<sup>2</sup>]. In Example 36, as conditions of the second pickling by the second pickling device 6, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], a pickling time was 20 [s], and a pickling inhibitor as an additive was added to the acid liquid. As a result, in Example 36, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0 [%].

[Example 37]

**[0080]** In Example 37, the same conditions as in Example 25 were used except that shot blasting as a preliminary breakage treatment was performed before the first pickling by the first pickling device 4, and as conditions of shot blasting, a particle velocity was 30 [m/s], and a projection density was 10 [kg/m<sup>2</sup>]. As a result, in Example 37, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 38]

**[0081]** In Example 38, the same conditions as in Example 26 were used except that shot blasting as a preliminary breakage treatment was performed before the first pickling by the first pickling device 4, and as conditions of shot blasting, a particle velocity was 30 [m/s], and a projection density was 10 [kg/m<sup>2</sup>]. As a result, in Example 38, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 39]

**[0082]** In Example 39, the same conditions as in Example 27 were used except that shot blasting as a preliminary breakage treatment was performed before the first pickling by the first pickling device 4, and as conditions of the shot blasting, a particle velocity was 30 [m/s], and a projection density was 10 [kg/m<sup>2</sup>]. As a result, in Example 39, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 40]

**[0083]** In Example 40, the same conditions as in Example 28 were used except that shot blasting as a preliminary breakage treatment was performed before the first pickling by the first pickling device 4, and as conditions of shot blasting, a particle velocity was 30 [m/s], and a projection density was 10 [kg/m<sup>2</sup>]. As a result, in Example 40, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 41]

**[0084]** In Example 41, the same conditions as in Example 29 were used except that shot blasting as a preliminary breakage treatment was performed before the first pickling by the first pickling device 4, and as conditions of shot blasting, a particle velocity was 30 [m/s], and a projection density was 10 [kg/m<sup>2</sup>]. As a result, in Example 41, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

**[0085]** Table 3 indicates that scale removal was not completed under the conditions of Comparative Example 3. That is, it is found that scale removal is not completed under the conditions that the mechanical preliminary breakage treatment of the scale is not performed before the first pickling by the first pickling device 4, a pickling accelerator is not added to the acid liquid used in the first pickling by the first pickling device 4, and the pickling time of the first pickling is 5 [s]. This is considered to be because a part of the easily pickled scale such as the external scale was not removed by the preliminary breakage treatment (shot blasting), and the pickling time of the first pickling was short, therefore removal of the easily pickled scale such as the external scale was not completed, therefore the film-like hardly pickled scale of the inner layer was not exposed, and mechanical breakage did not sufficiently act.

**[0086]** In addition, Table 3 indicates that scale removal is completed under the conditions of Examples 30 to 35. That is, it is found that scale removal is completed under the conditions that the mechanical preliminary breakage treatment of the scale is not performed before the first pickling by the first pickling device 4, a pickling accelerator is added to the acid liquid used in the first pickling by the first pickling device 4, and the pickling time of the first pickling is 5 [s] or more. This is considered to be because, due to an effect of the pickling accelerator, removal of the easily pickled scale such as the external scale was completed early even when the pickling time of the first pickling was as short as 5 [s] as in Example 30.

**[0087]** In addition, Table 3 indicates that scale removal is completed under the conditions of Examples 36 to 41. That is, it is found that scale removal is completed under the conditions that the preliminary breakage treatment (shot blasting) is performed before the first pickling by the first pickling device 4, a pickling accelerator is not added to the acid liquid used in the first pickling by the first pickling device 4, and the pickling time of the first pickling is 5 [s] or more. This is considered to be because a part of the easily pickled scale such as the external scale was removed by the preliminary breakage treatment (shot blasting), a crack was introduced into the remaining easily pickled scale to increase reactivity with the acid liquid, and therefore removal of the easily pickled scale was completed early even when the pickling time of the first pickling was as short as 5 [s] as in Example 36.

(Evaluation Experiment 4)

**[0088]** In Evaluation Experiment 4, a grinding brush is used as the breaking device 5, and an effect of application of the first pickling by the first pickling device 4 disposed on an upstream side of the breaking device 5 in a conveyance direction of the steel strip 1 is confirmed. For this purpose, as in Examples 42 to 47, an evaluation experiment of a descaling property and a cold rolling property was performed by changing a condition of the grinding brush in the breaking device 5 performed after the first pickling by the first pickling device 4. Table 4 presents conditions and results of pickling and a rolling experiment in Examples 42 to 47.

Table 4

| No.        | First pickling    |                  |          | Grinding brush | Second pickling   |                  |          | Scale removal | Fracture occurrence ratio in cold rolling [%] |
|------------|-------------------|------------------|----------|----------------|-------------------|------------------|----------|---------------|-----------------------------------------------|
|            | Acid liquid       | Temperature [°C] | Time [s] |                | Acid liquid       | Temperature [°C] | Time [s] |               |                                               |
| Example 42 | Hydrochloric acid | 80               | 20       | 500            | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 43 | Hydrochloric acid | 80               | 20       | 750            | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 44 | Hydrochloric acid | 80               | 20       | 1000           | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 45 | Hydrochloric acid | 80               | 20       | 1250           | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 46 | Hydrochloric acid | 80               | 20       | 1500           | Hydrochloric acid | 80               | 20       | ○             | 0                                             |
| Example 47 | Hydrochloric acid | 80               | 20       | 1750           | Hydrochloric acid | 80               | 20       | ○             | 0                                             |

[Example 42]

**[0089]** In Example 42, the first pickling by the first pickling device 4 was performed, and as conditions of the first pickling, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], and a pickling time was 20 [s]. In Example 42, a torque per sheet width of 1000 [mm] was 500 [Nm] as a condition of the grinding brush in the breaking device 5. In Example 42, as conditions of the second pickling by the second pickling device 6, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], and a pickling time was 20 [s]. As a result, in Example 42, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 43]

**[0090]** In Example 43, the same conditions as in Example 42 were used except that a torque per sheet width of 1000 [mm] was 750 [Nm] as a condition of the grinding brush in the breaking device 5. As a result, in Example 43, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 44]

**[0091]** In Example 44, the same conditions as in Example 42 were used except that a torque per sheet width of 1000 [mm] was 1000 [Nm] as a condition of the grinding brush in the breaking device 5. As a result, in Example 44, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 45]

**[0092]** In Example 45, the same conditions as in Example 42 were used except that a torque per sheet width of 1000 [mm] was 1250 [Nm] as a condition of the grinding brush in the breaking device 5. As a result, in Example 45, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 46]

**[0093]** In Example 46, the same conditions as in Example 42 were used except that a torque per sheet width of 1000 [mm] was 1500 [Nm] as a condition of the grinding brush in the breaking device 5. As a result, in Example 46, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 47]

**[0094]** In Example 47, the same conditions as in Example 42 were used except that a torque per sheet width of 1000 [mm] was 1750 [Nm] as a condition of the grinding brush in the breaking device 5. As a result, in Example 47, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

**[0095]** Table 4 indicates that, as in Examples 42 to 47, by performing the first pickling by the first pickling device 4, both scale removal and suppression of fracture occurrence in cold rolling can be achieved regardless of the size of a torque per sheet width of 1000 [mm] as a condition of the grinding brush in the breaking device 5.

(Evaluation Experiment 5)

**[0096]** Next, as Evaluation Experiment 5, influences of conditions (type, temperature, and time) of the acid liquid and the type of the breaking device 5 (shot blasting, a tension leveler, a grinding brush, and a laser cleaning device) are confirmed. For this purpose, an evaluation experiment of a descaling property and a cold rolling property was performed under conditions (Examples 48 to 63 and Comparative Examples 4 to 7) in which the acid liquid and the breaking device 5 were changed. Table 5 presents conditions and evaluation results of Examples 48 to 63 and Comparative Examples 4 to 7 in Evaluation Experiment 5.

Table 5

| No.                   | First pickling                  |                  |          |                      | Shot blasting   | Second pickling                 |                  |          |                    | Scale removal | Fracture occurrence ratio in cold rolling [%] |
|-----------------------|---------------------------------|------------------|----------|----------------------|-----------------|---------------------------------|------------------|----------|--------------------|---------------|-----------------------------------------------|
|                       | Acid liquid                     | Temperature [°C] | Time [s] | Additive             |                 | Acid liquid                     | Temperature [°C] | Time [s] | Additive           |               |                                               |
| Example 48            | Hydrochloric acid               | 90               | 20       | Pickling accelerator | Shot blasting   | Hydrochloric acid               | 90               | 20       | Pickling inhibitor | ○             | 0                                             |
| Example 49            | Hydrochloric acid               | 95               | 20       | Pickling accelerator | Tension leveler | Hydrochloric acid               | 95               | 20       | Pickling inhibitor | ○             | 0                                             |
| Example 50            | Hydrochloric acid               | 85               | 20       | Pickling accelerator | Grinding brush  | Hydrochloric acid               | 85               | 20       | Pickling inhibitor | ○             | 0                                             |
| Example 51            | Hydrochloric acid               | 75               | 20       | Pickling accelerator | Laser cleaning  | Hydrochloric acid               | 75               | 20       | Pickling inhibitor | ○             | 0                                             |
| Comparative Example 4 | Hydrochloric acid               | 80               | 20       | Pickling accelerator | None            | Hydrochloric acid               | 80               | 20       | Pickling inhibitor | ×             | 2                                             |
| Example 52            | Sulfuric acid                   | 90               | 20       | -                    | Shot blasting   | Sulfuric acid                   | 90               | 15       | -                  | ○             | 0                                             |
| Example 53            | Sulfuric acid                   | 95               | 20       | -                    | Tension leveler | Sulfuric acid                   | 95               | 15       | -                  | ○             | 0                                             |
| Example 54            | Sulfuric acid                   | 85               | 20       | -                    | Grinding brush  | Sulfuric acid                   | 85               | 15       | -                  | ○             | 0                                             |
| Example 55            | Sulfuric acid                   | 75               | 20       | -                    | Laser cleaning  | Sulfuric acid                   | 75               | 15       | -                  | ○             | 0                                             |
| Comparative Example 5 | Sulfuric acid                   | 80               | 20       | -                    | None            | Sulfuric acid                   | 80               | 15       | -                  | ×             | 3                                             |
| Example 56            | Hydrochloric acid + Nitric acid | 90               | 25       | -                    | Shot blasting   | Hydrochloric acid + Nitric acid | 90               | 25       | -                  | ○             | 0                                             |
| Example 57            | Hydrochloric acid + Nitric acid | 95               | 25       | -                    | Tension leveler | Hydrochloric acid + Nitric acid | 95               | 25       | -                  | ○             | 0                                             |

(continued)

| No.                   | First pickling                        |                  |          | Shot blasting   | Second pickling |          |                  |          | Scale removal | Fracture occurrence ratio in cold rolling [%] |
|-----------------------|---------------------------------------|------------------|----------|-----------------|-----------------|----------|------------------|----------|---------------|-----------------------------------------------|
|                       | Acid liquid                           | Temperature [°C] | Time [s] |                 | Additive        | Time [s] | Temperature [°C] | Additive |               |                                               |
| Example 58            | Hydrochloric acid + Nitric acid       | 85               | 25       | Grinding brush  | -               | 25       | 85               | -        | ○             | 0                                             |
| Example 59            | Hydrochloric acid + Nitric acid       | 75               | 25       | Laser cleaning  | -               | 25       | 75               | -        | ○             | 0                                             |
| Comparative Example 6 | Hydrochloric acid + Nitric acid       | 80               | 25       | None            | -               | 25       | 80               | -        | ×             | 3                                             |
| Example 60            | Hydrochloric acid + Hydrofluoric acid | 90               | 15       | Shot blasting   | -               | 10       | 90               | -        | ○             | 0                                             |
| Example 61            | Hydrochloric acid + Hydrofluoric acid | 95               | 15       | Tension leveler | -               | 10       | 95               | -        | ○             | 0                                             |
| Example 62            | Hydrochloric acid + Hydrofluoric acid | 85               | 15       | Grinding brush  | -               | 10       | 85               | -        | ○             | 0                                             |
| Example 63            | Hydrochloric acid + Hydrofluoric acid | 75               | 15       | Laser cleaning  | -               | 10       | 75               | -        | ○             | 0                                             |
| Comparative Example 7 | Hydrochloric acid + Hydrofluoric acid | 80               | 15       | None            | -               | 10       | 80               | -        | ×             | 2                                             |

[Example 48]

**[0097]** In Example 48, as conditions of the first pickling by the first pickling device 4, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 90[°C], a pickling time was 20 [s], and a pickling accelerator as an additive was added to the acid liquid. In Example 48, the type of the breaking device 5 was shot blasting. In Example 48, as conditions of the second pickling by the second pickling device 6, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 90[°C], a pickling time was 20 [s], and a pickling inhibitor as an additive was added to the acid liquid. As a result, in Example 48, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 49]

**[0098]** In Example 49, the same conditions as in Example 48 were used except that the temperature of the acid liquid was 95[°C] and the type of the breaking device 5 was a tension leveler as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 95[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 49, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 50]

**[0099]** In Example 50, the same conditions as in Example 48 were used except that the temperature of the acid liquid was 85[°C] and the type of the breaking device 5 was a grinding brush as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 85[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 50, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 51]

**[0100]** In Example 51, the same conditions as in Example 48 were used except that the temperature of the acid liquid was 75[°C] and the type of the breaking device 5 was a laser cleaning device as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 75[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 51, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Comparative Example 4]

**[0101]** In Comparative Example 4, as conditions of the first pickling by the first pickling device 4, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], a pickling time was 20 [s], and a pickling accelerator as an additive was added to the acid liquid. In Comparative Example 4, the breaking device 5 was not used. In Comparative Example 4, as conditions of the second pickling by the second pickling device 6, an acid liquid was hydrochloric acid, a temperature of the acid liquid was 80[°C], a pickling time was 20 [s], and a pickling inhibitor as an additive was added to the acid liquid. As a result, in Comparative Example 4, scale removal was not completed, and a fracture occurrence ratio in cold rolling was 2[%].

[Example 52]

**[0102]** In Example 52, as conditions of the first pickling by the first pickling device 4, an acid liquid was sulfuric acid, a temperature of the acid liquid was 90[°C], a pickling time was 20 [s], and no additive was used. In Example 52, the type of the breaking device 5 was shot blasting. In Example 52, as conditions of the second pickling by the second pickling device 6, an acid liquid was sulfuric acid, a temperature of the acid liquid was 90[°C], a pickling time was 15 [s], and no additive was used. As a result, in Example 52, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 53]

**[0103]** In Example 53, the same conditions as in Example 52 were used except that the temperature of the acid liquid was 95[°C] and the type of the breaking device 5 was a tension leveler as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 95[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 53, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 54]

**[0104]** In Example 54, the same conditions as in Example 52 were used except that the temperature of the acid liquid was 85[°C] and the type of the breaking device 5 was a grinding brush as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 85[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 54, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 55]

**[0105]** In Example 55, the same conditions as in Example 52 were used except that the temperature of the acid liquid was 75[°C] and the type of the breaking device 5 was a laser cleaning device as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 75[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 55, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Comparative Example 5]

**[0106]** In Comparative Example 5, as conditions of the first pickling by the first pickling device 4, an acid liquid was sulfuric acid, a temperature of the acid liquid was 80[°C], a pickling time was 20 [s], and no additive was used. In Comparative Example 5, the breaking device 5 was not used. In Comparative Example 5, as conditions of the second pickling by the second pickling device 6, an acid liquid was sulfuric acid, a temperature of the acid liquid was 80[°C], a pickling time was 15 [s], and no additive was used. As a result, in Comparative Example 5, scale removal was not completed, and a fracture occurrence ratio in cold rolling was 3[%].

[Example 56]

**[0107]** In Example 56, as conditions of the first pickling by the first pickling device 4, an acid liquid was hydrochloric acid + nitric acid, a temperature of the acid liquid was 90[°C], a pickling time was 25 [s], and no additive was used. In Example 56, the type of the breaking device 5 was shot blasting. In Example 56, as conditions of the second pickling by the second pickling device 6, an acid liquid was hydrochloric acid + nitric acid, a temperature of the acid liquid was 90[°C], a pickling time was 25 [s], and no additive was used. As a result, in Example 56, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 57]

**[0108]** In Example 57, the same conditions as in Example 56 were used except that the temperature of the acid liquid was 95[°C] and the type of the breaking device 5 was a tension leveler as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 95[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 57, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 58]

**[0109]** In Example 58, the same conditions as in Example 56 were used except that the temperature of the acid liquid was 85[°C] and the type of the breaking device 5 was a grinding brush as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 85[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 58, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 59]

**[0110]** In Example 59, the same conditions as in Example 56 were used except that the temperature of the acid liquid was 75[°C] and the type of the breaking device 5 was a laser cleaning device as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 75[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 59, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Comparative Example 6]

**[0111]** In Comparative Example 6, as conditions of the first pickling by the first pickling device 4, an acid liquid was hydrochloric acid + nitric acid, a temperature of the acid liquid was 80[°C], a pickling time was 25 [s], and no additive was

used. In Comparative Example 6, the breaking device 5 was not used. In Comparative Example 6, as conditions of the second pickling by the second pickling device 6, an acid liquid was hydrochloric acid + nitric acid, a temperature of the acid liquid was 80[°C], a pickling time was 25 [s], and no additive was used. As a result, in Comparative Example 6, scale removal was not completed, and a fracture occurrence ratio in cold rolling was 3[%].

[Example 60]

**[0112]** In Example 60, as conditions of the first pickling by the first pickling device 4, an acid liquid was hydrochloric acid + hydrofluoric acid, a temperature of the acid liquid was 90[°C], a pickling time was 15 [s], and no additive was used. In Example 60, the type of the breaking device 5 was shot blasting. In Example 60, as conditions of the second pickling by the second pickling device 6, an acid liquid was hydrochloric acid + nitric acid, a temperature of the acid liquid was 90[°C], a pickling time was 10 [s], and no additive was used. As a result, in Example 60, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 61]

**[0113]** In Example 61, the same conditions as in Example 60 were used except that the temperature of the acid liquid was 95[°C] and the type of the breaking device 5 was a tension leveler as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 95[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 61, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 62]

**[0114]** In Example 62, the same conditions as in Example 60 were used except that the temperature of the acid liquid was 85[°C] and the type of the breaking device 5 was a grinding brush as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 85[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 62, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Example 63]

**[0115]** In Example 63, the same conditions as in Example 60 were used except that the temperature of the acid liquid was 75[°C] and the type of the breaking device 5 was a laser cleaning device as conditions of the first pickling by the first pickling device 4, and the temperature of the acid liquid was 75[°C] as a condition of the second pickling by the second pickling device 6. As a result, in Example 63, scale removal was completed, and a fracture occurrence ratio in cold rolling was 0[%].

[Comparative Example 7]

**[0116]** In Comparative Example 7, as conditions of the first pickling by the first pickling device 4, an acid liquid was hydrochloric acid + hydrofluoric acid, a temperature of the acid liquid was 80[°C], a pickling time was 15 [s], and no additive was used. In Comparative Example 7, the breaking device 5 was not used. In Comparative Example 7, as conditions of the second pickling by the second pickling device 6, an acid liquid was hydrochloric acid + nitric acid, a temperature of the acid liquid was 80[°C], a pickling time was 10 [s], and no additive was used. As a result, in Comparative Example 7, scale removal was not completed, and a fracture occurrence ratio in cold rolling was 2[%].

**[0117]** Table 5 indicates that under the conditions that the breaking device 5 was not used and the mechanical breaking treatment of the scale was not performed as in Comparative Examples 4 to 7, scale removal was not completed and fracture occurred in cold rolling regardless of the type of the acid liquid used in the first pickling and the second pickling and the presence or absence of an additive. This is considered to be because a large amount of scale remained, and therefore the remaining scale served as a starting point of fracture to increase a fracture occurrence ratio in cold rolling. On the other hand, Table 5 indicates that under the conditions that the mechanical breaking treatment of the scale was performed by the breaking device 5 as in Examples 48 to 63, scale removal was completed regardless of the condition of the acid liquid used in the first pickling and the second pickling, the presence or absence of an additive, and the type of the breaking device 5. It is also found that no fracture occurred in cold rolling.

Industrial Applicability

**[0118]** The present invention can provide a steel sheet scale removal facility, a steel sheet manufacturing facility, a steel sheet scale removal method, and a steel sheet manufacturing method capable of achieving both a descaling property of a steel sheet and suppression of fracture occurrence in cold rolling.

Reference Signs List

[0119]

|    |     |                            |
|----|-----|----------------------------|
| 5  | 1   | STEEL STRIP                |
|    | 2   | PAY-OFF REEL               |
|    | 3   | WELDING MACHINE            |
|    | 4   | FIRST PICKLING DEVICE      |
| 10 | 5   | BREAKING DEVICE            |
|    | 6   | SECOND PICKLING DEVICE     |
|    | 7   | TENSION REEL               |
|    | 10  | SCALE REMOVAL FACILITY     |
|    | 20  | SCALE                      |
| 15 | 21  | EXTERNAL SCALE             |
|    | 22  | INTERNAL SCALE             |
|    | 23  | BASE METAL                 |
|    | 221 | ISLAND-LIKE INTERNAL SCALE |
|    | 222 | FILM-LIKE INTERNAL SCALE   |
| 20 | 223 | METAL IRON                 |

Claims

1. A steel sheet scale removal facility that removes a scale of a steel sheet to be conveyed, wherein  
 25 a first pickling device that performs first pickling on the steel sheet using a first acid liquid, a breaking device that mechanically breaks the scale, and a second pickling device that performs second pickling on the steel sheet using a second acid liquid are disposed in this order from an upstream side in a conveyance direction of the steel sheet.
2. The steel sheet scale removal facility according to claim 1, wherein a pickling inhibitor is added to the second acid  
 30 liquid.
3. The steel sheet scale removal facility according to claim 1 or 2, wherein a pickling accelerator is added to the first acid liquid, and a pickling time in the first pickling is 10 to 30 [s].
- 35 4. The steel sheet scale removal facility according to any one of claims 1 to 3, wherein a preliminary breaking device that mechanically breaks the scale is disposed on an upstream side of the first pickling device in the conveyance direction of the steel sheet.
- 40 5. A steel sheet manufacturing facility comprising:  
 a hot rolling facility that performs hot rolling on a steel material to obtain a hot rolled sheet;  
 a hot rolled sheet annealing facility that performs hot rolled sheet annealing on the hot rolled sheet as necessary;  
 a scale removal facility that removes a scale of the hot rolled sheet or the hot rolled sheet that has been subjected  
 45 to the hot rolled sheet annealing;  
 a cold rolling facility that performs cold rolling on the hot rolled sheet from which the scale has been removed to obtain a cold rolled sheet; and  
 a finish annealing facility that performs annealing on the cold rolled sheet to obtain a cold rolled annealed sheet,  
 wherein  
 the steel sheet scale removal facility according to any one of claims 1 to 4 is used as the scale removal facility.  
 50
6. A steel sheet scale removal method comprising:  
 pickling a steel sheet that has been subjected to hot rolling with a first pickling device that performs pickling using a  
 first acid liquid;  
 55 mechanically breaking a scale on a surface of the steel sheet pickled with the first pickling device with a breaking device; and  
 pickling the steel sheet treated by the breaking device with a second pickling device using a second acid liquid.

7. The steel sheet scale removal method according to claim 6, wherein a pickling inhibitor is added to the second acid liquid.

8. The steel sheet scale removal method according to claim 6 or 7, wherein a pickling accelerator is added to the first acid liquid, and a pickling time with the first pickling device is 10 to 30 [s].

9. The steel sheet scale removal method according to any one of claims 6 to 8, wherein a preliminary breaking device disposed on an upstream side of the first pickling device in a conveyance direction of the steel sheet mechanically breaks the scale.

10. A steel sheet manufacturing method comprising:

a hot rolling step of performing hot rolling on a steel material to obtain a hot rolled sheet;

a hot rolled sheet annealing step of performing hot rolled sheet annealing on the hot rolled sheet as necessary;

a scale removal step of removing a scale of the hot rolled sheet or the hot rolled sheet that has been subjected to the hot rolled sheet annealing;

a cold rolling step of performing cold rolling on the hot rolled sheet from which the scale has been removed to obtain a cold rolled sheet; and

a finish annealing step of performing annealing on the cold rolled sheet to obtain a cold rolled annealed sheet, wherein

the steel sheet scale removal method according to any one of claims 6 to 9 is used as the scale removal step.

FIG.1

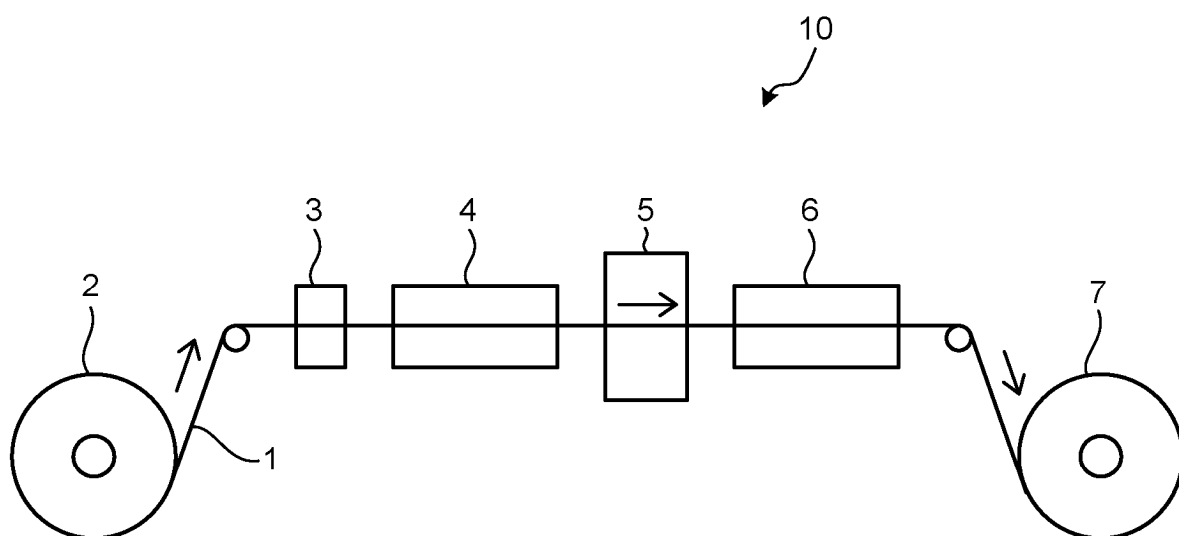
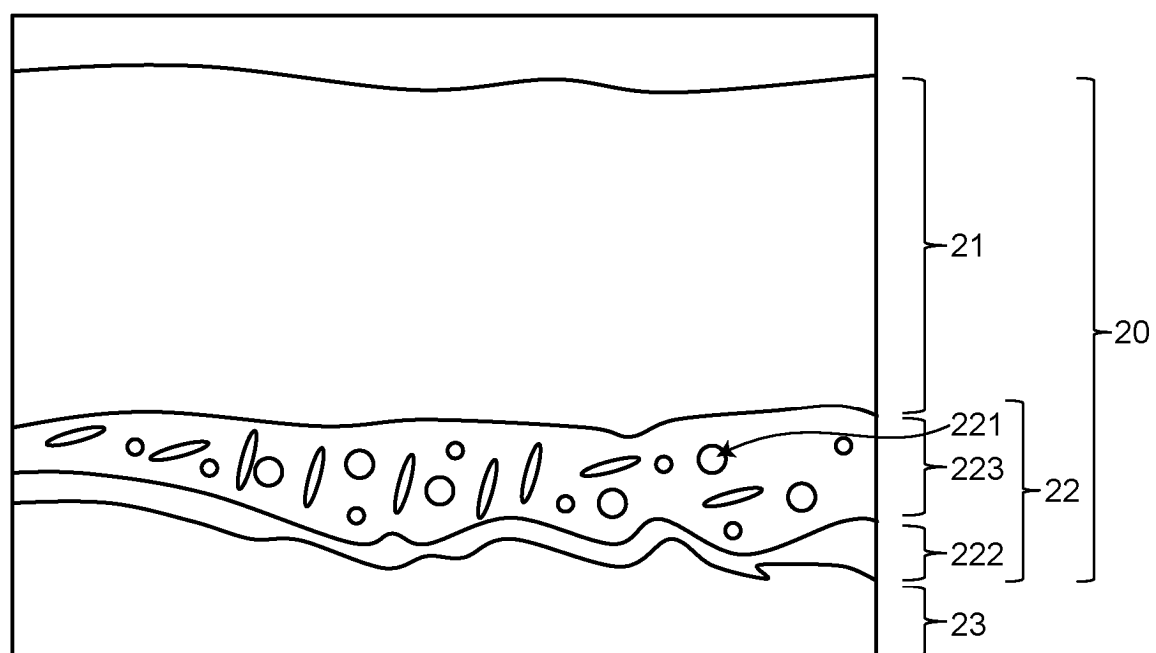


FIG.2



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/036301

**A. CLASSIFICATION OF SUBJECT MATTER**

**C23G 1/08**(2006.01)i; **B21B 45/06**(2006.01)i; **C23G 1/04**(2006.01)i  
FI: C23G1/08; C23G1/04; B21B45/06 R

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)  
C23G1/08; B21B45/06; C23G1/04

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

Published examined utility model applications of Japan 1922-1996  
Published unexamined utility model applications of Japan 1971-2024  
Registered utility model specifications of Japan 1996-2024  
Published registered utility model applications of Japan 1994-2024

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. |
|-----------|----------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | JP 2002-275666 A (NISSHIN STEEL CO., LTD.) 25 September 2002 (2002-09-25)<br>claims, paragraphs [0002], [0017]-[0049], fig. 1, 2 | 1-10                  |
| Y         | JP 2018-168426 A (KOBEL STEEL, LTD.) 01 November 2018 (2018-11-01)<br>claims, paragraphs [0040]-[0067]                           | 1-10                  |
| Y         | JP 2016-194153 A (KOBEL STEEL, LTD.) 17 November 2016 (2016-11-17)<br>claims, paragraphs [0034]-[0077]                           | 1-10                  |
| A         | JP 8-188892 A (SUMITOMO METAL INDUSTRIES, LTD.) 23 July 1996 (1996-07-23)<br>entire text, all drawings                           | 1-10                  |
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☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

\* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

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“E” earlier application or patent but published on or after the international filing date

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“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

16 December 2024

Date of mailing of the international search report

24 December 2024

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)  
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Japan

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Telephone No.

## INTERNATIONAL SEARCH REPORT

### Information on patent family members

International application No.

**PCT/JP2024/036301**

| Patent document cited in search report |             |   | Publication date (day/month/year) | Patent family member(s) | Publication date (day/month/year) |
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