

DESCRIPTION

TITLE OF INVENTION: METHOD OF PRODUCING STEEL SHEET PILE,
AND ROLLING EQUIPMENT LINE FOR PRODUCING STEEL SHEET PILE

5

Technical Field

[0001]

The present invention relates to a method of
producing a steel sheet pile and to a rolling equipment
10 line for producing the steel sheet pile, and more
particularly relates to a method of producing a high-
height steel sheet pile and to a rolling equipment line
for producing the steel sheet pile.

15 Background Art

[0002]

Steel sheet piles suitable as earth retaining
members or the like in engineering works include hat-
shaped steel sheet piles, U-shaped steel sheet piles, and
20 so on. As examples of product shapes, FIGS. 1A and 1B
illustrate cross-sectional shapes of a hat-shaped steel
sheet pile (FIG. 1A) and a U-shaped steel sheet pile
(FIG. 1B), respectively.

[0003]

25 Usually, using a slab, a bloom, or the like as a
material, a steel sheet pile 1 is produced in a rolling
equipment line 2 for steel sheet pile production
illustrated in FIG. 2, for example. In the rolling

equipment line 2 illustrated, the material is charged into a heating device 3 to be heated at a predetermined temperature, for example, at 1300°C, and then the heated material is transferred into a roughing rolling mill 4, intermediate rolling mills 5, and a finishing rolling mill 6 in this order to be rolled into a predetermined cross-sectional shape, thus being formed into a product shape. Rolling in the roughing rolling mill 4 may also be referred to as rough rolling, rolling in the intermediate rolling mills 5 as intermediate rolling, and rolling in the finishing rolling mill 6 as finish rolling. These rolling mills each include rolling rolls including an upper roll and a lower roll that are engraved with a groove called a caliber. Hereinafter, an upper roll and a lower roll may also be collectively referred to as upper and lower rolls or a roll pair.

[0004]

FIG. 3 illustrates one example of calibers engraved on upper and lower rolls of the roughing rolling mill 4 that is used in rough rolling of a hat-shaped steel sheet pile. Three calibers, i.e., a Box caliber 71, a K8 caliber 72, and a K7 caliber 73, are engraved on an upper roll 41 and a lower roll 42. In the rough rolling that uses these calibers, using a slab as a material, first, the width rolling reduction of the slab is performed by the Box caliber 71. Then, the bending deformation of the slab into a hat shape and the thickness rolling reduction are performed by the K8 caliber 72. Further, the

thickness rolling reduction is performed by the K7
caliber 73 so that the material is formed into a shape
close to a product cross-sectional shape. A plurality of
passes of rolling are performed by each of the K8 caliber
5 72 and the K7 caliber 73.

[0005]

Like the roughing rolling mill 4, the intermediate
rolling mill 5 that is used in intermediate rolling also
includes rolling rolls including upper and lower rolls
10 engraved with about two to four calibers. FIG. 4
illustrates one example of calibers engraved on the upper
and lower rolls of the intermediate rolling mill 5 that
is used in the intermediate rolling of the hat-shaped
steel sheet pile. In FIG. 4, two calibers, i.e., a K3
15 caliber 75 and a K6 caliber 74, are engraved on an upper
roll 51 and a lower roll 52. Although not particularly
illustrated, two calibers, i.e., a K4 caliber 77 and a K5
caliber 76, are likewise engraved on upper and lower
rolls of the other intermediate rolling mill 5. In the
20 intermediate rolling, the rough-rolled material is rolled
by these calibers in consecutive order to perform the
thickness rolling reduction and the shape forming so that
the material is formed into a shape more close to the
product cross-sectional shape.

25 [0006]

Likewise, also in the finishing rolling mill 6 that
is used in finish rolling, upper and lower rolls are
engraved with about one to three calibers. FIG. 5

illustrates one example of calibers engraved on the upper and lower rolls of the finishing rolling mill 6 that is used in the finish rolling of the hat-shaped steel sheet pile. In FIG. 5, two calibers, i.e., a K2 caliber 78 and
5 a K1 caliber 79, are engraved on an upper roll 61 and a lower roll 62. In the finish rolling, for the intermediate-rolled material, the final thickness rolling reduction is performed by the K2 caliber 78, and then the bending forming of joint portions 14 is performed by the
10 K1 caliber 79 so that the material is formed into a final product cross-sectional shape.

In the intermediate rolling and the finish rolling, the number of rolling passes by each caliber is basically one, and the number of rolling passes by the same caliber
15 is set to about 2 or 3 at maximum.

[0007]

Also in the case of a U-shaped steel sheet pile, like the hat-shaped steel sheet pile, caliber rolling is performed by a plurality of rolling mills to gradually
20 create a product cross-sectional shape so that a product is produced.

Recently, with respect to such steel sheet piles, there is a tendency to an increase in the size thereof for improving the rigidity and the section modulus and in
25 addition improving the workability.

[0008]

In view of such a tendency, for example, PTL 1 describes a "roll forming machine" that forms a light

steel sheet pile with a large height dimension. The "roll forming machine" described in PTL 1 is a roll forming machine in which a claw forming roll stand, a first half bending forming roll stand, a second half bending forming roll stand, and a shape determining roll stand are configured in this order. The claw forming roll stand includes a pair of upper and lower horizontal caliber rolls that form claws in advance at both ends of a flat material. The first half bending forming roll stand includes a pair of upper and lower horizontal flat rolls that perform the rolling reduction of only a web portion of a light steel sheet pile, and pairs of upper and lower horizontal V-bending rolls that are provided on roll shafts respectively independent of those of the flat rolls and perform the bending forming of second bent portions. It is described that the first half bending forming roll stand performs part of the forming of first bent portions and most of the forming of the second bent portions. The second half bending forming roll stand includes a pair of upper and lower horizontal flat rolls that sandwich the web portion, inclined rolls that are provided on inclined roll shafts and contact the outer surfaces of flange portions, and receiving rolls that receive the lower surface sides of the second bent portions. In PTL 1, it is described that the second half bending forming roll stand performs the final forming of the first bent portions. In PTL 1, it is described that the shape determining roll stand, like conventional,

includes a pair of upper and lower caliber rolls formed with a caliber of a final cross-sectional shape so as to form a shape of a product. With the roll forming machine described in PTL 1, it is described that even when
5 forming a cross-sectional shape with a large height dimension, it is possible to significantly reduce the roll diameter.

[0009]

PTL 2 describes a "steel sheet pile producing
10 method". The technology described in PTL 2 is a steel sheet pile producing method that produces a hat-shaped or U-shaped steel sheet pile by hot rolling and then processes the steel sheet pile by cold working to obtain a steel sheet pile with a different cross-sectional
15 shape. In the technology described in PTL 2, it is described that the cold working is preferably working that increases or reduces the dimension of the steel sheet pile in its width direction or working that increases or reduces the angles of corner portions of the
20 steel sheet pile. According to the technology described in PTL 2, it is described that it is possible to produce even a steel sheet pile that cannot be produced by the same hot rolling equipment, and therefore, the production of a steel sheet pile with a high degree of freedom is
25 made possible.

[0010]

PTL 3 describes a "channel member producing method". The technology described in PTL 3 is a "channel member

producing method" that performs a roughing rolling process and a finishing process in this order. Herein, in the roughing rolling process of PTL 3, the caliber rolling working is performed on a rolling material heated at a predetermined temperature, by a plurality of pairs of double rolling rolls formed with predetermined calibers, thereby producing an intermediate product. In this event, the intermediate product is obtained by forming the shape of a cross section of the rolling material in such a way that a pair of flange portions are inclined outward with respect to the perpendicular, that a web portion has a convex shape protruding to the flange portion side with its middle portion being flat, that both ends of the web portion are joined to the flange portions at approximately right angles, and that the thicknesses of the flange portions and the web portion are approximately the same as the dimensions of a product. Then, in the roughing rolling process, using four-axis rolling rolls, distal end portions of the flange portions of this intermediate product are formed into a concave shape having a middle high portion bulging in the thickness direction in the cross-sectional shape, and then the distal end portions of the flange portions are further rolled in the thickness direction to perform an adjustment that enhances the flatness of the flange portions. The finishing process is a process that processes the convex-shaped web portion of the intermediate product by a plurality of pairs of forming

rolls disposed parallel to each other, so as to form by roll working (cold, warm, hot) a channel member having the flange portions perpendicular to the web portion and approximately parallel to each other, and the flat web portion. In the technology described in PTL 3, it is described that, even in the case of a material with low hot ductility, it is possible to enhance the flatness of the distal end portion end faces of the flange portions while suppressing the occurrence of surface flaws.

10 [0011]

PTL 4 describes a "channel steel producing method". In the "channel steel producing method" described in PTL 4, channel steel is produced by performing rolling with a plurality of pairs of horizontal caliber rolls in order.

15 In this event, the thickness difference of [web > flange] is provided to a web portion and flange portions of a rolled material before a pre-finishing pass and rolling is performed in a shape in which the web and the flanges are curved, and then the opening angles of the flanges are reduced by performing hot rough forming between the pre-finishing pass and a final finishing pass without contacting the rolls with the flange portions.

Subsequently, in PTL 4, bending correction of the rolled material is performed by hot correction after passing through the final finishing pass. In the technology described in PTL 4, it is described that it is possible to mass-produce channel steel made of high alloy steel

easily and at low cost without generating roll slip flaws.

[0012]

PTL 5 describes a "hot rolling channel producing
5 method". The technology described in PTL 5 is a method
of producing a hot rolling channel by performing, using a
plurality of pairs of rolling rolls formed with
predetermined calibers, a hot rolling process that
produces, by hot rolling, a W-shaped work intermediate
10 member having a web portion of a curved surface shape
with a concave surface and a convex surface on its front
and back, and flange portions respectively extending at
approximately right angles from both left and right ends
of the web portion, and a forming process that produces a
15]-shaped channel from the produced W-shaped work
intermediate member by bending forming. In the
technology described in PTL 5, it is described that the
forming process performs, by hot forming, a rough forming
process that uses a first roll contacting the concave
20 surface of the web portion of the work intermediate
member, and a second roll contacting a middle protruding
portion of the convex surface of the web portion and
having a gap from end neighboring portions located closer
to the ends than the middle protruding portion. It is
25 described that, in the rough forming process, it is
preferable to press the flange portions inward by a pair
of left and right guide rolls provided on the left and
right of the first roll and the second roll, thereby

facilitating the bending forming described above.

According to the technology described in PTL 5, it is described that it is possible to perform the production thoroughly by hot working to produce a hot rolling
5 channel of excellent quality.

Citation List

Patent Literature

[0013]

- 10 PTL 1: JP H07-088562 A
PTL 2: JP 2003-230916 A
PTL 3: JP H04-066202 A
PTL 4: JP H05-154502 A
PTL 5: JP 2001-276902 A

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Summary of Invention

Technical Problem

[0014]

However, the technology described in PTL 1 is
20 limited to the production of the light steel sheet pile by the cold bending forming and requires the cold roll forming equipment with the complicated configuration. With the technology described in PTL 2, there is a problem that the cold working equipment is further
25 required in addition to the hot rolling equipment. The technologies described in PTL 3 to PTL 5 are each the method of producing the channel steel or the channel member, and there is a problem that, with the rolling

method targeting the channel steel (the channel member), the bending forming of the web portion and the flange portions is unstable, and further that it is difficult to apply such a rolling method to a steel sheet pile that
5 requires the forming of claws of joint portions in the final stage of the hot rolling. Further, recently, there is a demand for large steel sheet piles with an effective width W of 900 mm and an effective height H exceeding 300 mm.

10 [0015]

In order to roll a steel sheet pile with an effective height H being high (hereinafter also referred to as a "high-height" steel sheet pile), it is necessary to perform the forming (rolling) using a roll having a
15 deep caliber. However, when the deep caliber is engraved on the roll, the diameter of a small diameter portion of the roll becomes so small that the transverse rupture strength of the roll at the time of rolling is reduced. Further, in the rolling of a steel sheet pile with an
20 effective height H being high and an effective width W being wide, when the rolling is performed under the same rolling conditions as the rolling of a conventional steel sheet pile with a narrow effective width, the rolling load and the rolling torque are increased. In the
25 production of the large steel sheet pile, there is a possibility that such a reduction in the transverse rupture strength of the roll and such an increase in the rolling load are combined to cause breakage of the roll

at the time of rolling to disable the rolling. Further,
since the deep caliber is engraved on the roll, the
diameter of the small diameter portion of the roll
becomes too small, and therefore, there is also a problem
5 that the effective margin of use (effective range of use)
of the roll is largely reduced.

[0016]

The present invention has an object to solve the
problems of the conventional technologies described above
10 and to provide a steel sheet pile producing method and a
rolling equipment line for steel sheet pile production
that can produce a high-height steel sheet pile only by a
hot rolling process without using cold rolling. The
"high-height" steel sheet pile referred to herein refers
15 to a large steel sheet pile with an effective width W
equal to or greater than 900 mm and an effective height H
greater than 300 mm and preferably equal to or greater
than 350 mm.

20 Solution to Problem

[0017]

In order to achieve the object described above, the
present inventors have intensively studied on a method of
producing a high-height steel sheet pile without using a
25 rolling roll with a deep caliber. As a result, the
present inventors have come up with performing rolling so
that a flange portion takes a shape that is curved or
bent outward, in a rolling pass in which the rolling load

tends to increase with respect to the caliber depth, for example, in part of rough rolling and intermediate rolling. That is, the present inventors have found that if the rolling is performed so that the flange portion
5 takes the shape that is curved or bent outward after the intermediate rolling, compared to a case where a flange portion has a rectilinear shape, it is possible to allow a caliber of a rolling roll to be a shallow caliber, prevent a reduction in the transverse rupture strength of
10 the rolling roll, and increase the margin of use (effective range of use) of the roll.

[0018]

The present invention has been completed based on such findings and by adding further studies. That is,
15 the gist of the present invention is as follows.

[1] A steel sheet pile producing method wherein rough rolling, intermediate rolling, and finish rolling are applied to a heated material in this order by using a plurality of calibers to produce a steel sheet pile
20 having a flange portion of a predetermined shape, the steel sheet pile producing method including: in the intermediate rolling, performing rolling so that a shape of the flange portion after the intermediate rolling takes a first shape curved or bent outward; and in the
25 finish rolling following the intermediate rolling, performing bending forming so that the flange portion of the first shape takes a rectilinear shape or a second shape curved or bent inward.

[0019]

[2] The steel sheet pile producing method according to [1], wherein a rolling pass configured to perform the bending forming in the finish rolling is a rolling pass
5 configured to use a web guide on a rolling entry side.

[3] The steel sheet pile producing method according to [2], wherein, in a cross section perpendicular to a rolling direction, the web guide has a width of a web guide upper surface equal to or narrower than a lower
10 surface width of a web of a material after a final rolling pass of the intermediate rolling and has an angle formed by a web guide upper surface and a web guide side surface, the angle being equal to an angle formed by a joining portion between the web portion and a flange
15 portion of the material after the final rolling pass of the intermediate rolling.

[4] The steel sheet pile producing method according to any one of [1] to [3], wherein, in the finish rolling, claw bending forming is performed in a rolling pass
20 following a rolling pass configured to perform the bending forming.

[5] The steel sheet pile producing method according to [4], wherein claw bending preforming is performed on an exit side of the rolling pass configured to perform the
25 bending forming in the finish rolling, and the claw bending forming is performed after the claw bending preforming.

[0020]

[6] A rolling equipment line for producing a steel sheet pile, the rolling equipment line including a heating device, a roughing rolling mill, an intermediate rolling mill, and a finishing rolling mill disposed in this
5 order, wherein: the roughing rolling mill, the intermediate rolling mill, and the finishing rolling mill are rolling mills each including upper and lower rolls engraved with a caliber; at least the caliber of the entire intermediate rolling mill or the caliber of a part
10 of the intermediate rolling mill on its downstream side is a caliber engraved so that a flange portion takes a first shape curved or bent outward; and the caliber of a part of the finishing rolling mill is a caliber engraved so that the flange portion of the first shape is bent and
15 formed into a rectilinear shape or a second shape curved or bent inward.

Advantageous Effects of Invention

[0021]

20 According to the present invention, a steel sheet pile with a high effective height and a large effective width can be easily and stably produced with high productivity without an accident such as breakage of a roll only by a hot rolling process without using cold
25 rolling, so that an industrially remarkable effect is exhibited.

Brief Description of Drawings

[0022]

FIGS. 1A and 1B are explanatory diagrams schematically illustrating examples of product shapes of steel sheet piles, wherein FIG. 1A is an example of a hat-shaped steel sheet pile, and FIG. 1B is an example of a U-shaped steel sheet pile;

FIG. 2 is an explanatory diagram illustrating one example of a rolling equipment line for steel sheet pile production;

10 FIG. 3 is an explanatory diagram illustrating one example of rough rolling calibers (cross section) that are used for producing a hat-shaped steel sheet pile;

FIG. 4 is an explanatory diagram illustrating one example of intermediate rolling calibers (cross section) that are used for producing the hat-shaped steel sheet pile;

FIG. 5 is an explanatory diagram illustrating one example of finish rolling calibers (cross section) that are used for producing the hat-shaped steel sheet pile;

20 FIG. 6 is a cross-sectional view illustrating one example of a rough rolling caliber K7 suitable for producing a hat-shaped steel sheet pile in the present invention;

FIGS. 7A and 7B are cross-sectional views illustrating examples of intermediate rolling calibers K3 each suitable for producing the hat-shaped steel sheet pile in the present invention, wherein FIG. 7A illustrates an example in which flange portions are

curved outward, and FIG. 7B illustrates an example in which flange portions are bent outward;

FIG. 8 is a cross-sectional view illustrating one example of a finish rolling caliber K2 suitable for
5 producing the hat-shaped steel sheet pile in the present invention;

FIG. 9 is an explanatory diagram schematically illustrating one example of a product shape of a steel sheet pile;

10 FIGS. 10A and 10B are cross-sectional views schematically illustrating a state of unbending forming of flange portions in finish rolling;

FIGS. 11A and 11B are explanatory diagrams schematically illustrating a web guide, wherein FIG. 11A
15 illustrates a shape of the web guide, and FIG. 11B illustrates an arrangement position of the web guide; and

FIG. 12 is an explanatory diagram schematically illustrating one example of a claw bending roller.

20 Description of Embodiments

[0023]

In an embodiment of the present invention, a steel sheet pile 1 is produced using a rolling equipment line 2 illustrated in FIG. 2, for example.

25 In this embodiment, a material (steel material; e.g., a rectangular slab) is charged into a heating device 3 to be heated at a predetermined temperature, for example, at 1300°C. Thereafter, the heated material is

transferred into a roughing rolling mill 4, intermediate rolling mills 5, and a finishing rolling mill 6 in this order to be rolled, thereby producing a hat-shaped steel sheet pile 1A having a cross-sectional shape illustrated in FIG. 1A, for example. In the rolling equipment line 2, by rolling a plurality of materials in sequence, it is possible to continuously produce products (hat-shaped steel sheet piles 1A) of the same size.

[0024]

10 In the rolling (rough rolling) in the roughing rolling mill 4, the rough rolling of the heated material is performed by three calibers, i.e., a Box caliber 71, a K8 caliber 72, and a K7 caliber 73, that are engraved on upper and lower rolls 41, 42 as illustrated in FIG. 3. A
15 plurality of passes of rolling are performed by each of the K8 caliber 72 and the K7 caliber 73. In the rough rolling, using the slab as the material, first, the width rolling reduction of the material (slab) is performed by the Box caliber 71, then the slab is turned by 90
20 degrees, and then the bending deformation of the slab into a hat shape and the thickness rolling reduction (thickness reduction) are performed by the K8 caliber 72. Further, the thickness rolling reduction and the rough forming of joint portions are continuously performed by
25 the K7 caliber 73 so that the slab is formed into a shape close to a product cross-sectional shape. A height H7 of the K7 caliber 73 is set to be greater than a height H8

of the K8 caliber 72, and the stretching deformation of flange portions is also performed by the K7 caliber 73.

[0025]

As illustrated in FIG. 6, a K7 caliber 731 may be
5 engraved so that the flange portions take a shape that is curved outward, thereby making it possible to roll the flange portions into the shape that is curved outward. The flange portions may alternatively be rolled into a shape that is bent outward. However, in the rough
10 rolling stage, in a rolling pass other than a rolling pass in which the roll strength tends to be a problem with respect to the rolling load due to the caliber depth being deep, it is not necessary to roll the flange portions into the shape that is curved or bent outward.

15 Then, using a caliber engraved on upper and lower rolls of the intermediate rolling mill 5, the rolling (intermediate rolling) is applied to the material (intermediate material) shaped by the rough rolling. In the rolling equipment line 2 illustrated in FIG. 2, two
20 rolling mills (two roll pairs) are disposed as the intermediate rolling mills 5 so that it is also possible to perform tandem rolling by two calibers arranged side by side in the rolling direction. In this rolling (intermediate rolling), the thickness rolling reduction
25 of the material is mainly performed, but it is also possible to add the stretching deformation of the flange portions.

[0026]

In the present invention, the rolling is performed so that the shape after the intermediate rolling takes a first shape being a shape in which a flange portion is curved or bent outward. The flange portion of the first
5 shape refers to a flange portion having a shape that is curved or bent outward after the intermediate rolling.

In a rolling pass in which the rolling load tends to increase with respect to the caliber depth, a material is rolled using a caliber engraved on upper and lower rolls
10 (a roll pair) so that flange portions take a shape that is curved or bent outward. As such a rolling pass in which the rolling load tends to increase with respect to the caliber depth, there can be cited, for example, a rolling pass of part of the rough rolling, a rolling pass
15 of the entire intermediate rolling, a rolling pass of part of the intermediate rolling on its downstream side, or the like. In the present invention, it is preferable that, in order to allow flange portions to have a shape that is curved or bent outward after the intermediate
20 rolling, a caliber engraved on upper and lower rolls (a roll pair) so that the flange portions take the shape curved or bent outward be used as at least a rolling pass of the entire intermediate rolling or a rolling pass of part of the intermediate rolling on its downstream side.
25 As the caliber to be used, a caliber that is engraved so that flange portions take a shape curved outward is preferable, for example, as illustrated in FIG. 6 in the rough rolling and FIG. 7A in the intermediate rolling.

It may alternatively be a caliber that is engraved so that flange portions take a shape bent outward as illustrated in FIG. 7B. This makes it possible to make the height H (H3 in each of FIGS. 7A and 7B) of the
5 caliber smaller than a case where flange portions have a rectilinear shape, so that the effective margin of use (effective range of use) of the roll is increased.

[0027]

The intermediate rolling mills 5 include, as a
10 second intermediate rolling mill, for example, rolling rolls in which an upper roll 51 and a lower roll 52 are engraved with two calibers, i.e., a K3 caliber 751 (see each of FIGS. 7A and 7B) and a K6 caliber 741 (not illustrated), and, although not illustrated, include, as
15 a first intermediate rolling mill, for example, rolling rolls in which upper and lower rolls are engraved with two calibers, i.e., a K5 caliber 761 and a K4 caliber 771. Using these calibers that are engraved so that the flange portions take a shape curved or bent outward after
20 the intermediate rolling, it is possible to perform rolling including tandem rolling in order as the intermediate rolling on the rough-rolled material.

[0028]

Assuming that the heights H of the calibers that are
25 used in the intermediate rolling are, for example, H6 in the K6 caliber, H5 in the K5 caliber, H4 in the K4 caliber, and H3 in the K3 caliber in order of rolling

pass, it is preferable to set the heights of the calibers so as to satisfy formula (1) below.

$$H_6 \leq H_5 \leq H_4 \leq H_3 \quad (1)$$

By setting the heights of the calibers used in the intermediate rolling so as to satisfy the formula (1), it is possible to add the stretching deformation of the flange portions by the respective calibers in consecutive order so that it is possible to expect an effect that the rolling can be stably performed on the material of a high-height steel sheet pile.

[0029]

Then, using a caliber engraved on upper and lower rolls of the finishing rolling mill 6, the rolling (finish rolling) is further applied to the intermediate material shaped by the intermediate rolling.

The finishing rolling mill 6 includes, for example, rolling rolls in which an upper roll 61 and a lower roll 62 are engraved with two calibers, i.e., a K2 caliber 78 (see FIG. 8) and a K1 caliber 79 (not illustrated). In the finish rolling of this embodiment, the unbending forming of the flange portions is performed using the K2 caliber 78 in a first rolling pass to form the flange portions into a rectilinear shape. The K2 caliber 78 is a caliber that is engraved on the upper and lower rolls so that the flange portions take a rectilinear shape. In the K2 caliber, it is preferable that a web lower surface width of the K2 caliber (B2 in FIG. 8) be equal to a web lower surface width before the K2 caliber rolling (B3 in

each of FIGS. 7A and 7B) and that an angle formed by the web and the flange of the K2 caliber (θ_2 in FIG. 8) be equal to an angle formed by the web and the flange before the K2 caliber rolling (θ_3 in each of FIGS. 7A and 7B).

5 This makes it possible to stably perform the unbending forming of the flange portions at the time of the unbending forming of the flange portions without shifting of the material in the up-down direction or the left-right direction.

10 [0030]

The description has been given above of the example in which the flange portions take the rectilinear shape in the final product shape, but the flange portions in the product shape may have a shape other than the
15 rectilinear shape. For example, like a cross-sectional shape schematically illustrated in FIG. 9, the flange portions may be formed into a shape that is curved or bent inward, thereby obtaining a final product shape. The K2 caliber 78 in this case is a caliber that is
20 engraved on the upper and lower rolls so that the flange portions take the shape that is curved or bent inward.

The shape of the flanges shaped by the bending forming in the finish rolling, i.e., the rectilinear shape of the flange portions or the shape in which the
25 flange portions are curved or bent inward, will be referred to as a second shape.

[0031]

FIGS. 10A and 10B illustrate the outline of the unbending forming of the flange portions by the K2 caliber 78. FIG. 10A is a cross-sectional view schematically illustrating a state when the material
5 (intermediate material) after a final rolling pass of the intermediate rolling starts to contact the K2 caliber (at the time of biting). FIG. 10B is a cross-sectional view illustrating a state where the forming has been completed by the K2 caliber (at the time of the completion of the
10 bending forming). In this unbending forming, it is preferable to engrave a caliber so that while a web portion 11, flange portions 12, and arm portions 13 of the material (intermediate material) contact the rolls (caliber) so as to be subjected to the unbending forming,
15 joint portions 14 are prevented from contacting the rolls (caliber) so as not to be deformed. The bending forming of claw portions of the joint portions is performed by the K1 caliber 79. The number of rolling passes by each of the K2 caliber 78 and the K1 caliber 79 is basically
20 one.

In the first rolling pass of the finish rolling, the unbending forming of the flange portions is performed as described above, and it is more preferable to perform the rolling using a web guide 60 on the entry side of the
25 rolling so as to make it possible to stably perform the unbending forming of the flange portions without variation in unsteady length at front and rear ends of the material shaped by the intermediate rolling due to

shifting of the material in the up-down direction or the left-right direction.

[0032]

Preferably, the web guide 60 to be used has a shape
5 in which a width B of a web guide upper surface 601 is
equal to a web lower surface width B3 so as to match the
web lower surface width B3 after the completion of the
intermediate rolling, or is slightly narrower than the
web lower surface width B3, and has a shape in which an
10 angle θ formed by the web guide upper surface 601 and a
web guide side surface 602 is equal to θ_3 of the caliber
K3 at the time of the completion of the intermediate
rolling (an angle formed by a joining portion between the
web portion 11 and the flange portion 12). There is a
15 possibility of generating scratches on the flange inner
surfaces or the web lower surface with the web guide in
which the width B of the web guide upper surface 601 is
equal to the web lower surface width B3, it is preferable
that, usually, B be set to be narrower than B3 by about 2
20 mm to 8 mm. FIG. 11A illustrates a preferred shape of
the web guide. FIG. 11B illustrates an arrangement
position of the web guide 60.

[0033]

By using the web guide 60 described above on the
25 rolling entry side of the first rolling pass of the
finish rolling, the web lower surface and the joining
portions between the web portion and the flange portions
of the material shaped by the intermediate rolling can be

sufficiently held and guided to the K2 caliber 78. As a result, it is possible to prevent shifting of the material in the up-down direction or the left-right direction, thereby stably performing the unbending forming of the flange portions.

[0034]

The bending forming of the claw portions of the joint portions 14 is performed by the K1 caliber 79 serving as a final caliber. However, there is a case where, only with this single caliber, the claw bending amount becomes excessive so that proper claw bending forming cannot be performed. In such a case, it is preferable to perform claw bending preforming of the joint portions. It is preferable that the claw bending preforming of the joint portions be performed by disposing claw bending rollers described in JP 2006-272343 A on the exit side (rear surface) of the K2 caliber 78, for example.

In the preforming that bends a claw inward from the outside, using a claw bending roller 8 illustrated in FIG. 12, a claw 7A is bent inward from the outside by a vertical roller 81 in a state where a bent portion of the arm portion 13 is restricted by a vertical roller 82, and a horizontal portion of the arm portion 13 is vertically restricted by horizontal rollers 83a, 83b. The vertical roller 81 is disposed so that the center axis is located outward of the claw 7A.

[0035]

By performing the claw bending forming by the K1 caliber after performing the claw bending preforming of the joint portions using the claw bending rollers
5 described above, it is possible to optimize the claw bending amount by the K1 caliber.

In the embodiment described above, the unbending forming of the flange portions is performed in the first rolling pass of the finish rolling, but the unbending
10 forming may alternatively be performed step by step by a plurality of rolling passes including the first rolling pass. In this case, the unbending forming of the flanges may be performed using the K1 caliber 79 in addition to the K2 caliber 78, or the unbending forming may be
15 performed by providing another caliber between the K2 caliber 78 and the K1 caliber 79.

[0036]

Hereinafter, the present invention will be further described based on Examples.

20

Examples

[0037]

Using the rolling equipment line 2 illustrated in FIG. 2, a material (steel slab (steel grade: SYW295)) was
25 charged into the heating device 3 and heated at a heating temperature: 1300°C, and then was subjected to the rolling in the roughing rolling mill 4, the intermediate rolling mills 5, and the finishing rolling mill 6,

thereby producing a high-height hat-shaped steel sheet pile having a shape illustrated in FIGS. 1A and 1B, with a web portion thickness: 17 mm, a flange portion thickness: 12 mm, an effective height H: 370 mm, and an effective width W: 900 mm.

In the rough rolling, the heated material (steel material) was rolled by the roughing rolling mill 4 including the upper and lower rolls engraved with the Box caliber, the K8 caliber, and the K7 caliber, so that the material was formed into a shape close to a product cross-sectional shape. Then, the rolling (intermediate rolling) was applied to the material shaped by the rough rolling, using the first intermediate rolling mill 5 including the upper and lower rolls engraved with the K5 caliber and the K4 caliber, and the second intermediate rolling mill 5 including the upper and lower rolls engraved with the K6 caliber and the K3 caliber, in this order. Specifically, in the intermediate rolling, the rolling was performed by the caliber K5 and the caliber K6 in this order (rolling reduction was not performed by K5) in a first rolling pass, the rolling was performed by the caliber K6 and the caliber K5 in this order in a second rolling pass, and the rolling was performed by the caliber K4 and the caliber K3 in this order in a third rolling pass.

[0038]

In order to allow the flange portions to have a first shape curved or bent outward after the completion

of the intermediate rolling, the caliber used in the intermediate rolling was a caliber with a shallow caliber depth, for example, having a shape illustrated in FIG. 7A in the case of the K3 caliber. Likewise, the K6 caliber, the K5 caliber, and the K4 caliber were also calibers each having a shallow caliber depth. Further, in the intermediate rolling, the caliber depths H of the used calibers were changed to satisfy formula (1) below in order of the passed calibers (in order of the K6 caliber, the K5 caliber, the K4 caliber, and the K3 caliber).

$$H_6 \leq H_5 \leq H_4 \leq H_3 \quad (1)$$

The depths H of the used calibers are each indicated in Table 1 by a ratio relative to a product height (reference: 1.0). A steel sheet pile No. 3 is a comparative example in which calibers each allowing flange portions to take a rectilinear shape were used in all rolling passes of the intermediate rolling.

[0039]

With respect to the rolling rolls engraved with each of the calibers with the depths H described above, using a finite element method in advance, the stress generated on portions of the rolling rolls at the time of the rolling was calculated, thereby calculating a rolling withstand load (unit MN) with each of the calibers in such a way that the stress does not exceed the allowable stress of the roll material. The obtained results are indicated together in Table 1. Naturally, as the caliber

depth H increases, the value of the withstand load decreases so that the risk of roll breakage increases.

Then, the material shaped by the intermediate rolling was subjected to the finish rolling so as to be
5 formed into a product shape. In a first rolling pass of the finish rolling, using the K2 caliber 78, the unbending forming of the flange portions was performed from a shape with the flange portions being bent outward to a second shape with the flange portions being
10 rectilinear.

[0040]

In part of the first rolling pass of the finish rolling, the rolling was performed using the web guide 60 on the rolling entry side. The web guide 60 had the
15 shape illustrated in FIG. 11A, in which the width B of the upper surface (web guide upper surface) was set to the dimension approximately equal to the web lower surface width B3 of the K3 caliber (the dimension narrower than B3 by 4 mm), and the angle θ formed by the
20 web guide upper surface and the web guide side surface was set to be equal to the angle θ_3 formed by the joining portion between the web portion and the flange portion at the time of the completion of the intermediate rolling.

After performing the first rolling pass of the
25 finish rolling, the claw bending forming of the joint portions was performed using the K2 caliber 79, thereby obtaining a hat-shaped steel sheet pile (product). In either of the examples of the present invention, the

preforming of the claw bending forming was performed using claw bending rollers on the exit side of the first rolling pass, and then the claw bending forming was performed.

5 [0041]

With respect to the obtained product (steel sheet pile), the effective width dimension W and the height dimension H (see FIG. 1A) were measured from a rolling front end portion and the joint shape was visually
10 confirmed, and the unsteady portion lengths (lengths (m) in the longitudinal direction) of rolling front and rear end portions where these dimensions W and H and the joint shape did not fall in the tolerance ranges, were measured.

15 The obtained results are indicated together in Table 1.

[0042]

[Table 1]

Steel sheet pile No.	Intermediate rolling								Finish rolling	Production results			Remarks
	Caliber depth H (ratio)*				Roll withstand load (MN)				Use or nonuse of web guide in first rolling pass	Length of unsteady portion (m)		Others	
	K6	K5	K4	K3	K6	K5	K4	K3		Front end portion	Rear end portion		
1	0.84	0.85	0.86	0.86	16.7	16.5	15.8	15.7	No	1.9	1.7	-	Example of the present invention
2	0.84	0.85	0.86	0.86	16.7	16.5	15.8	15.7	Yes	1.0	0.9	-	Example of the present invention
3	0.93	0.95	0.96	0.96	12.6	12.4	12.1	11.8	No	-	-	Stopped in K5 rolling	Comparative example

*) The ratio of the depth of a caliber when the height of a product is used as a reference (= 1.0)

[0043]

With respect to any conditions of steel sheet piles No. 1 and No. 2 being the examples of the present invention, the rolling up to a final pass of the finish
5 rolling was able to be performed, thus having succeeded in collection of the products. In particular, in the case of the steel sheet pile No. 2, the occurrence of unsteady portions, i.e., a front end portion and a rear end portion, that did not serve as a product was reduced
10 by the effect of the web guide so that the good results were obtained.

On the other hand, in the case of the steel sheet pile No. 3 being the comparative example, the actual rolling load reached 12.54 MN in the rolling by the K5
15 caliber to exceed a roll withstand load of 12.45 MN, and therefore, further rolling was determined to be dangerous so that the rolling by the K4 caliber and thereafter was abandoned.

In this way, according to the present invention, the
20 unbending forming of the flange portions and further the claw bending forming thereafter can be stably performed so that it is possible to easily produce a high-height steel sheet pile. Further, according to the present invention, the depth of the caliber engraved on the
25 rolling rolls can be made shallow so that a reduction in the transverse rupture strength of the rolls is suppressed.

Reference Signs List

[0044]

- 1 steel sheet pile
- 1A hat-shaped steel sheet pile
- 5 1B U-shaped steel sheet pile
- 2 rolling equipment line (rolling equipment line
for steel sheet pile production)
- 3 heating device
- 4 roughing rolling mill
- 10 5 intermediate rolling mill
- 6 finishing rolling mill
- 8 claw bending roller
- 11 web portion
- 12 flange portion
- 15 13 arm portion
- 14 joint portion
- 41 upper roll (upper roughing roll)
- 42 lower roll (lower roughing roll)
- 51 upper roll (upper intermediate roll)
- 20 52 lower roll (lower intermediate roll)
- 60 web guide
- 61 upper roll (upper finishing roll)
- 62 lower roll (lower finishing roll)
- 81 vertical roller
- 25 82 vertical roller
- 83 horizontal roller
- 601 web guide upper surface
- 602 web guide side surface

CLAIMS

1. A steel sheet pile producing method wherein rough rolling, intermediate rolling, and finish rolling
5 are applied to a heated material in this order by using a plurality of calibers to produce a steel sheet pile having a flange portion of a predetermined shape, the steel sheet pile producing method comprising:

in the intermediate rolling, performing rolling so
10 that a shape of the flange portion after the intermediate rolling takes a first shape curved or bent outward; and

in the finish rolling following the intermediate rolling, performing bending forming so that the flange portion of the first shape takes a rectilinear shape or a
15 second shape curved or bent inward.

2. The steel sheet pile producing method according to claim 1, wherein a rolling pass configured to perform the bending forming in the finish rolling is a
20 rolling pass configured to use a web guide on a rolling entry side.

3. The steel sheet pile producing method according to claim 2, wherein, in a cross section
25 perpendicular to a rolling direction, the web guide has a width of a web guide upper surface equal to or narrower than a lower surface width of a material web after a final rolling pass of the intermediate rolling and has an

angle formed by a web guide upper surface and a web guide side surface, the angle being equal to an angle formed by a joining portion between the material web and a material flange after the final rolling pass of the intermediate
5 rolling.

4. The steel sheet pile producing method according to any one of claims 1 to 3, wherein, in the finish rolling, claw bending forming is performed in a
10 rolling pass following a rolling pass configured to perform the bending forming.

5. The steel sheet pile producing method according to claim 4, wherein claw bending preforming is
15 performed on an exit side of the rolling pass configured to perform the bending forming in the finish rolling, and the claw bending forming is performed after the claw bending preforming.

20 6. A rolling equipment line for producing a steel sheet pile, the rolling equipment line including a heating device, a roughing rolling mill, an intermediate rolling mill, and a finishing rolling mill disposed in this order, wherein:

25 the roughing rolling mill, the intermediate rolling mill, and the finishing rolling mill are rolling mills each including upper and lower rolls engraved with a caliber;

at least the caliber of a part of the intermediate rolling mill is a caliber engraved so that a flange portion takes a first shape curved or bent outward; and

the caliber of a part of the finishing rolling mill
5 is a caliber engraved so that the flange portion of the first shape is bent and formed into a rectilinear shape or a second shape curved or bent inward.