

Description

Title of Invention:

STEEL SHEET PILE STRAIGHTER AND STRAIGHTENING METHOD AND
5 STEEL SHEET PILE PRODUCING METHOD

Technical Field

[0001] The present invention relates to a straightener and a straightening method of a steel sheet pile having joints at both ends in the width direction of
10 the steel sheet pile, such as a substantially U-shaped steel sheet pile that includes a web, flanges on both sides of the web, and further joints at both outer ends of the flanges, or a hat-shaped steel sheet pile that has arms between the flanges and the joints, and also relates to a method of producing such a steel sheet pile.

15 Background Art

[0002] Steel sheet piles of various cross-sectional shapes have been developed as civil works have increased in scale and new construction methods have been developed, and they are roughly classified into a U-shaped steel sheet pile type in which joints are provided directly at both outer ends of flanges in the
20 width direction of the steel sheet pile and a hat-shaped steel sheet pile type in which arms are provided between the flanges and the joints. FIG. 3 is a view showing a cross-sectional shape of a U-shaped steel sheet pile 110, and Figure 4 is a view showing a cross-sectional shape of a hat-shaped steel sheet pile 120. The distance between the outer edges of left and right joints 104 is referred to as
25 the total width W.

[0003] In a common production method of these steel sheet piles, a continuously cast slab or a steel slab adjusted to an appropriate size and shape is hot-rolled using caliber rolls that form it into a target shape. It is known that a U-shaped steel sheet pile and a hat-shaped steel sheet pile cooled after
30 undergoing this rolling step is deformed in a longitudinal (conveying) direction after rolling and cooling due to the difference in temperature upon completion of rolling between a flange 102 and a web 101 attributable to the difference in plate

thickness. Specifically, for example, a deformation of a so-called upward camber in which the hat-shaped steel sheet pile 120 curves with the side of the web 101 as the inner side of the curve as shown in FIG. 5, or a deformation of a so-called downward camber in which the hat-shaped steel sheet pile 120 curves with the side of arms 103 as the inner side of the curve as shown in FIG. 6 occurs.

[0004] To remove such a camber and obtain a straight product, a cold straightening step is typically performed before shipment of the product. For example, in a roll-straightening method, the web 101 of a steel sheet pile having developed such a camber is restrained by rolls from the upper and lower sides, and a force enough to cause the steel sheet pile to partially plastically deform is applied alternately from the upper side and the lower side. Thus, the steel sheet pile is bent and unbent to remove the camber.

[0005] FIG. 7 shows a typical arrangement of rolls 2, 3 of a straightener 21 in the roll-straightening method. The upper rolls 2 and the lower rolls 3 are arranged in the feeding direction F of the steel sheet pile 100, on the upper side of the web 101 and the lower side of the web 101, respectively, in a vertically staggered (alternating) manner.

[0006] Further, these upper and lower rolls 2, 3 are arranged such that the lowermost end of the outer circumferential surface of each roll of the upper rolls 2 is located below the uppermost end of the outer circumferential surface of each roll of the lower rolls 3, so that the steel sheet pile 100 passes through a feeding path (pass line P) having concave and convex parts alternately in the vertical direction.

[0007] As a result, while being supported at three points between the upper rolls 2 and the lower rolls 3, the steel sheet pile 100 can be bent and unbent alternately from the upper side and the lower side to remove the camber.

[0008] For example, in Patent Literature 1 concerning a method of straightening a hat-shaped steel sheet pile, an interval between roll surfaces of side rolls in the width direction is set to become smaller from the upstream side toward the downstream side of a feeding path. The hat-shaped steel sheet pile is passed through the feeding path such that a web, both flanges, and both arms are

held between a roll surface of an upper roll and a roll surface of a lower roll while both joints are held between the roll surfaces of the side rolls from outer sides in the width direction. In this way, the web, both flanges, and both arms are bent and unbent in the up-down direction alternately and repeatedly to correct the camber of the hat-shaped steel sheet pile and at the same time reduce the total width of the hat-shaped steel sheet pile.

[0009] Patent Literature 2 discloses a technique in which a roll-straightening machine that includes horizontal rolls and presses a web of an H-section steel to thereby correct its bend is equipped with vertical rolls that press flanges of the H-section steel from both side surfaces thereof and a device that generates a pressing force in the web height direction through the vertical rolls. The horizontal rolls and the vertical rolls are arranged so as to be offset from each other in the axial direction of the horizontal rolls such that a cross-section of the web is subjected to a bending stress that is placed as the web is pressed and a compression stress that is placed by the vertical rolls. Thus, the H-section steel is bent in the strong-axis direction at the same time as being bent in the up-down direction to thereby correct the shape of the H-section steel.

Citation List

Patent Literature

[0010] Patent Literature 1: JP-2017-131899A
Patent Literature 2: JP-H08-174071A

Summary of Invention

Technical Problem

[0011] However, the above-described conventional techniques have the following problems yet to be solved.

The technique disclosed in Patent Literature 1 is a straightening technique relating to a hat-shaped steel sheet pile and cannot be applied to a U-shaped steel sheet pile. It has also a problem in that it takes time to change the interval between the roll surfaces of the side rolls in the width direction and the inclination angles of the roll surfaces of the side rolls.

[0012] The technique disclosed in Patent Literature 2 is a straightening technique relating to an H-section steel and cannot be applied to a U-shaped steel sheet pile or a hat-shaped steel sheet pile. Thus, appropriate conditions for steel sheet piles are difficult to estimate, as well as an enormous cost of equipment investment is incurred as the vertical rolls that press the flanges from both side surfaces are significantly increased in number.

[0013] Having been contrived in view of these circumstances, the present invention aims to provide a technique for correcting both deformation in the width direction and camber of a steel sheet pile at the same time. This technique can be applied to a U-shaped steel sheet pile or a hat-shaped steel sheet pile having joints at both ends in the width direction, facilitating changing a set width and allowing a set value to be changed for each product produced at the same production timing. In addition, the present invention provides a technique for efficient straightening that is excellent in maintainability and cost-effectiveness.

Solution to Problem

[0014] A steel sheet pile straightener according to the present invention that has been developed to solve the above-described problems and achieve the above-described aim is a device to straighten a steel sheet pile having joints at both ends in a width direction of the steel sheet pile. The steel sheet pile straightener has a roll-straightening unit having a plurality of upper rolls and a plurality of lower rolls arranged in a staggered manner, and a pair of vertical rolls disposed on a downstream side of the roll-straightening unit in a conveying direction of the steel sheet pile, and is characterized in that a separation distance between the pair of vertical rolls is set to be smaller than a total width of a product of the steel sheet pile.

[0015] The steel sheet pile straightener according to the present invention is considered to have more preferable solutions as follows:

a. The roll-straightening unit includes, in at least one lower roll among the plurality of lower rolls or at least one upper roll among the plurality of upper rolls, a pair of joint straightening parts that corrects the total width of the

product of the steel sheet pile by pressing the joints, and a separation distance between the pair of joint straightening parts is larger than the separation distance between the pair of vertical rolls.

5 b. The pair of vertical rolls are formed by flat rolls that are vertically installed.

c. The steel sheet pile straightener is configured such that the separation distance between the pair of vertical rolls is adjustable according to the total width of the product of the steel sheet pile.

10 d. The separation distance WL between the pair of vertical rolls and the total width W of the product of the steel sheet pile satisfy the following expression (1):

$$0.70 \leq WL/W \leq 0.98 \cdots (1).$$

[0016] A steel sheet pile straightening method according to the present invention that has been developed to solve the above-described problems and
15 achieve the above-described aim is characterized by, by using one of the above-described steel sheet pile straighteners, straightening a steel sheet pile having joints at both ends in a width direction of the steel sheet pile by means of the roll-straightening unit, and then pressing the joints toward a center of the steel sheet pile in the width direction by means of the pair of vertical rolls.

20 **[0017]** A method of producing a steel sheet pile according to the present invention that has been developed to solve the above-described problems and achieve the above-described aim is characterized by having a step of straightening a steel sheet pile using the above-described steel sheet pile straightening method.

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Advantageous Effects of Invention

[0018] According to the present invention, the difference in total width between end portions and each position in the longitudinal position of a product of a U-shaped steel sheet pile or a hat-shaped steel sheet pile having joints at
30 both ends in the width direction can be corrected to be smaller than that before straightening. Moreover, the present invention allows efficient adjustment of the vertical rolls, in addition to being able to significantly reduce the number of

vertical rolls and being excellent in maintainability and cost effectiveness.

Brief Description of Drawings

[0019] FIGS. 1(a) and 1(b) are conceptual views showing an arrangement of rolls of a steel sheet pile straightener according to one embodiment of the present invention, with FIG. 1(a) being a simplified side view and FIG. 1(b) being a top view.

FIGS. 2(a) and 2(b) are graphs showing the results of straightening a steel sheet pile using the steel sheet pile straightener of the embodiment and studying the total widths at plural position in the longitudinal positions before and after straightening, with FIG. 2(a) representing a case where vertical rolls were not used and FIG. 2(b) representing a case where pressure by the vertical rolls was performed.

FIG. 3 is a sectional view showing one example of a U-shaped steel sheet pile that is an object to be straightened by the present invention.

FIG. 4 is a sectional view showing one example of a hat-shaped steel sheet pile that is an object to be straightened by the present invention.

FIG. 5 is a conceptual view illustrating an upward camber of the hat-shaped steel sheet pile.

FIG. 6 is a conceptual view illustrating a downward camber of the hat-shaped steel sheet pile.

FIGS. 7(a) and 7(b) are simplified illustrations showing a typical arrangement of rolls in a conventional roll-straightening method, with FIG. 7(a) being a simplified side view and FIG. 7(b) being a top view.

FIG. 8 (a) is a schematic view showing the shapes of rolls of a roll-straightening unit, and FIG. 8 (b) is a schematic view showing a hat-shaped steel sheet pile that is a material to be straightened.

FIG. 9 is a graph showing the result of studying total widths at plural positions in the longitudinal direction before and after straightening under conventional straightening conditions that did not use vertical rolls.

Description of Embodiment

[0020] An embodiment of the present invention will be described below with reference to the drawings. A steel sheet pile in this embodiment will be described, as to its shape, as being handled in a posture in which a web is located above a flange (a so-called inverted-U posture), but of course the scope of application of the present invention covers handling in other postures (e.g., a U-posture).

[0021] The present inventors closely studied changes in the dimension of the total width W of a hat-shaped steel sheet pile 10H (a product of which the second moment of area per meter of wall width is about $10,000 \times 10^{-8} \text{ m}^4/\text{m}$) during roll-straightening.

FIG. 7 is a schematic view showing an arrangement of rolls of a conventional roll-straightener 21 that was used for the study. In the roll-straightener 21, nine sets of upper and lower rolls 2, 3 in total are arranged in a staggered manner (alternately on the upper side and the lower side) with a feeding path (pass line) P therebetween. The upper roll 2 has a roll surface of a shape conforming to a convex outer surface of the steel sheet pile 100, and the lower roll 3 has a roll surface of a shape conforming to a concave inner surface of the steel sheet pile 100.

[0022] FIG. 8 (a) is a schematic view showing the shapes of rolls of the conventional roll-straightener 21, and FIG. 8 (b) is a schematic view showing a hat-shaped steel sheet pile 120 that is a material to be straightened. FIG. 8 (a) is a schematic view of left halves of the upper and lower rolls 2, 3 as seen from the feeding direction F . The upper roll 2 has, fitted on an upper arbor 4, an upper-roll sleeve 5 for pressing a web 101 of the hat-shaped steel sheet pile 120 and, on an outer side thereof, an upper-roll sleeve 9 for pressing an arm 103. The lower roll 3 has, fitted on a lower arbor 6, a lower-roll sleeve 7 for pressing the web 101 of the hat-shaped steel sheet pile 120 and, on an outer side thereof, a lower-roll sleeve 10 for pressing the arm 103. In the embodiment of FIG. 8 (a), an outer roll 11 that restrains an outer edge of a joint 104 is further fitted on the lower arbor 6. The hat-shaped steel sheet pile 120 studied is a standardized product 10H with dimensions of the effective width $W_0 = 900 \text{ mm}$, the effective height $H = 230 \text{ mm}$, and a web plate thickness $t = 10.8 \text{ mm}$.

[0023] In the study, using the roll-straightener 21 shown in FIG. 7 and FIG. 8, the total widths W at plural positions in the longitudinal direction before and after straightening under conventional straightening conditions were studied.

The results are shown in FIG. 9. In the shape before straightening, the total width W at the central portion of the product in the longitudinal direction is larger than that at each end by about 5 mm, and the central portion in the longitudinal direction exceeds an allowable value of the total width W (a range of 928 to 942 mm indicated by the dashed two-dotted lines). In addition, the total width is smaller at the leading and tail end portions than at other portions, and this tendency remains after the width was corrected by the outer roll 11.

[0024] In roll-straightening the steel sheet pile 100, it is necessary to remove a camber by repeated unbending and to adjust the total widths W of the product in the longitudinal direction to be within the allowable dimensional range. That is, making a set width of the outer rolls 11 too small so as to reduce the total width W leads to a problem that a local camber occurs. Conversely, making the set width of the outer rolls 11 too large results in a reduced restraining force in the width direction, so that the amount of variation in the total width in the longitudinal direction increases or the camber correcting effect cannot be expected to improve.

[0025] The present invention has been contrived through further studies conducted based on the insight gained by the above studies.

[0026] FIGS. 1(a) and 1(b) are conceptual views showing an arrangement of rolls of a steel sheet pile straightener according to one embodiment of the present invention, with FIG. 1(a) being a simplified side view and FIG. 1(b) being a top view. In this embodiment, a straightener 20 of the steel sheet pile 100 is composed of a roll-straightening unit 1 and vertical rolls 12. In the example of FIG. 1, the roll-straightening unit 1 has nine sets of upper and lower rolls 2, 3 in total arranged in a staggered manner (alternately) on the upper side and the lower side of the steel sheet pile 100. The vertical rolls 12 are disposed a predetermined distance away from a final axis (the ninth axis) of the roll-straightening unit 1. In this embodiment, flat rolls are used as the vertical rolls. It is preferable that the center-to-center distance LL between the vertical roll 12

and the final axis of the roll-straightening unit 1 is larger than the sum of maximum radii of the respective rolls and equal to or smaller than half the length of the steel sheet pile 100 that is a material to be straightened.

[0027] The total widths W of the hat-shaped steel sheet pile 120 of the product standard 10H before and after straightening were studied under the two conditions of a condition in which the vertical rolls were not used (FIG. 2 (a)) and a condition in which the vertical rolls were brought close by 20 mm on each side (FIG. 2 (b)), with the straightening conditions of the roll-straightening unit 1 being the same fixed conditions. The study results are shown in FIG. 2. The straightening conditions of the roll-straightening unit 1 in this case are shown in Table 1. The intermesh (mm) shown in Table 1 represents an amount of pressing up by the lower rolls 3 relative to a straight pass line P of the steel sheet pile 100.

[0028] [Table 1]

Lower roll axis No.	1	3	5	7	9
Intermesh [mm]	8	14	12	10	4

[0029] Under the condition of FIG. 2 (a) in which the vertical rolls 12 were not used, the difference in total width W between the leading and tail ends and the central portion of the product was 4 to 10 mm before straightening, whereas under the condition of FIG. 2 (b) in which the vertical rolls 12 were used, the difference in total width W was reduced to 1 mm or less at both the leading and tail ends after straightening. In particular, a product of good shape without deformation at the joints or the flange was obtained. By contrast, under the condition (a) in which the vertical rolls 12 were not used, the difference in total width between the leading and tail ends and the central portion of the product after correction of the camber was too large, which made it necessary to thereafter correct the total width by press-straightening.

These results demonstrate the advantages of the present invention.

[0030] While the product standard 10H among hat-shaped steel sheet piles has been shown in this embodiment, it was also confirmed that the same

advantages could be achieved for steel sheet piles having other cross-sectional sizes (e.g., a U-shaped steel sheet pile 2W and a hat-shaped steel sheet pile 25H). It was also confirmed that straightening with a plurality of vertical rolls arrayed on a downstream side of a roll-straightening machine could achieve a
 5 straightening effect equivalent to that under the condition of one pair of vertical rolls. Thus, the number of vertical rolls does not matter.

[0031] In this embodiment, it is preferable that the pair of vertical rolls 12 is installed with the separation distance WL smaller than the total width W of the product of the steel sheet pile 100 so as to be able to correct the total width W of
 10 the steel sheet pile 100. To sufficiently exhibit the pressing effect of the vertical rolls 12, it is preferable that the relationship between the separation distance between the outer rolls 11 of the roll-straightening unit 1 as the joint straightening parts and the separation distance WL between the pair of vertical rolls 12 is such that the separation distance between the outer rolls 11 is larger
 15 than the separation distance WL between the pair of vertical rolls 12. In addition, it is preferable that the separation distance WL between the pair of vertical rolls 12 is set to be within a range of 0.70 times to 0.98 times of the total width W of the steel sheet pile 100. When the separation distance WL is smaller than the lower limit, dimensional deviation due to local plastic
 20 deformation of the steel sheet pile 100 or clogging of a material between the vertical rolls 12 can occur, whereas when it exceeds the upper limit, the pressing effect of the vertical rolls on the total width W may fail to be sufficiently exhibited.

[0032] It is preferable that the vertical rolls be flat rolls in case the positions
 25 of the outer edges of the joints 104 of the steel sheet pile 100 vary in the up-down direction. It is also preferable that the straightener 20 is configured such that the separation distance WL between the pair of vertical rolls 12 is adjustable according to changes in the total width W of the product of the steel sheet pile 100.

30 **[0033]** A steel sheet pile straightening method according to the present invention is a steel sheet pile straightening method using the straightener 20 of the above embodiment that includes the roll-straightening unit 1 and the vertical

rolls 12. This method corrects a camber of a steel sheet pile having joints at both ends in the width direction by means of the roll-straightening unit 1 and adjusts the total width W to be within a predetermined range. Then, this method holds the joints 104 at both ends between the vertical rolls 12 and presses them

5 so as to reduce the difference in the total width W.

[0034] A method of producing a steel sheet pile according to the present invention can use an ordinary method for a step of hot-rolling the steel sheet pile 100. Specifically, a step in which a continuously cast slab or a steel slab formed into an appropriate shape is heated in a heating furnace and then hot-rolled by a

10 plurality of stages of caliber roll can be used. The hot-rolled steel sheet pile 100 is cooled and then fed into the straightener 20 of the above embodiment, and the above-described straightening method is applied.

Industrial Applicability

15 **[0035]** The present invention is suitably applied to a case where straightening an elongated steel member or the like that cambers as a result of hot-rolling requires controlling the total width thereof.

Reference Signs List

20	[0036]	1	Roll-straightening unit
		2	Upper roll
		3	Lower roll
		4	Upper arbor
		5	Upper-roll sleeve (for pressing web)
25		6	Lower arbor
		7	Lower-roll sleeve (for pressing web)
		9	Upper-roll sleeve (for pressing arm)
		10	Lower-roll sleeve (for pressing arm)
		11	Outer roll (outer restraining roll)
30		12	Vertical roll
		20	Straightener
		21	Conventional roll-straightener

	100	Steel sheet pile
	101	Web
	102	Flange
	103	Arm
5	104	Joint
	110	U-shaped steel sheet pile
	120	Hat-shaped steel sheet pile
	F	Feeding direction (conveying direction)
	P	Pass line
10	O	Reference position

Claims

[Claim 1]

5 A steel sheet pile straightener that straightens a steel sheet pile having joints at both ends in a width direction of the steel sheet pile, the steel sheet pile straightener comprising:

a roll-straightening unit having a plurality of upper rolls and a plurality of lower rolls arranged in a staggered manner; and

10 a pair of vertical rolls disposed on a downstream side of the roll-straightening unit in a conveying direction of the steel sheet pile, characterized in that a separation distance between the pair of vertical rolls is set to be smaller than a total width of a product of the steel sheet pile.

[Claim 2]

15 The steel sheet pile straightener according to claim 1, wherein: the roll-straightening unit includes, in at least one lower roll among the plurality of lower rolls or at least one upper roll among the plurality of upper rolls, one pair of joint straightening parts that corrects the total width of the product of the steel sheet pile by pressing the joints; and

20 a separation distance between the pair of joint straightening parts is larger than the separation distance between the pair of vertical rolls.

[Claim 3]

The steel sheet pile straightener according to claim 1 or 2, wherein the pair of vertical rolls are formed by flat rolls that are vertically installed.

25 [Claim 4]

The steel sheet pile straightener according to any one of claims 1 to 3, wherein

30 the steel sheet pile straightener is configured such that the separation distance between the pair of vertical rolls is adjustable according to the total width of the product of the steel sheet pile.

[Claim 5]

The steel sheet pile straightener according to any one of claims 1 to 4,

wherein

the separation distance WL between the pair of vertical rolls and the total width W of the product of the steel sheet pile satisfy a following expression (1):

$$5 \quad 0.70 \leq WL/W \leq 0.98 \cdots (1).$$

[Claim 6]

A straightening method of a steel sheet pile characterized by,
by using the steel sheet pile straightener according to any one of
claims 1 to 5,

10 straightening a steel sheet pile having joints at both ends in a width
direction of the steel sheet pile by means of the roll-straightening unit, and then
pressing the joints toward a center of the steel sheet pile in the width
direction by means of the pair of vertical rolls.

[Claim 7]

15 A method of producing steel sheet pile characterized by having a step
of straightening a steel sheet pile using the straightening method of a steel sheet
pile according to claim 6.