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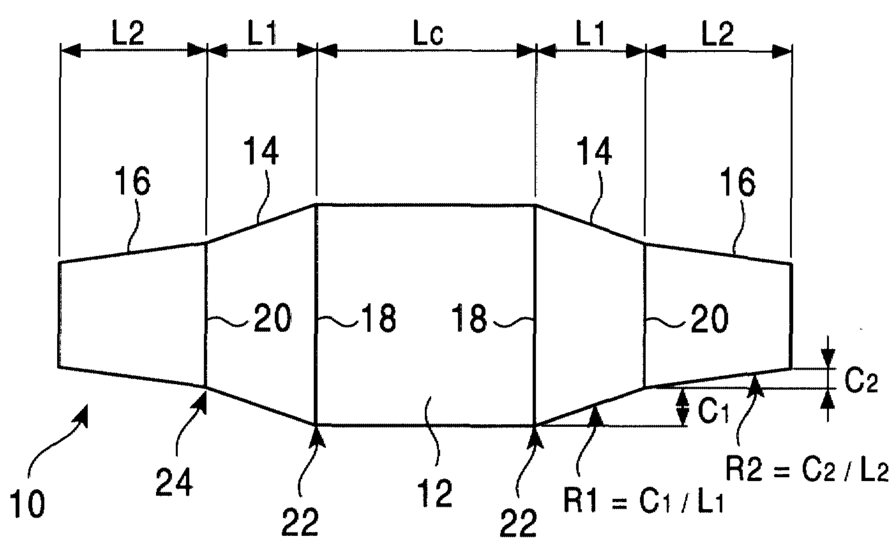
(54) Hearth rolls for a vertical heat treating furnace including a heating furnace and a soaking furnace and vertical furnace including the hearth rolls

(57) A vertical heat treating furnace for passing a metal strip therethrough for heat treatment and a hearth roll applied to a heating/soaking furnace of the vertical heat treating furnace are disclosed. The hearth roll (10) can be configured such that the taper angle (R1) of each of first taper sections (14) continuous to a flat section (12) at a central portion of the hearth roll from a roll axial direction is larger than the taper angle (R2) of each of second taper sections (16) continuous to each of the first taper sections (14) from the roll axial direction. The length Lc (mm) of the flat section and the length L1 (mm) of the first taper section can satisfy the following relationships: 0.5 Wmin ≤ Lc ≤ Wmin and Wmin ≤ Lc + 2 × L1 ≤ Wmax - 400, where Wmin is the minimum width (mm) of the metal strip, and Wmax is the maximum width (mm) of the metal strip. This design of the hearth roll can prevent meandering or buckling of steel sheets even in a wide range of sheet width.

FIG. 1



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Description

[0001] The present invention relates to hearth rolls for a heating furnace and a soaking furnace of a vertical heat treating furnace. The present invention also relates to a vertical heat treating furnace using the hearth rolls.

[0002] Vertical heat treating furnaces are ordinarily divided into respective sections of a heating furnace, a soaking furnace, and a cooling furnace, and a predetermined heat treatment cycle is performed. Hereinafter, the heating furnace and the soaking furnace contained in the vertical heat treating furnace are described as one set of equipment in the present invention, and are referred to as "a heating/soaking furnace." Further, the vertical heat treating furnace includes a plurality of hearth rolls as transfer rolls located on the upper portion and the lower portion of the vertical heat treating furnace, and a metal strip is passed while being suspended by these hearth rolls and subjected to a necessary heat treatment in the process.

[0003] However, because metal strips to be passed are not always flat and include a bent portion and a locally extended portion, a transfer problem such as meandering and the like is liable to occur while they are being passed.

[0004] In particular, large vertical heat treating furnaces (of a size class such that the distance between upper rollers and lower rollers exceeds 15-20 m) have been constructed in large numbers, and the prevention of transfer problems is a leading problem to be solved in these furnaces. To prevent problems in the transfer of metal strip, the shape of hearth rolls has been variously devised such as by the formation of a crown and the like on the hearth rolls. However, when a large crown is formed to prevent meandering as a transfer problem, there is a possibility that a problem called "buckling" ,in which a metal strip is buckled in a width direction, can occur. This problem is significant, particularly when the furnace temperature is high and a problem is caused when a sheet is passed. Thus, buckling is one of the leading causes of lowered operating efficiency of equipment and product yield.

[0005] There have been made various devices to effectively prevent meandering and buckling, which are problems caused when a metal strip is passed in a vertical heat treating furnace.

[0006] Japanese Unexamined Patent Application Publications Nos. 55-100919 and 57-137431, for example, disclose controlling the crown of a roll using the thermal expansion in a hearth roll by devising (designing/modifying) the inner structure of the hearth roll.

[0007] Further, Japanese Unexamined Patent Application Publications Nos. 7-331335 and 3-47926 disclose controlling the crown of a hearth roll by controlling its temperature by applying heat to the hearth role from the outside.

[0008] Japanese Unexamined Patent Application Publications Nos. 8-199247, 7-138656, 58-120739, and 52-136812 disclose conventional examples in which the shape of a hearth roll itself is devised. These publications disclose a hearth roll having a one-stepped taper, which is arranged such that the central portion of the hearth roll has a flat shape or a crown shape, with both sides of the roll having a taper.

[0009] The applicant has disclosed in Japanese Unexamined Patent Application Publication No. 59-116331 that a roll having a two-stepped taper shape can be used together with the above roll having a one-stepped taper shape and a crown shape.

[0010] Recently, however, a steel sheet of a width much larger than that of a conventional steel sheet has been required as a steel sheet for integrally forming an automobile body.

[0011] Therefore, it has been required to pass a metal sheet, in particular, a steel sheet having a wider range of sheet width, which is larger than a conventional range, in a single vertical heat treating furnace.

[0012] Regarding a steel sheet for automobiles, a line was conventionally operated with a sheet width ranging from 800 mm to 1500 mm. Recently, it has been required to pass a steel sheet having a sheet width of about 800-1500 mm, and sometimes a steel sheet having a sheet width larger than this, in the same line.

[0013] When a range of sheet width is wide as described above, a transfer problem cannot be sufficiently overcome by simply devising only the roll shape of a one-stepped taper roll as in the conventional technology.

[0014] An optimum roll shape has been known as to the one-stepped taper roll and used as an effective means for preventing meandering and buckling in the operation in the conventional range of sheet width. However, the roll shape cannot be used as it is in a wide range of sheet widths having a ratio of maximum to minimum sheet width of, for example, 2 or more.

[0015] The present inventors have discovered the one-stepped taper roll has a problem in that while it can effectively prevent the occurrence of buckling in a wide metal strip when the inclination of a taper is reduced, meandering is liable to occur in a narrow metal strip. In contrast, when the inclination of the taper is increased, while meandering can be effectively prevented in a narrow metal strip,buckling is liable to occur in a wide metal strip, particularly when its thickness is thin. Thus, it is impossible to follow a wide range of sheet width and to cope with a problem caused by the wide range of sheet width by the use of the one-stepped taper roll.

[0016] Further, even if the method of controlling the crown of a hearth roll by temperature control is applied, it is impossible to follow the wide range of sheet thickness and to cope with a problem caused by the wide range using this method, and it is necessary to reconfigure equipment on a large scale to follow the wide range of sheet width.

[0017] Further, a metal strip can be passed stably in a vertical heat treating furnace even by a conventional hearth roll to a certain extent when the metal strip is in a steady state in which it is passed at an approximately constant speed. However, when operating conditions are varied in a furnace to treat metal strips having a wide variety of sizes and various kinds of metal strips, the sheet passing speed is often changed considerably. Meandering and buckling often occur when the speed is changed (by changes corresponding to 40-50% of a steady speed). In the conventional hearth roll, it is very difficult to achieve a stable sheet passing property by taking even the change of sheet passing speed into consideration, and further it is not easy to achieve this property even by the use of the two-stepped taper roll.

[0018] In a continuous annealing furnace for steel strip, for example, an ordinary sheet passing speed is about 200-400 m/min in a steady state.

[0019] The present invention can cope with the transfer of a steel strip in a wide range of sheet width only by simply optimizing a hearth roll at a low equipment cost without the need for remodeling equipment on a large scale. The present invention is preferable to a heating/soaking furnace of a vertical heat treating furnace for treating a steel strip having a wide range of sheet width in which a rate of maximum to minimum sheet width is 2 or more.

[0020] The inventors have discovered that meandering and buckling can be prevented by optimizing the shape and disposition of two-stepped taper rolls more effectively than conventional taper rolls also in correspondence particularly to a wide range of sheet width and to a change in speed.

[0021] That is, the above-described problems of the known apparatus have been solved by a hearth roll for a heating/soaking furnace of a vertical heat treating furnace, which comprises a flat section at a central portion and two-stepped taper sections on both sides of the flat section. The inclination of each of first taper sections continuous to the flat section is larger than the inclination of each of second taper sections further continuous to each of the first taper sections. The length Lc (mm) of the flat section and the length L1 (mm) of each of the first taper sections are related according to the following formulas (1) and (2).

[0022] Preferably, a convex curve section and a concave curve section are formed at the boundary between the flat section and each of the first taper sections, and at the boundary between each of the first taper sections and each of the second taper sections, respectively. Each of the convex and concave sections has a radius of curvature of at least 20 m.

[0023] Preferably, the inclination R1 of each of the first taper sections is within the range of 0.2×10^{-3} to 10×10^{-3}, and the inclination R2 of each of the second taper sections is within the range of 0.05×10^{-3} to 4×10^{-3}.

[0024] The above-described problems have been solved by a vertical heat treating furnace using hearth rolls for a heating/soaking furnace. The hearth rolls at the inlet of the vertical heat treating furnace satisfy the following formulas (3) and (4) and the hearth rolls from the intermediate portion to the outlet of the vertical heat treating furnace satisfy the following formulas (5) and (6), as well as the lengths Lc and ($Lc + 2 \times L1$) are increased from the inlet to the outlet of the furnace, stepwise or sequentially, in the hearth roll groups of the respective ones of upper rolls and lower rolls disposed side by side in the furnace.

[0025] Further, the above-described problems have been solved by a vertical heat treating furnace using hearth rolls for a heating/soaking furnace as transfer rolls. The hearth rolls at the inlet of the vertical heat treating furnace satisfy the following formulas (3), (4), (7) and (8), and the hearth rolls from the intermediate portion to the outlet of the furnace satisfy the following formulas (5), (6), (9) and (10), as well as the lengths Lc and ($Lc + 2 \times L1$) are increased from the inlet to the outlet of the furnace, stepwise or sequentially, in the hearth roll groups of the respective ones of upper rolls and lower rolls disposed side by side in the furnace and the inclinations R1 and R2 of the tapers are reduced from the inlet to the outlet of the furnace stepwise or sequentially.

$$0.5\ Wmin \leq Lc \leq Wmin \tag{1}$$

$$Wmin \leq Lc + 2 \times L1 \leq Wmax - 400 \tag{2}$$

$$0.5\ Wmin \leq Lc \leq 0.7\ Wmin \tag{3}$$

$$Wmin \leq Lc + 2 \times L1\ (Wmin + Wmax - 400)/2 \tag{4}$$

$$0.7\ Wmin \leq Lc \leq Wmin \tag{5}$$

$$(Wmin + Wmax - 400)/2 \leq Lc + 2 \times L1 \leq Wmax - 400 \tag{6}$$

$$3.0 \times 10^{-3} \leq R1 \leq 10 \times 10^{-3} \quad (7)$$

$$1.2 \times 10^{-3} \leq R2 \leq 4.0 \times 10^{-3} \quad (8)$$

$$0.2 \times 10^{-3} \leq R1 \leq 3.0 \times 10^{-3} \quad (9)$$

$$0.05 \times 10^{-3} \leq R2 \leq 1.2 \times 10^{-3} \quad (10)$$

where,

Wmin is the minimum width (mm) of metal strip to be subjected to heat treatment, and
Wmax is the maximum width (mm) of metal strip to be subjected to heat treatment.

[0026] The furnace may be optionally partitioned into the inlet portion, the intermediate portion and the outlet portion of the furnace.

[0027] Further, the stepwise increase of the length means that the value of Lc and the like is increased in the next roll in adjacent rolls (when upper rolls and lower rolls are handled as belonging to different roll systems, adjacent rolls in each system) at least any one position from the inlet to the outlet of the furnace, while the same value may be sometimes set in the adjacent rolls. This is also applicable to the case in which the inclinations R1 and R2 are reduced stepwise. It is contemplated as a typical case of the above arrangement to separate the interior of the furnace into several blocks and to change the value among the blocks.

[0028] In the drawings:

Fig. 1 illustrates an exemplary embodiment of a hearth roll of the present invention;
Fig. 2 is a schematic view of a vertical heat treating furnace;
Fig. 3 is a graph showing conditions under which meandering and buckling occur depending upon the width and thickness of sheet;
Fig. 4 is a graph showing the condition of Lc under which meandering and buckling occur in a vertical heat treating furnace;
Fig. 5 is a graph showing the condition of (Lc + 2 × L1) under which meandering and buckling occur in the vertical heat treating furnace;
Fig. 6 shows an example, using the invention, of reducing an operation rate resulting from meandering and buckling; and
Fig. 7 shows an example, using the invention, of reducing a speed achieving rate resulting from meandering and buckling.

[0029] First, a two-stepped taper roll, which is used as an embodiment of a hearth roll of the present invention, will be described with reference to Fig. 1.

[0030] The hearth roll 10 of this embodiment has a two-stepped taper structure, which is symmetrical on the right and left sides of the hearth roll 10. The hearth roll 10 includes a flat section 12 having a length of Lc (mm) formed at the central portion of the hearth roll 10, first taper sections 14 each having a length of L1 (mm) formed on both sides of the flat section 12, and second taper sections 16 each having a length of L2 (mm) formed on both sides of the first taper sections 14.

[0031] The flat section 12 may be approximately flat and, for example, may be formed as a gentle curved surface having a radius of curvature of, for example, at least 100 m.

[0032] When the inclination of each of the first taper sections 14 (C1/L1) is represented by R1, and the inclination of each of the second taper sections 16 (C2/L2) is represented by R2, then R1 > R2.

[0033] Further, it is preferable that the boundary 18 between the flat section 12 and each of the first taper sections 14, and the boundary 20 between each of the first taper sections 14 and each of the second taper sections 16 are formed in a round shape without any corner as a catching part. It is also preferable that these boundaries 18, 20 are arranged as a convex curve section 22 and a concave curve section 24, respectively. However, because it is desirable to make the connecting portions thereof as gentle as possible, it is preferable to set the radii of curvature thereof to at least 20 m, respectively. The two-stepped taper sections 14, 16 on both sides of the flat section 12 are not necessarily symmetrical and the inclinations of the two-stepped taper sections 14, 16 on the right and left sides may be varied, or the widths of the taper sections 14, 16 may be varied.

[0034] Next, Fig. 2 schematically shows a typical vertical heat treating furnace to which the present invention is applied.

[0035] In the example shown in Fig. 2, the vertical heat treating furnace 30 comprises a heating furnace 32 for performing heating, and a soaking furnace 34 for performing soaking, and these furnaces 32, 34 are arranged continuously. A preheating furnace may be disposed in front of the heating furnace 32. At the time, however, the hearth rolls of the preheating furnace can be regarded as the same as a group of hearth rolls on the inlet side of the heating furnace.

[0036] A metal strip 36 enters the furnace from the inlet of the vertical heat treating furnace 30. That is, the metal strip 36 enters the heating furnace 32 and is passed while being suspended by upper hearth rolls 38 and lower hearth rolls 40 disposed on the upper side and the lower side, respectively, of the furnace. The metal strip 36, which is passed in the furnace, is heated by heating elements 42. While the heating elements 42 are shown only partly in Fig. 2 for simplicity, a plurality of the heating elements 42 are disposed at desired positions in the heating furnace 32 and the soaking furnace 34. A radiant tube or the like can be used as a heating element.

[0037] A shield plate 44 is conventionally interposed between a hearth roll 10 and a heating element 42, such as a radiant tube, so that the crown of the hearth roll 10 is not deformed by the radiant heat from the heating element 42.

[0038] The most effective position of the shield plate 44 also has been examined. As a result, it has been confirmed that the effect of the shield plate 44 is not significant in the latter half section of the heating furnace 32 and in the soaking furnace 34 where the temperature of the metal strip 36 approaches the temperature in the furnace and the temperature of the heating element 42. It has also been confirmed that the shield plate 44 has a large effect in the former half section of the heating furnace 32 where the temperature of the metal strip 36 is considerably lower than the temperature in the furnace and the temperature of the heating element 42.

[0039] When the shield plate 44 is not used, both of the ends of the hearth roll 10 located in the former half section of the heating furnace 32 are heated by the heating element 42, while the central portion of the hearth roll 10 is kept at a low temperature by the metal strip 36 having a low temperature. Accordingly, the hearth roll 10 is liable to develop a concave crown, whereby the metal strip 36 is liable to be meandered.

[0040] It has been found that the installation of the shield plate 44 makes it difficult for both of the ends of the hearth roll 10 to be heated by the heating element 42 so that the crown of the hearth roll 10 remains in a normal state and meandering is reduced.

[0041] Fig. 3 graphically illustrates how meandering and buckling properties can be improved, and how operation can be stabilized, by the two-stepped taper roll of the present invention as compared to a conventional one-stepped taper roll. In Fig. 3, the abscissa represents the sheet width of a metal strip passed in the furnace and the ordinate represents the sheet thickness of the metal strip.

[0042] The taper angle of the roll, the radius of curvature of the taper boundary of the roll, and the like of the two-stepped taper roll employed in Fig. 3 meet the above-described preferred conditions according to the present invention. Further, the occurrence of respective sheet passing problems was determined depending upon whether the problems were caused when the sheet passing speed was lowered by 50% as compared with an ordinary sheet passing speed (300 m/min). This also is applied likewise to Figs. 4 and 5 which are described below.

[0043] The conventional one-stepped taper roll can approximately prevent meandering and buckling and stabilize operation when the maximum/minimum ratio of sheet width of a metal strip (Wmax/Wmin) is less than 1-2, at most. When, Wmax/Wmin is 2 or more, the occurrence of buckling cannot be completely prevented in a metal strip having a large width and a small thickness even if the length of the flat portion of the hearth roll, the taper length, and the like thereof are variously adjusted.

[0044] In contrast, in a two-stepped hearth roll of the present invention, meandering and buckling can be effectively prevented over a wide range in which Wmax/Wmin is 2 or more, so long as satisfactory conditions are used for the hearth roll.

[0045] The inventors have conducted more detailed studies based on the above-described knowledge and developed the present invention. The knowledge obtained as a result of the studies carried out by the inventors is described below.

[0046] First, the optimum value of the length Lc of the flat portion of a hearth roll 10 having a two-stepped taper as shown in Fig. 1 is determined based on the minimum sheet width Wmin of a metal sheet to be passed, and it is preferable to set the length Lc as follows:

$$0.5\ \mathrm{Wmin} \le \mathrm{Lc} \le \mathrm{Wmin} \qquad (1)$$

[0047] When Lc is less than 0.5 Wmin, the width of a sheet is ordinarily made too large at taper portions and buckling is likely to occur.

[0048] To cope with this problem, it is preferable to vary the value depending upon the position at which the hearth roll is disposed in the vertical heat treating furnace 30 as shown in Fig. 2, and it has been found that it is most preferable to set the value of Lc to satisfy the relationship 0.5 Wmin ≤ Lc ≤ 0.7 Wmin at the inlet of the vertical heat treating furnace 30 (that is, at the inlet of the heating furnace 32), to prevent the meandering of a narrow metal strip, and to set the value of Lc to satisfy the relationship 0.7 Wmin ≤ Lc ≤ Wmin at a location from the intermediate portion of the furnace to the outlet of the vertical heat treating furnace 30 (that is, the outlet of the soaking furnace 34) because the temperature of the metal strip is increased.

[0049] The shape of a sheet is ordinarily improved in the latter half section of the vertical heat treating furnace 30 and meandering is unlikely to occur. Therefore, it has been found that it is effective to set Lc to a larger value within the range of 0.7 × Wmin or more to prevent buckling.

[0050] As shown in Fig. 4, when Wmin is too large at the inlet of the heating furnace, meandering often occurs even if the tapers on both of the sides of the hearth roll are variously adjusted, because the shape of a metal strip is not yet completely restored, whereby problems such as the reduction of speed and the like are caused.

[0051] On the contrary, unless Lc is set larger from the central portion of the heating furnace 32 to the soaking furnace 34 as compared with the inlet of the heating furnace 32 as shown in Fig. 4, the problem of buckling is often caused in a wide metal strip, even if the tapers on both of the sides of the hearth roll are variously adjusted. However, the maximum value of Lc does not exceed Wmin. This is because if Lc is set larger than Wmin, meandering is caused from the central portion of the heating furnace 32 to the soaking furnace 34 in case of Wmin, while the shape of the metal strip is corrected from the central portion of the heating furnace 32 to the soaking furnace 34.

[0052] Next, as a result of repeated studies and tests on actually operating equipment also as to the width L1 of each of the first taper sections, it has been found that it is most preferable to form the hearth roll such that Lc + 2 × L1 is sequentially increased from the inlet of the heating furnace 32 to the outlet of the heating furnace within the range of the following formula (2):

$$\mathrm{Wmin} \leq \mathrm{Lc} + 2 \times \mathrm{L1} \leq \mathrm{Wmax} - 400 \qquad (2)$$

[0053] Lc + 2 × L1 must be set larger than the minimum width Wmin of a metal strip to prevent the meandering of a narrow metal strip. Further, when Lc + 2 × L1 is larger than the maximum width Wmax - 400, buckling is likely to occur in a wide metal strip even if any value is selected as the inclinations R1 and R2 of the two-stepped taper portions of the hearth roll.

[0054] Fig. 5 shows the optimum range of Lc + 2 × L1 and how meandering and buckling are caused when the optimum range is not satisfied. It has been found that it is difficult to completely prevent the occurrence of meandering and buckling unless Lc + 2 × L1 is set properly, even if any value is selected as R1 and R2. Further, it has become apparent that the inclinations R1 and R2 of the taper portions are preferably set when the relationship of R1 > R2 is achieved, R1 is set to a value from 0.2×10^{-3} to 10×10^{-3} and R2 is set to a value from 0.05×10^{-3} to 4×10^{-3}.

[0055] Further, it has been found as to R1 and R2 that it is more preferable for them to satisfy the following relationships: $3.0 \times 10^{-3} \leq R1 \leq 10 \times 10^{-3}$ and $1.2 \times 10^{-3} \leq R2 \leq 4.0 \times 10^{-3}$, respectively on the inlet of the furnace, and to satisfy the following relationships: $0.2 \times 10^{-3} \leq R1 \leq 3.0 \times 10^{-3}$ and $0.05 \times 10^{-3} \leq R2 \leq 1.2 \times 10^{-3}$, respectively, on the outlet of the furnace. The inclinations R1 and R2 are set as described above because it is preferable to put greater emphasis on the prevention of buckling in the latter half section of the furnace in design likewise in the case of Lc and other parameters.

[0056] It is preferable that the respective values of L1 and Lc + 2 × L1 are sequentially increased from the inlet to the outlet of the vertical heat treating furnace 30, or, in some embodiments, made equal to each other. As a method of sequentially increasing the values, the values may be varied in the former half section and the latter half section of the vertical heat treating furnace 30 by dividing the interior the furnace into the two portions. Otherwise, the values may be sequentially increased at about three to five steps in some embodiments. Further, the values may be sequentially and continuously increased in other embodiments. It also has been found that several special rolls such as CPC (meandering correcting) rolls and the like, which are ordinarily installed in a furnace, need not be included in the scope of the roll shape of the present invention because only a small number of these special rolls are typically used, and the effects of the present invention can be sufficiently obtained even if they are arranged as, for example, flat rolls.

[0057] It also has been become apparent that while hearth rolls are disposed on the upper portion and the lower portion in the interior of the vertical heat treating furnace 30, it is preferable to sequentially increase the above-described roll parameters(L1,Lc+2 × L1) in the individual roll groups of the upper rolls and the lower rolls because tension is differently imposed on a metal strip on the upper portion and the lower portion of the furnace due to the influence of gravity and other factors.

[0058] Several examples of the actual shapes of hearth roll (prescribed by Lc and L1) are exemplified in TABLE 1.

[0059] TABLE 1 shows the relationship between Lc and L1 of a hearth roll applied in the vertical heat treating furnace for the respective cases of metal strips which are passed through the furnace and whose minimum and maximum widths are Wmin and Wmax.

[0060] TABLE 1 shows the minimum value (min), median value (mid) and maximum value (max) of L1 to each of the minimum value (min), median value (mid) and maximum value (max) of Lc as a matrix with respect to the respective cases of Wmin and Wmax. The values shown in the parentheses are not actually used.

[0061] In the present invention, it is preferable to use values in the ranges of the min and mid of Lc and the min and mid of L1 at the inlet of the heating/soaking furnace in the vertical heat treating furnace, and it is preferable to use values within the ranges of the mid and max of Lc and the mid and max of L1 from the intermediate portion to the outlet of the heating/soaking furnace in the vertical heat treating furnace.

TABLE 1

					L1 (mm)			Transfer problem	
case	Wmin (mm)	Wmax (mm)	Wmax/Wmin	Lc(mm)	min	mid	max	meandering	buckling
1	500	1000	2.0	min:250	125	150	(175)	O	O
				mid:350	75	100	125		
				max:500	(0)	25	50		
2	500	1500	3.0	min:250	125	275	(425)	O	O
				mid:350	75	225	375		
				max:500	(0)	150	300		
3	800	1500	1.9	min:400	200	275	(350)	O	O
				mid:560	120	195	270		
				max:800	(0)	75	150		
4	800	1800	2.3	min:400	250	350	(500)	O	O
				mid:560	150	270	420		
				max:800	(0)	150	300		
5	800	2000	2.5	min:400	250	400	(600)	O	O
				mid:560	150	300	520		
				max:800	(0)	200	400		
6	1000	2000	2.0	min:500	250	400	(550)	O	O
				mid:700	150	300	450		
				max:1000	(0)	150	300		
7	800	1800	2.3	min:700	400	450	500	X	O
				mid:850	300	350	400		
				max:1000	250	275	300		
8	800	1800	2.3	min:200	250	275	300	O	X
				mid:300	200	225	250		
				max:400	150	175	200		

Wmin ≤Lc + 2X L1 ≤ Wmax - 400
Wmin: min width; Wmax: max width
O: no problems
X: occurrence of problems
Lc: length of flat section;
L1: length of first taper sections

[0062] In the case 7 in which Lc + 2 × L1 was excessively large, buckling substantially did not occur, but meandering frequently occurred and sheet passing was significantly disturbed.

[0063] In contrast, in the case 8 in which $Lc + 2 \times L1$ was excessively small, buckling frequently occurred in a wide material, while the occurrence of meandering was suppressed.

[0064] The reduction of the operation rate of equipment and the reduction of a speed achieving rate, which were caused by meandering and buckling, could be greatly improved as shown in Figs. 6 and 7 by the use of the present invention, in addition to that the yield of product, which was deteriorated by defective products resulting from the stopping of a line, the reduction of the line speed and the like, could be improved by an average of 0.2%.

[0065] Fig. 6 shows the reduction of the operation rate of equipment caused by meandering and buckling when a vertical heat treating furnace embodying the present invention is used and also when a conventional vertical furnace is used. When a steel sheet is meandered a large amount, or when it is greatly drawn, operation is finally carried out at a lowered speed. However, when the degree of meandering and buckling is greatly increased, the steel sheet must be subjected to a countermeasure by stopping the operation and lowering the temperature of the furnace, which reduces the operation rate of the equipment. In this case, the reduction of the operation rate of the equipment is represented by the rate between a time during which the equipment is interrupted by meandering and buckling and a working time. The reduction of the operation rate, which was conventionally about 3%, can be reduced to 0.5% or less by an embodiment of the present invention. The working time is typically represented as a possible operation time, which is determined by subtracting the out of work time, the setup change time and the like, from a calendar time.

[0066] Fig. 7 shows the reduction of the speed achieving rate of equipment caused by meandering and buckling when the vertical heat treating furnace embodying the present invention was employed and when the conventional vertical furnace was employed. The speed achieving rate is the rate between a speed calculated from a capacity of equipment and an actual operation rate, and it serves as an index representing a capacity in operation. When meandering or buckling occurs in a steel sheet, while a countermeasure is typically employed to continue operation without the occurrence of serious disadvantages caused by speed reduction, the speed achieving rate is finally lowered and the desired amount of production cannot be achieved. The reduction of the speed achieving rate, which was conventionally about 7%, can be reduced to about 2% by the embodiment of the present invention.

[0067] Steel strips were passed through continuous annealing furnaces (Nos. 1, 2, 4, 5, and 6) having roll arrangements shown in TABLES 2-4 below and continuous galvanizing furnaces (Nos. 3, 7 and 8) (distance between upper rolls and lower rolls was 20 m and a steady sheet passing speed was 300 m/min).

[0068] It has been confirmed in the present invention that even if the sheet passing speed is varied by 40% or more (50% under optimum conditions) in the vertical heat treating furnace capable of coping with a wide range of sheet width ($Wmax/Wmin \geq 2$), no meandering and buckling problems occur and sheets can be stably passed.

[0069] The shape and size of hearth rolls in the vertical heat treating furnace, that is, in the heating/soaking furnace can be optimized by the present invention and operation can be stably conducted without the occurrence of meandering and buckling in metal strips having a wide range of sheet width. As a result, the occurrence of problems such as the reduction of yield, line stopping, the reduction of line speed, and other problems can be prevented.

Table 2

No.	sheet width (mm)	0.5 Wmin	0.7 Wmin	Radius of curvature (m)	Block 1 (upper line:upper rolls; lower line:lower rolls)						Block 2 (upper line:upper rolls; lower line:lower rolls)					
	Wmin Wmax	*1	Wmax-400	convex concave	hearth rolls (No.)	LC (mm)	L1 (mm)	Lc + 2 xL1 (mm)	R1 (10^{-3})	R2 (10^{-3})	hearth rolls (No.)	Lc (mm)	L1 (mm)	Lc + 2 x L1 (mm)	R1 (10^{-3})	R2 (10^{-3})
1	700 1850	350 1075	490 1450	40 40	1~4 1~4	350 350	250 250	850 850	5.0 7.5	2.2 3.0	5~7 5~7	500 500	300 300	1100 1100	1.5 2.5	0.8 1.2
2	800 2000	400 1200	450 1600	30 30	1~3 1~3	450 450	200 200	850 850	7.0 10.0	3.0 4.0	4~5 4~5	550 550	250 250	1050 1050	3.0 4.0	2.0 3.0
3	600 1800	300 1000	420 1400	50 50	1~3 1~3	400 400	250 250	900 900	4.0 5.5	1.5 2.5	4~7 4~7	500 500	300 300	1100 1100	0.3 0.5	0.2 0.3
4	900 1900	450 1200	630 1500	40 40	1~5 1~4	600 500	275 250	1150 1000	4.8 7.2	2.0 2.8	6~7 5~6	700 650	300 250	1300 1150	1.3 2.2	0.9 1.1
5	500 1500	250 800	350 1100	40 40	1~5 1~4	300 300	200 200	700 700	5.0 7.0	2.0 3.0	6~7 5~6	400 400	250 250	900 900	2.0 3.0	1.0 1.5
6	700 1800	350 1050	490 1400		1~4 1~4	350 350	250 250	850 850	5.0 7.5	2.2 3.0	5~8 5~7	500 500	350 350	1200 1200	1.5 2.5	0.8 1.2
7	600 1800	300 1000	420 1400	50 50	1~2 1~2	400 400	250 250	900 900	11.0 12.0	4.5 5.0	3~7 3~7	500 500	300 300	1100 1100	0.05 0.1	0.02 0.03
8	600 1800	300 1000	420 1400	50 50	1~3 1~3	400 400	250 250	900 900	3.0 3.5	1.5 2.0	4~5 4~5	500 500	300 300	1100 1100	3.5 4.0	2.0 2.5

*1: (Wmin + Wmax - 400)/2

TABLE 3

No.	block 3 (upper line:upper rolls; lower line:lower rolls)						block 4 (upper line:upper rolls; lower line:lower rolls)					
	hearth rolls (No.)	Lc (mm)	L1 (mm)	Lc + 2xL1 (mm)	R1	R2	hearth rolls (No.)	Lc (mm)	L1 (mm)	Lc + 2 x L1 (mm)	R1	R2
					(10^{-3})						(10^{-3})	
1	8~20 8~20	600 600	350 350	1300 1300	0.2 0.4	0.1 0.2						
2	6~7 6~7	600 600	300 300	1200 1200	1.0 1.5	0.8 1.2	8~11 8~11	650 650	350 350	1350 1350	0.4 0.6	0.2 0.4
3												
4	8~20 7~20	850 800	325 275	1500 1350	0.2 0.35	0.15 0.25						
5	8~20 7~20	500 500	250 250	1000 1000	0.3 0.5	0.2 0.3						
6	9~20 8~20	700 700	325 325	1350 1350	0.2 0.4	0.1 0.2						
7												
8	6~7 6~7	600 600	300 300	1200 1200	0.3 0.5	0.2 0.3						

TABLE 4

	block 5 (upper line:upper rolls; lower line:lower rolls)						*2	
No.	hearth rolls (No.)	Lc (mm)	L1 (mm)	Lc + 2 x L1 (mm)	R1	R2	meandering buckling	remarks
					(10^{-3})			
1							≥50% ≥50%	present invention
2	12~20 12~20	750 750	400 400	1550 1550	0.15 0.2	0.05 0.1	≥50% ≥50%	present invention
3							≥50% ≥50%	present invention
4							≥50% ≥50%	present invention
5							≥50% ≥50%	present invention
6							40% 40%	present invention
7							40% 40%	present invention
8							45% 45%	present invention

$$*2: \frac{(\text{sheet passing speed}) - (\text{steady sheet passing speed}) \times 100\%}{(\text{steady sheet passing speed})}$$

Claims

1. A hearth roll for use in a heating/soaking furnace of a vertical heat treating furnace, comprising a flat section at a central portion and two-stepped taper sections on opposed sides of the flat section, the taper sections including first taper sections and second taper sections, wherein the inclination of each of the first taper sections continuous to said flat section is larger than the inclination of each of the second taper sections continuous to each of said first taper sections, and the length Lc (mm) of said flat section and the length L1 (mm) of each of said first taper sections have the relationship given by the following formulas (1) and (2):

$$0.5\,Wmin \le Lc \le Wmin \quad (1)$$

$$Wmin \le Lc + 2 \times L1 \le Wmax - 400 \quad (2)$$

where,

Wmin is a minimum width (mm) of a metal strip to be subjected to heat treatment, and
Wmax is a maximum width (mm) of the metal strip to be subjected to heat treatment.

2. The hearth roll according to claim 1, wherein a convex curve section and a concave curve section are formed at a boundary between said flat section and each of said first taper sections, and at a boundary between each of said first taper sections and each of said second taper sections, respectively, and each of said convex and concave sections has a radius of curvature of at least 20 m.

3. The hearth roll according to any one of claims 1 and 2, wherein each of the said first taper sections has an inclination R1 within the range of 0.2×10^{-3} to 10×10^{-3}, and each of the second taper sections has an inclination R2 within the range of 0.05×10^{-3} to 4×10^{-3}.

4. A vertical heat treating furnace, comprising:

a heating/soaking furnace;
an inlet;
a outlet;
an intermediate portion between the inlet and the outlet; and
a plurality of hearth rolls according to any one of claims 1 to 3 used as transfer rolls and disposed between the inlet and the outlet;
wherein the hearth rolls disposed at the inlet of the vertical heat treating furnace satisfy the following formulas (3) and (4), the hearth rolls disposed from the intermediate portion to the outlet satisfy the following formulas (5) and (6), and the lengths Lc and (Lc + 2 × L1) of the hearth rolls are increased from the inlet to the outlet of the vertical heat treating furnace, stepwise or sequentially, in the hearth roll groups of the respective ones of upper rolls and lower rolls disposed side by side in the vertical heat treating furnace:

$$0.5\ Wmin \leq Lc \leq 0.7\ Wmin, \tag{3}$$

$$Wmin \leq Lc + 2 \times L1 \leq (Wmin + Wmax - 400)/2, \tag{4}$$

$$0.7\ Wmin \leq Lc \leq Wmin, \tag{5}$$

$$(Wmin + Wmax - 400)/2 \leq Lc + 2 \times L1 \leq Wmax - 400 \tag{6}$$

5. A vertical heat treating furnace, comprising:

a heating/soaking furnace;
an inlet;
an outlet;
an intermediate portion between the inlet and the outlet; and
a plurality of the hearth rolls according to claim 1, 2, or 3 used as transfer rolls;
wherein the hearth rolls disposed at the inlet of the vertical heat treating furnace satisfy the following formulas (3), (4), (7) and (8), the hearth rolls disposed from the intermediate portion to the outlet satisfy the following formulas (5), (6), (9), and (10), and the lengths Lc and (Lc + 2 × L1) are increased from the inlet to the outlet, stepwise or sequentially, in the hearth roll groups of the respective ones of upper rolls and lower rolls disposed side by side in the vertical treat heating furnace, and the inclinations R1 and R2 of the first and second taper sections, respectively, are reduced from the inlet to the outlet of the vertical heat treating furnace, stepwise or sequentially:

$$0.5\ Wmin \leq Lc \leq 0.7\ Wmin \tag{3}$$

$$Wmin \leq Lc + 2 \times L1\ (Wmin + Wmax - 400)/2 \tag{4}$$

$$0.7\ Wmin \leq Lc \leq Wmin \tag{5}$$

$$(Wmin + Wmax - 400)/2 \leq Lc + 2 \times L1 \leq Wmax - 400 \quad (6)$$

$$3.0 \times 10^{-3} \leq R1 \leq 10 \times 10^{-3} \quad (7)$$

$$1.2 \times 10^{-3} \leq R2 \leq 4.0 \times 10^{-3} \quad (8)$$

$$0.2 \times 10^{-3} \leq R1 \leq 3.0 \times 10^{-3} \quad (9)$$

$$0.05 \times 10^{-3} \leq R2 \leq 1.2 \times 10^{-3} \quad (10)$$

6. A vertical heat treating furnace according to any one of claims 4 and 5, further comprising partition plates disposed at least between the hearth rolls of a former half section of the heating/soaking furnace and heating elements.

FIG. 1

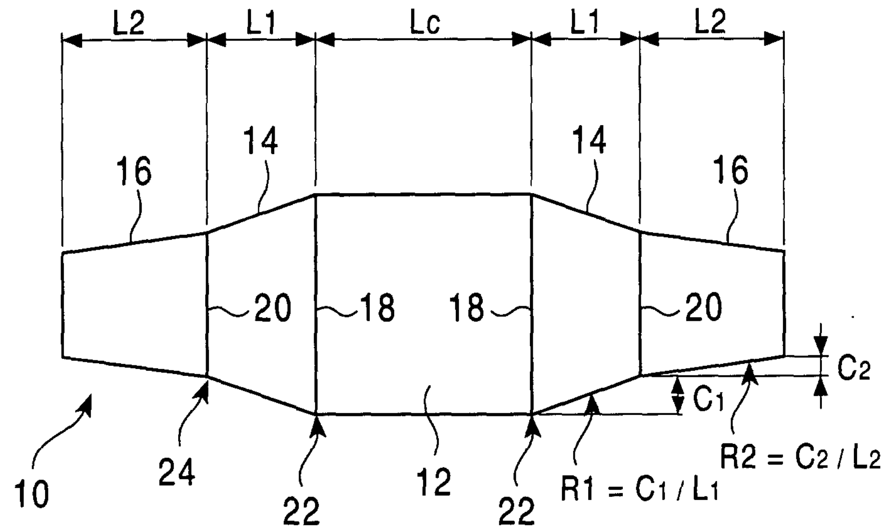

L2
L1
Lc
L1
L2
16
14
14
16
20
18
18
20
C2
C1
10
24
22
12
22
R1 = C1 / L1
R2 = C2 / L2

FIG. 2

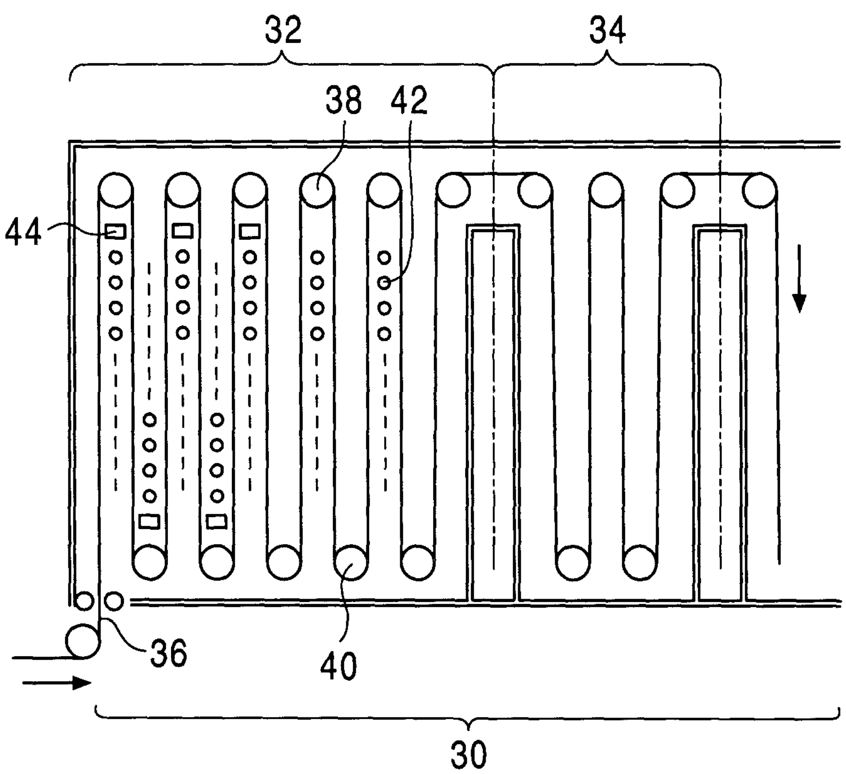

32
34
38
42
44
36
40
30

FIG. 3

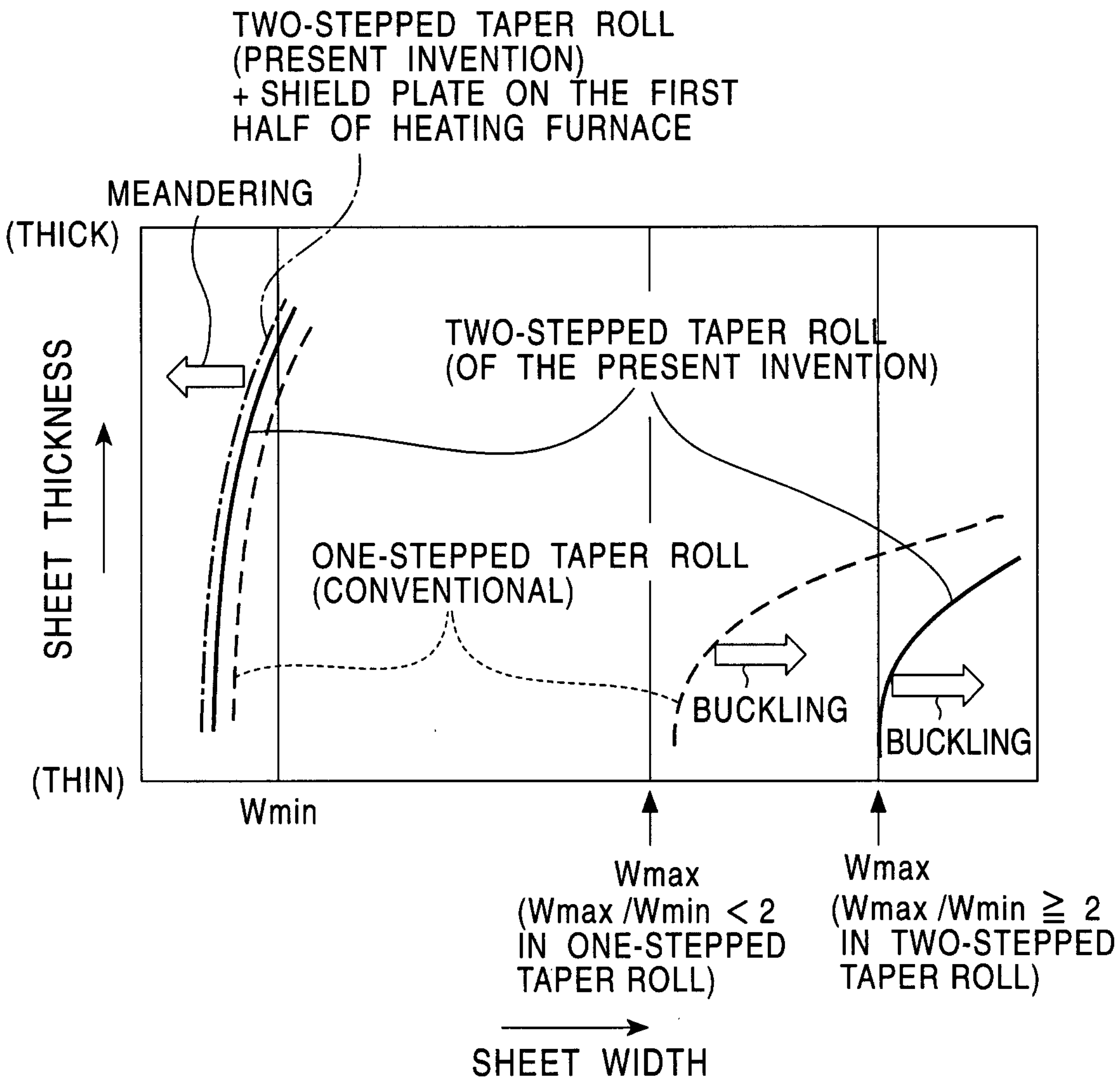

TWO-STEPPED TAPER ROLL
(PRESENT INVENTION)
+ SHIELD PLATE ON THE FIRST
HALF OF HEATING FURNACE
MEANDERING
(THICK)
SHEET THICKNESS
(THIN)
TWO-STEPPED TAPER ROLL
(OF THE PRESENT INVENTION)
ONE-STEPPED TAPER ROLL
(CONVENTIONAL)
BUCKLING
BUCKLING
Wmin
Wmax
(Wmax /Wmin < 2
IN ONE-STEPPED
TAPER ROLL)
Wmax
(Wmax /Wmin ≧ 2
IN TWO-STEPPED
TAPER ROLL)
SHEET WIDTH

FIG. 4

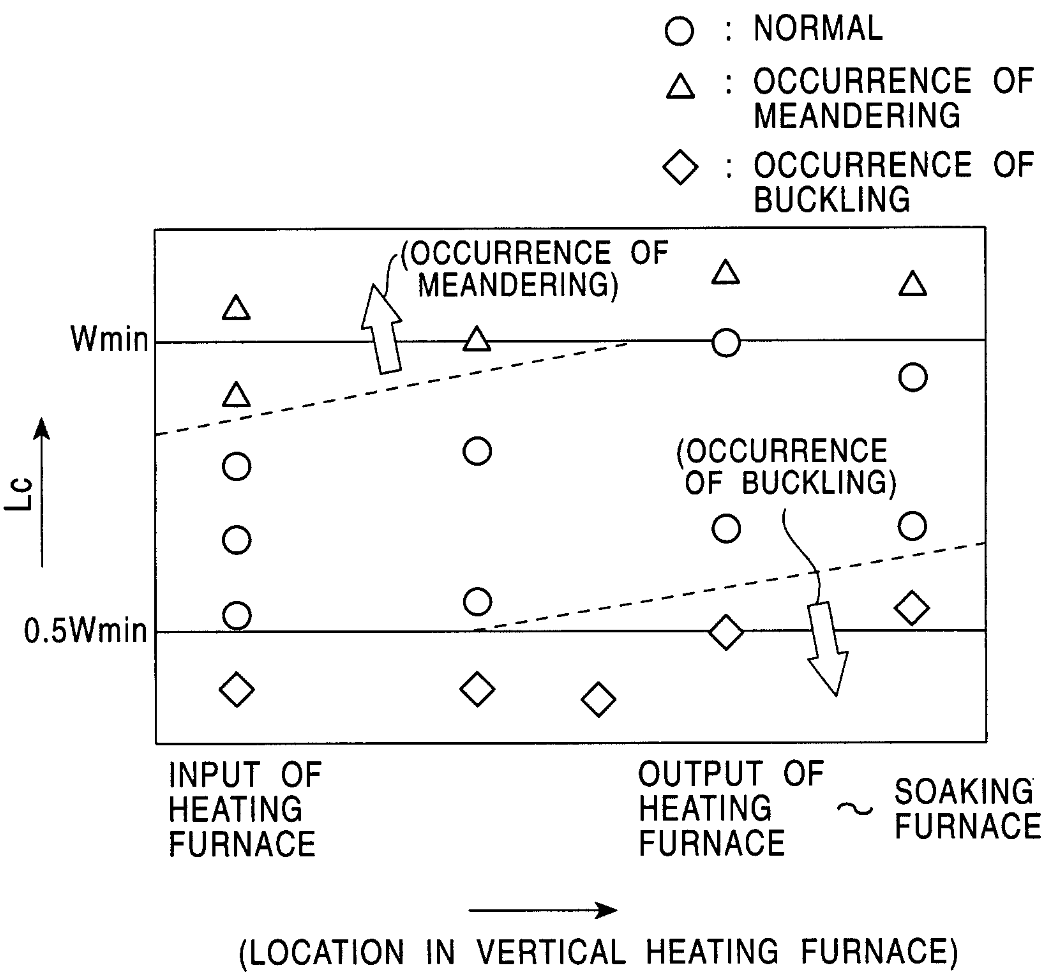

○ : NORMAL
△ : OCCURRENCE OF MEANDERING
◇ : OCCURRENCE OF BUCKLING
(OCCURRENCE OF MEANDERING)
Wmin
Lc
(OCCURRENCE OF BUCKLING)
0.5Wmin
INPUT OF HEATING FURNACE
OUTPUT OF HEATING FURNACE
~
SOAKING FURNACE
(LOCATION IN VERTICAL HEATING FURNACE)

FIG. 5

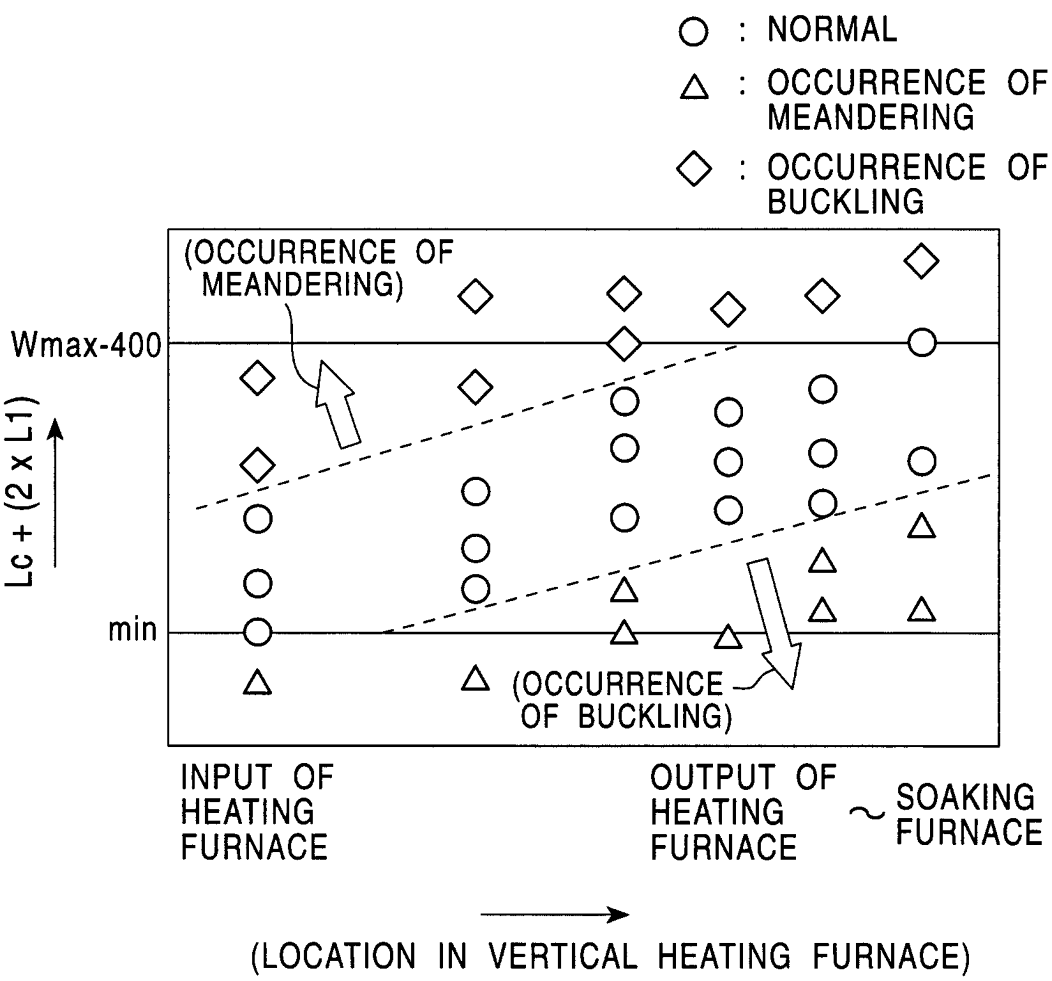

○ : NORMAL
△ : OCCURRENCE OF MEANDERING
◇ : OCCURRENCE OF BUCKLING
(OCCURRENCE OF MEANDERING)
Wmax-400
Lc + (2 x L1)
min
(OCCURRENCE OF BUCKLING)
INPUT OF HEATING FURNACE
OUTPUT OF HEATING FURNACE
~ SOAKING FURNACE
(LOCATION IN VERTICAL HEATING FURNACE)

FIG. 6

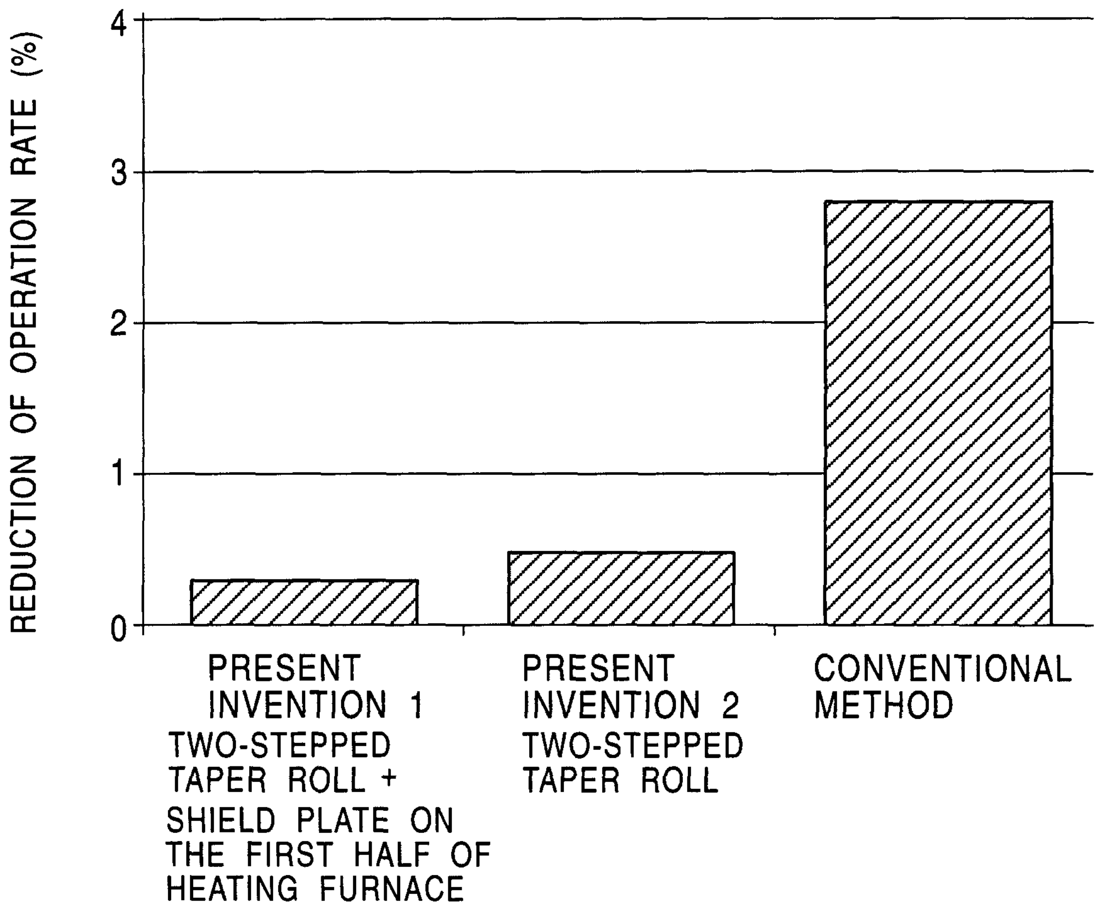
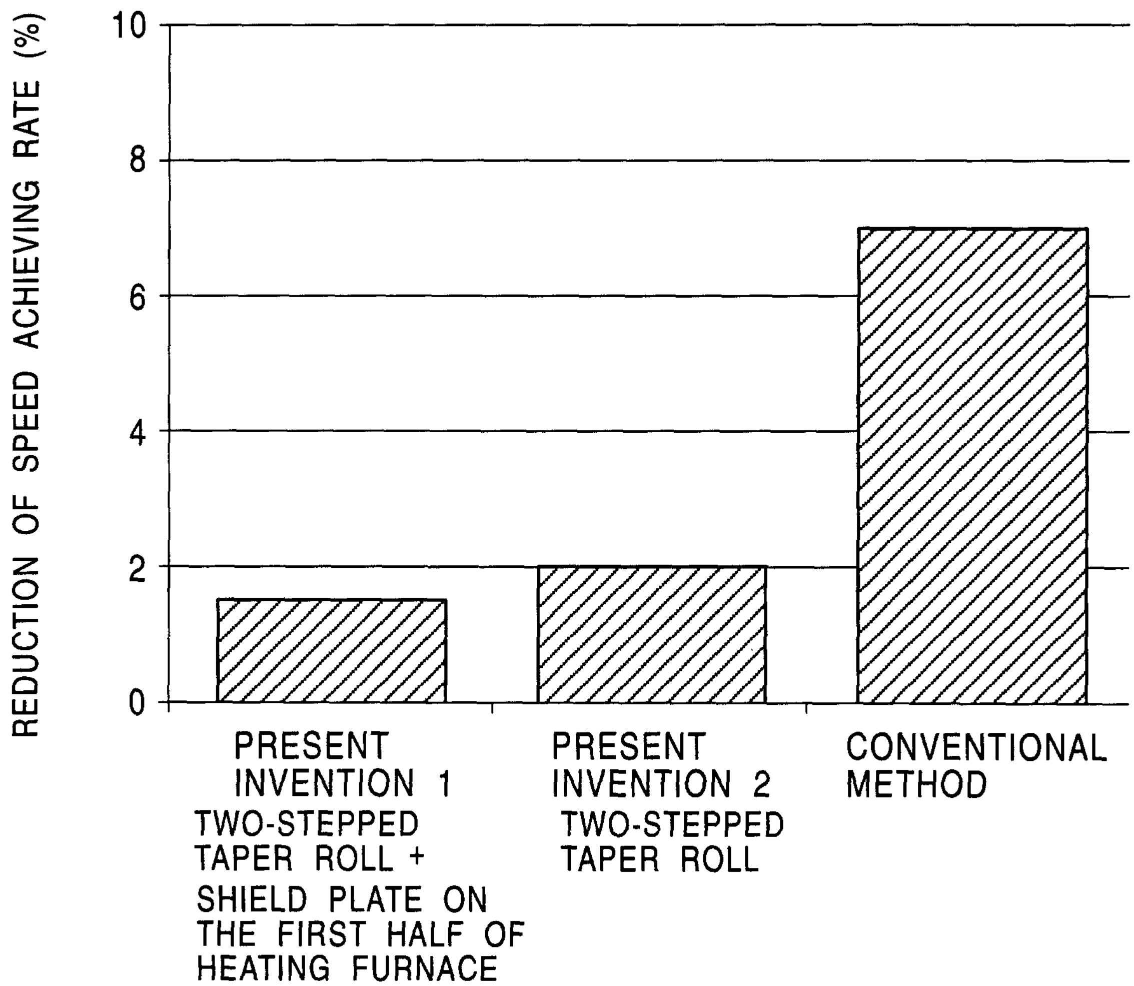

REDUCTION OF OPERATION RATE (%)
4
3
2
1
0
PRESENT INVENTION 1
TWO-STEPPED TAPER ROLL + SHIELD PLATE ON THE FIRST HALF OF HEATING FURNACE
PRESENT INVENTION 2
TWO-STEPPED TAPER ROLL
CONVENTIONAL METHOD

FIG. 7


REDUCTION OF SPEED ACHIEVING RATE (%)
10
8
6
4
2
0
PRESENT INVENTION 1
TWO-STEPPED TAPER ROLL + SHIELD PLATE ON THE FIRST HALF OF HEATING FURNACE
PRESENT INVENTION 2
TWO-STEPPED TAPER ROLL
CONVENTIONAL METHOD

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 4408

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 3 070 362 A (G.H.YOUNG) 25 December 1962 (1962-12-25)		C21D9/56
A	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 02, 26 February 1999 (1999-02-26) & JP 10 298666 A (SUMITOMO METAL IND LTD), 10 November 1998 (1998-11-10) * abstract *		
A	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 06, 30 June 1997 (1997-06-30) & JP 09 031550 A (KOBE STEEL LTD), 4 February 1997 (1997-02-04) * abstract *		
A,D	PATENT ABSTRACTS OF JAPAN vol. 002, no. 034 (C-005), 8 March 1978 (1978-03-08) & JP 52 136812 A (NIPPON KOKAN KK), 15 November 1977 (1977-11-15) * abstract *		

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
C21D
F27D
C21C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	9 November 2000	Coulomb, J

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09-11-2000

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JP 10298666	A	10-11-1998	NONE	
JP 09031550	A	04-02-1997	NONE	
JP 52136812	A	15-11-1977	NONE	

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82