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(54) SIX-STAGE ROLLING MILL

SECHS-WALZEN-WALZWERK

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(56) References cited:
EP-A- 0 049 798
EP-A- 0 258 482
DE-A- 3 638 331
DE-A- 3 712 043
JP-A- 54 013 442
JP-A- 58 187 207
JP-A- 59 056 905
JP-A- 62 282 717

- **PATENT ABSTRACTS OF JAPAN vol. 16, no. 132 (M-1229) 3 April 1992 & JP-A-03 294 006 (KAWASAKI) 25 December 1991**
- **PATENT ABSTRACTS OF JAPAN vol. 12, no. 218 (M-711) 22 June 1988 & JP-A-63 016 802 (KAWASAKI) 23 January 1988**
- **PATENT ABSTRACTS OF JAPAN vol. 11, no. 380 (M-650) 11 December 1987 & JP-A-62 151 203 (KAWASAKI) 6 July 1987**

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Description

Technical Field

[0001] This invention relates to a hot rolling mill and is concerned with a hot finish rolling mill for hot rolling a sheet bar rolled by a rough rolling mill to a product thickness or to a six high rolling mill for cold rolling strip sheet rolled by a hot finish rolling mill, in particular, to precisely control the sheet crown which is defined as the difference in the sheet thickness between a central portion of the sheet width and portions in the vicinity of edges, thereby preventing the sheet edges from becoming extremely thin because of edge drop.

Background art

[0002] Generally, when a hot rolled steel sheet is produced by means of a hot finish rolling mill, the rolls of the mill are deflected due to the rolling load, thereby the sheet thickness at the central portion of the sheet width becomes greater than the sheet thickness at portions in the vicinity of the opposite edges of the rolled sheet, that is a sheet crown is formed in the rolled sheet. By the way, the sheet crown, if the sheet crown becomes large, makes it difficult to provide an adequate sheet profile when cold rolling in the next step, which also results in shape deficiency and unavoidably results in a reduction in yield. Thus it is required for the hot finish rolling mill to make the sheet crown as small as possible.

[0003] Thus, for the purpose of controlling the shape of sheet to reduce the sheet crown, for example, JP-B-62-10722 discloses a six high rolling mill to be installed in a post-stage stand, wherein a rolling mill array includes intermediate rolls having a constant diameter over the full length thereof arranged between backup rolls and work rolls, respectively, and these intermediate rolls are adapted to shift in mutually opposite axial directions, whereby the ability to control the sheet crown is enhanced. Furthermore, JP-A-57-91807 discloses a rolling mill in which an S-shaped crown is formed on any one of a work roll, an intermediate roll or a backup roll, and the roll having the S-shaped crown is shifted in the axial direction, whereby the ability for controlling the sheet crown is enhanced.

[0004] However, in the former prior art disclosed in JP-B-62-10722, the length of the intermediate roll is made approximately the same as the lengths of the backup roll and the work roll, so that when the intermediate roll is shifted in order to make the sheet crown small, the length of contact of the intermediate roll with the backup roll and the work roll becomes short, and the mill rigidity of the rolling mill decreases. Hence there has been the problem that, when the rolling load changes due to temperature deviation in the sheet bar or the like, the roll gap between the pair of work rolls greatly changes, and no predetermined accuracy in the sheet thickness can be provided. There has been such a problem that, when the center of the sheet in the width direction deviates from the center of the rolling mill due to deviation of the sheet bar or the like, meanderings resulting from the difference in rigidity of the right and left portions of the rolling mill occur and sometimes it becomes impossible to carry out rolling because of reduction ears caused by miss rolling.

[0005] In addition, there has been the problem that spalling occurs on the surfaces of the rolls resulting from the increase in pressure between the rolls on account of the short length of contact of the intermediate roll, and the service life of the rolls decreases.

[0006] It is noted that the problem mentioned above can be avoided by decreasing the shift amount of the intermediate rolls, but the ability to control the crown of the work rolls in the rolling mill is then greatly limited.

[0007] Also in the later prior art disclosed in JP-A-57-91807, there has been the problem that, when profile control is performed by shifting intermediate rolls provided with an S-shaped crown, the control of crown becomes impossible due to the abrasion of the rolls.

[0008] Furthermore, when profile control is performed by providing a curved roll crown on the intermediate roll or the backup roll, it becomes necessary to enlarge the roll crown in order to ensure a large control amount for the crown, but when a sheet bar having a relatively narrow width is rolled with small rolling load by providing such a large roll crown, non-contact portions are generated between the backup roll and the intermediate roll or between the backup roll and the work roll, and the mill rigidity of the rolling mill becomes low, which unavoidably results in a decrease in the accuracy of the sheet thickness. In addition, there has been the problem that, when the non-contact portions are generated, meander and reduction ears occur in the rolled sheet as a result of the difference in rigidity in the axial direction of the rolls and as a result rolling of the sheet sometimes becomes impossible.

Disclosure of the Invention

[0009] This invention solves all such problems in the prior art and provides a six high rolling mill adapted for controlling both the sheet crown and edge drop of the sheets to prevent a decrease in mill rigidity of the rolling mill and meander of the sheet resulting from great shifting of the intermediate roll and to attain an increase in service life of the rolls.

[0010] According to the present invention there is provided a six high rolling mill comprising upper and lower work rolls, a pair of intermediate rolls and a pair of backup rolls wherein at least the intermediate rolls and the work rolls are adapted to be shifted in their axial directions, said intermediate rolls are provided with roll crowns which are in a point symmetrical relationship with reference to the centre point of the mill, and said work rolls have roll profiles which are in a point symmetrical relationship with reference to the centre point of the mill characterised in that the roll profile of one of the intermediate rolls is expressed by the following ternary equation (1):

$$y_1(x) = -a[\{x-(\delta+OF)\}/L]^3+b(x/L) \quad (1)$$

where

y_1 is the generating line of the crown of the roll,
a is a coefficient of the third order,
b is a coefficient of the first order,
x is the coordinate of the barrel center,
L is 1/2 of the barrel length of the intermediate roll,
δ is the shift amount of the intermediate roll relative to a start point where $x=L_B$, and
OF is the offset amount in the axial direction; in that the roll profile of the other of the intermediate rolls is expressed by the following ternary equation (2):

$$y_2(x) = -a[\{x+(\delta+OF)\}/L]^3+b(x/L) \quad (2)$$

where y_2 is the generating line of the crown of the roll; and in that each of the intermediate rolls has a barrel length 1.5 times as long as that of its backup roll such that the intermediate rolls always contact the backup rolls over the full length thereof at the maximum and minimum shifted positions of the intermediate rolls.

[0011] In a preferred embodiment of the present invention, the barrel length of the work roll is longer than that of the intermediate roll and preferably 1.4 to 2.5 times longer than that of the intermediate roll.

[0012] The work roll may be provided with a roll crown having a shape such as a one side taper shape where the barrel diameter is gradually reduced towards one end of the roll barrel or a two side taper shape where the barrel diameter is gradually reduced towards the opposite ends from the center of the barrel length.

[0013] The six high rolling mill according to the invention is able to reduce the load affected between rolls, in particular, the barrel end portions of the intermediate and work rolls by providing the roll crown for the intermediate rolls, thereby improving the ability to control the crown. Particularly, the "S" shaped roll crown can effectively reduce the rolling load applied on both edge portions of the sheet, and when the intermediate rolls are respectively shifted in the opposite directions relative to each other in the point symmetry relationship, the aforementioned function is more remarkably attained and as a result a greater crown control ability can be attained.

[0014] In the rolling mill according to the invention, since the intermediate roll has a barrel length longer than that of the backup roll as mentioned above, even if the intermediate roll is greatly shifted, the intermediate roll can always effectively contact the backup roll over the full length thereof so that the mill rigidity of the rolling mill is effectively prevented from decreasing due to profile control. Therefore accuracy of the sheet thickness is greatly improved without being affected by variation in the width of the sheet to be rolled. Furthermore, even if the sheet to be rolled has camber, the sheet is subjected to uniform reduction through the whole sheet width so that the occurence of meander can be effectively reduced.

[0015] It should be noted that if the roll barrel of the intermediate roll had a length which was the same as the roll barrel of the backup roll, it would be necessary to use a large roll crown so as to provide a large difference between the maximum diameter and minimum diameter of the roll barrel of the intermediate roll in order to attain the necessary crown control. As a result, the contact pressure generated between contacting rolls increases and causes spalling on the surfaces of the rolls and also reduce the service life of the rolls. Furthermore, when the sheet bar has a relatively narrow width and the rolling load is small, non-contact portions are generated between the barrels of the intermediate and backup rolls or between the barrels of the intermediate and work rolls. Thus, the mill rigidity of the rolling mill reduces and as a resuit the desired accuracy of the sheet thickness can not be obtained. Therefore, in order to remove the aforementioned problems, the barrel length of the intermediate roll is 1.5 times as long as the barrel length of the back up roll.

[0016] Furthermore, the barrel length of each work roll is preferably longer than that of the intermediate roll, and advantageously the line barrel length of the work roll is 1.4～2.5 times as long as the intermediate roll so that the work roll always effectively contacts the intermediate roll in spite of shifting of the intermediate roll to improve the mill rigidity of the rolling mill and particularly reduce meandering of the sheet. Moreover, the service life of the roll is improved by increasing the contact range between the rolls and by preventing the contact pressure between the rolls from increasing.

Brief Description of Drawing

[0017]

Fig. 1 is a schematic front view of a rolling mill according to the present invention;
Fig. 2 is a diagrammatic view illustrating the roll crown for an intermediate roll of the mill of Fig. 1;
Fig. 3 is a schematic view illustrating the intermediate rolls of Fig. 1 in their in shifted positions;
Fig. 4 is a block diagram of a control system of the rolling mill of Fig. 1;
Fig. 5 shows graphs showing the relationship between the pressure between the rolls of the mill and the sheet crown;
Fig. 6 is a graph showing the relationship between the ratio of the barrel length of the intermediate and backup rolls of the mill and the maximum pressure between rolls;
Fig. 7 is a graph showing the contact conditions between the rolls of the mill with respect to the ratio of the barrel length of the intermediate and backup rolls;
Fig. 8 is a diagrammatic view illustrating bending of the intermediate rolls of the mill;
Fig. 9 is a graph showing the relationship between the ratio of the barrel length of the intermediate and backup rolls of the mill and the deflection amount of the intermediate rolls;
Fig. 10 is a graph showing the distribution of sheet crown with respect to the number of rolled sheets;
Fig. 11 is a diagrammatic side view of a mill of the invention illustrating the supply of lubricant;
Fig. 12 is a diagrammatic front view of the mill of Fig. 11; and
Fig. 13 is a graph showing the relationship between the diameter of the work rolls and the crown control amount.

The Best Mode for Carrying the Invention

[0018] This invention will be explained hereinafter on the basis of examples shown in drawings.
[0019] Fig. 1 illustrates a six high rolling mill according to the present invention.
[0020] Referring to Fig. 1, a housing 1 is provided with pairs of upper and lower work rolls 2, intermediate rolls 3 and backup rolls 4, respectively. Both work rolls 2 are capable of being shifted in mutually opposite directions along their axes by means of shifting units 5 for each of them. Both intermediate rolls 3 are also capable of being shifted in mutually opposite directions along their axes by means of other shifting units 6 for each of them.
[0021] Each of the backup rolls 4 is constituted by a so-called plain roll having a constant barrel diameter throughout its entire length, and each of the intermediate rolls 3 is constituted by a roll having a barrel length longer than that of the backup roll and a "S" shaped roll crown.
[0022] It is preferred that the "S" shaped roll crown of the intermediate rolls has a difference between maximum and minimum roll diameters not larger than 1mm.
[0023] The intermediate rolls 3 with such a roll crown are arranged in mutually opposite positions as shown in Fig. 1 and shifted in mutually opposite directions between the maximum and minimum shift positions shown in Fig. 3(a) and (b) by means of shifting units 6.
[0024] In the minimum shift position shown in Fig. 3 (a), one barrel end 3a of the intermediate roll 3 is just aligned to one barrel end 4a of its backup roll 4, while in the maximum shift position shown in Fig. 3(b) the other barrel end 3b of the intermediate roll 3 is just aligned to the other barrel end 4b of its backup roll 4. Thus the intermediate rolls contact their respective backup rolls along the full length of the backup rolls at the maximum and minimum shifted positions.
[0025] As can be seen from Figs. 1 and 3, the work rolls 2 are plain rolls having a constant diameter and having the same barrel length as that of the backup rolls.
[0026] Referring to Fig. 1, in the rolling mill with rolls 2, 3 and 4 arranged as mentioned above, each of the work rolls 2 is connected to a reduction gear 10, attached to a motor 9, successively by means of a spindle 7 and a pinion stand 8. In this case, the shifting position of the work roll 2 (caused by the shifting unit 5, connected to the work roll 2 through the spindle 7 and the pinion stand 8) is detected by a position detecting unit 11 which can be, for example, a magnet scale, and the shifting position of the intermediate roll 3 (caused by the shifting unit 6 connected to the intermediate roll 3) is detected by another position detecting unit 12 which can be also, for example, a magnet scale.
[0027] Incidentally, in the figure, 13, 14 and 15 denote a rolled sheet as a product, a work roll bender and an intermediate roll bender, respectively, and 16 indicates a load cell.
[0028] Fig. 4 is a diagrammatic view of a control system of the rolling mill as described above.

[0029] In the figure, 21 indicates an arithmetic unit, and into this arithmetic unit 21 are inputted beforehand rolling conditions in one cycle such as the shape and size of any tapered portion of the work roll 2, the roll crown and size of the intermediate roll 3, the sheet width, the draft at each roll stand, the sheet finish thickness, the target sheet crown, the target sheet shape and the like, and the arithmetic unit 21 calculates the setting values for the shifting amount of the intermediate roll 3 and the bending force of each of the roll benders 14 and 15 on the basis of such information and the cyclic shifting amount of the work roll 2 in order to provide a sheet crown and a sheet shape as required by the target.

[0030] On the basis of the calculation result, each of a shifting control unit 22 and a bender control unit 23 controls the operations of the shifting unit 6 and the roll benders 14 and 15 so that the shifting amount of the intermediate roll 3 and the roll bending force are used as setting values to wait for the start of rolling in such a state.

[0031] On the other hand, during the rolling, on the basis of feedback signals from a sheet shape detecting unit 24 and a sheet crown detecting unit 25 to the arithmetic unit 21, in order to realize the target sheet shape and the target sheet crown with high accuracy, the arithmetic unit 21 calculates corrected values of the intermediate roll shifting amount and the roll bending force, and the shifting control unit 22 and bender control unit 23 adjust the shift amount of the intermediate roll 3 and the bending force of the roll benders 14, 15 in accordance with the correction values.

[0032] When rolling is carried out by the aforementioned rolling mill, especially under the function of the roll crown acting on the intermediate roll 3, the rolling load exerted on the side edge portions of a sheet bar by the work roll can be very effectively lowered. Therefore, in addition to the actions of the roll benders 14, 15, not only the sheet crown can be controlled with high accuracy but by shifting the intermediate roll 3, its control range can be sufficiently extended.

[0033] Next, a method to give a roll crown to the intermediate roll 3 will be explained, by way of an example in which a roll crown is given in accordance with an equation of the third order as shown in Fig. 2.

[0034] That is, the lower roll profile of the intermediate roll 3 shown in Fig. 2(a) is the same as the curve shown in Fig. 2(b), and this curve can be expressed by the following equation (1).

$$y_1(x) = -a[\{x - (\delta + OF)\}/L]^3 + b(x/L) \qquad (1)$$

where

- y_1: generating line of the roll crown,
- a : coefficient of the third order,
- b : coefficient of the first order,
- x : coordinate of the barrel center,
- L : 1/2 of the barrel length of the intermediate roll,
- δ : shift amount of the intermediate roll (The start point is x = LB.), and
- OF: offset amount in the axial direction.

[0035] On the other hand, the upper roll profile of the intermediate roll 3 being in point symmetry to the lower roll profile with respect to the centre point of the mill can be expressed by the following equation (2) wherein y_2 is the generating line of the roll crown.

$$y_2(x) = -a[\{x + (\delta + OF)\}/L]^3 + b(x/L) \qquad (2)$$

[0036] From the aforementioned equations (1) and (2), the gap Δy between the upper and lower rolls is expressed by the following equation.

$$\Delta y(x) = y_1 - y_2 = 2 \cdot a \cdot \left(\frac{\delta + OF}{L}\right)\left[3\left(\frac{x}{L}\right)^2 + \left(\frac{\delta + OF}{L}\right)^2\right] \qquad (3)$$

[0037] Composite roll crown CR formed by the upper and lower intermediate rolls can be expressed by the following equation (4), wherein the mill center is set to be zero (0).

$$CR = \Delta y(O) - \Delta y(x) = -6a\{(\delta + OF)/L\}(x/L)^2 \qquad (4)$$

[0038] The maximum shift amount δ_{max} to give the maximum composite roll crown can be expressed as follows.

$$\delta_{max} = L - L_B \quad (5)$$

where L_B: 1/2 of the barrel length of the backup roll. In order to make the composite crown of the upper and lower intermediate rolls to be zero when the shift amount is the minimum value of δ_{min} {=-(L - L_B)}, the offset amount OF must be as follows.

$$OF = L - L_B \quad (6)$$

[0039] In a normal hot rolling process, the minimum crown amount may be when the composite crown of the upper and lower rolls is zero. However, when it is necessary to make the minimum composite crown larger or smaller than zero, offset amount OF using the position where the shift amount of the intermediate roll is zero (x = L) as a starting point, may be determined as follows.

$$OF = C(L = L_B)$$

where C is a constant.
[0040] In order to reduce the difference between the maximum and minimum diameters of the intermediate roll without changing the composite roll crown, it is effective to use the following equation obtained when equations (5) and (6) are substituted for equation (4).

$$CR = -6a\{(1 + C)(L - L_B)/L^3\}\cdot x^3 \quad (8)$$

and to make the third order coefficient "a" to be minimum, therefore to make $(L - LB)/L^3$ to be maximum in the afore-mentioned equation. In order to make $(L-L_B)/L^3$ to be maximum, the following equation is applied.

$$L = 1.5L_B \quad (9)$$

[0041] Accordingly, when the barrel length of the intermediate roll is made 1.5 times as long as that of the backup roll, the maximum and minimum diameter differences of the intermediate roll can be made small, that is, when an S-shaped roll crown is formed on the intermediate roll, the grinding amount can be reduced, so that the life of the intermediate roll can be lengthened in the process of roll grinding.
[0042] Fig. 5 shows the result of a comparison of the pressure distribution between rolls and the sheet crown when using an intermediate roll of $L = 1.1L_B$. As shown in Fig. 5, when the barrel length is $1.5L_B$ (solid line), the work roll is bent along the intermediate roll, so that the sheet crown is reduced as compared with a case in which the barrel crown is $1.1L_B$. Also, as shown in Table 1, it is apparent that the maximum pressure is smaller when the barrel length is $1.5L_B$, so that it contributes to improve the roll life.

Table 1

Length of intermediate roll	Line pressure (kgf/mm) between intermediate and backup rolls	Line pressure (kgf/mm) between intermediate and work rolls
$1.5L_B$	911	986
$1.1L_B$	1140	1155

[Experimental Example]

[0043] Next, the results of an experiment concerning the intermediate roll, especially barrel length, will be explained as follows.
[0044] That is the barrel length of the work roll used was 2300 mm, its diameter was 680 mm, the barrel length of the backup roll used was 2300 mm, and its diameter was 1330 mm. The barrel length of the intermediate roll was

variously changed in which the third order coefficient "a" of equation (8) was 0.833. Sheet bars, having a width of 1500 mm and a thickness of 5.2 mm, were rolled to a thickness of 4.16 mm, and various investigations were made.

[0045] First, Fig. 6 shows the relationship between the ratio (L/L_B) of the intermediate and backup roll barrel lengths, and the maximum pressure between the intermediate and backup rolls. As shown in the drawing, when the ratio (L/L_B) is increased to not less than 1.2 times, the pressure is gently lowered, so that it is apparent that an intermediate roll of long barrel length is favorable.

[0046] Fig. 7 shows the contact condition between the intermediate and backup rolls with respect to the ratio of barrel length under the condition that the same sheet crown is obtained. As can be seen from Fig. 7, when the ratio is increased to not less than 1.2 times, the occurrence of a non-contact region can be prevented, and it is effective to improve the sheet thickness accuracy and to inhibit the occurrence of sheet meander and reduction ears.

[0047] In general, when a gap is formed between a block installed in a mill housing for shifting an intermediate roll, and a chock of the intermediate roll (this gap is formed due to abrasion caused by the sliding of the intermediate roll, and also due to defective accuracy of the machine), a deflection is generated in the intermediate roll 3 as shown in Fig. 8(a). Fig. 9 shows the relationship between the horizontal deflection amount t and the ratio (L/L_B) of the barrel length of the intermediate and backup rolls under the condition that the aforementioned gap is 3 mm, wherein the maximum displacement amount t between the chocks shown in Fig. 8(b) is defined as the horizontal deflection amount.

[0048] As shown in Fig. 9, the more the ratio is increased, the more the horizontal deflection amount is increased. When the horizontal deflection amount is increased, the gap between the upper and lower work rolls is changed and when the horizontal deflection amount of the upper intermediate roll and that of the lower intermediate roll become different, the roll gap between the upper and lower work rolls becomes varied in the axial direction. Therefore the sheet crown and the sheet profile fluctuate during the rolling operation. For that reason, in order to reduce the barrel length ratio, the intermediate roll length is preferred to be short. However, in the case where the horizontal bending amount is to the extent of 0.45 mm, it has little influence on the sheet crown and profile, so that it causes no problem in a normal rolling operation. Further, the aforementioned gap is usually controlled to be not more than 3 mm. Therefore, it is apparent that when the barrel of the intermediate roll is not more than 2.5 times as long as the backup roll, the rolling can be carried out.

[Specific Example]

[0049] A comparative example will be explained as follows in which a crown distribution with respect to the number of rolled sheets and others were investigated when using a rolling mill according to the present invention and also when using a conventional rolling mill.

Rolling Mill of the Present Invention

[0050] In a rolling mill train in which six high rolling mills structured as shown in Fig. 1 were arranged in three rolling stands in the rear stage, sheet bars of 900 to 1600 mm width and 40 mm thickness, were rolled to produce a low carbon steel thin sheet of 1.6 to 3.2 mm finished thickness, and then the sheet crown was measured every 5 coils at a position spaced from the edge by 25 mm.

[0051] In this case, the barrel length of the work rolls was 2300 mm, that of the intermediate roll was 3450 mm, and that of the backup roll was 2300 mm. Also, the difference between the maximum and minimum diameters of the intermediate roll was 0.8 mm, and the intermediate roll was shifted within a range from 0 mm to 700 mm.

Rolling Mill of the Prior Art

[0052] In a rolling mill train, six high mills were arranged in three rolling stands in the rear stage including the final rolling stand. Each six high mill had work rolls, intermediate rolls and backup rolls, all of them being plain rolls and all having a barrel length of 2300 mm. The intermediate rolls were shifted, and rolling operations were carried out in the same manner as the rolling mill of the invention, and the sheet crown was measured in the same manner.

Results of Experiments

[0053] Results of measurement are shown in the graph of Fig. 10.

[0054] According to the results shown in Fig. 10, when the rolling mill of the present invention was used, it is apparent that it was possible to carry out a highly accurate sheet rolling operation to obtain a sheet crown close to the target sheet crown out even when the target crown was changed. In this case, the rolling schedule with respect to the sheet width of the rolling mill of the present invention was set to be the same as that of the rolling mill of the prior art.

[0055] The frequency of occurrence of reduction ears, the accuracy of the sheet thickness, and the average value of the sheet crown are shown in Table 2 in the case where 100,000 tons of sheets were rolled in a thin cycle rolling schedule using the aforementioned rolling mills of the invention and the conventional rolling mills. According to this table, both the sheet thickness accuracy and the pass property (decrease in the occurrence of reduction ears) of the rolling mill of the invention are far superior to those of the conventional rolling mill.

Table 2

	Average crown E_{25} (μm)	Sheet thickness accuracy lσ (μm)	Frequency of ears (time)
Inventive rolling mill	40	±46	2
Conventional rolling mill	45	±60	11

[0056] In the rolling mill of the invention as described above, it is preferable to supply lubricant to gaps between the backup and intermediate rolls and/or the intermediate and work rolls.

[0057] Referring to Fig. 11, lubricant supplying nozzles 26 are arranged to direct lubricant from these nozzles to a gap between the backup roll 4 and the intermediate roll 3 and to a gap between the intermediate roll 3 and the work roll 2. The lubricant is supplied to the lubricant supplying nozzles 26 by supply pipes 29 from a lubricant tank 27 by means of a pump 28. Furthermore, coolant is supplied to the intermediate rolls 3 and the work rolls 2 from cooling nozzles 32 by coolant supply pipes 31 and a coolant pump 30. The preferred lubricant is a highly concentrated emulsion of basic oil including a high pressure agent, but when the lubricant is also used for cooling the rolls, a lubricant having a low concentration may be used.

[0058] Referring to Fig. 12, the distance between the lubricant supply nozzles 26 for the barrel portion of the intermediate roll 3 having the larger diameter is preferably smaller than that for the barrel portion having the smaller diameter to increase the amount of lubricant supplied. Instead of increasing the amount of lubricant supplied, the concentration of the lubricant may be varied in the axial direction of the intermediate roll to obtain the same effect as mentioned above.

[0059] The rolling mill shown in Fig. 1 was used to roll the sheet bars mentioned above using a 10% emulsion as lubricant and, as coolant, industrial water in a manner as shown in Fig. 11 and at least 120 strips were rolled without roll seizure occurring. In a comparison example, the sheet bars were rolled in the same manner as mentioned above but using only industrial water as coolant. In this case roll seizure occurred on the work roll and the intermediate roll when 100 strips had been rolled and the rolling operation was stopped.

[0060] In a rolling mill including an intermediate roll provided with roll crown, distribution of the contact pressure between rolls is varied to vary the bending of the work roll, thereby controlling the sheet crown, and therefore the shape of the sheet. Thus, the amount of crown control is not varied by the change of rolling load. Accordingly, when the diameter of the work roll is small, the deflection amount of the center line of the work roll is greatly varied so that the amount of crown control generated by shifting the intermediate roll becomes large. While, when the diameter of the work roll is large, change in the deflection amount of the center line of the work roll is small so that the amount of crown control generated by shifting the intermediate roll becomes small.

[0061] Results of test carried on rolled sheets of 1500 mm width with respect to the diameter of the work roll and the amount of crown control are shown in Fig. 13. As can be seen from Fig. 13, when the diameter of the work roll is small, preferably not more than 700 mm, the amount of crown control becomes large, but when the diameter of the work roll is smaller than 400 mm, the amount of horizontal bending of the work roll becomes large and the roll profile becomes wrong. Thus the work roll is difficult to drive and the affect caused by bending of the work roll is decreased. Accordingly, a work roll of a diameter of at least 400 mm is desirable.

Claims

1. A six high rolling mill comprising upper and lower work rolls (2), a pair of intermediate rolls (3) and a pair of backup rolls (4) wherein at least the intermediate rolls and the work rolls are adapted to be shifted in their axial directions, said intermediate rolls are provided with roll crowns which are in a point symmetrical relationship with reference to the centre point of the mill, and said work rolls have roll profiles which are in a point symmetrical relationship with reference to the centre point of the mill **characterised in that**
the roll profile of one of the intermediate rolls (3) is expressed by the following ternary equation (1):

$$y_1(x) = -a[\{x-(\delta+OF)\}/L]^3 + b(x/L) \quad (1)$$

where

y_1 is the generating line of the crown of the roll,
a is a coefficient of the third order,
b is a coefficient of the first order,
x is the coordinate of the barrel center,
L is 1/2 of the barrel length of the intermediate roll,
δ is the shift amount of the intermediate roll relative to a start point where $x=L_B$, and
OF is the offset amount in the axial direction; **in that** the roll profile of the other of the intermediate rolls is expressed by the following ternary equation (2):

$$y_2(x)= -a[\{x+(\delta+OF)\}/L]^3+b(x/L) \quad (2)$$

where y_2 is the generating line of the crown of the roll; and **in that** each of the intermediate rolls has a barrel length 1.5 times as long as that of its backup roll such that the intermediate rolls always contact the backup rolls over the full length thereof at the maximum and minimum shifted positions of the intermediate rolls.

2. The six high rolling mill according to claim 1, wherein each work roll (2) is a plain roll having a constant diameter.

3. The six high rolling mill according to claim 1 or 2, wherein each of the upper and lower work rolls (2) has a one side taper-shape roll crown which is tapered from one of the barrel ends towards the other.

Patentansprüche

1. Sechswalzen-Walzgerüst, umfassend obere und untere Arbeitswalzen (2), ein Paar Zwischenwalzen (3) und ein Paar Stützwalzen (4), wobei zumindest die Zwischenwalzen und die Arbeitswalzen so eingerichtet sind, daß sie in Richtung ihrer Achsen verschiebbar sind, und die Zwischenwalzen Balligkeiten aufweisen, die punktsymmetrisch bezüglich des Gerüstmittelpunkts sind, und die Arbeitswalzen Walzenprofile aufweisen, die punktsymmetrisch bezüglich des Gerüstmittelpunkts sind,

dadurch gekennzeichnet, daß das Walzenprofil einer der Zwischenwalzen (3) durch die folgende Gleichung (1) dritten Grades ausdrückbar ist

$$y_1(x) = -a[\{x - (\delta + OF)\}/L]^3 + b(x/L)\ , \quad (1)$$

wobei gilt:

y_1 ist die Erzeugende der Walzenballigkeit,
a ist der Koeffizient des Terms dritter Ordnung,
b ist der Koeffizient des Terms erster Ordnung,
x ist die Koordinate der Ballenmitte,
L ist die Hälfte der Ballenlänge der Zwischenwalze,
δ ist die Größe der Verschiebung der Zwischenwalze relativ zu einem Anfangspunkt, für den $x = L_B$ gilt, und
OF ist die Versatzgröße in Achsenrichtung;

und dadurch, daß das Walzenprofil der anderen Zwischenwalze durch die folgende Gleichung (2) dritten Grades ausdrückbar ist

$$y_2(x) = -a[\{x + (\delta + OF)\}/L]^3 + b(x/L)\ , \quad (2)$$

wobei y_2 die Erzeugende der Walzenballigkeit ist;

und dadurch, daß jede der Zwischenwalzen eine Ballenlänge hat, die 1,5mal so lang ist wie die ihrer Stützwalze, so daß die Zwischenwalzen in ihrer größten und kleinsten Verschiebestellung die Stützwalzen stets auf ihrer gesamten Länge berühren.

2. Sechswalzen-Walzgerüst nach Anspruch 1, wobei jede Arbeitswalze (2) eine Glattwalze ist, die einen konstanten Durchmesser aufweist.

3. Sechswalzen-Walzgerüst nach Anspruch 1 oder 2, wobei sowohl die untere als auch die obere Arbeitswalze (2) eine einseitig konische Walzenballigkeit aufweist, die von einem Ballenende zum anderen konisch verläuft.

Revendications

1. Laminoir à six étages comprenant des cylindres de travail supérieur et inférieur (2), une paire de cylindres intermédiaires (3) et une paire de cylindres d'appui (4), dans lequel les cylindres intermédiaires et les cylindres de travail au moins peuvent être décalés dans leur direction axiale, lesdits cylindres intermédiaires ayant des bombés qui sont en relation de symétrie centrale par rapport au point central du laminoir, et lesdits cylindres de travail ayant des profils qui sont en relation de symétrie centrale par rapport au point central du laminoir,
caractérisé :

- **en ce que** le profil de l'un des cylindres intermédiaires (3) est exprimé par l'équation du troisième degré (1) suivante :

$$y_1(x) = -a[\{x - (\delta+OF)\}/L]^3 + b(x/L) \tag{1}$$

dans laquelle :

y_1 est la ligne génératrice du bombé du cylindre,
a est un coefficient du troisième ordre,
b est un coefficient du premier ordre,
x est la coordonnée du centre du fût,
L est la moitié de la longueur du fût du cylindre intermédiaire,
δ est le décalage du cylindre intermédiaire par rapport à un point d'origine où $x = L_B$, et
OF est la valeur du décalage dans la direction axiale,

- **en ce que** le profil de l'autre cylindre intermédiaire est exprimé par l'équation du troisième degré (2) suivante :

$$y_2(x) = -a[\{x + (\delta+OF)\}/L]^3 + b(x/L) \tag{2}$$

dans laquelle :

y_2 est la ligne génératrice du bombé du cylindre,

- et **en ce que** chacun des cylindres intermédiaires a une longueur de fût qui est 1,5 fois plus grande que celle de son cylindre d'appui, si bien que les cylindres intermédiaires sont toujours en contact avec les cylindres d'appui sur toute la longueur de ceux-ci pour les positions de décalage maximal et minimal des cylindres intermédiaires.

2. Laminoir à six étages selon la revendication 1, dans lequel chaque cylindre de travail (2) est un cylindre simple, de diamètre constant.

3. Laminoir à six étages selon la revendication 1 ou 2, dans lequel chacun des cylindres de travail supérieur et inférieur (2) a un bombé en forme de cône à un seul côté qui diminue d'une des extrémités du fût à l'autre.

FIG_1

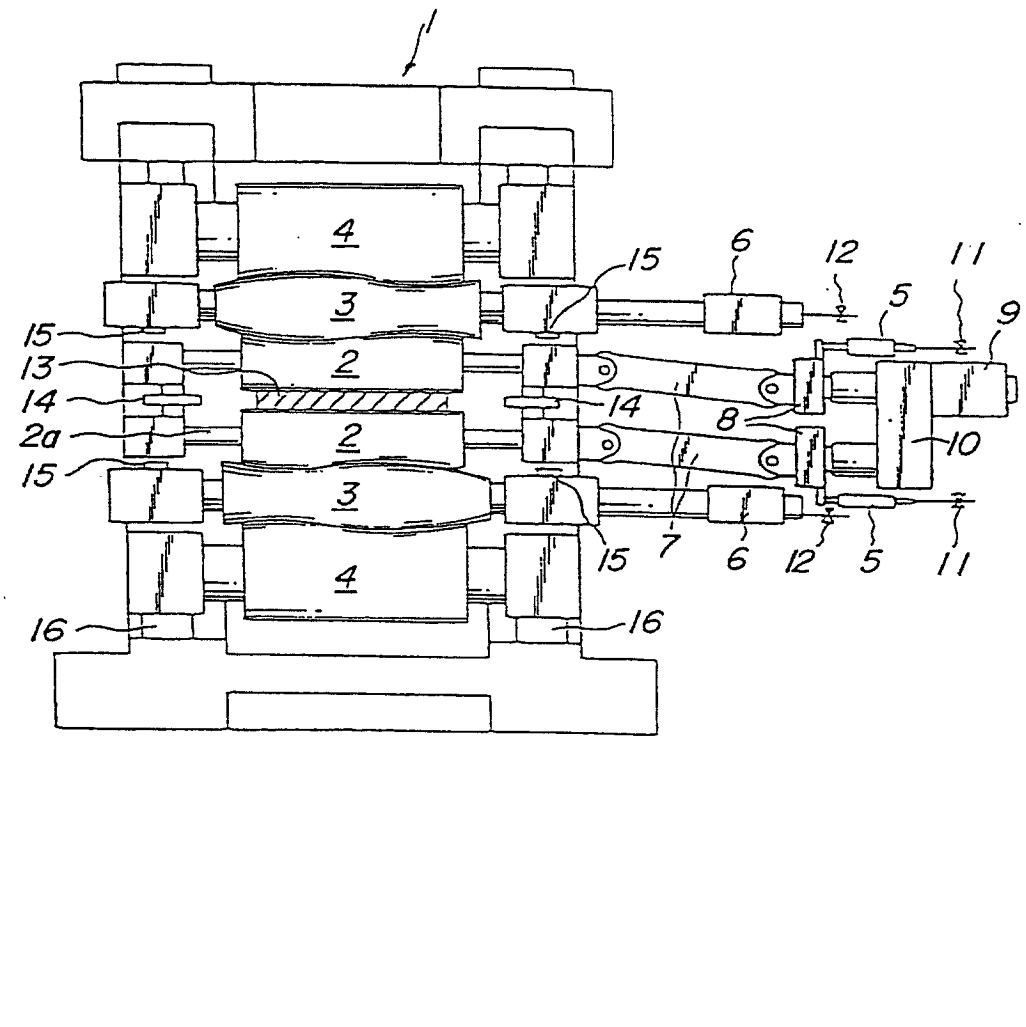
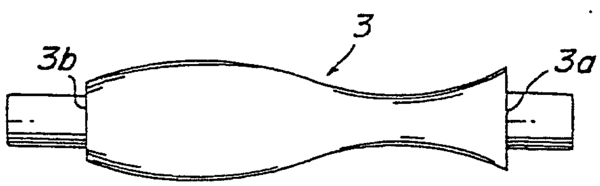


FIG_2

(a)



(b)

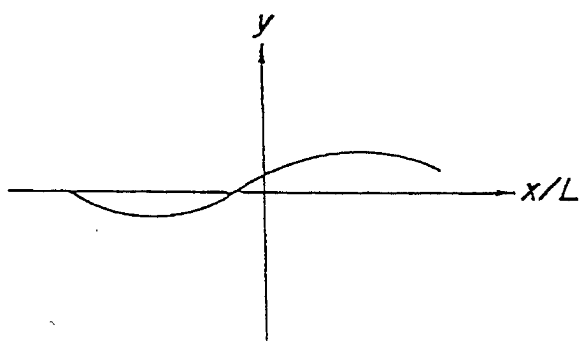
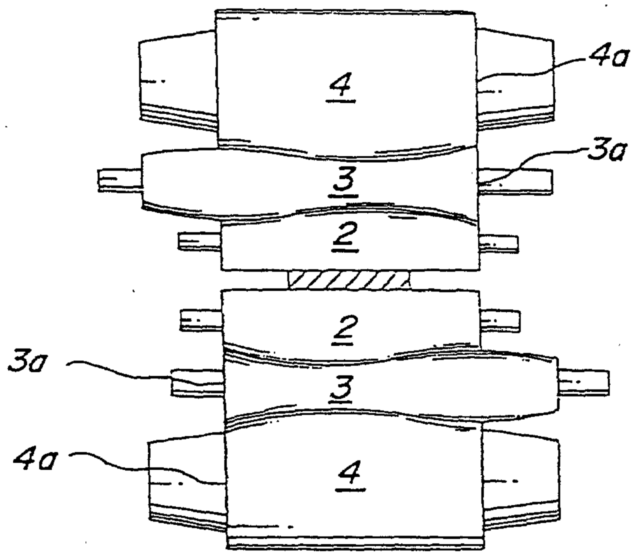


FIG_3

(a)



(b)

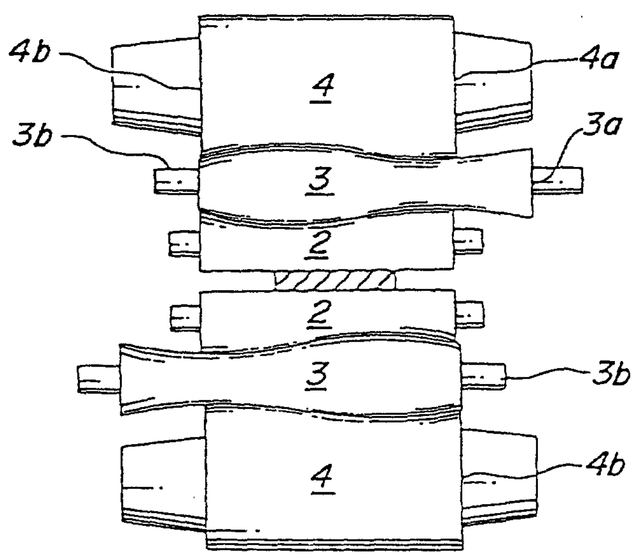


FIG.4

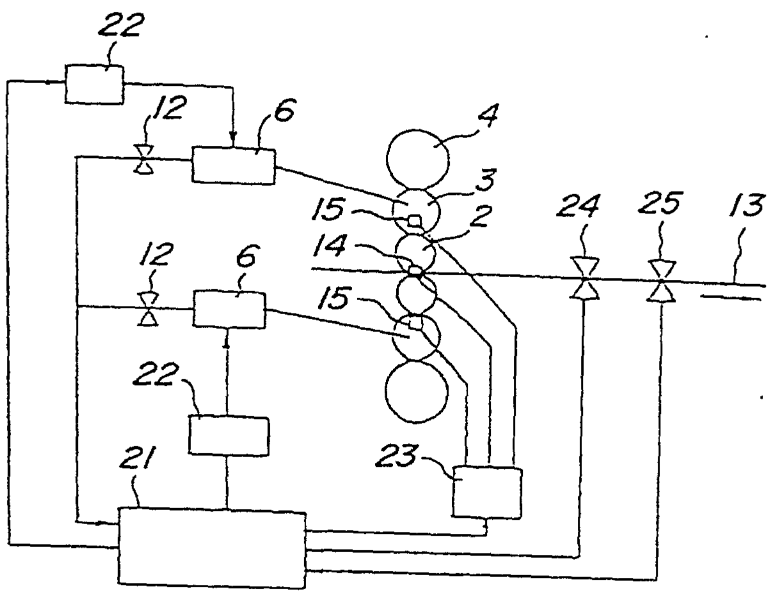


FIG_5

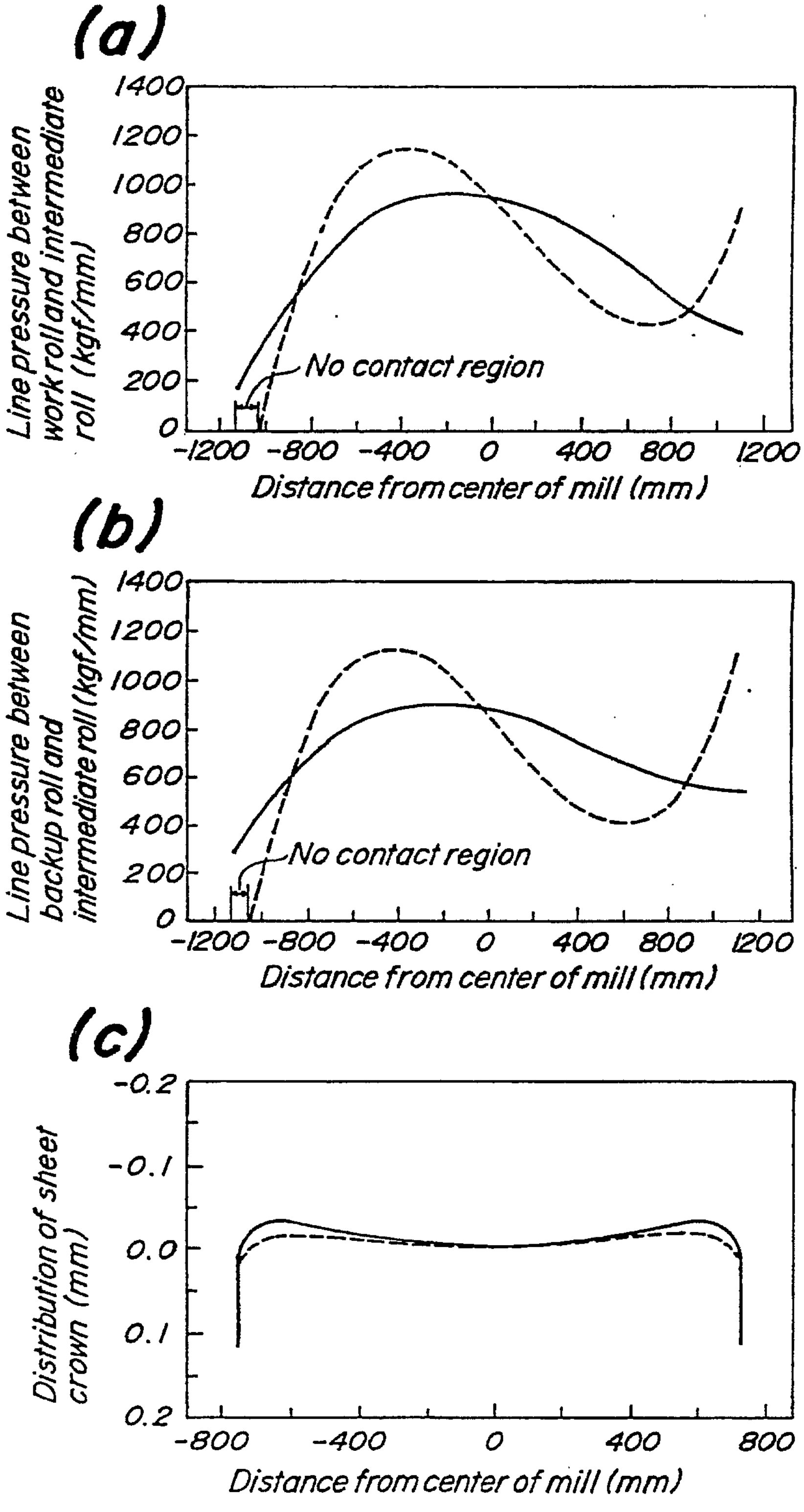

(a)
Line pressure between work roll and intermediate roll (kgf/mm)
1400
1200
1000
800
600
400
200
0
No contact region
-1200 -800 -400 0 400 800 1200
Distance from center of mill (mm)
(b)
Line pressure between backup roll and intermediate roll (kgf/mm)
1400
1200
1000
800
600
400
200
0
No contact region
-1200 -800 -400 0 400 800 1200
Distance from center of mill (mm)
(c)
Distribution of sheet crown (mm)
-0.2
-0.1
0.0
0.1
0.2
-800 -400 0 400 800
Distance from center of mill (mm)

FIG. 6

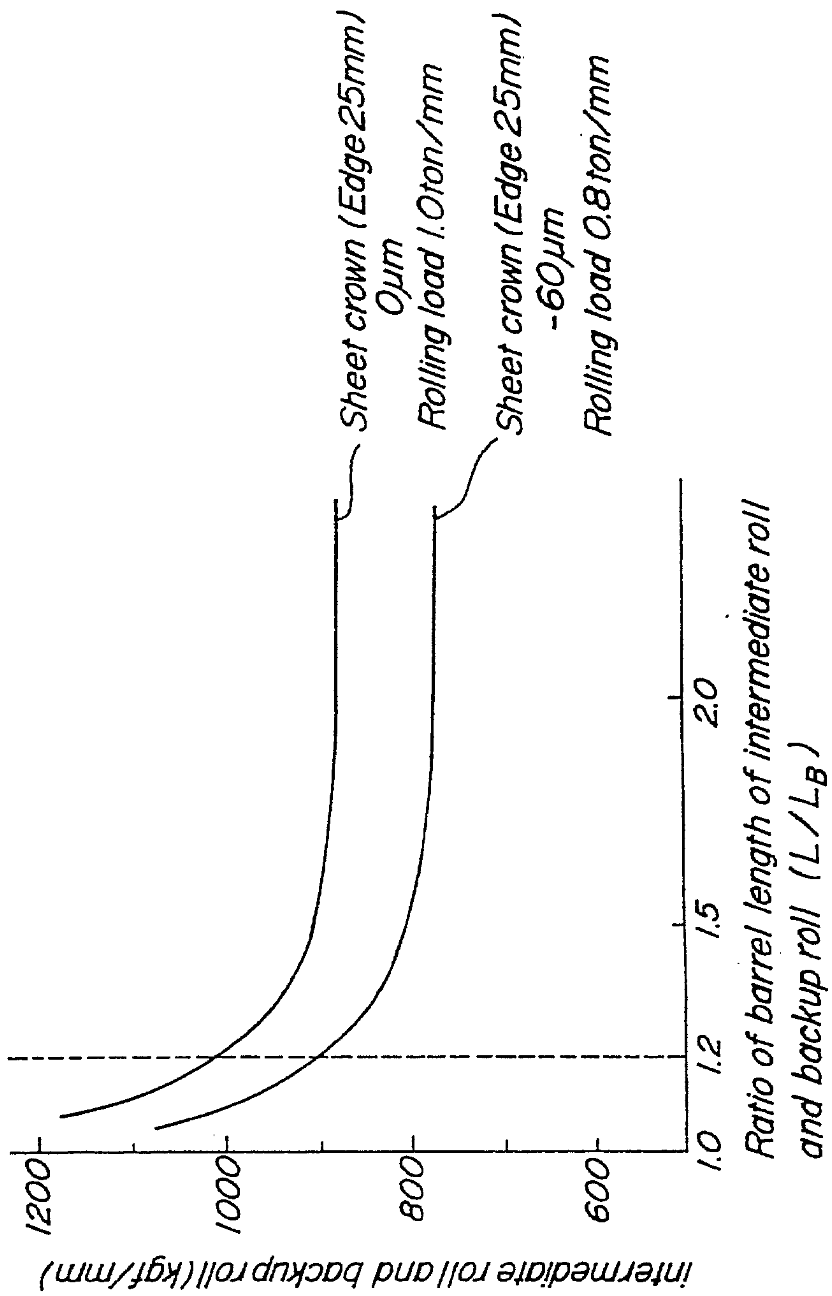

Sheet crown (Edge 25mm) 0μm
Rolling load 1.0ton/mm
Sheet crown (Edge 25mm) -60μm
Rolling load 0.8ton/mm
Maximum line pressure between intermediate roll and backup roll (kgf/mm)
1200
1000
800
600
1.0
1.2
1.5
2.0
Ratio of barrel length of intermediate roll and backup roll (L/L_B)

FIG. 7

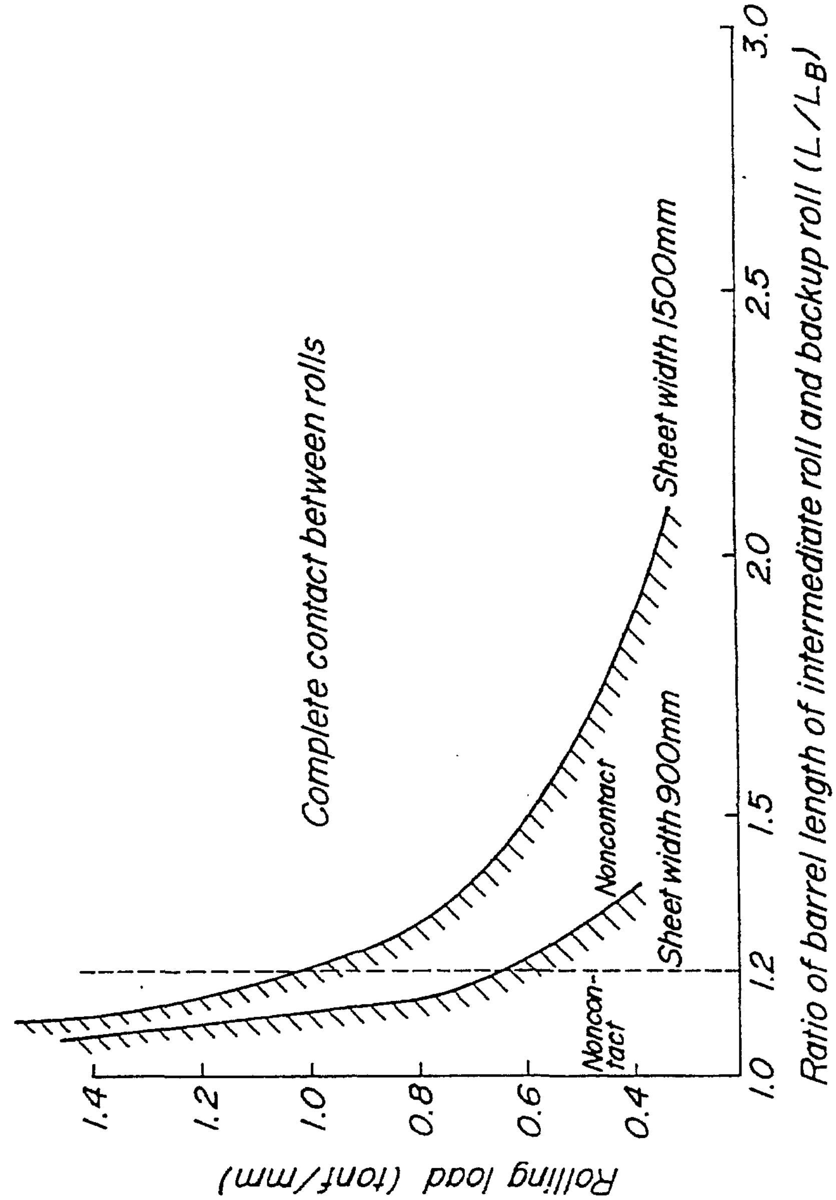

Complete contact between rolls
Sheet width 1500mm
Sheet width 900mm
Noncontact
Noncon-
tact
Rolling load (tonf/mm)
1.4
1.2
1.0
0.8
0.6
0.4
1.0
1.2
1.5
2.0
2.5
3.0
Ratio of barrel length of intermediate roll and backup roll (L/L_B)

FIG_8

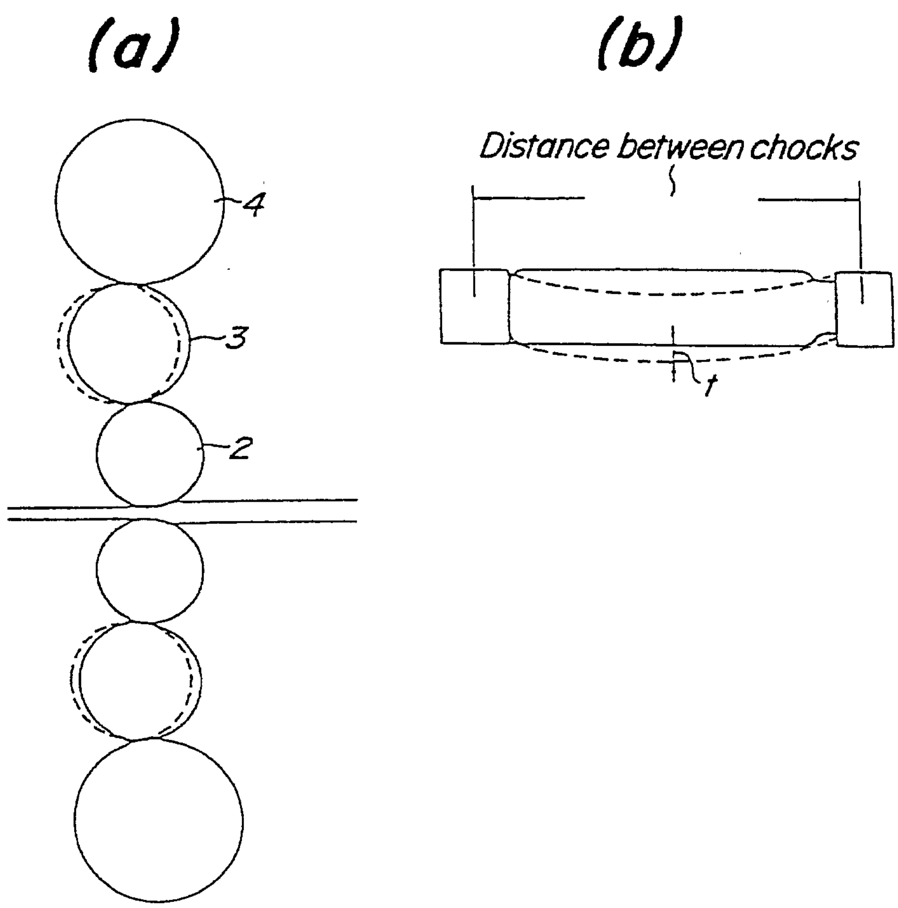


FIG_9

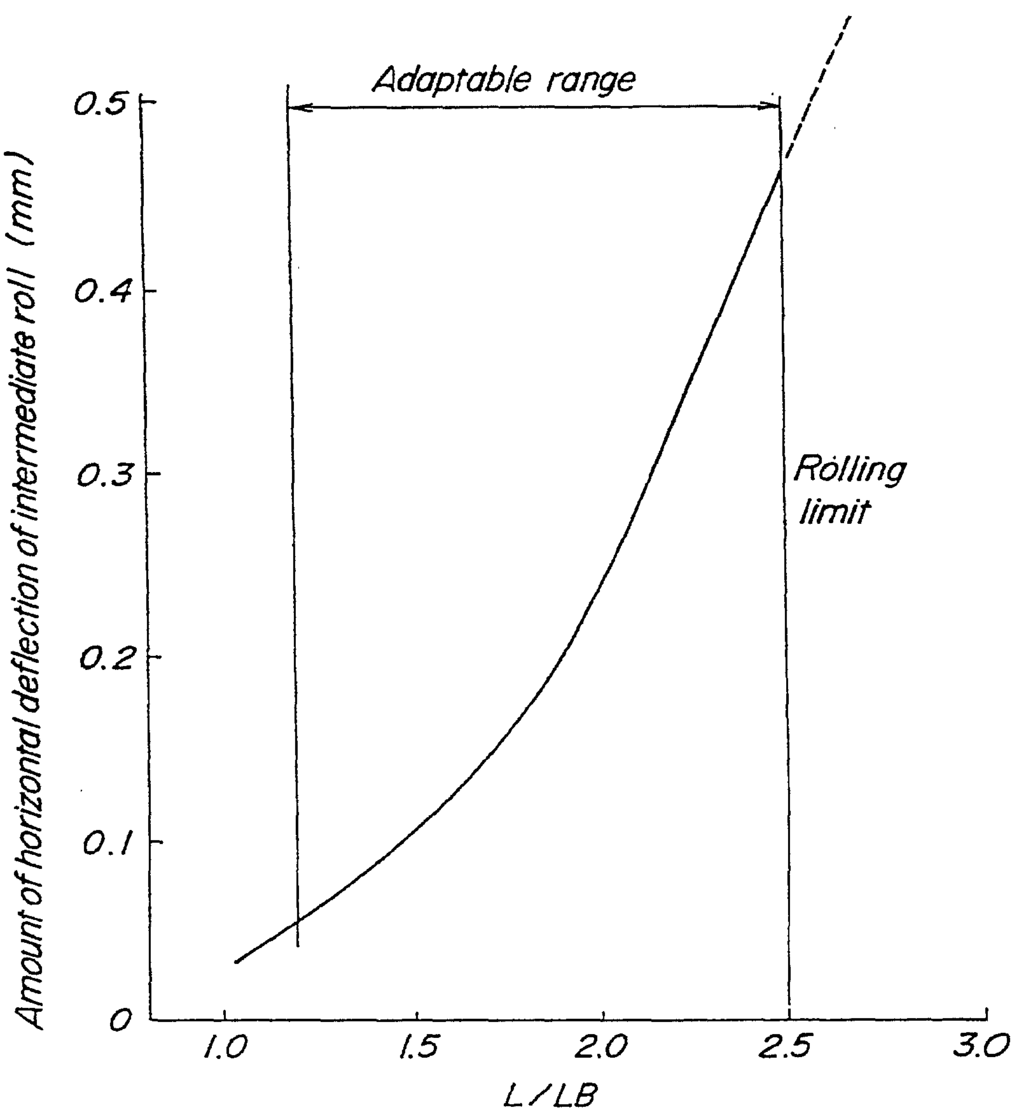

Adaptable range
Rolling limit
Amount of horizontal deflection of intermediate roll (mm)
0.5
0.4
0.3
0.2
0.1
0
1.0
1.5
2.0
2.5
3.0
L/LB

FIG_10

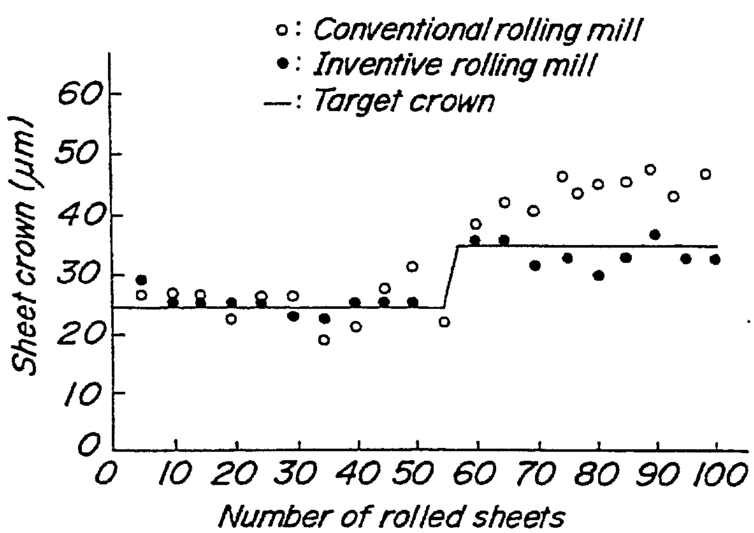

○: Conventional rolling mill
●: Inventive rolling mill
—: Target crown
Sheet crown (μm)
0
10
20
30
40
50
60
0
10
20
30
40
50
60
70
80
90
100
Number of rolled sheets

FIG_11

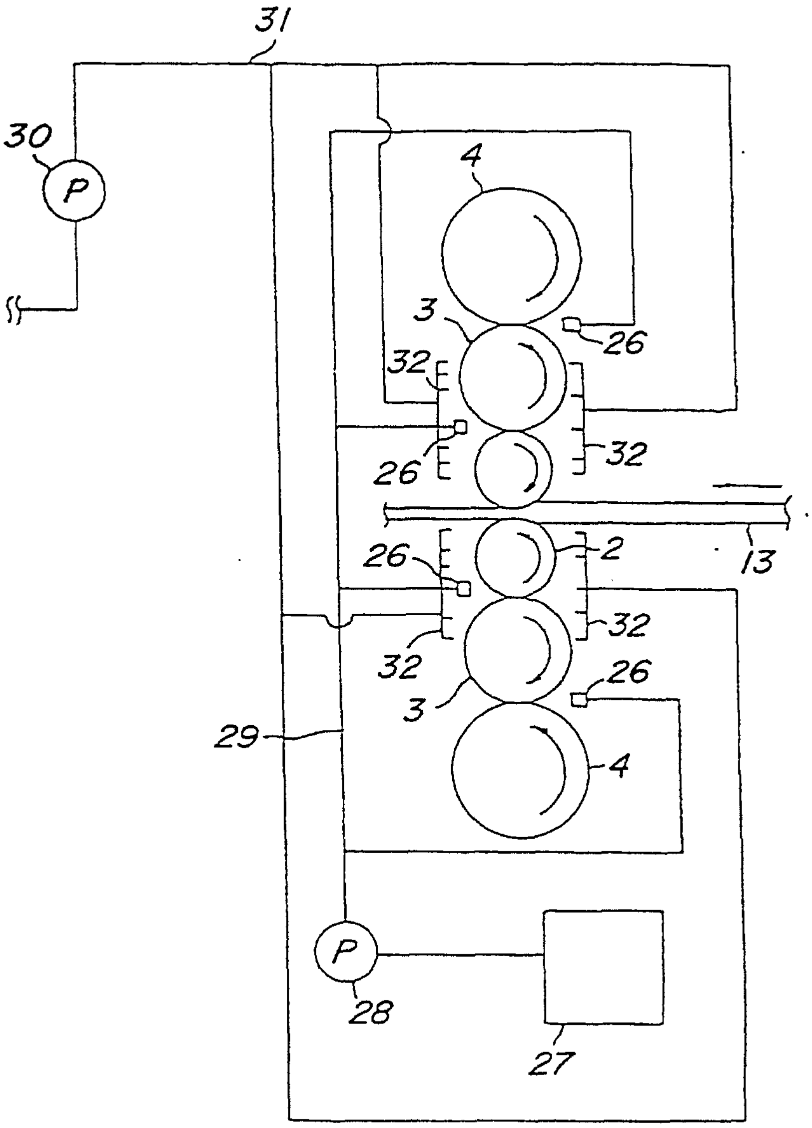


FIG_12

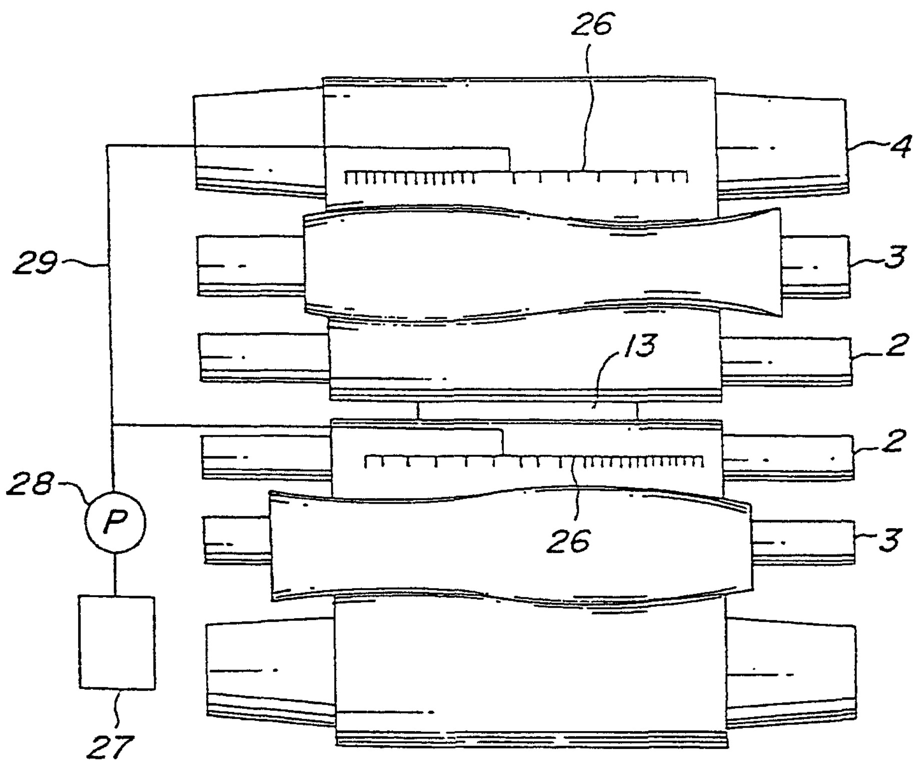
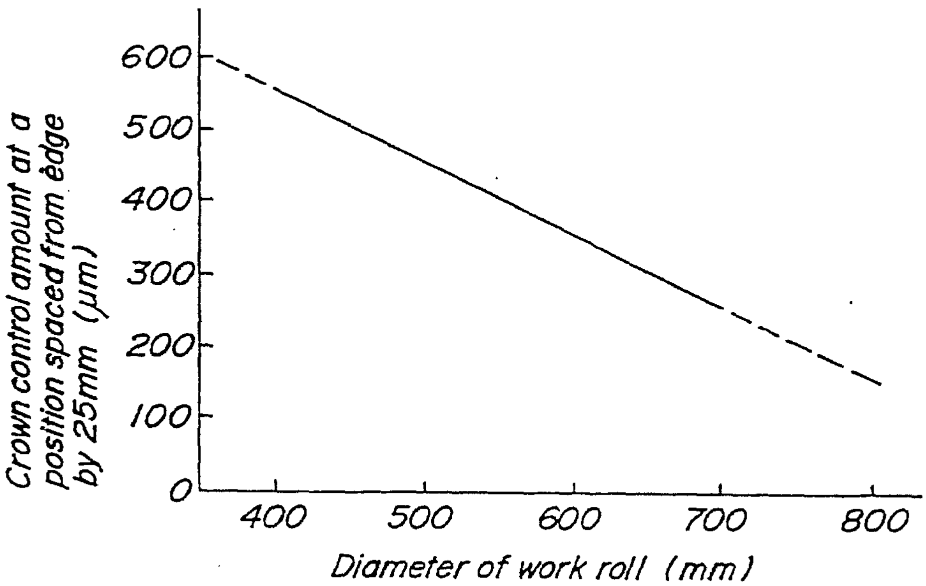


FIG_13


600
500
400
300
200
100
0
400
500
600
700
800
Crown control amount at a position spaced from edge by 25mm (μm)
Diameter of work roll (mm)