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(54) **Method of rolling in a five-high rolling mill**

Walzverfahren in einem Fünfwalzen-Walzwerk

Procédé de laminage dans un laminoir à cinq cylindres

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- **PATENT ABSTRACTS OF JAPAN vol. 9, no. 303 (M-434)(2026) 30 November 1985 & JP-A-60 141 310 (ISHIKAWAJIMA HARIMA JUKOGYO K.K.) 26 July 1985**
- **PATENT ABSTRACTS OF JAPAN vol. 006, no. 109 (M-137)(987) 19 June 1982& JP-A-57 039 007 (ISHIKAWAJIMA HARIMA JUKOGYO K.K.) 4 March 1982**
- **PATENT ABSTRACTS OF JAPAN vol. 006, no. 150 (M-148)10 August 1982 & JP-A-57 068 206 (ISHIKAWAJIMA HARIMA HEAVY IND. CO LTD) 26 April 1982**

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Description

The invention relates to a method for rolling a sheet material with a small rolling force and a small rolling reduction in a five-high rolling mill as it is defined in the first part of claim 1 (see US-A-4 194 382, Column 6, lines 19-32).

As a rolling mill of a small rolling reduction and a small rolling force, e.g., a skinpass rolling mill, there has been often employed a four-high rolling mill which includes upper and lower work rolls provided with bending devices and upper and lower backup rolls supporting these work rolls, as disclosed in the JP-A-48-22344. However, such a four-high rolling mill does not have a sufficient ability in shape control, and insufficiency of this ability is compensated with various work rolls provided with different crowns.

A six-high rolling mill superior in the shape control ability has been suggested and applied to practical use (see JP-B-57-55484; US 4 194 382). This six-high rolling mill is arranged in such a manner that upper and lower intermediate rolls are disposed between upper and lower work rolls of the same diameter and upper and lower backup rolls of the same diameter, respectively and that roll bending devices are installed on the upper and lower work rolls and the upper and lower intermediate rolls, both sets of these bending devices being capable of providing a great ability in the shape control. In case of skinpass rolling with a small rolling reduction, this six-high rolling mill causes portions of the side ends of a rolling stock to remain non-rolled so that edge wrinkles are formed on the side ends of the rolling stock, thereby resulting in a problem that formation of such edge wrinkles cannot be adequately prevented.

A conventional multi-high rolling mill whose sections above and below a rolling stock have different numbers of rolls or a conventional five-high rolling mill in particular is disclosed in the US 4 194 382 and and in the JP-B 62-46245. Such a five-high rolling mill includes upper and lower work rolls of different diameters, with the upper work roll being a roll of the smaller diameter, and thus, a large rolling reduction can be obtained from a small rolling force. Further, bending devices are installed on both the intermediate roll and the lower work roll of the larger diameter so as to cause the five-high rolling mill to exhibit its ability in controlling a sheet crown. Hence it is possible to control a simply curved (concaved or convex) crown of the rolling stock in its entire width, decrease the rolling force, and enhance the effect of the benders as a result.

On the contrary, in case of i) a rolling operation with both the rolling reduction and the rolling force having small values, ii) a rolling operation which requires an excellent ability in the sheet surface control enabling composite shape control, and iii) a rolling operation which requires prevention of the edge wrinkles, for example, in case of skinpass rolling, rough-surface dull rolls, that is, work rolls in the above-mentioned five-high rolling mill including the upper and lower work rolls of different diameters are extremely shortened in life and, and the rolled material is apt to be unfavorably warped. Besides, if the work rolls have small diameters, another problem is caused in that a cross buckle or a folding is apt to be generated during the rolling operation.

A five-high rolling mill including an intermediate roll which has the same drum length as the width of the rolled strip sheet, in which upper and lower work rolls of the same diameter are provided with bending devices, is disclosed in the JP-A-54-39349 and in the JP-B-53-34789. In use of such five-high rolling mill, it is necessary to replace the intermediate roll with a new one every time the sheet width of the rolled strip sheet is changed, and the rolling operation must be stopped in each occasion like this, so that the productivity of the rolling mill will be lowered to a great extent, and that the rolling mill will fail to be practical in use. Especially in case of a skinpass rolling mill installed in a continuous annealing line, since a rolling stock of different widths are continuously supplied thereto, the above-mentioned five-high rolling mill is quite unlikely to be applied to practical use.

Further, five-high rolling mill in which upper and lower work rolls are of the same diameter and these upper and lower work rolls and an intermediate roll of a diameter smaller than that of the work rolls are respectively provided with bending devices is disclosed in the JP-A-56-151103. However, the intermediate roll of such five-high rolling mill which has a small diameter and the same drum length as that of the backup roll and the work roll, is in contact with the backup roll and the work roll over its entire length, and therefore, the control characteristic of the intermediate roll becomes similar to that of the upper work roll, thereby resulting in a problem that it is basically impossible to accomplish either the composite shape control or the control for prevention of the edge wrinkles.

Although the conventional rolling mills described above are all intended to improve the abilities in shape correction, they cannot satisfactorily perform the skinpass rolling operation in which the rolling reduction and the rolling force are both small and it is necessary to obtain an excellent quality of the surface. More particularly, examples of characteristics of the skinpass rolling operation can be expressed as follows:

i) The rolling reduction is not more than several percent, and the rolling force is not more than half the force of normal cold rolling.

ii) A rough-surface dull roll is often used as a work roll so that the surface of the product will be pear-skinned.

iii) When the side end portions of the stock remain non-rolled, irregularities (edge wrinkles) of the surface are formed thereon due to the stretcher strain, and this is because the rolled stock has been annealed in advance. iv) Since the stock after the skinpass rolling often becomes a finished product as it is, the product is required to have an excellent surface quality.

Referring to these characteristics, requirements of a skinpass rolling mill will be reviewed.

First, as for the diameters of work rolls, the rolls are required to have relatively large diameters in order to prevent the cross buckle or folding in the skinpass rolling operation. Also, it is desirable for upper and lower work rolls to have the same diameter (practically the same diameter) in terms of lives of dull of the work rolls and prevention of warping of a strip sheet after the skinpass rolling process.

As for the shape control of the rolling material to obtain a strip sheet of the excellent surface quality, it is necessary for the rolling mill to have an ability in composite shape control for correcting both of edge wrinkles and center buckle.

Lastly, it is very important to reduce the widths of the non-rolled side end portions of the strip sheet where edge wrinkles are formed. Since these portions having edge wrinkles are to be cut off as defective parts in the following process, reduction of the widths of the wrinkled portions serves to improve the yield efficiently.

The characteristics of the rolling mill suitable for the skinpass rolling operation can be summarized as follows:

1) Work rolls are practically of the same diameter and also of a relatively large diameter.
2) In order to perform the composite shape control for providing the excellent surface quality, two kinds of control means of different control characteristics are necessary.
3) Third control means other than those means for the composite shape control are required for reducing the edge wrinkles of the strip sheet.

The object of the present invention is to provide a rolling method in the multi-high rolling mill by which the ability of the composite shape control of the rolled material can be fully exhibited during the rolling operation of a small rolling reduction and also formation of any edge wrinkles on the side end portions of the strip sheet can be prevented.

This object will be solved by the featurs of claim 1.

In the rolling method according to the invention applied to the five-high rolling mill, the roll bending devices installed on the intermediate roll and the roll bending devices installed on the work roll in the roll set where this intermediate roll is disposed are all actuated to control a composite crown of a strip sheet over its entire width. The roll bending devices installed on the work roll directly supported by the backup roll are actuated to control the crown of the strip sheet in its side end portions, thereby performing both of the composite shape control of the strip sheet and the control of the widths of the side end portions of the strip sheet which are not to be rolled.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a broken-away front view showing a five-high rolling mill;
Fig. 2 is a broken-away side view showing a first five-high rolling mill;
Fig. 3 is a schematical view of this first rolling mill, showing a condition of effects produced by bending force;
Fig. 4 is a broken-away front view showing a different five-high rolling mill;
Figs. 5A and 5B are schematical views showing another five-high rolling mill;
Figs. 6 and 7 are a broken-away front view and a schematical view showing a further five-high rolling mill;
Fig. 8 is a diagram showing curves of values of $\underline{x}$ to certain powers;
Figs. 9 and 10 are diagrams showing the characteristics of control errors (defects of the shape) that are controlled by roll bending operations; and
Fig. 11 is a diagram showing a condition of a side end portion of a strip sheet which is not rolled.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The principle of a rolling mill which may be used to perform the method according to the present invention will now be explained.

The present invention may employ a multi-high rolling mill which has an excellent ability in composite shape control for accomplishing improvement of the surface quality of strip sheet so that edge wrinkles can be prevented from forming on the side ends of strip sheet. For this purpose, the rolling mill includes an intermediate roll disposed between one of upper and lower work rolls having substantially the same diameter and a backup roll, the drum length of the intermediate roll being formed to be larger than an extent of the maximum width of the strip sheet, and the upper and lower work rolls and the intermediate roll are respectively provided with roll bending devices which have different control characteristics for moderating a crown shape of the strip sheet.

The composite shape control of strip sheet is mainly performed by the intermediate roll bender and the work roll bender on one side where the intermediate roll is disposed, so as to improve the surface quality of the strip sheet, and the widths of side end portions of the strip sheet which have not been rolled are controlled by the work roll bender on the other side where the intermediate roll is not disposed, so as to remarkably reduce the non-rolled side end portions of the strip sheet, thereby preventing the formation of edge wrinkles.

The rolling mill is provided with the roll benders of three kinds, i.e., the intermediate roll bender, the work roll bender on the side where the intermediate roll is disposed (hereinafter referred to as the 6H-side), and the work roll bender on the side where the intermediate roll is not disposed (hereinafter referred to as the 4H-side). These roll benders have such shape control degrees as to differ the respective characteristics for controlling the crown of the rolled strip sheet from one another, and thus, not only the composite shape but also the widths of the side end portions having edge wrinkles can be controlled. In case of a five-high rolling mill, for example, having roll sizes representative of a skinpass rolling mill where the work roll is 475 mm in diameter; the intermediate roll is 530 mm in diameter; the backup roll is 1000 mm in diameter; and the rolling surface of each roll is 2050 mm long with a sheet width of 1880 mm, calculation results of control degrees of the respective benders are shown in Table 1. In this case, a control degree expresses a change of crown of rolled strip sheet which can be controlled by the roll bending devices.

Table 1

Control degrees by roll bending				
Case	4H-side work roll	6H-side		Control degree
		Work Roll	Intermediate Roll	
1	○	-	-	2.8
2	-	○	-	2.2
3	-	-	○	1.8
4	○	○	-	2.4

In Table 1, Case 1 indicates a control degree when only the roll bender for the 4H-side work roll directly supported by the backup roll is actuated, and this control degree generally has a value from 2.6 to 3.3. Case 2 indicates a control degree when only the roll bender for the 6H-side work roll supported by the intermediate roll is actuated, and this control degree generally has a value from 2.0 to 2.5. Case 3 indicates a control degree when only the roll bender for the intermediate roll is actuated, and this control degree generally has a value from 1.7 to 1.9. Further, Case 4 indicates a control degree when both of the above-mentioned roll benders for the 4H-side and 6H-side work rolls are actuated.

As shown above in Table 1, it is difficult to offer the effect of the 4H-side work roll bender of the five--high rolling mill onto the center of the rolled strip sheet because the associated work roll is in contact with the backup roll of an extremely high flexural rigidity over the entire length, thus resulting in a high control degree. On the other hand, the effect of the 6H-side work roll bender is readily produced at the center of the strip sheet because the associated work roll is in contact with the intermediate roll, and the control degree is lower than that of the 4H-side bender. The intermediate roll bender tends to produce the effect essentially at the center of the strip sheet, and therefore, the control degree has the smallest value.

As disturbances for shape in the skinpass rolling process, there are a change of rolling force, a change of the sheet crown, and a change of a thermal crown of work rolls. Changes of the rolling force and the sheet crown are depicted with substantially the same curve of the second degree, and the thermal crown in case of the skinpass rolling process is changed as time elapses, depicting a curve of the 1.8 to 2.5 degree. Consequently, the composite shape control is necessary to obtain a desirable shape and two kinds of shape control means are required for this composite shape control, with its control degree being preferably in a range of 1.8 to 2.5.

Now, speculation is given to errors in the shape control, i.e., defects of the surface shape.

In case of controlling a shape disturbance x^{β} by means of one kind of bender having a degree m, an error after shape correction can be expressed with the following equation:

$$y = x^{\beta} - ax^{m}$$

In this case although a coefficient a can be changed by force of the bender, the degree m will not be changed. Even if the force of the bender is suitably selected, i.e., even if the coefficient a has an optimum value, the value y will not become zero in the entire w dth of the strip sheet unless β is equal to m, thereby resulting in the error as indicated with a chain line in Fig. 9. This error has two extreme values, and when these extreme values are denoted by δ_1 and δ_2, the maximum value δ can be derived from the following equation:

$$\delta = \max(\delta_1, \delta_2) = \frac{\beta(m - \beta)}{(m + \beta + 1)(\beta + 1)} \quad (1)$$

Similarly, in case of controlling the shape disturbance x^{β} by means of two kinds of benders having degrees m and n, an error after shape correction can be expressed with the following equation (as indicated with a dashed line in Fig. 10):

$$y = x^{\beta} - (ax^{m} + bx^{n})$$

In this case, coefficients a and b can be changed by force of the benders. In the same manner as described above, even if the force of the benders is suitably selected, there remains the error unless β is equal to m or β is equal to n. This error has three extreme values, and the maximal value δ can be derived from the following equation:

$$\delta = \max(\delta_1, \delta_2, \delta_3) = \frac{(m - \beta)(n - \beta)}{(m + \beta + 1)(n + \beta + 1)} \quad (2)$$

It is clearly understood from the equations (1) and (2) that the error in case of the control by two kinds of benders is remarkably smaller than that of the control by one kind of bender. This is numerically shown in Table 2.

Table 2

Errors in shape control				
Case	Degree of disturbance	Control degree		Shape defect %
		m	n	
1	2	1.8	2.2	0.16
2	2.5	1.8	2.4	0.22
3	2	2.2	-	2.6
4	2	2.8	-	10.2

For example, when the disturbance of the second degree is controlled by one kind of bender having a degree of 2.2, the error is 2.6%, and when it is controlled by two kinds of benders having degrees of 1.8 and 2.2, the error is drastically reduced to 0.16% (which is 1/16.3 of 2.6%).

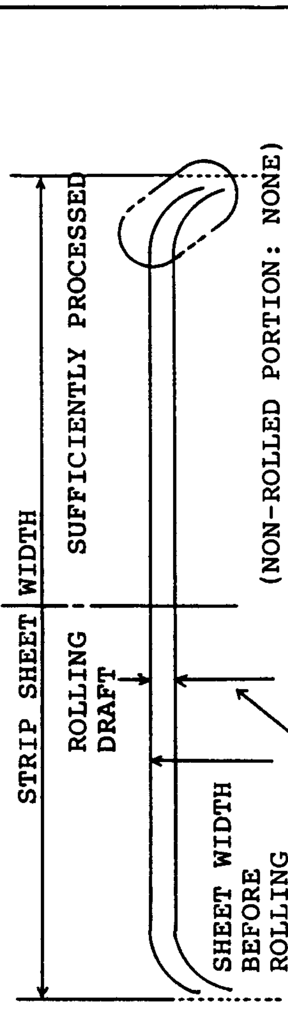
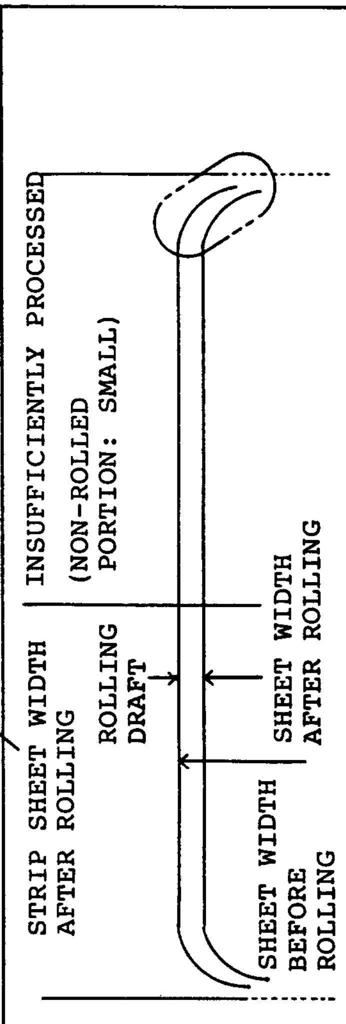
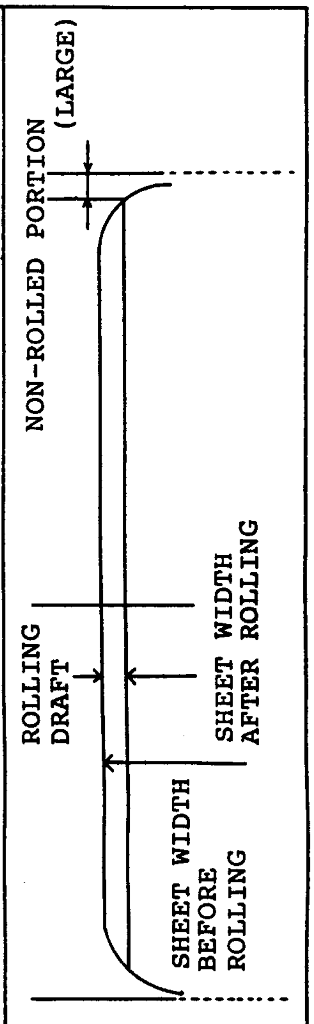
Next, there will be considered a case of controlling two kinds of shape disturbances having degrees of β_1 and β_2 by means of two kinds of benders having degrees m and n. In this case, it is not necessary to control the disturbance with the degree β_1 by means of the bender with the degree m and control the disturbance with the degree β_2 by means of the bender with the degree n, but the following steps may be taken. That is to say, the disturbance with the order β_1 is controlled by the benders with the degrees m and n, and its error is expressed with δ_A. Also, the disturbance with the degree β_2 is controlled by the same benders with the degrees m and n. Its error is expressed with δ_B. This operation can be carried out when the benders are equipped with the abilities for that purpose.

$$\delta_A = \max\{x^{\beta_1} - (a_1 m^{m} + b_1 x^{n})\} \quad (3)$$

$$\delta_B = \max\{x^{\beta_2} - (a_2 m^{m} + b_2 x^{n})\} \quad (4)$$

In this case, the overall shape defect (i.e., errors) can be expressed with $\delta = \delta_A + \delta_B$, and because each of the errors δ_A and δ_B is extremely small, the overall shape defect can be also made very small. In the rolling mill, as described so far, three kinds of benders having control degrees different from one another can perform the control. In the above embodiment, for example, the intermediate roll bender conducts the control with the degree of 1.8; the 6H-side work roll bender conducts the control with the degree of 2.2; and the 4H-side work roll bender conducts the control with the degree of 2.8. Therefore, the composite shape control and the control of the widths of the wrinkıed side end portions can be simultaneously effected. It is ideal to perform the composite shape control of strip sheet material by the intermediate roll bender and the 6H-side work roll bender and to control the widths of wrinkled side end portions of the rolled strip sheet by means of the 4H-side work roll bender. Actually, if the 4H-side work roll bender is functioned, the shape will be disturbed, and therefore, it will be necessary to slightly change the force of the intermediate roll bender and that of the 6H-side work roll bender. Results of simulations concerning relations between the force of the benders and the shape are shown in Table 3. If the force of the 4H-side work roll bender is changed from -30$ to 100$, it will be understood how much the widths of the non-rolled side end portions of the strip sheet can be changed. In this case, the force of the intermediate roll bender and that of the 6H-side work roll bender are slightly changed not to disturb the shape of the central portion of the strip sheet.

Table 3 Relationship between bender force and widths of non-rolled side ends

Bender force	Side end shape
F_I (INTERMEDIATE ROLL BENDER) = 45% F_{W6} (6H-SIDE WORK ROLL BENDER) = 9.5% F_{W4} (4H-SIDE WORK ROLL BENDER) = -30%	 STRIP SHEET WIDTH SUFFICIENTLY PROCESSED ROLLING DRAFT SHEET WIDTH BEFORE ROLLING (NON-ROLLED PORTION: NONE)
F_I = 45% F_{W6} = 4.5% F_{W4} = 4.5%	 STRIP SHEET WIDTH AFTER ROLLING INSUFFICIENTLY PROCESSED (NON-ROLLED PORTION: SMALL) ROLLING DRAFT SHEET WIDTH BEFORE ROLLING SHEET WIDTH AFTER ROLLING
F_I = 32% F_{W6} = 0% F_{W4} = 100%	 ROLLING DRAFT NON-ROLLED PORTION (LARGE) SHEET WIDTH BEFORE ROLLING SHEET WIDTH AFTER ROLLING

As described so far, the five-high rolling mill makes it possible to reduce the widths of the wrinkled side end portions to a great extent while maintaining the strip sheet in the desirable shape. This has never been accomplished by any conventional five-high rolling mill before.

The point of the invention is that the control degrees m and n differ from each other as much as possible, i.e., it is more preferable that the control degree of the 4H-side work roll bender has a value, for example, from 2.6 to 3.3 at most; the control degree of the intermediate roll bender has a value from 1.7 to 1.9 at least; and the control degree of the 6H-side work roll bender has a value between that of the 4H-side work roll bender and that of the intermediate roll bender, e.g., from 2.0 to 2.4. For establishing this relationship, the intermediate roll is required to have a diameter larger than that of the work rolls. In case the control degrees m has value close to that of the control degree n, the effect will not be much different from that of the control by one kind of bender, thereby causing a large shape defect.

A rolling mill will be hereinafter described with reference to Figs. 1, 2 and 3. In these drawings, reference numerals 1 and 2 denote upper and lower work rolls which are arranged to have substantially the same diameter. Reference numerals 3 and 4 are upper and lower backup rolls, and reference numeral 5 denotes an intermediate roll which is disposed between one of the work rolls, i.e., the upper work roll 1 and the upper backup roll 3. Increase bending cylinders 10 for the upper work roll 1 are provided in projecting blocks 17 for sustaining bearing boxes 7 of the 6H-side upper work roll 1, respectively. Also, increase bending cylinders 11 and decrease bending cylinders 12 for the lower work roll 2 are provided in the same projecting blocks 17 for sustaining bearing boxes 8 of the lower work roll 2, respectively. These bending cylinders 10, 11 and 12 exert the bending force on the respective bearing boxes 7 and 8 of the upper and lower work rolls 1 and 2 so as to control degrees of bending of the work rolls 1 and 2. As for the intermediate roll 5, bending cylinders 13 provided in projecting blocks 19 for sustaining bearing boxes 9 thereof are arranged to exert the bending force on such bearing boxes 9, thus causing the intermediate roll 5 to be bent.

Since the five-high rolling mill is of the above-described structure, the bending effect of the 6H-side upper work roll 1 only reaches the vicinities of the end portions of the upper work roll 1 due to the existance of the intermediate roll so that the thicknesses of side end portions of strip sheet 6 can be controlled by bending the axis of the work roll 1 in the vicinities of its end portions. Besides, since the bending effect of the intermediate roll 5 covers the roll in its entire length, the sheet thickness over the entire width can be controlled by controlling the axial bending of the intermediate roll in the entire length through the work roll 1. Therefore, the composite shape control of the strip sheet can be achieved by properly combining these two kinds of roll bending effects, thereby enabling the rolling of the strip sheet having an excellent surface quality under the conditions of a small rolling reduction and a small rolling force.

On the other hand, the bending effect of the 4H-side lower work roll 2 does not reach the center of the lower work roll 2, and accordingly, the axial bending of this work roll in its end portions is largely controlled, so that the side end portions of the strip sheet which have not been rolled conventionally can be effectively rolled, thus preventing edge wrinkles from being produced on the side end portions of the strip sheet.

Especially, the decrease benders 12 serving as the rolling bending devices provided on the 4H-side work roll 2 cause the side end portions of the work roll 2 to be bent toward the strip sheet 6 and pressed onto the surface of the strip sheet so as to remarkably reduce the non-rolled side end portions of the strip sheet 6, thereby preventing the formation of edge wrinkles (see Fig. 11).

In the above description of the rolling mill, the 6H-side work roll benders 10 and the intermediate roll benders 13 are nothing but increase benders. However, it goes without saying that if the shape is largely disturbed, for example, if the rolling force is large, or if the change of the sheet crown is large, decrease benders in addition to the increase benders are installed for expanding the control range of the bending so as to deal with the shape disturbance mentioned above. Moreover, in order to enhance the effect of the present invention, the effective drum length of the 6H-side backup roll 3 may be made smaller than the maximum width of the strip sheet 6, as shown in Figs. 4, 5A and 5B. In other words, as shown in Fig. 5B, when the effective drum length of the 4H-side backup roll 4 is expressed by L, the maximum sheet width is expressed by B_{max}, and the effective drum length of the 6H-side backup roll 3 is expressed by ℓ, they are arranged in a relation $L > B_{max} > \ell$. Alternatively, as shown in Fig. 5A, when the backup roll 4 is suitably provided with a roll crown of a high degree, the bonding effects of the 6H-side work roll 1 and the intermediate roll 5 can be enhanced without changing the control degrees of the work roll 1 and the intermediate roll 5.

When the effective drum length of the 6H-side backup roll is made smaller than that of the intermediate roll, or when the intermediate roll is oscillated by a stroke of ± 10 mm or so in case of the five-high rolling mill including the 6H-side backup roll which is provided with a relatively large roll crown when applied to the rolling condition of a large rolling force, defects caused by the shoulders of the backup roll can be prevented from remaining on the strip sheet conveniently.

Furthermore, in case the drum length of the intermediate roll 5 is made larger than the maximum sheet width B_{max} of the strip sheet 6, and the backup roll 3 directly supporting this intermediate roll 5 is formed to be in contact with the intermediate roll 5 over a distance larger than the minimum sheet width B_{min} of the strip sheet and smaller than the maximum sheet width B_{max} of the same, both the bending effects of the work roll and the intermediate roll can be further enlarged without changing the control degrees.

Next, the rolling mill can be also described as follows. That is to say, a multi-high rolling mill is constituted of the upper and lower work rolls 1 and 2 of substantially the same diameter and also a certain number of supporting rolls and a different number of supporting rolls for respectively supporting these work rolls 1 and 2 so that the upper section and the lower section of the rolling mill with respect to the strip sheet include sets of the rolls in different numbers. The roll bending devices 13 are installed on the supporting roll 5 which directly supports the work roll 1 in the roll set having the larger number of the rolls, and the upper and lower roll sets are arranged to have different control degrees each indicating a degree of change in the sheet crown of the strip sheet which can be controlled by the roll bending devices 13. The roll bending devices 10 and 11 are installed on the respective work rolls 1 and 2 of the upper and lower roll sets in order to differ the control degrees of the sheet crown for the upper and lower work rolls 1 and 2 which can be controlled by the respective roll bending devices 10 and 11, and as for the control orders of these roll bending devices 13, 10 and 11, the supporting roll 5 in one of the roll sets having the larger number of the rolls, the work roll 1 in this roll set, and the work roll 2 in the other roll set having the smaller number of the rolls are controlled with the control degree of values gradually increasing in this order.

As shown in Table 1, seeing that the control degree of the roll bending devices for the supporting roll 5 in the one roll set having the larger number of the rolls has a value which is set close to and not more than 2, e.g., 1.8; that of the devices for the work roll 1 in this roll set has a value which is set close to and not less than 2, e.g., 2.2; and that of the devices for the work roll 2 in the other roll set having the smaller number of the rolls has a value which is set close to and not more than 3, e.g., 2.8, the rolling mill of the invention significantly requires including three kinds of control means which have control orders different from one another.

Another embodiment for enhancing the roll bending effects of the rolling mill is shown in Figs. 6 and 7, in which the drum length of the 6H-side intermediate roll 5 is made as small as possible in a range larger than the maximum sheet width of the strip sheet 6. That is to say, when the intermediate roll 5 has a small drum length, the end portions thereof are not in contact with the backup roll 3 of a large diameter, and consequently, not only the effect of the benders for the 6H-side intermediate roll 5 but also the effect of the benders for the upper work roll 1 is enhanced. The reason why the drum length of the intermediate roll is larger than the maximum sheet width in this embodiment is that if the drum length of the intermediate roll is smaller than the maximum sheet width, the surface roughness of a portion of the work roll which is in contact with the intermediate roll will differ from that of a portion of the work roll which is not in contact with it, and as a result, the roughness of the sheet surface will be varied, thus damaging the surface quality of the strip sheet. This is particularly noticeable when the work roll is a dull roll.

In this manner, the five-high rolling mill is exquisitely equipped with both the characteristic of a six-high rolling mill that the roll bending effect is apt to reach the center of the strip sheet and the characteristic of a four-high rolling mill that the roll bending effect is apt to be produced on the side end portions of the strip sheet. Thus, there can be provided the multi-high rolling mill which is capable of multiple bending control of the work rolls, efficient control of the shape of the strip sheet, and preventing the formation of edge wrinkles.

A rolling method of the multi-high rolling mill according to the present invention will be described hereinbelow.

In this rolling method, there is employed the multi-high rolling mill including the upper and lower work rolls 1 and 2 of substantially the same diameter, the upper and lower backup rolls 3 and 4 supporting those work rolls 1 and 2, respectively, and the intermediate roll 5 located between one of the upper and lower work rolls 1, 2 and the associated backup roll 3, 4. The roll bending devices 13 installed on the intermediate roll 5 and the roll bending devices 10 installed on the work roll in the roll set where the intermediate roll is disposed are both actuated to control the composite sheet crown of the strip sheet 6 in its entire width, and the roll bending devices 11 which are installed on the other work roll directly supported by the associated backup roll are actuated to control the sheet crown of the side end portions of the strip sheet 6. In this manner, the rolling method is arranged to perform both the composite shape control of the strip sheet and the control of the widths of the non-rolled side end portions of the strip sheet. Therefore, by properly combining the effects of the bending operations which have control characteristics different from each other, i.e., the effect of bending the intermediate roll which enables the bending control over the entire length of the roll and the effect of bending the work roll in the roll set where the intermediate roll is disposed which enables the bending control of the vicinities of the roll end portions, the sheet thickness in the entire width can be desirably controlled and thus, it is possible to provide the rolling method which can effect the composite shape control of the strip sheet even when the rolling operation is performed under the condition of a small rolling reduction. In addition, due to the bending effect of the work roll directly supported by the associated backup roll, the end portions of this work roll are largely bent to effectively control the thickness of the side end portions of the strip sheet 6 and reduce the widths of the non-rolled portions, and consequently, it is possible to provide the rolling method which can sufficiently prevent edge wrinkles from forming on the side end portions of the strip sheet.

Although the above description relates to the skinpass rolling mill, it should be noted that when the rolling mill is applied as a rolling mill of a small rolling force for materials such as copper and aluminum except iron, it is to effective that the composite shape control covering a wide range can be performed.

The present invention can provide a rolling method which has an excellent composite shape control for remarkably improving the surface quality of the strip sheet and which reduces the non-rolled portions in the vicinities of the sheet side ends for preventing the formation of edge wrinkles, thereby producing a great effect.

Claims

1. Method for rolling a sheet material in a five-high rolling mill with a small reduction and a small rolling force including upper and lower work rolls (1, 2) of the same diameter, upper and lower back-up rolls (3, 5) supporting the work rolls, respectively, an intermediate roll (5) located between one of said work rolls (1, 2) and the associated back-up roll (3, 4) having a diameter larger than that of the work rolls and smaller than that of the back-up rolls, and roll bending devices (10, 12, 13) installed on said work rolls (1, 2) and on said intermediate roll (5), said method is **characterized** in that

   - the roll bending devices (13) installed on the intermediate roll (5) and the roll bending devices (10) installed on the work roll (1) directly supported by the intermediate roll (5), all generate increase bending forces for controlling a composite sheet crown of the rolled material (6) over its entire width, and
   - the roll bending devices (11) installed on the other work roll (2) directly supported by its associated back-up roll (4) generate a decrease bending force for controlling the sheet crown of the side end portions of the rolled material (6),
   - thereby performing both, the composite shape control of the rolled material and the control of the width of the side end portions of the rolled material which are not to be rolled.

2. Rolling method according to claim 1,
   characterized in that
   said roll bending devices (10, 12, 13) are actuated during a rolling operation under the conditions of a small rolling reduction and a small rolling force.

3. Rolling method according to claim 1 or 2,
   characterized in that
   the bending devices (10, 13) acting on the intermediate roll (5) and on its associated work roll (1) are actuated individually.

4. Rolling method according to claims 1 to 3,
   characterized in that
   the intermediate roll (5), the work roll (1) associated with said intermediate roll and the other work roll (2) associated with the back-up roll (4) are controlled respectively by their bending devices (10, 12, 13) with gradually increased values of control degrees n.

5. Rolling method according to claims 1 to 4,
   characterized in that
   the composite sheet crown of the rolled material (6) will be controlled by the shape of one back-up roll (3) or the drum length of the intermediate roll (5).

Patentansprüche

1. Verfahren zum Walzen von Flachgut in einem Fünf-Walzengerüst mit geringer Stichabnahme und geringer Walzkraft, bestehend aus

   - oberen und unteren Arbeitswalzen (1, 2) von gleichem Durchmesser
   - oberen und unteren Stützwalzen (3, 4) zum Abstützen der jeweiligen Arbeitswalzen (1, 2)
   - einer zwischen einer Arbeitswalze und einer Stützwalze angeordneten Zwischenwalze (5), deren Durchmesser größer als der der Arbeitswalzen (1, 2) und kleiner als der der Stützwalze (3, 4) ist, und
   - an den Arbeitswalzen (1, 2) und an der Zwischenwalze (5) angebauten Walzenbiegeeinrichtungen (10, 12, 13)

   dadurch gekennzeichnet, daß

   - die Walzenbiegeeinrichtungen (13) der Zwischenwalze (5) und der von der Zwischenwalze direkt abgestützten Arbeitswalze (1) vergrößerte Biegekräfte zur Steuerung der zusammengesetzten Balligkeit des gewalzten Flachguts (6) über seine gesamte Breite und
   - die Walzenbiegeeinrichtungen (11) der anderen direkt von der Stützwalze (4) abgestützten Arbeitswalze (2) eine verminderte Biegekraft zur Steuerung der Balligkeit der seitlichen Flachgutränder erzeugt,
   - so daß die zusammengesetzte Formsteuerung des gewalzten Flachguts und die Breite der seitlichen nicht ausgewalzten Flachgutränder durchgeführt wird.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die Walzenbiegeeinrichtungen (10, 12, 13) während des Walzbetriebes mit geringer Stichabnahme und geringer Walzkraft betätigt werden.

3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die auf die Zwischenwalze (5) und deren zugeordnete Arbeitswalze (1) einwirkenden Biegeeinrichtungen (10, 13) individuell betätigt werden.

4. Verfahren nach den Ansprüchen 1 bis 3, dadurch gekennzeichnet, daß die Zwischenwalze (5) die ihr zugeordnete Arbeitswalze (1) und die der Stützwalze (4) zugeordnete andere Arbeitswalze (2) jeweils durch ihre Biegeeinrichtungen (10, 12, 13) mit graduell vergrößerten Werten der Steuergrade n gesteuert werden.

5. Verfahren nach Anspruch 1 bis 4, dadurch gekennzeichnet, daß die zusammengesetzte Balligkeit des gewalzten Flachguts (6) durch die Form einer Stützwalze (3) oder durch die Ballenlänge der Zwischenwalze (5) gesteuert wird.

Revendications

1. Procédé pour laminer une matière en tôle dans un laminoir à cinq cylindres à faible réduction d'épaisseur et faible force de laminage comportant des cylindres supérieur et inférieur de travail (1, 2) du même diamètre, des cylindres supérieur et inférieur d'appui (3, 5) supportant respectivement les cylindres de travail, un cylindre intermédiaire (5) situé entre un desdits cylindres de travail (1, 2) et le cylindre d'appui correspondant (3, 4) ayant un diamètre plus grand que celui des cylindres de travail et plus petit que celui des cylindres d'appui, et des dispositifs (10, 12, 13) de cintrage de cylindres installés sur lesdits cylindres de travail (1, 2) et sur ledit cylindre intermédiaire (5), ledit procédé étant
caractérisé en ce que

- les dispositifs (13) de cintrage de cylindres installés sur le cylindre intermédiaire (5) et les dispositifs (10) de cintrage de cylindres installés sur le cylindre de travail (1) supporté directement par le cylindre intermédiaire (5) créent tous ensemble des forces de cintrage croissantes pour déterminer un bombé de tôle composite de la matière laminée (6) sur toute sa largeur, et
- les dispositifs (11) de cintrage de cylindres installés sur l'autre cylindre de travail (2) supporté directement par son cylindre d'appui correspondant créent une force de cintrage décroissante pour déterminer le bombé de tôle des extrémités latérales de la matière laminée (6),
- réalisant de ce fait à la fois la détermination de la forme composite de la matière laminée et la détermination de la largeur des extrémités latérales de la matière laminée qui ne sont pas à laminer.

2. Procédé de laminage selon la revendication 1,
caractérisé en ce que
lesdits dispositifs (10, 12, 13) de cintrage de cylindres sont actionnés pendant une passe de laminage dans les conditions d'une faible réduction d'épaisseur par laminage et d'une faible force de laminage.

3. Procédé de laminage selon la revendication 1 ou 2,
caractérisé en ce que
les dispositifs de cintrage (10, 13) agissant sur le cylindre intermédiaire (5) et sur son cylindre de travail correspondant (1) sont actionnés individuellement.

4. Procédé de laminage selon les revendications 1 à 3,
caractérisé en ce que
le cylindre intermédiaire (5), le cylindre de travail (1) associé audit cylindre intermédiaire et l'autre cylindre de travail (2) associé au cylindre d'appui (4) sont respectivement commandés par leurs dispositifs de cintrage (10, 12, 13) avec des valeurs progressivement croissantes de degrés n de commande.

5. Procédé de laminage selon les revendications 1 à 4,
caractérisé en ce que
le bombé de tôle composite de la matière laminée (6) sera déterminé par la forme d'un seul cylindre d'appui (3) ou par la longueur de partie cylindrique du cylindre intermédiaire (5).

FIG. 1

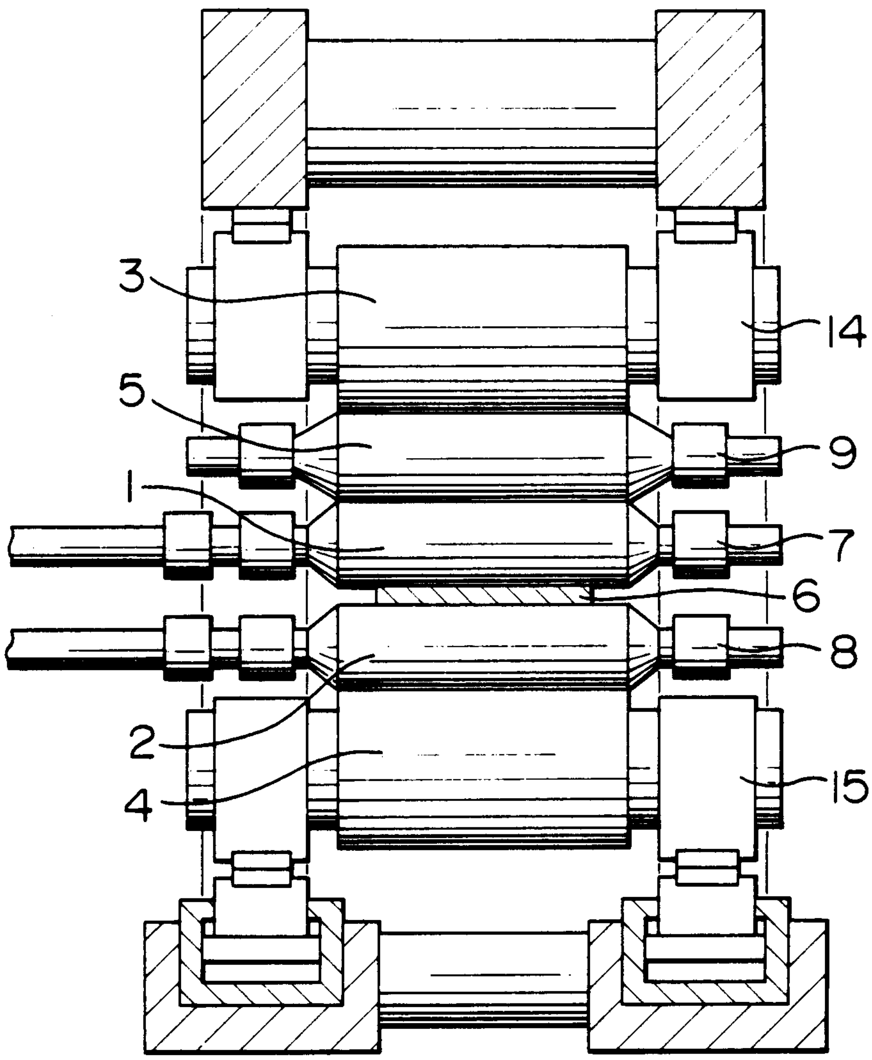


FIG. 2

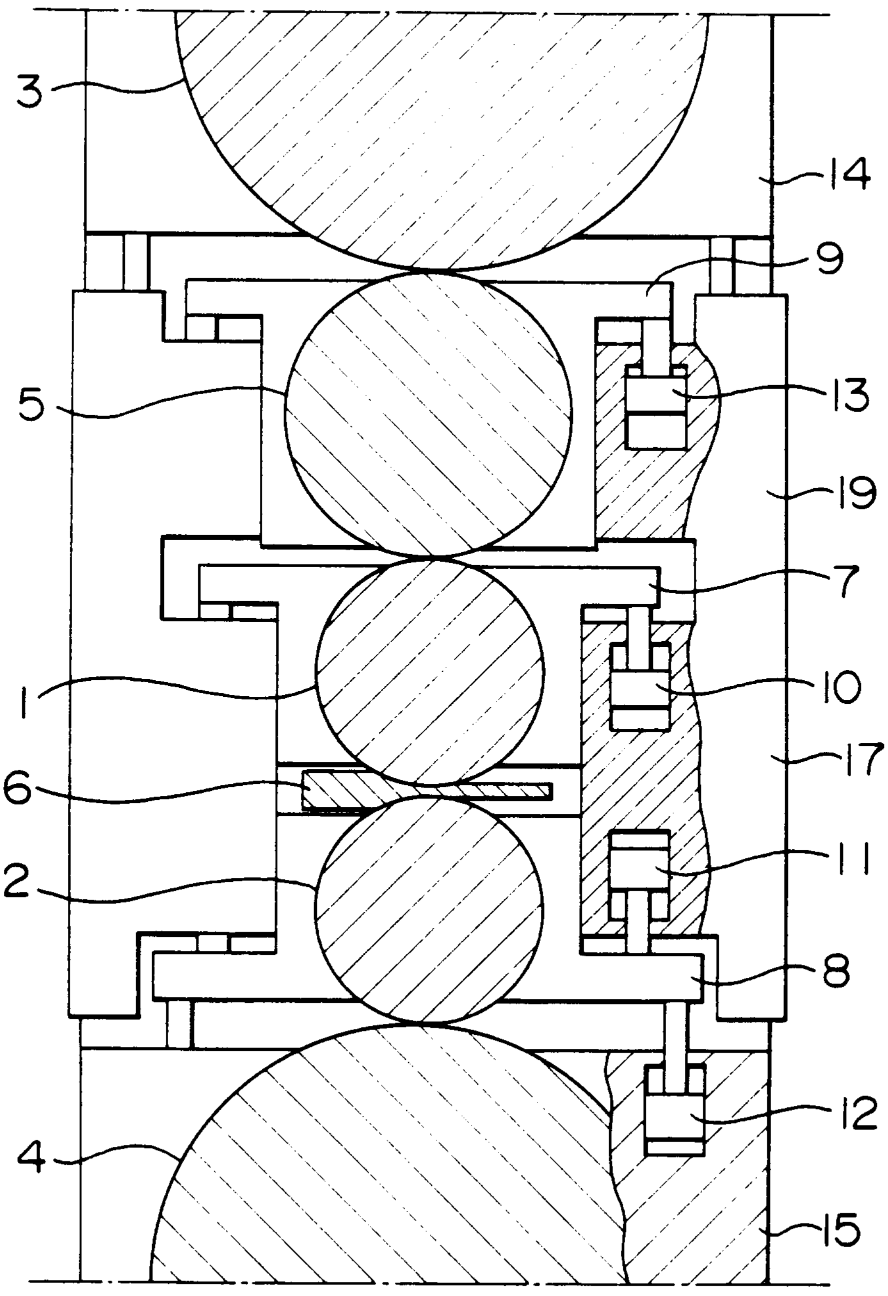


FIG. 3

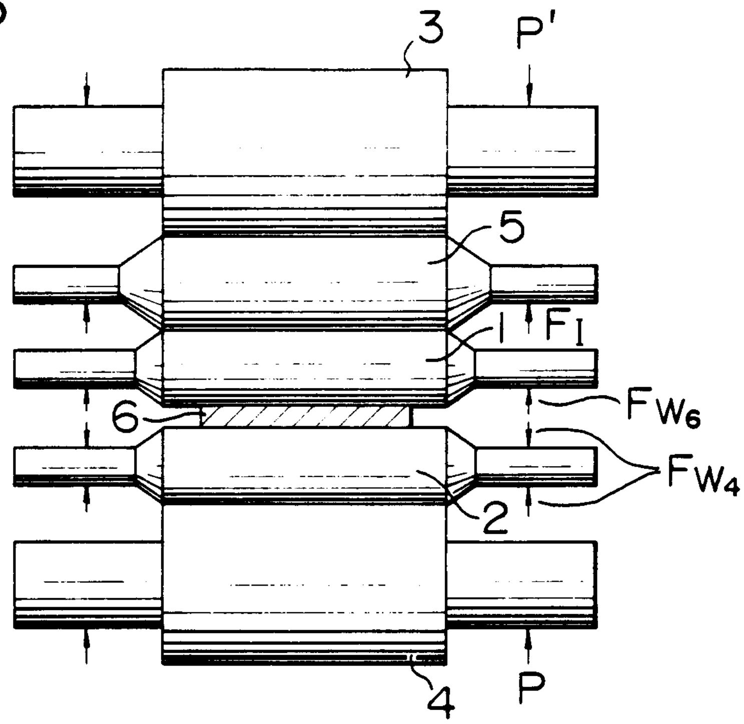


FIG. 4

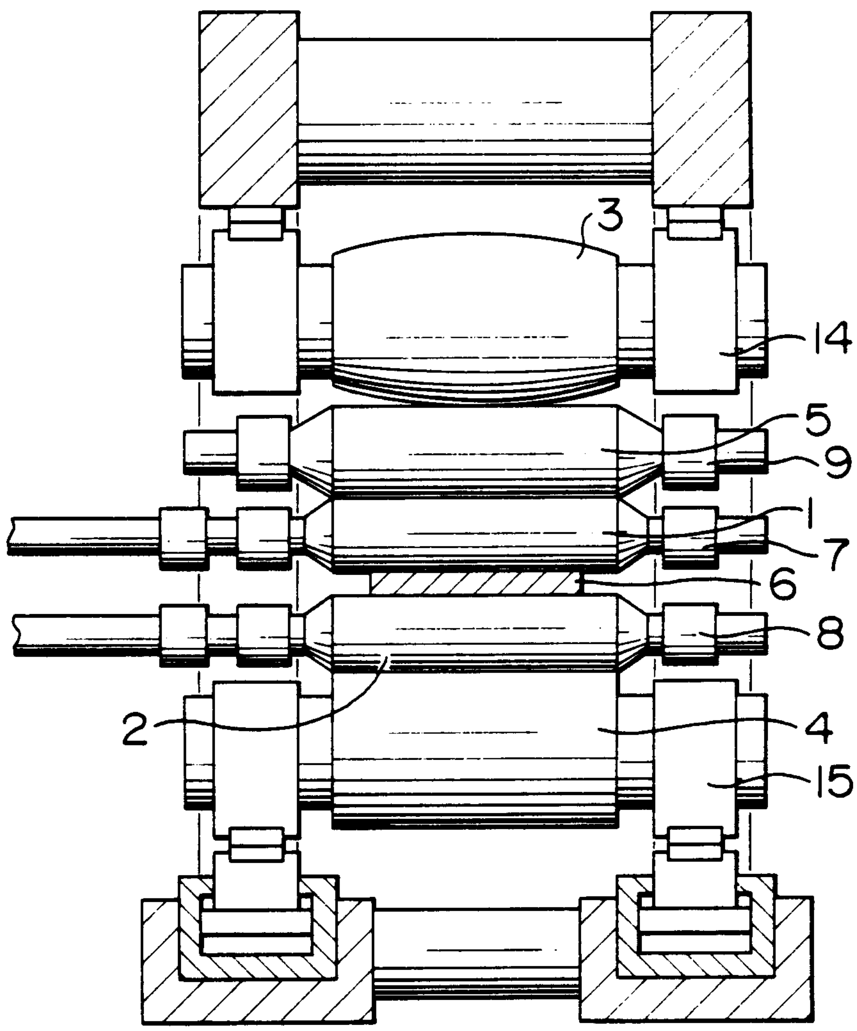


FIG. 5A

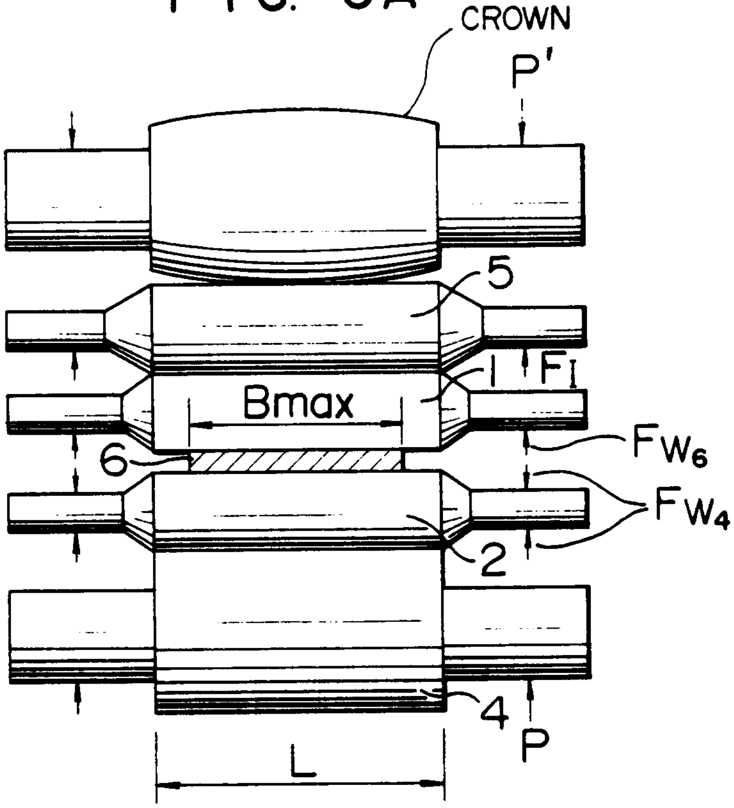


FIG. 5B

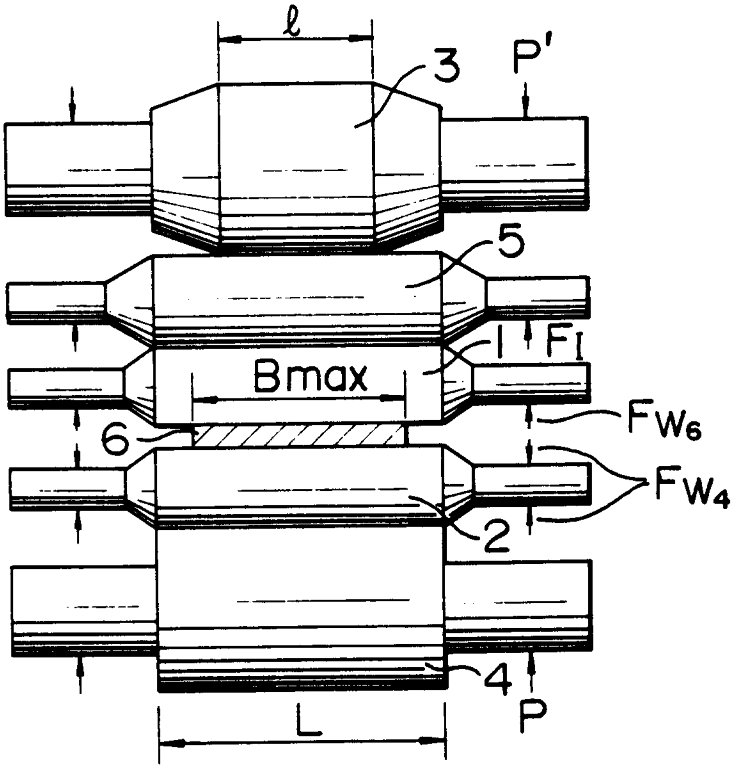


FIG. 6

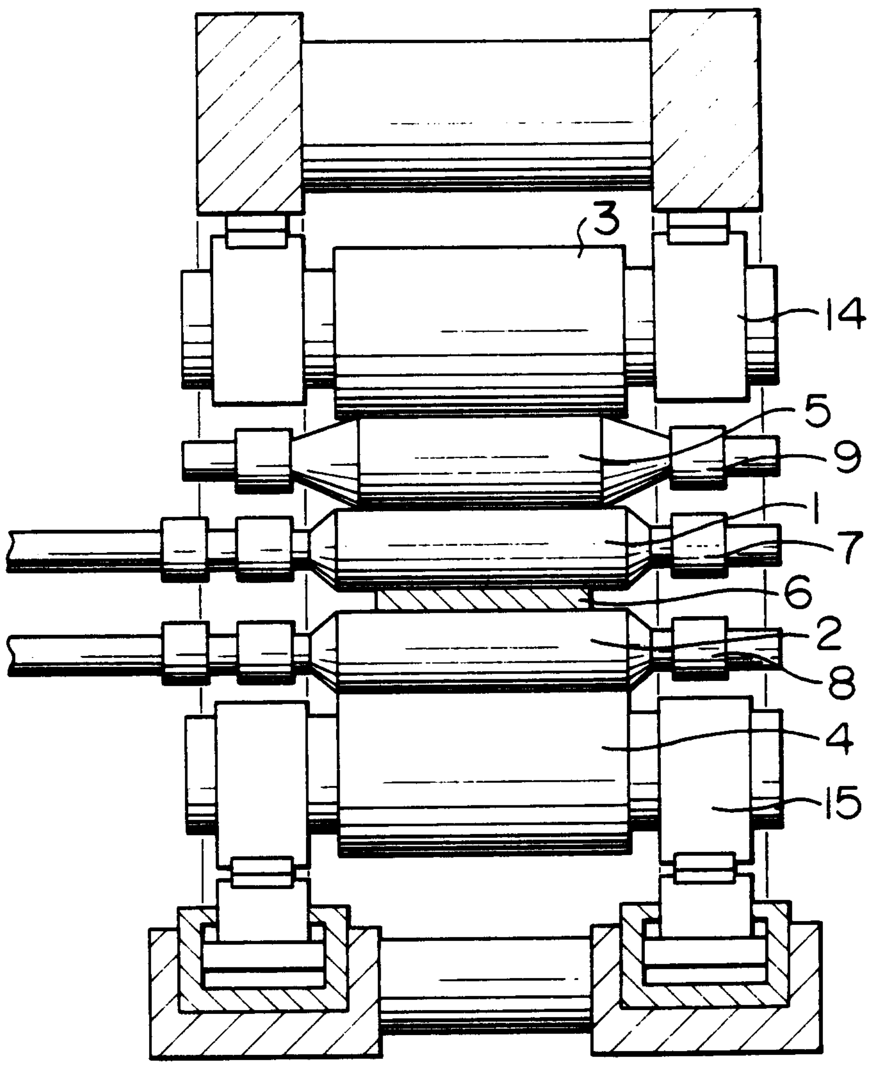


FIG. 7

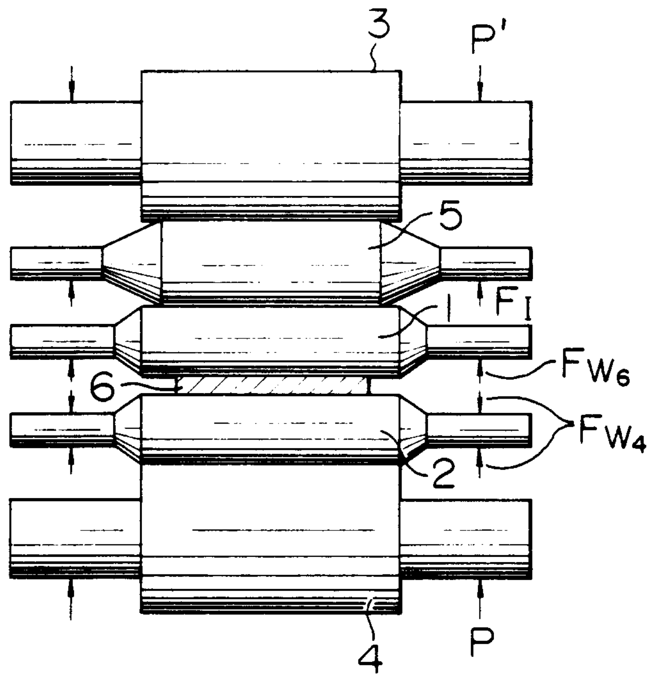

3
P'
5
F_I
1
Fw_6
6
Fw_4
2
4
P

FIG. 8

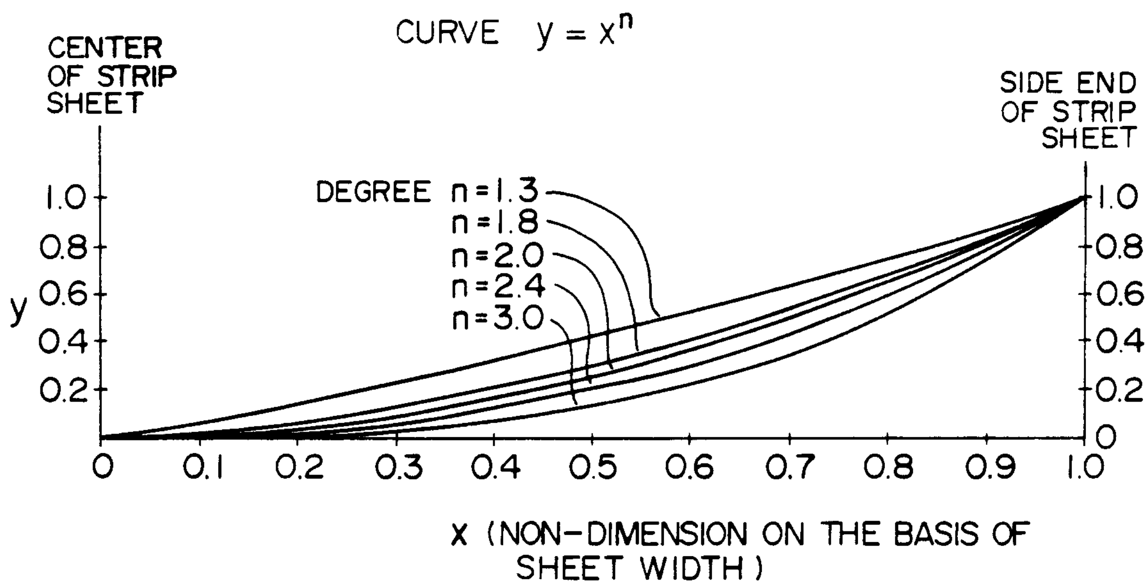

CURVE y = x^n
CENTER OF STRIP SHEET
SIDE END OF STRIP SHEET
DEGREE n=1.3
n=1.8
n=2.0
n=2.4
n=3.0
y
1.0
0.8
0.6
0.4
0.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
X (NON-DIMENSION ON THE BASIS OF SHEET WIDTH)

FIG. 9

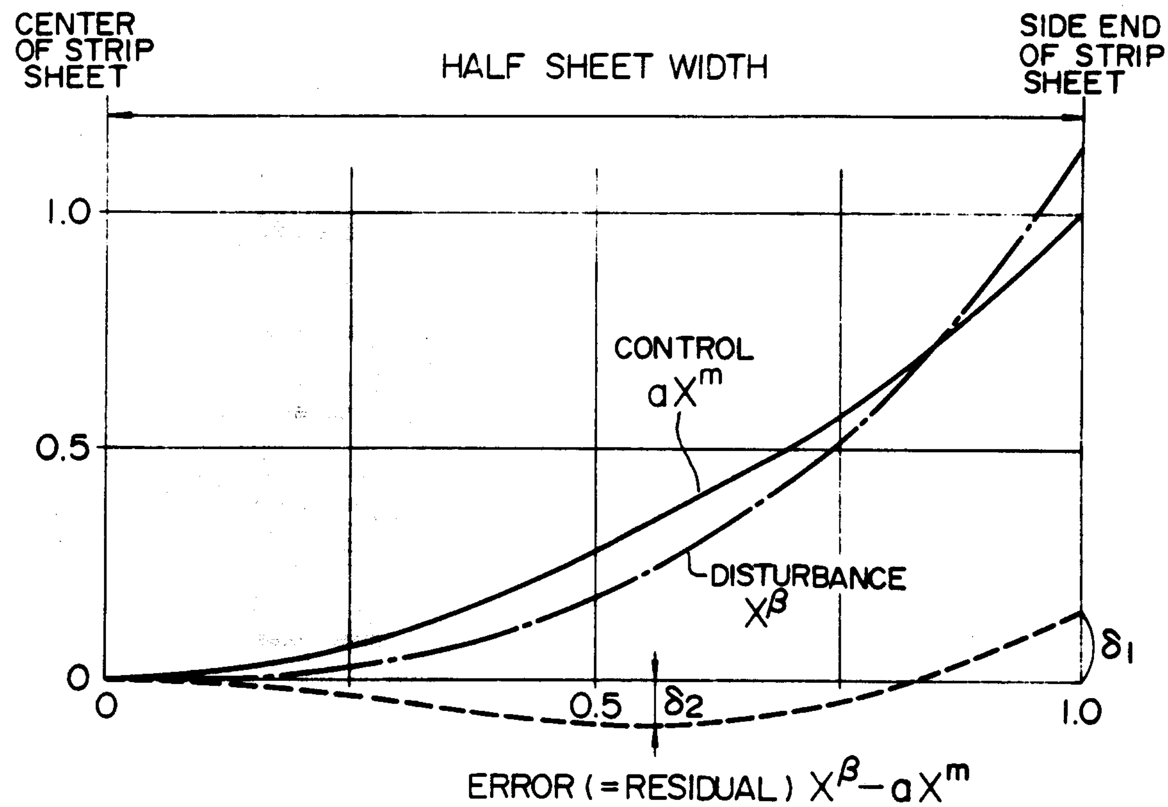

CENTER OF STRIP SHEET
HALF SHEET WIDTH
SIDE END OF STRIP SHEET
1.0
0.5
0
0
0.5
1.0
CONTROL
aX^m
DISTURBANCE
X^β
δ1
δ2
ERROR (=RESIDUAL) X^β−aX^m

FIG. 10

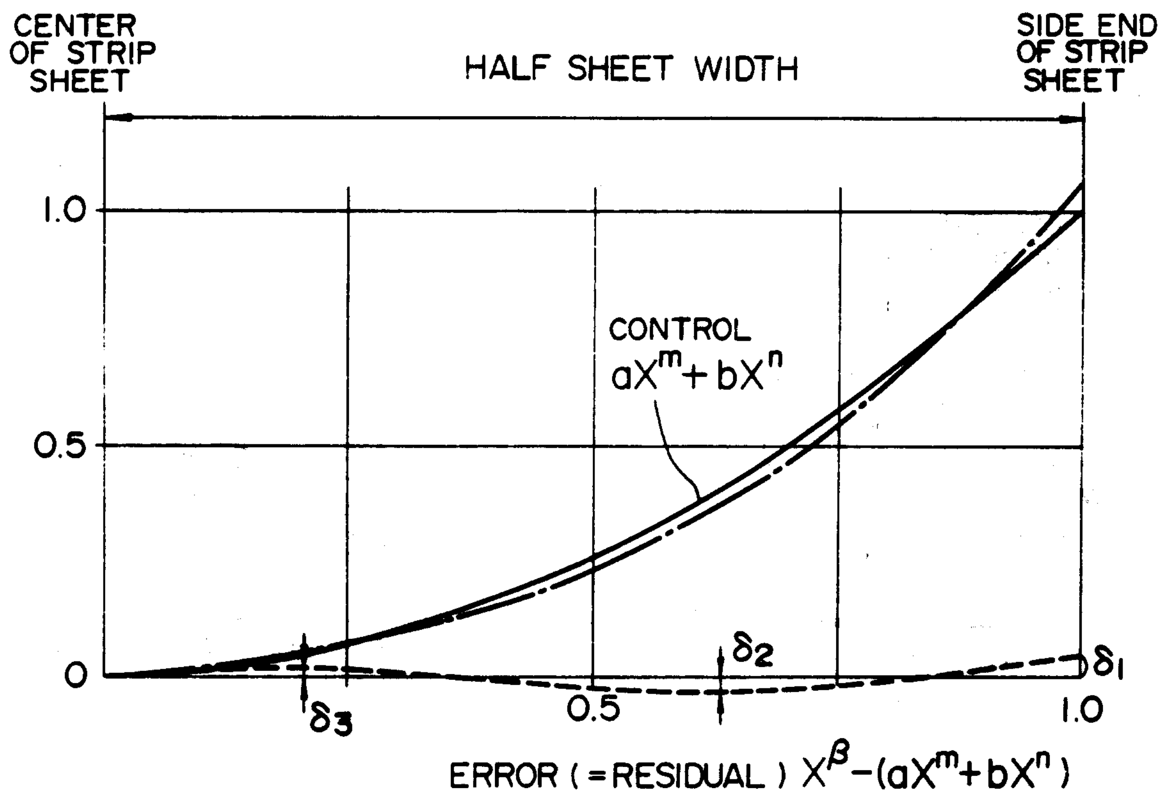
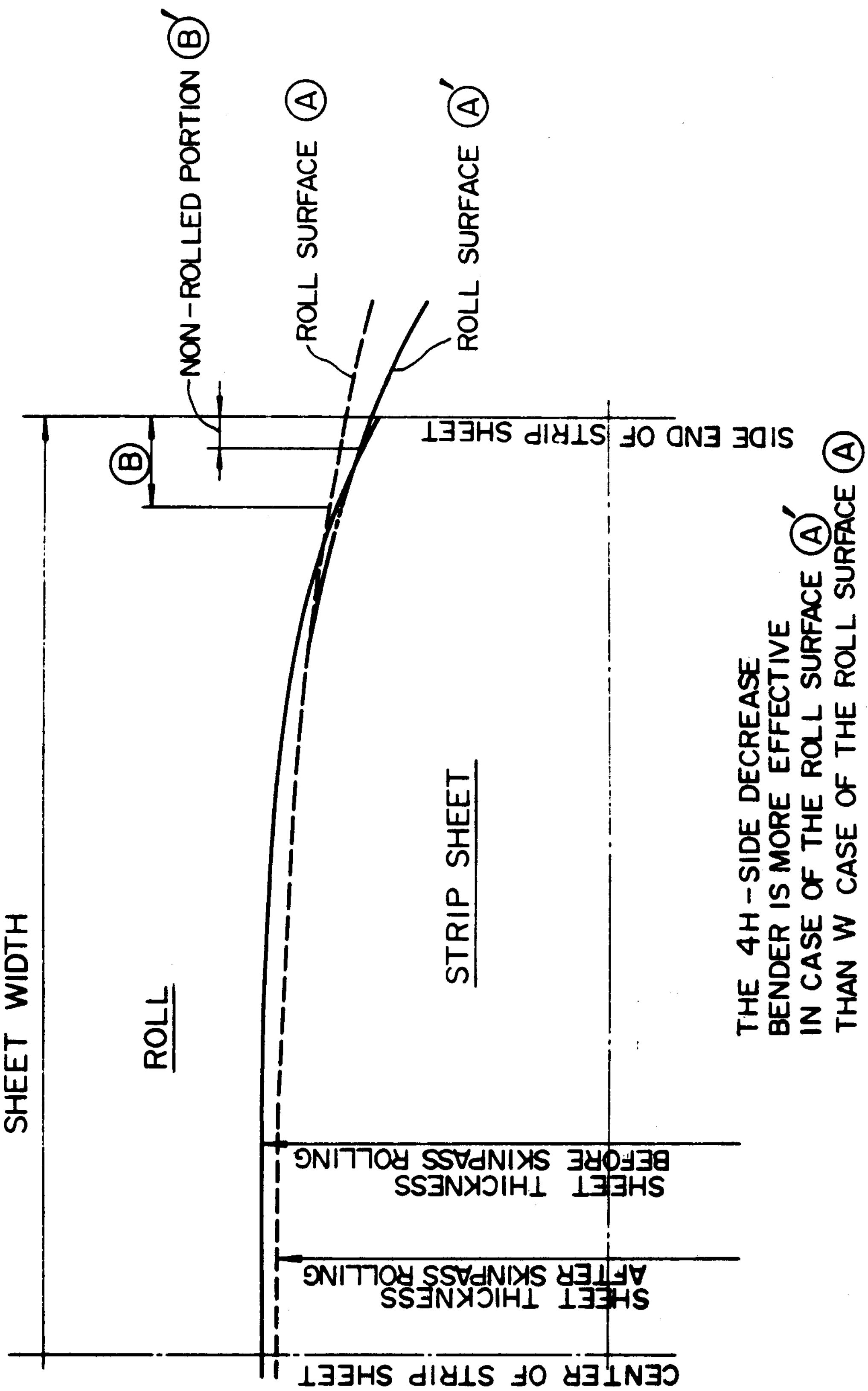

CENTER OF STRIP SHEET
HALF SHEET WIDTH
SIDE END OF STRIP SHEET
1.0
0.5
0
0.5
1.0
CONTROL
aX^m+bX^n
δ1
δ2
δ3
ERROR (=RESIDUAL) X^β−(aX^m+bX^n)

FIG. 11


SHEET WIDTH
ROLL
STRIP SHEET
NON-ROLLED PORTION (B)'
ROLL SURFACE (A)
ROLL SURFACE (A)'
(B)
SIDE END OF STRIP SHEET
BEFORE SKINPASS ROLLING SHEET THICKNESS
AFTER SKINPASS ROLLING SHEET THICKNESS
CENTER OF STRIP SHEET
THE 4H-SIDE DECREASE
BENDER IS MORE EFFECTIVE
IN CASE OF THE ROLL SURFACE (A)'
THAN W CASE OF THE ROLL SURFACE (A)