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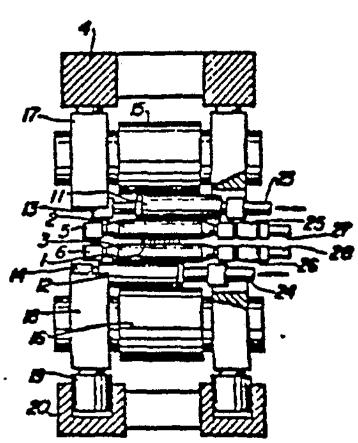
(54) Roll for rolling mill.

(57) A pair of rolls (11, 12) displaceable axially in accordance with the rolled sheet width are arranged at the upper and/or lower sides of a pair of work rolls (2, 3) having a high flexural rigidity, such that the axes of the axially displaceable rolls (11, 12) are substantially in the same plane as the axes of the work rolls (2, 3), so that the shape control of the rolled sheet (1) is performed by the axial adjustment of the axially displaceable rolls (11, 12). Each axially displaceable roll (11, 12) has an axial end portion the diameter of which is gradually decreased toward the axial outer extremity with such a rate that the reduction in radius of said axial end portion within the range of 100 mm is at least 0,3 mm. Stress concentration at the displaceable roll (11, 12) end, spalling and scoring are avoided, and the shape controllability is improved considerably.

FIG. 1



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Croydon Printing Company Ltd.

ROLL FOR ROLLING MILL

BACKGROUND OF THE INVENTION

The present invention relates to a rolling mill incorporating a pair of rolls displaceable in the axial direction in accordance with the sheet width of the rolled sheet to permit a shape control of the rolled sheet and, more particularly, to the shape and size of the axial end portion of such displaceable rolls.

In recent years, there is an increasing demand for an enhanced precision of thickness of the rolled sheet and improved flatness (shape) of the same.

To cope with this demand, the present inventors have already proposed in the specification of the United States Patent No. 3818743 a rolling mill having intermediate rolls disposed between an upper work roll and an upper backup roll and between a lower work roll and a lower backup roll, respectively, the intermediate rolls being axially displaceable in opposite directions, and a work roll bender.

In this rolling mill, the length of contact between cooperating rolls is changed by the axial displacement of the intermediate rolls to permit the control of the deflection of the work roll. This rolling mill, therefore, can remarkably improve the quality of control of the shape of the rolled product, thanks to the combination of the axial displacement of the intermediate rolls and the operation of the work roll bender. In addition, this rolling mill offers various additional advantages such as improvements in efficiency of the rolling equipment as a whole, rate of operation of the rolling mill and enhanced yield of the product, as well as saving of labour and energy.

In the rolling mill having axially displaceable rolls of the kind described, rolls are arranged in an asymetric manner with respect to the central axis of the rolling mill, so that an asymmetric axial load distribution is formed between the axially displaceable rolls and the cooperating rolls contacting the latter. In particular, the greatest load is produced at each axial end portion of the axially displaceable rolls.

This problem is serious particularly when the axially displaceable roll has end portions having a stepped form, because in such a case an extremely large stress concentration takes place in the portions of the roll surface near the stepped ends, because the roll is abruptly released from the rolling load at the stepped axial ends.

Thus, the axial end portions of the axially displaceable roll suffer double disadvantages in connection with the load as compared with the roll of the conventional rolling mill, resulting in a shortened life of the roll and/or generation of spalling.

In addition, in the event that the axially displaceable roll has stepped end portions, linear surface flaws or scores are formed in the surface of the adjacent roll. Such surface flow or score not only shortens the life of the roll but also is transferred to the rolled product to seriously degrade the quality of the latter if it is formed within the span or width of the rolled product.

The rolls of rolling mills are usually made of forged steel or cast steel. It is, therefore, extremely difficult to overcome the above-described problems by drastically enhancing the roll strength. The use of expensive hard materials, needless to say, uneconomically raises the cost of the roll.

Under these circumstances, it is an important technical subject to be achieved in the fieled of rolling mill to ensure a high quality of the rolled products by avoiding flaws or scores, while realizing sufficient durability and anti-spalling characteristics of the roll, using the conventional less expensive roll materials.

The rolling mill of the kind described inherently has a superior shape controllability. Thus, it is also an important technical subject to optimize the shape and size of the axial end portion of the axially displaceable roll so as to further improve or at least to maintain the superior shape controllability.

The present inventors have made proposals, on an assumption to provide the axial end portion of the axially displaceable roll with an arcuate profile, to represent the radius of curvature of the arcuate profile by a value of no dimension in relation to the roll diameter. In this connection, a reference shall be made to Japanese Patent Publication No. 16784/1978. This proposal, however, provides a solution to a problem concerning the determination of the starting point of the axial end portion of the roll, i.e. the junction between the cylindrical roll body portion and the arcuate axial end portion.

If the load is applied to the rolls in such a state that an axial end portion of the displaceable roll contacts the lengthwise mid portion of the adjacent roll, a flattening deformation is caused in the contact regions of both rolls, so that the axial contact length is increased as compared with that presented when there is no load applied to the rolls. It is true that the stress concentration and the scoring in the rolled product can be avoided to some extent by adopting an arcuate profile of radius R of curvature at the axial end portions of the displaceable roll. However, if the portion of the increased length due to application of load has inadequate shape and size, the contact region between two rolls is abruptly terminated so that the problems experienced with the use of displaceable roll having stepped axial end portions are encountered even if the displaceable roll has axial end portions of arcuate profile.

The rolling mill of the type described permits good rolling for varying rolling load and rolling width. In fact, the rolling can be satisfactorily performed even at such a high reduction ratio of about 50%. In the rolling operation at such a high reduction ratio, the amount of flattening deformation between the rolls is innegligibly large, and the above-mentioned problems cannot be obviated solely by adopting arcuate profile of the axial end portions of displaceable roll.

SUMMARY OF THE INVENTION

It is, therefore, an object of the invention to provide a roll having axial end portions shaped and sized to avoid, even if the length of contact region between two contacting rolls is increased under the application of the rolling load, undesirable stress concentration, as well as generation of spalling and score at the axial end portion of the roll to improve the durability of the roll thereby to overcome the above-described problems of the prior art, while improving the shape controllability of the rolling mill.

It is another object of the invention to provide a roll which can eliminate the generation of surface flaw or score in the contacting roll, thereby to ensure a good quality of the rolled products.

It is still another object of the invention to provide a roll capable of eliminating the aforementioned stress concentration, spalling and scoring under the application of rolling load, even when conventional less-expensive material such as forged steel, cast steel or the like is used as the material of the roll thereby to make it possible to overcome the problems of the prior art without incurring a rise of the cost.

It is a further object of the invention to provide a roll incorporated in a rolling mill adapted to make a shape control of the rolled product by an axial adjustment of axially displaceable roll or by a combination of such an axial adjustment and an adjustment of bending force of the work rolls having high flexural rigidity, the roll having axial end portions shaped and sized to permit the roll to be applied to a wide variety of size and use of the rolling mill, e.g. rolling mill for aluminum, iron, hard metals and so forth.

To this end, according to the invention, there is provided a roll for use in a rolling mill having upper and lower work rolls arranged in pair and adapted to make contact with the material being rolled to roll the latter, each work roll having a diameter at least 15% of the roll barrel length thereof and a high flexural rigidity, and a pair of displaceable rolls disposed at one side or upper and lower sides of said pair of work rolls in such a manner that a plane defined by the axes of said displaceable rolls substantially or exactly coincides with a plane defined by the axes of said work rolls and that said displaceable rolls can be displaced in the axial direction in accordance with the width of the rolled sheet thereby to permit a shape control to control the shape of the rolled product, characterized in that each displaceable roll has an axial end portion having a diameter decreasing gradually toward the axial extremity and that the reduction in the radius of the axial end portion within the axial region of 100 mm as measured from the starting point of the axial end portion is at least 0.3 mm.

In the rolling mill of the invention, the end portion of the displaceable roll is suitably located in relation to the widthwise end of the rolled material to perform a good shape control. Unfortunately, however, there is a problem that the boundary between the contacting region and non-contacting region of the displaceable roll with the adjacent roll is moved due to a Hertz flattening of the rolls when the rolling load is actually applied. According to the invention, even if the above-mentioned boundary is shifted this problem is fairly overcome to ensure a good shape control while avoiding the stress concentration and generation of spalling and scoring of the roll, because, in the rolling mill according to the invention, each displaceable roll has an axial end portion which is shaped in such a manner that a diameter gradually reduces toward the axial outer extremity and that the reduction in radius in each axial end portion within the axial region of 100 mm as measured from the starting point of the axial end portion is at least 0.3 mm.

These and other objects, as well as advantageous features of the invention will become clear from the following description of the preferred embodiments taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view of a rolling mill having axially displaceable rolls the axial end portions of which being specifically shaped and sized in accordance with the invention;

Fig. 2 is a side elevational view of the rolling mill as shown in Fig. 1;

Fig. 3 is an enlarged view of axial end portion of the axially displaceable roll;

Figs. 4A, 4B and 4C are illustrations of positional relationships of the rolls incorporated in the rolling mill;

Fig. 5 is a chart showing the relationship between the amount of Hertz flattening of rolls and roll line load;

Fig. 6 is an illustration of deformation of a roll of small diameter;

Fig. 7 is a chart showing the relationship between the sheet width and the rolled sheet and the diameter of small work roll;

Figs. 8 and 9 are illustrations of other shapes of the axial end portion of the axially displaceable roll;

Fig. 10 is an illustration of load distribution on the roll;

and

Figs. 11 and 12 show different rolling mills in which the axially displaceable rolls having axial end portions specifically sized and shaped in accordance with the invention are incorporated.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the invention will be described hereinunder.

Figs. 1 and 2 show a six high mill embodying the invention having axially displaceable rolls the axial end portions of which are shaped and sized in accordance with the invention. More specifically, Fig. 1 is a sectional view of the rolling mill, while Fig. 2 is a side elevational view.

Upper and lower work rolls 2, 3 for rolling the material 1 to be rolled in direct contact with the latter are supported by metal chocks 5, 6 held in the roll housing 4 at their both ends. The metal chocks 5, 6 in turn are carried by the inside of the left and right projections 7, 8 provided on the roll housing 4 for free vertical adjustment. The projections 7, 8 incorporate hydraulic rams 9, 10 for effecting bending of the upper and lower work rolls.

Upper and lower intermediate rolls 11, 12 arranged in pair and contacting the work rolls 2, 3, respectively, are disposed such that their axes are substantially in the same plane as those of the upper and lower work rolls 2, 3, and are supported at their both ends by metal chocks 13, 14. Each intermediate roll has an axial end portion having an arcuate profile and of a diameter gradually decreasing toward the axial outer extremity. More specifically, the intermediate rolls are arranged such that their arcuate axial end portions are located at opposite sides of the rolling mill. In other words, the arcuate axial end portion of one intermediate roll is located at left side of the path of the rolled material, while the arcuate axial end portion of the other intermediate roll is located at the right side of the same.

Upper and lower backup rolls 15, 16 are arranged in a pair, in contact with the upper side of the upper intermediate roll 11 and the lower side of the lower intermediate roll 12, respectively, such that the axes of these backup rolls are in the same plane as the axes of the intermediate and work rolls. These backup rolls 15, 16 are supported at their both ends by metal chocks 17, 18 provided in the roll housing 4. A hydraulic ram 19 for effecting the roll reduction is connected to the lower side of the metal chock 18 and is received by a cylinder 20. The metal chocks 13, 14 for the intermediate rolls are received by recesses 21, 22 of the metal chocks 17, 18 for backup rolls, so as to permit the intermediate rolls 11, 12 to be displaced in the upward and downward direction, as well as in the axial direction.

The intermediate rolls 11, 12 are coupled, through shafts 23, 24 connected to their one ends, with means (not shown) for axially displacing the intermediate rolls in opposite axial directions. The work rolls 2, 3 are drivingly coupled with driving means (not shown) through respective universal joints 25, 26 and drive shafts 27, 28.

In the rolling mill having the described construction, the axial end portion of each intermediate roll is axially adjusted in accordance with the width of the sheet being rolled in such a manner that, for example, the starting point of the axial end portion of decreasing diameter is located to a position corresponding to the widthwise end of the rolled sheet or its vicinity. In consequence, the undesirable deflection of the work roll, due to the load imposed by the backup roll contacting therewith, is avoided to prevent excessive rolling of the rolled sheet at both axial ends of the work roll. In addition, the roll bending effect is well performed by the hydraulic ram for bending, because each work roll is freed at its one axial end from contact with the backup roll.

Hereinafter, a description will be made as to the shape and size of the axial end portion of the axially displaceable roll.

Fig. 3 is an enlarged view of the axial end portion of the intermediate roll, in which x_{ℓ}, R and y_e represent, respectively, the axial length, radius of curvature and radius reduction(relief) of the axial end portion of the intermediate roll. Also, the diameter of the cylindrical body portion and the point at which the axial end portion starts are designated with D and S, respectively. The direction of roll axis is represented by x-axis, while the upward and downward direction as viewed in this Figure is represented by y-axis, with the crossing point of the vertical line passing the starting point S and the horizontal plane containing the intermediate roll surface constituting the origin of the coordinate.

Figs. 4A to 4C show the positional relationship of rolls. More specifically, Fig. 4A shows the state in which no rolling load is imposed, Fig. 4B shows the state in which the roll end portion is in contact with the cooperating roll over the entire axial length thereof due to a rolling load imposed thereon and Fig. 4C shows the state in which the rolling load is imposed but the axial end portion makes contact with the cooperating roll only at a part of axial length thereof.

In order to achieve the object of the invention, it is necessary to satisfy the following three requirements:

(1) To make sure that the axial end portion of the axially displaceable roll does not make contact over its entire axial length with the cooperating roll even when under the presence of the rolling load as shown in Fig. 4C, i.e. to have the minimum required relief y_t.

(2) To provide the axial end portion with a shape and size which eliminate the problems concerning the roll strength and scoring of the roll even when the boundary between the contacting and non-contacting axial regions of the axial end portion of the displaceable roll is shifted due to the application of rolling load.

(3) To provide the axial end portion with a shape and size which ensure a higher shape controllability of the rolling mill, as will be described later in more detail.

In order to determine the relief amount y_t as stated in item (1) above, it is necessary to obtain the amount of deformation of rolls due to contact under the presence of the load.

There are two kinds of deformation, one of which is usually referred to as Hertz flattening.

Fig. 5 shows the theoretically obtained

relationship between the amount δ of Hertz flattening generated between two rolls 29, 30 and the line load p (load per unit axial length of roll) imposed on the roll. This relationship is theoretically defined by the following equation.

$$\delta = \frac{p}{\pi} A \left(\frac{2}{3} + \ln\frac{\pi(d_1 + d_2)}{2A} - \ln p\right)$$

$$\text{and } A = \frac{2(1 - \nu^2)}{E}$$

where,

E: Young's modulus

ν: Poisson's ratio

Thus, the Hertz flattening amount can be expressed by the following equation, if the sum $(d_1 + d_2)$ of diameters of two rolls 29, 30 fall within the practical range.

$$\delta \doteqdot 3 \times 10^{-4}\, p$$

where,

δ: mm

p: Kg/mm

The roll line load adopted in actual rolling mills usually falls within the following ranges:

(a) p = 200 to 500 Kg/mm: small-sized rolling mill, rolling mill for aluminum, skin pass rolling mill for iron

(b) p = 800 to 1000 Kg/mm: large-sized rolling mill, rolling mill for hard material

Thus, the amount of Hertz flattening δ is calculated to be 0.06 to 0.15 mm and 0.24 to 0.3 mm for the rolling mills belonging to the categories (a) and (b). Therefore, in order to ensure that the contact between the axial end portion of the displaceable roll and the cooperating roll takes place only over a portion of the axial end portion of the displaceable roll by providing the relief amount y_e in only one of these rolls, the relief amount y_e should be at least 0.3 mm.

Another factor which influences the roll relief amount y_e is an increase in the length of contact region between the rolls owing to the deflection of rolls.

Namely, referring to Fig. 6, if the cooperating work roll 2 has a small diameter and low rigidity, such a work roll makes a large deflection so that it is necessary to provide a sufficiently large amount of relief. In the case where the portion at which the contact between two rolls is terminated is created by the axial displacement of the displaceable roll as in the case of the rolling mill of the invention, there is a practical limit in increasing the relief amount when the cooperating roll has a small diameter as in the case of work roll.

Fig. 7 shows a relationship between the rolled sheet width and the minimum diameter of work roll as obtained through a theoretical calculation on an assumption that the diameters of the backup roll and the intermediate roll are 1400 mm and 650 mm, respectively, and that the roll barrel length of the intermediate roll is 1420 mm. It is necessary that the work roll diameter D' has to be determined in relation to the rolled sheet width B to satisfy the relationship expressed by $D' \geqq 0.2B$. This condition is generally met by practical sizes of rolls. This relationship expresses the limit for avoiding the so-called composite elongation of the rolled material. In other words, this relation determines the threshold value for avoiding an abrupt deflection of the cooperating roll at a portion of the latter where the support by the displaceable roll is lost due to the axial displacement of the latter.

Taking account of the meandering of the rolled material during rolling, in the practical rolling mills, the rolls having roll barrel length 100 to 150 mm greater than the rolled sheet width are employed. For instance, for satisfactorily rolling a sheet having a maximum width of 800 mm, the minimum required diameter of the work roll is 160 mm and the roll barrel length is selected to be 900 to 950 mm. Thus, the ratio of work roll diameter to the roll barrel length is 17 to 18%. Since the invention is applied to the rolling mill having work roll of a high flexural rigidity and the ratio of diameter to roll barrel length of work roll exceeding at least 15%, each work roll can be supported by only one roll which is, in the arrangement shown in Fig. 1, the intermediate roll which is disposed at each of upper and lower sides of the pair of work rolls.

Therefore, provided that the diameter of the cooperating roll is selected to be greater than the above-mentioned minimum limit or threshold value, it is not necessary to take into consideration the expansion of the contact region attributable to the abrupt deflection of the cooperating roll.

To sum up, it is required that the amount of relief at the axial extremity or edge of the axially displaceable roll is at least 0.3 mm in radius.

An explanation will be made hereinunder as to the item (2) of the aforementioned requirements. It is possible to preserve a non-contacting portion in the axial end portion of the displaceable roll, if the axial end portion has a relief amount in excess of 0.3 mm as stated above. In order to avoid the concentration of stress to the boundary between the contacting and non-contacting regions in the axial end portion of the displaceable roll, as well as scoring in the cooperating roll at the position of such a boundary, it is preferred that the roll diameter of the axial end portion is decreased toward the axial extremity or edge as gradually as possible. When the axial end portion is formed in an arcuate shape, it is preferred that such an arcuate axial end portion has a radius of curvature in excess of 200 mm. Since a stress concentration tends to occur at the starting point of the axial end portion, i.e. at the boundary between the cylindrical body portion and axial end portion of the displaceable roll, it is preferred that the axial end portion has an arcuate profile of a radius of curvature of at least 200 mm, more preferably between 300 and 4000 mm to gradually decrease the roll diameter at such an axial end portion.

Referring now to the item (3) of the aforementioned requirements, although it is preferred to reduce the diameter of axial end portion of the displaceable roll as gradually as possible to avoid the stress concentration and scoring, a too small rate of decrease in the roll diameter will cause a large change of contact length between the axially displaceable roll and the adjacent roll due to the action of the rolling load which in turn hinders the precise location of the axial end portion of displaceable roll in relation to the rolled material, resulting in an insufficient shape controllability.

According to the results of studies made by the present inventors, it has been made clear that, in the large-size rolling mill having a roll line pressure p of 800 to 1000 Kg/mm, the axial displacement of the boundary between the contacting region and non-contacting region is preferably smaller than 10 mm. A discussion will be made hereinunder as to the condition for maintaining the axial displacement within the range below the above-specified limit value.

Representing the axial displacements when the roll line load p is 800 Kg/mm and 1000 Kg/mm, respectively, by X_2 and X_1, and assuming that the axial end portion of the displaceable roll has an arcuate profile of radius R of curvature for simplification of calculation, there exist the relationships expressed by the following equations. As stated already, the amounts of Hertz flattening δ are 0.24 mm and 0.3 mm, respectively, when the roll line load p is 800 Kg/mm and 1000 Kg/mm.

$$0.3 = \frac{X_1^2}{2R}$$

$$0.24 = \frac{X_2^2}{2R} = \frac{(X_1 - 10)^2}{2R}$$

From the above equations, it is derived that the axial displacement X_1 is 94.7 mm. Thus, as a standard, it is required to provide a relief amount y_e in axial end portion of at least 0.3 mm in radius within the region of 100 mm as measured from the starring point of the axial end portion toward the axial extremity or edge of the displaceable roll. Under the presence of the rolling load, the boundary between the contacting and non-contacting regions exist between the starting point S of the axial end portion and the axial extremity or edge of the displaceable roll. The roll line load is decreased as such boundary is shifted toward the axial extremity. It is, therefore, possible to make the axial outer part of the axial end portion have a radius R of curvature smaller than that at the starting point of the axial end portion or to form such an axial outer part by a straight line of a large gradient. By so doing, it is possible to obtain the smaller length between the starting point S of the axial end portion and the point at which the radius reduction of 0.3 mm is achieved.

For minimizing the axial length of the axial end portion of the displaceable roll while avoiding the inconveniences such as lack of strength at the starting point S of the axial end portion, it is suggested as a preferred embodiment that the arcuate axial end portion of the displaceable roll has a radius of curvature between 300 and 4000 mm. Although the similar calculation is omitted, since the change of rolling load for the same rolling mill is reduced, it is desirable that the length between the starting point S of the axial end portion of the displaceable roll and the point at which the radius reduction of 0.3 mm or greater is reached is selected to be smaller than 100 mm.

Figs. 8 and 9 show different forms of the axial end portion of the displaceable roll. More specifically, in the arrangement shown in Fig. 8, the part of the axial end portion between the starting point and the point at which the relief amount of 0.5 mm is achieved has a radius of curvature of 5000 mmR and the part of the axial end portion beyond the above-mentioned point is formed with a radius of curvature of 500 mmR, the parts of 500 mmR and 5000 mmR being connected smoothly.

On the other hand, Fig. 9 shows the form of the axial end portion in which the axial outer part of the axial end portion is relieved by a straight line. The forms of roll end portion as shown in Figs. 8 and 9 offer an advantage that the axial length between the starting point of the axial end portion and the axial extremity or edge of the displaceable roll is diminished to shorten the time required for grinding the axial end portion of the displaceable roll, which is usually troublesome and time consuming. In addition, it is possible to obtain the large relief amount in radius with a small axial length of the axial end portion, e.g. an amount of Hertz flattening of 1 mm or so generated in the worst case such as a rolling accident.

In the foregoing description, the explanation is focussed only specifically on the axial end portion of the displaceable intermediate roll. It is clear, however, that the axial end portion of the work roll cooperating with the displaceable intermediate roll makes a contact with the cylindrical body portion of the latter, as a result of the axial adjustment of the displaceable roll, as shown in Fig. 10. In the point of such a contact, the load distribution of roll contact between the rolls is so small, as shown in Fig. 10, that no substantial problem is imposed concerning the strength. However, in order to avoid the scoring in the displaceable roll caused by the axial end portion of the work roll, it is suggested that the work roll has an axial end portion the diameter of which is gradually decreased toward the axial extremity, e.g. in an arcuate profile as shown in Fig. 10. Incidentally, in Fig. 10 the mark P represents the rolling load.

Furthermore, although the invention has been described specifically through a six high mill having two intermediate rolls displaceable in opposite axial directions and disposed between the upper work roll and upper backup roll and between the lower work roll and lower backup roll, this is not exclusive and the invention is applicable to a four high mill as shown in Fig. 11 in which backup rolls are axially displaceable, a multi-stage mill as shown in Fig. 12 having two intermediate rolls axially displaceable in opposite directions and disposed between the upper work roll and upper backup roll and various other types of rolling mill.

The invention can be applied also to a rolling mill incorporating rolls having a crown over their entire axial length. In such a case, the point at which the curvature of the crown or the taper is abruptly changed is considered as being the starting point of the axial end portion of roll.

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WHAT IS CLAIMED IS:

1. A roll for use in a rolling mill of a type having upper and lower work rolls arranged in a pair and adapted to roll the material to be rolled in direct contact with the latter, each of said work rolls having diameter of at least 15% of the roll barrel length and, hence, a sufficiently high flexural rigidity, and a pair of axially displaceable rolls arranged at upper and lower sides or only at one side of said pair of work rolls in such a manner that a plane defined by the axes of said axially displaceable rolls substantially or exactly coincides with a plane defined by the axes of said work rolls, said axially displaceable rolls being adapted to be displaced in the axial direction in accordance with the width of the rolled sheet to permit the shape control of said rolled sheet, characterized in that each of said axially displaceable rolls has an axial end portion the diameter of which is gradually decreased toward the axial outer extremity or edge and that the reduction in radius of said axial end portion within the range of 100 mm as measured from the starting point of said axial end portion toward said axial outer extremity is at least 0.3 mm.

2. A roll as claimed in claim 1, wherein the gradual reduction in radius of said axial end portion is commenced at said starting point with a radius of curbature of 200 mm or greater.

3. A roll as claimed in claim 2, wherein said radius of curvature falls between 300 mm and 4000 mm.

4. A roll for use in a rolling mill of a type having upper and lower work rolls arranged in a pair and adapted to roll the material to be rolled in direct contact with the latter, each of said work rolls having a diameter of at least 15% of the roll barrel length and, hence, a sufficiently high flexural rigidity, a pair of intermediate rolls arranged at the upper and lower sides of said pair of work wolls in contact with the latter, said intermediate rolls being displaceable in the axial directions in accordance with the width of the rolled sheet, backup rolls arranged at the upper and lower side of said pair of intermediate rolls in contact with the latter, and means for effecting a roll bending on said work rolls, thereby to effe , a shape control of the rolled sheet by a combination of the axial adjustment of said intermediate rolls and the work roll bending action, characterized in that each of said intermediate rolls has an axial end portion the diameter of which is gradually decreased toward the axial outer extremity or edge and that the reduction in radius of said axial end portion within the region of 100 mm as measured from the starting point of said axial end portion toward said axial outer extremity is at least 0.3 mm.

5. A roll as claimed in claim 4, wherein the gradual reduction in radius of said axial end portion

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is commenced at said starting point with a radius of curvature of 200 mm or greater.

6. A roll for use in a rolling mill of a type having upper and lower work rolls arranged in a pair and adapted to roll the material to be rolled in direct contact with the latter, each of said work rolls having a diameter of at least 15% of the roll barrel length and, hence, a sufficiently high flexural rigidity, a pair of backup rolls disposed at the upper and lower sides of said pair of work rolls and dispaceable in the axial direction in accordance with the width of the rolled sheet, and means for effecting a roll bending on said work rolls, thereby to make the shape control of the rolled sheet by the axial adjustment of said backup rolls, characterized in that each of said backup rolls has an axial end portion the diameter of which is gradually decreased toward the axial outer extremity or edge and that the reduction in radius of said axial end portion within the region of 100 mm as measured from the starting point of said axial end portion toward said axial outer extremity is at least 0.3 mm.

7. A roll as claimed in claim 6, wherein the gradual reduction in radius of said axial end portion is commenced at said starting point with a radius of curvature of 200 mm or greater.

8. A roll for use in a rolling mill of a type having upper and lower work rolls arranged in a pair

and adapted to roll the material to be rolled in direct contact with the latter, each of said work rolls having a diameter of at least 15% of the roll barrel length and, hence, a sufficiently high flexural rigidity, backup rolls backing up said work rolls and a pair of intermediate rolls disposed at least between one work roll and the associated backup roll, said intermediate rolls being displaceable in the axial direction to permit a shape control of the rolled sheet, characterized in that each of said intermediate rolls has an axial end portion the diameter of which is gradually decreased toward the axial outer extremity or edge and that the reduction in radius of said axial end portion within the region of 100 mm as measured from the starting point of said axial end portion toward said axial outer extremity is at least 0.3 mm.

9. A roll as claimed in claim 8, wherein the gradual reduction in radius of said axial end portion is commenced at said starting point with a radius of curvature of 200 mm or greater.

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FIG. 1

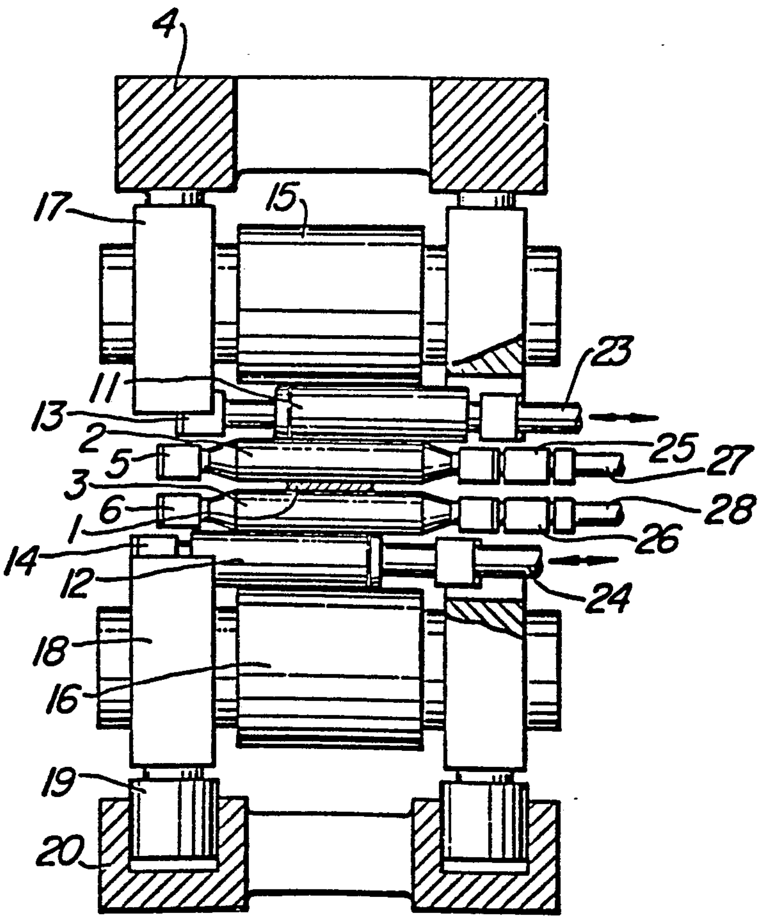

FIG. 2

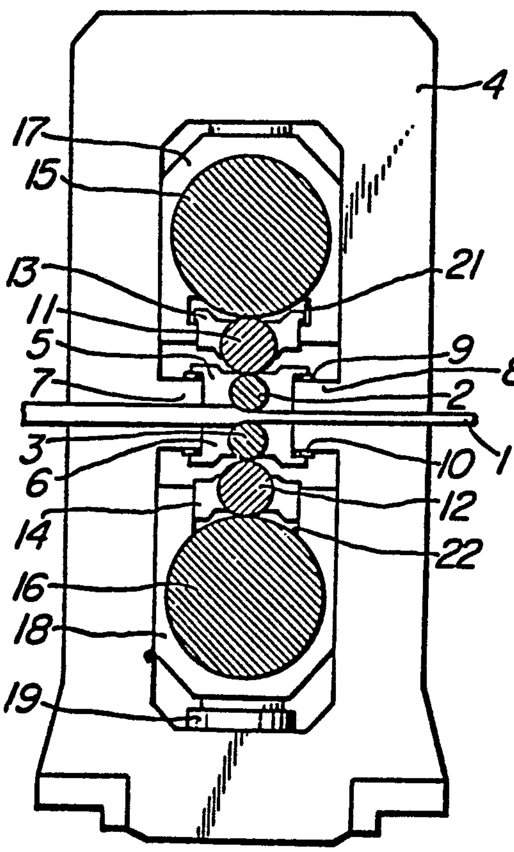

FIG. 3

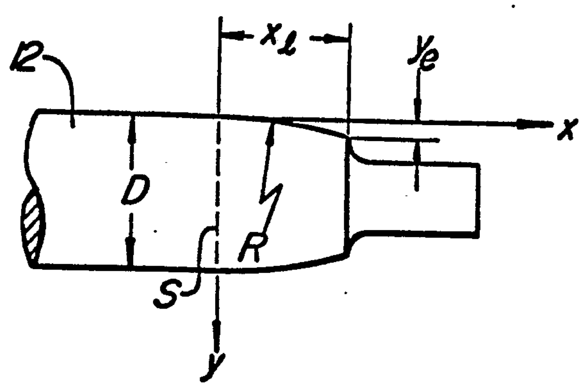

FIG. 4A

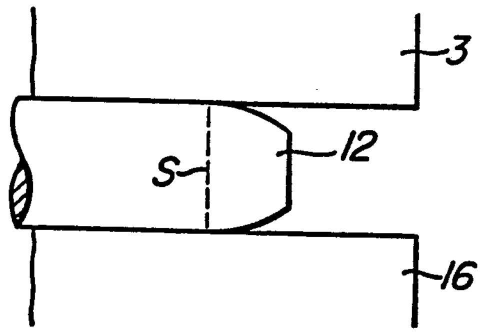

FIG. 4B

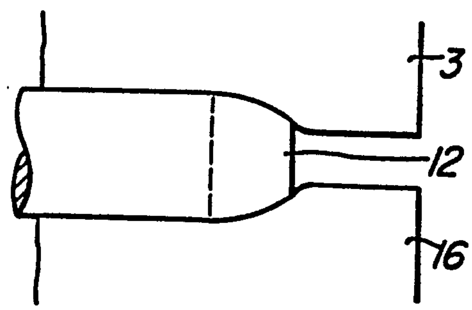

FIG. 4C

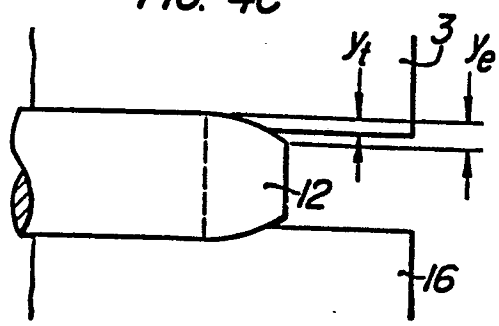

FIG. 5

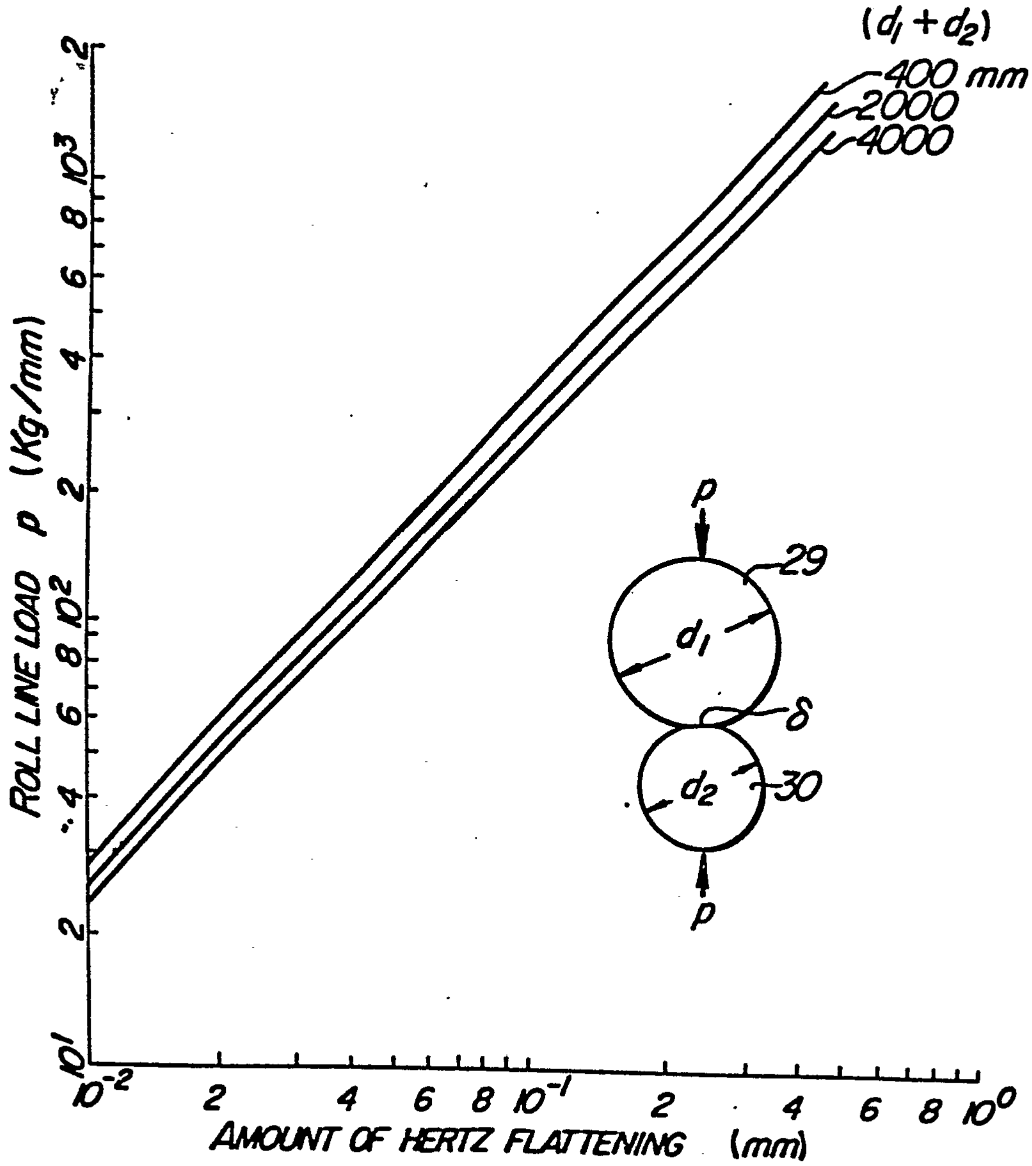
ROLL LINE LOAD p (Kg/mm)
AMOUNT OF HERTZ FLATTENING (mm)
$(d_1 + d_2)$
400 mm
2000
4000
p
29
d_1
δ
d_2
30
p

FIG. 6

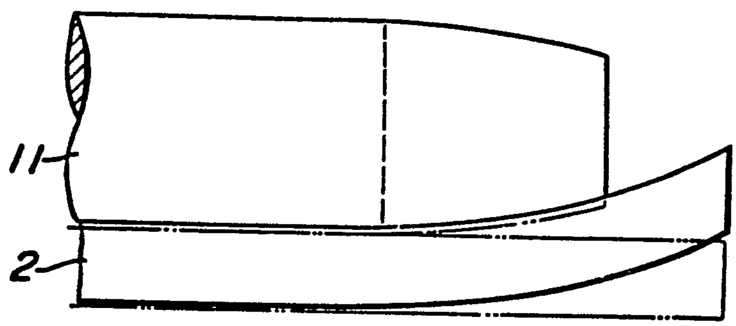
11
2

FIG. 7

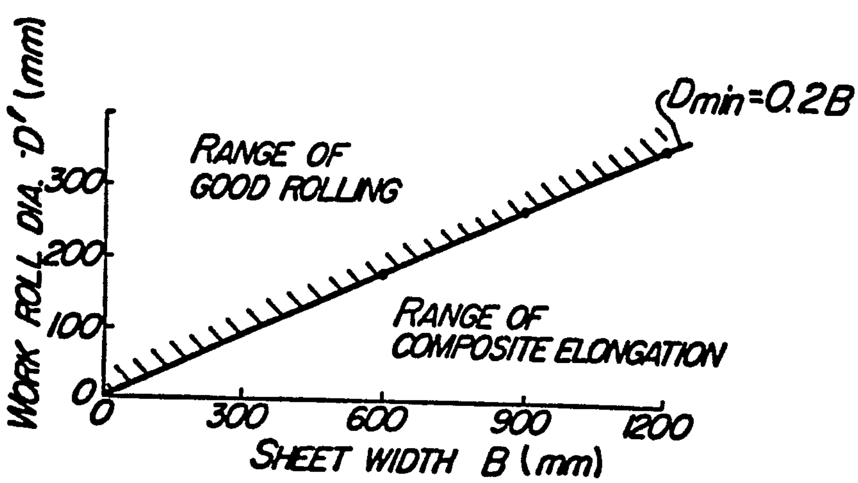
Dmin=0.2B
RANGE OF
GOOD ROLLING
RANGE OF
COMPOSITE ELONGATION
WORK ROLL DIA. 'D' (mm)
300
200
100
0
0
300
600
900
1200
SHEET WIDTH B (mm)

FIG. 8

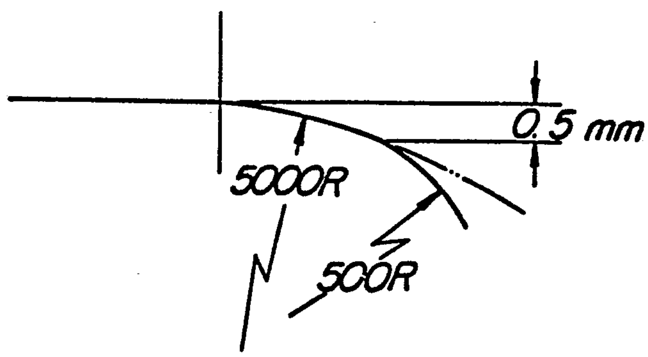

FIG. 9

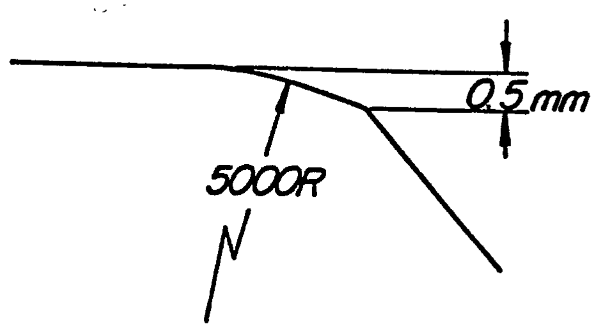

FIG. 10

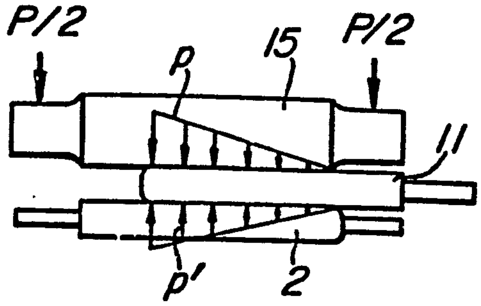

FIG. 11

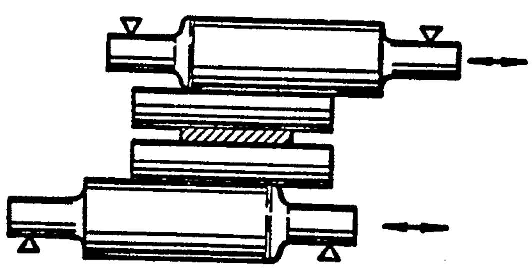

FIG. 12