In a rolling mill having a pair of working rolls and a pair of back up rolls, the working rolls are respectively shifted axially according to the varying plate width of a strip material being rolled to make the contact length of rolls, defined by said working rolls, substantially equal to the plate width of said strip material, whereby accurate flatness control of the rolled strip becomes possible, and further roll bending is applied to the working rolls, whereby more complete flatness control of the rolled strip can be achieved.
FIG. 3

(i)

(ii)

(iii)

(iv)
ROLLING MILL AND ROLLING METHOD

Recently, the requirement for accuracy in flatness of rolled products is becoming increasingly severe. The accuracy of rolled materials in respect of flatness in the longitudinal direction has been increased to a considerably high level, owing to the rapid development of automatic gauge control techniques but no means has been developed as yet for the effective control of flatness in the widthwise direction. Of course, a working roll bending method has been developed in four high rolling mills as a measure for controlling the widthwise flatness of rolled materials, with considerably good results, but the conventional roll bending method has a limitation in its capacity of controlling the flatness of rolled material or in the so-called correcting capacity, and its correcting capacity is insufficient and hence the method is not effective particularly when the plate width of a material being rolled varies largely. In conventional rolling facilities, it has been a common practice to permit a certain degree of unflatness as being unavoidable or to change working rolls every time the plate width of a material to be rolled changes thereby to change the initial crowns of rolls. In either case, however, there has been the great disadvantage that degradation of the quality or increase of the production cost of the rolled product is inevitable.

Further, in the event when the working rolls in contact with a material being rolled are subjected to heavy wear, such as those of a hot rolling mill, the thickness unevenness of the rolled material in the widthwise direction becomes greater due to wear of the working rolls and after all, quality degradation of the rolled products has been unavoidable in the past, unless the working rolls are changed frequently and the resultant substantial lowering of operating efficiency is tolerated. Namely, in rolling materials having different plate widths (in such a case, it is usual to roll the materials sequentially from the one having a larger width), the working roll is worn out more at the central portion and less at the opposite end portions, because while the wear proceeds constantly at the central portion of the roll, the opposite end portions of the roll are used for rolling at less opportunities. Therefore, while the rolling is not being carried out, the opposite end portions only of the roll are held in contact with a back up roll, with the central portion thereof being out of contact with the back up roll. Namely, a small gap is formed between the working roll and back up roll at the central portion of said working roll. If rolling is carried out under such condition, the central portion of the working roll will be bent and the resultant rolled product will become high at its central portion or will be a so-called mid-high produce with a poor flatness. The roll bending method is employed in an attempt to overcome such disadvantage. In this method, a force in counterbalance with the working roll bending force is applied to the working roll. However, the counterbalancing force does not act over the entire length of the working roll due to the presence of the unworn opposite ends of the roll which are in contact with the back up roll.

The present invention aims to obtain rolled materials with high accuracy in flatness, by rational and effective means.

An object of the invention is to make possible rolling with high accuracy of flatness even when the plate width of a material to be rolled changes.

Another object of the invention is to carry out rolling with no or a very little bending moment being applied to the working roll, and thereby to eliminate the influence of the bending moment on the rolled material.

Still another object of the invention is to control effectively the flatness of the rolled material.

A further object of the invention is to make it possible to carry out rolling with high efficiency even when the plate width of a material to be rolled changes, and yet to increase the accuracy in flatness of the rolled material.

An additional object of the invention is to the detrimental influence of a deformation due to wear of the working roll on the flatness accuracy of the rolled material.

Still further object of the invention is to enhance the roll bending effect.

Other objects of the invention will become apparent from the following detailed description.

The present invention relates to a rolling mill which performs rolling, with the end portions of the working surface of a working roll being located between the end portions of the back-up surface of a back-up roll and the opposite edges of a material being rolled respectively, or in register with said opposite edges of a material being rolled.

FIGS. 1 and 2 are illustrative views respectively showing the states during rolling of a four-high rolling mill according to one embodiment of the present invention;

FIG. 3 is a set of illustrative views respectively showing the relative position of the upper back up roll and upper working roll, shown in FIG. 1, and materials of different widths being rolled;

FIGS. 4 and 5 are a detailed front sectional view and a side sectional view respectively of the four-high rolling mill shown in FIG. 1;

FIGS. 6 and 7 are detailed views of portions of the embodiment shown in FIG. 5 respectively; and

FIGS. 8 and 9 are a front sectional view and a side view respectively of another embodiment of the rolling mill of the invention.

Now, embodiments of the present invention will be described with reference to the drawings. In FIG. 1 there is shown the state during rolling of a four-high rolling mill according to one embodiment of the invention, in which working rolls 6, 7 are shifted axially in accordance with the varying plate width of a material 10 being rolled, with the contact length of rolls defined by the upper and lower working rolls being substantially equal to the width of the material 10. The working rolls 6, 7 respectively have at one ends thereof reduced diameter portions 32, 34 connected integrally with the main portions of the rolls through frusto-conical portions 33, 35. Therefore, by matching the opposite side edges of the rolled material 10 with the frusto-conical portions 33, 35 of the working rolls 6, 7 respectively, it is possible to prevent the working rolls 6, 7 from being deformed by the moments produced by contact loads between said working rolls and back up rolls 8, 9, to prevent the rolled material 10 from being rolled excessively at its side edge portions and to enhance the roll bending effect as the working rolls are not restrained by the back up rolls 8, 9.

For reducing the bending moments acting on the working rolls 6, 7, the working rolls are shifted axially to locate the ends 62, 72 of the working surfaces 61, 71
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Fig. 3 illustrates the relative position of the rolled material 10 having a varying width and the upper back up roll 8 and upper working roll 6 during rolling. Fig. 3(i) shows the state in which the unworn working roll 6 starts rolling the rolled material 10 whose width is largest. The phantom lines in this figure indicate the diameter of the working roll after said working roll has been worn out as a result of continuous rolling of the material 10 at its width. In this case, the ends of the rolled material and the end of the working roll are substantially in vertical alignment with each other on the side indicated by the character W so that an annular step is formed on the surface of the working roll due to wear only on the side indicated by the character D. As the plate width of the material changes successively from the state shown in Fig. 3(i) to the states shown in Figs. 3(ii), 3(iii) and 3(iv), the working roll is axially shifted accordingly and the stepped portion of the roll is moved out of contact with the back up roll, so that the rolling portion of the working roll is always cylindrical in shape and hence a rolled product having a uniform thickness can be obtained.

Figs. 4 and 5 show the practical construction of the four-high rolling mill of the invention described above. The upper and lower working rolls 6, 7 are respectively supported by metal chocks 16, 17 mounted within a roll housing 15. The upper and lower back up rolls 8, 9 in contact with the working rolls 6, 7 are respectively supported by vertically movable metal chocks 21, 22 mounted within the roll housing 15. The metal chocks 16, 17 are vertically movably received or their opposite ends in left and right blocks 19 provided on the inside surface of the roll housing 15, respectively and have disposed therein hydraulic rams 18, 18' for bending the working rolls, respectively. The outer ends of the hydraulic rams 18, 18' are in engagement with a projection 20 formed on each block 19. The driven ends of the upper and lower working rolls 6, 7 respectively have spindles 30, 31 connected thereto through couplings 28, 29. These spindles 30, 31 are respectively connected to a driving device and an axial shifting device which will be described later, to transmit rotational torques to the upper and lower working rolls, 6, 7 and to shift said upper and lower working rolls axially in opposite directions to each other according to the varying plate width of the rolled material, therethrough. As stated previously, the other end portions of the upper and lower working rolls 6, 7 are reduced in diameter, and the junction between the reduced diameter end portion and the main portion of each working roll is shaped in a frusto-conical shape or other suitable shape. In the embodiment shown, the left hand end 32 of the upper working roll 6 is reduced in diameter, forming a frusto-conical portion 33, while the end 34 of the lower working roll 7 on the opposite side to the end 32 of the upper working roll is reduced in diameter, forming a frusto-conical portion 35. In Figs. 4 and 5, reference numeral 23 designates depression screws for adjusting the roll clearance, 24 back up roll balancing hydraulic rams, 25 liners interposed between the metal chocks 22 and the roll housing 15, and 26 and 27 upper and lower distance pieces uniting the roll housings 15.

As stated, the spindles 30, 31 for driving and axially shifting the working rolls 6, 7 are connected to one end of said rolls through the universal gear couplings 28, 29 respectively. The coupling 28 or 29, as exemplified in Fig. 6, includes an inner coupling member 69 which is shrink-fitted over the spindle 30 or 31 and fastened by means of bolts, and an outer coupling member 64 which is fixed to the working roll 6 or 7 by means of pins 65 and a ring 66, said inner and outer coupling members 69, 64 being pivotally engaged with each other, with their threaded portions 60 meshing with each other, and being connected with each other by a connecting pin 61 having a spherical head, a holding plate 62 and a nut 67. Further, the spindles 30, 31 are respectively connected through universal gear couplings 70, 71 to output shafts 76 of a pinion stand 74 and said output shafts 76 are in turn connected to a motor 72 through a coupling 73. The universal gear couplings 70, 71 each includes an inner coupling member 77 which is shrink-fitted over and secured by means of bolts to the spindle 30 or 31 and an outer coupling member 82 which is connected to the aforesaid output shaft 76, as shown in Fig. 7, said inner and outer coupling members 77, 82 being pivotally engaged with each other, with their threaded portions 78 meshing with each other and being connected with each other by a connecting pin 79 having a spherical head, a holding plate 80 and a nut 83. As shown in Fig. 7, the universal gear couplings 70, 71 are each connected through a thrust bearing 85 to a roll axial shifting device 95 mounted on a stand base 75 in adjacent relation to the pinion stand 74. Namely, the thrust bearing 85 is mounted around the outer coupling member 82 of the universal gear coupling 70 or 71, by a casing 84 and a cover 88, and is held against movement in the axial direction of the roll by a collar 86 and a nut 87. On the other hand, the roll axial shifting device 95 comprises screws 91 rotatably supported by projections 93, 94 of a pair of frames 89 provided on the stand base 75 on both sides of the universal gear coupling 70 or 71, sprockets 92 mounted fixedly on said screws 91 respectively for transmitting the driving force from a motor not shown, to said screws, and nuts 90 fixedly mounted on said screws 91 in engagement with the casing 84.

With the construction described above, the thickness unevenness in the widthwise direction of the rolled material can be minimized even if the plate width of the rolled material changes, as already explained with reference to Fig. 1, but for achieving the intended purpose more completely, it is preferable to make the effective length of the back up roll also equal to the plate width of the rolled material. In practice, however, it is difficult to shift the back up roll in the axial direction, by reasons of a depressing device, etc.

In the embodiment shown in Figs. 1 and 2, the contact length of rolls defined by the upper and lower working rolls is made substantially equal to the plate width of the rolled material, by shifting said working rolls in the axial direction according to the varying plate width of said rolled material. However, should the operator not mind taking the trouble to change the working rolls, it is of course possible to obtain a contact length of rolls substantially equal to the plate width of the rolled material, also by changing the working rolls sequentially according to the varying plate width of said rolled material. In either case, the portions of the
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working rolls substantially in contact with the rolled material are substantially equal to the plate width of the rolled material, and hence no bending moment or a little bending moment, if any, occurs in the working rolls.

FIGS. 8 and 9 show another embodiment of the rolling mill according to the invention. In this embodiment, the constructions of the upper and lower working roll assembly and the upper and lower back up roll assembly are the same as those shown in FIG. 4, as indicated by the same reference numerals as those in FIG. 4, but intermediate rolls 40, 41 are respectively provided between the upper working roll 6 and upper back up roll 8 and between the lower working roll 7 and lower back up roll 9, as shown in FIG. 8. These intermediate rolls 40, 41 are supported by vertically movable metal chocks 44, 45 respectively which are mounted in cavities 42, 43 formed in the metal chocks 21, 22 supporting the upper and lower back up rolls. Further, as shown in FIG. 9, the intermediate rolls 40, 41, similar to the upper and lower working rolls 6, 7, are shiftable in the axial direction by a suitable shifting device, and the right hand end portion 46 of the intermediate roll 40 is progressively reduced in diameter in a frusto-conical shape and the left hand end portion 47 of the intermediate roll 41 is also progressively reduced in diameter in a frusto-conical shape.

Therefore, it will be understood that by shifting the intermediate rolls 40, 41 axially according to the varying plate width of a rolled material in such a manner that the larger diameter ends of the frusto-conical end portions 46, 47 of the respective intermediate rolls may be held in vertical alignment with the opposite side edges of the rolled material respectively, the flatness of the rolled material can be controlled more effectively, together with the effect of shifting the working rolls 6, 7 axially and the bending effect.

In the embodiment described above, it is obviously possible to shift the working rolls and intermediate rolls in the axial direction individually independently of each other, but it is also possible to shift the same concurrently in the predetermined directions and in the same amount. It will also be understood that for driving the working roll, intermediate roll and back up roll, any one of these rolls may be used as a driving roll.

What is claimed is:

1. A rolling mill comprising: a pair of upper and lower working rolls each contacting a material being rolled, a pair of back up rolls backing up said working rolls, one of said back up rolls being positioned on said upper working roll and the other of said back up rolls being positioned under said lower working roll, said working rolls and said back up rolls being arranged in a vertical plane, means for shifting said upper working roll in the axial direction to locate one terminal end of the working surface of said upper working roll between the adjacent end of the associated back up roll and the adjacent edge of the material being rolled, and means for shifting said lower working roll in the axial direction to locate the terminal end of the working surface of said lower working roll which is opposite to said terminal end of the upper working roll between the adjacent end of the associated back up roll and the adjacent edge of said material being rolled, whereby the flatness of the rolled material is controlled.

2. A rolling mill according to claim 1, wherein means for applying roll bending forces to the pair of upper and lower working rolls are provided at the ends of and between said upper and lower working rolls.

3. A rolling mill having a pair of upper and lower working rolls respectively supported by metal chocks and back up rolls respectively supported by metal chocks and backing up said working rolls, said rolling mill comprising means for shifting each of said working rolls in the axial direction to locate the terminal end of the working surface of said working roll between the adjacent end of the associated back up roll and the adjacent edge of a material being rolled, and intermediate rolls are provided between the working rolls and the back up rolls respectively, and means are provided for shifting the upper intermediate roll in the same direction as the direction in which to lower working roll is shifted and shifting the lower intermediate roll in the same direction as the direction in which the upper working roll is shifted thereby to control the flatness of the rolled material.

4. A rolling mill having upper and lower working rolls, each contacting a material being rolled, a pair of back up rolls backing up said working rolls, one of said back up rolls being positioned on the upper working roll, and the other being positioned under the lower working roll, said working rolls and back up rolls being arranged in a vertical plane, means for shifting at least one of the upper and lower working rolls in the axial direction according to the varying plate width of the material being rolled to adjust the contact length of the rolls defined by the upper and lower working rolls to substantially equal the plate width of the rolled material and thereby to control the flatness of the rolled material and means for applying roll bending forces to the pair of upper and lower working rolls are provided at the ends of and between said upper and lower working rolls.

5. A rolling mill according to claim 4, wherein intermediate rolls are provided between the working rolls and back up rolls respectively.

6. A rolling mill having upper and lower working rolls, each contacting a material being rolled, a pair of back up rolls backing up said work rolls, one of said back up rolls being positioned on the upper working roll, and the other being positioned under the lower working roll, said working rolls and back up rolls being arranged in a vertical plane, means for shifting at least one of the upper and lower working rolls in the axial direction according to the varying plate width of the material being rolled to adjust the contact length of the rolls defined by the upper and lower working rolls to substantially equal the plate width of the rolled material and thereby to control the flatness of the rolled material, intermediate rolls provided between the working rolls and back up rolls respectively, and means for shifting the upper intermediate roll in the same direction as the direction in which the lower working roll is shifted and shifting the lower intermediate roll in the same direction as the direction in which the upper working roll is shifted.

7. A rolling mill according to claim 6, wherein said shifting means makes the length contact plane, defined by the intermediate roll and the associated working roll, substantially equal to the length of the rolling plane.

8. A rolling mill according to claim 7, wherein means for applying roll bending forces to the pair of upper and
lower working rolls are provided at the ends of and between said upper and lower working rolls.

9. A rolling mill according to claim 8, wherein said roll bending means comprises a cylinder disposed in the metal chock supporting the working roll and a hydraulic ram disposed in said cylinder and being slidable on the surface of a projection formed on a block provided on the inside surface of a roll housing.

10. A rolling mill comprising a pair of upper and lower working rolls each contacting a material being rolled, a pair of back up rolls backing up said working rolls, one of said back up rolls being positioned on the upper working roller, the other being positioned under the lower working roll, said working rolls and said back up rolls being arranged in a vertical plane, coupling means respectively connected to the driven ends of said upper and lower working rolls, spindles respectively connected to said spindles, and axial shifting means connected to said spindles and adapted to shift the upper and lower working rolls in opposite directions to each other respectively to locate one terminal end of the working surface of said upper working roll between the adjacent end of the associated back up roll and the adjacent edge of the material being rolled.

11. A rolling mill according to claim 10, which further comprises cylinders each disposed in each of the metal chocks supporting the working rolls, blocks provided on the inside surface of a roll housing, and hydraulic rams each provided in each of said cylinders and being slidable on the surface of a projection formed on each of said blocks.

12. A rolling mill according to claim 10, wherein said coupling means connected to the driven ends of said upper and lower working rolls includes a universal coupling.

13. A rolling mill according to claim 12, wherein said universal coupling includes an outer coupling member disposed on a respective working roller, an inner coupling member disposed on a respective spindle and received in said outer coupling member, and means for pivotally connecting said inner and outer coupling members.

14. A rolling mill according to claim 10, wherein said driving means includes a pinion stand having at least a pair of output shafts, and wherein universal coupling means are provided for coupling each of said output shafts with a respective spindle.

15. A rolling mill according to claim 14, wherein said universal coupling includes an outer coupling member disposed on each of said output shafts, an inner coupling member disposed on a respective spindle and received in said outer coupling member, and means for pivotally connecting said inner and outer coupling members.

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