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Rolling mill using variable crown roll.

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Rolling mill using a variable crown roll

The present invention relates to a multi-high rolling mill including at least one pair of work rolls and one or more back-up rolls, at least one of the rolls being a variable crown roll, wherein the extent of the crowning is controlled by means of a pressure medium.

The term "work roll" as used herein and in the claims is to be understood to mean a roll in direct contact with a material to be rolled and the term "back-up roll" is to be understood to mean a roll directly or indirectly supporting the work roll.

In order to counteract the effect of the bending of working rolls under the applied pressure on the evenness of the rolled plate a number of measures have been adopted, in particular the use of suitably supported back-up rolls. Detailed discussions of these measures may be found in the publications mentioned hereunder.

For use in cases in which it is not expedient to reinforce the supports of back-up rolls any further, DE—A—1 452 008 describes variable crown backing rolls, which can be mounted, for example, in a four-high rolling mill. Each backing roll consists of a solid cylindrical core or mandrel, mounted on the machine stand so as to be non-rotatable, which is surrounded by a rotatable roll sleeve, the outer circumferential surface of which acts as the back-up surface of the roll. Through a system of axial and radial passages formed within the solid cylindrical core a pressurized fluid can be supplied to portions of the outer surface of the cylindrical core to provide a back-up pressure against the inner wall of the rotatable outer sleeve at positions along the line of contact with the work roll.

US—A—3 457 617 reports the proposal to subject the working rolls to preliminary bending by means of forces acting on the roll necks in such manner as to compensate the bending caused by the rolling force, but states that complete compensation is impossible because the rolling force produces a bending line different from that of the preliminary bending by the forces on the roll necks and that the whole roll stand must be of more robust design to withstand the additional forces. As a more satisfactory solution, a working roll having a variable camber is described. This roll has an annular cavity below its rolling surface which is filled with a liquid through a system of axial and radial channels formed within the roll. The camber can be controlled by varying the pressure of the liquid and adapted, by means of thickness gauges, automatically to the material being rolled. This roll is said to make it possible to use simple two-high rolling mills instead of expensive four-high rolling mills.

DE—A—1 602 200 describes a method for controlling the crown of working rolls during the rolling of metal strip and other materials in hot and cold rolling mills, wherein a hollow interior axial space of one or more of the rolls of a rollstand is filled with a highly pressurized fluid, the pressure of which is variable. Sudden rolling-pressure fluctuations can be detected by a pressure gauge and compensated automatically.

In US—A—3 604 086 it is reported that it is known in the art to deflect the rolls of a rolling mill towards the roll gap by applying a suitable force to the roll journals in order to compensate the roll deflections occurring as a result of the rolling pressure in a direction away from the roll gap. It is stated to be possible to counteract the roll deflection with comparative accuracy, but that the design of the rolling mill involves increased costs. A crown-controlled roll is described, having a sleeve mounted on a mandrel. A controlled pressurized fluid medium is transmittable into the gap between the sleeve and the mandrel, to cause the sleeve to assume a barrel-shaped form and equalize various roll deflections.

DE—A—2 507 233 describes the interposition of hydraulic elements between an inner core and a rotatable roll sleeve of a back-up roller to back up the pressure of the outer sleeve against the working rolls at positions at which the backing roller sleeve acts on the working rolls.

Two-high rolling mills using conventional variable crown rolls (hereinafter referred to as VC rolls) have had several disadvantages, such as the work rolls being unable to withstand the high rolling load, the manufacture of roll sleeves of high hardness being difficult, the toughness of the sleeves being decreased as the requirement of higher surface hardness is fulfilled and shape defects being caused in the rolled strip in the neighbourhood of the pressure receiving sleeve end, so that these rolling mills, whilst suitable for light rolling such as temper rolling, were not suited for heavy load rolling such as common hot or cold rolling.

The following considerations, however, may be deterrents, to the use of VC rolls, particularly as back-up rolls, in multi-high rolling mills:

(1) As the work rolls may have diameters as large as 500—600 mm, VC rolls are not expected to be effective as back-up rolls.

(2) The achievement of satisfactory rolling with pipe-shaped rolls as used in VC rolls is uncertain.

(3) The surface of a VC roll of expanded diameter may be depressed by a high rolling load, so as to render the roll ineffective.

(4) The sleeve holding force may be insufficient, so as to permit roll bending.

(5) VC rolls may be dangerous, because of a low fatigue safety factor.

After many years of experience, as well as theoretical and experimental work, the inventors have come to the following conclusions concerning the above:
The crowning effect of the back-up roll is transmitted to the rolled material through the work rolls so that the thickness of the rolled material is changed by an amount equal to approximately 1/2 — 1/5 of an expansion of the outer diameter of the back-up roll. This is sufficient to control the crown and the shape.

For a VC roll provided with a small cavity only within the pressure receiving sleeve portion of the roll, the mill rigidity is substantially the same as that of a solid roll.

The diametrical expansion of a VC roll can be made larger than the surface depression caused by a high rolling load.

When the back-up roll is a VC roll, a large sleeve holding force can be provided, because the pressure-receiving partial sleeve length of the back-up roll need not be larger than the width of the material to be rolled. In general, the work rolls of milling mills are driven, so that the torque exerted on the back-up rolls is smaller than that exerted on the work rolls.

It is possible to design VC rolls having a fatigue safety factor 1.5—3.

Accordingly there is sufficient reason to state that a VC roll can be used satisfactorily in multi-high rolling mills. However, it has been found that complicated shape effects such as quarter buckle can arise, which are difficult to correct.

It is therefore the object of the present invention to provide a multi-high rolling mill including work rolls and back-up rolls, in which at least one of the rolls is a VC roll, in which control of the surface shape of the rolled material is improved, so that extensive and manifold rolling becomes practicable.

This object is achieved by providing roll benders between the work rolls and/or the back-up rolls to control the extent of crowning of the variable crown roll and the roll bending force, thereby controlling the sheet crown and the shape of the material being rolled.

The rolling mill of the present invention thus includes at least a pair of work rolls and one back-up roll in an arrangement which is at least three-high and mainly four high in a single stand or in tandem stands, as well as roll benders. It can be used for either hot or cold rolling.

The VC roll used is constructed so that its crowning is controllable by means of a fluid or viscous material introduced under pressure into a predetermined cavity defined between an arbor and a sleeve.

The invention and preferred embodiments thereof are described in further detail below, with reference to the accompanying drawings.

Figs. 1 is a schematic sectional view of a VC roll;
Figs. 2A to 2F are schematic illustrations of typical roll arrangements of the rolling mill of the present invention;
Figs. 3A and 3B are schematic illustrations of roll stand arrangements of the rolling mill of the present invention;
Fig. 4 is an illustration of the function of roll benders;
Figs. 5 to 8 are illustrations of roll arrangements of embodiments of the present invention;
Figs. 9 and 10 are schematic cross sectional views of a four-high rolling mill of another embodiment of the present invention;
Fig. 11 is an illustration of control of the shape and the crowing of the material being rolled by the rolling mill according to the present invention;
Figs. 12 to 17 are graphs showing the results of various tests in the rolling mills;
Fig. 18 is a schematic cross sectional view showing the construction in which the roll benders are assembled to the four-high rolling mill according to the present invention; and
Figs. 19 to 21 are graphs showing the results of various tests in the rolling mill of Fig. 18.

Before describing the present invention in detail, the construction and the function of the VC roll used in the present invention will be described briefly with reference to Fig. 1.
In the basic construction of the VC roll, as shown in Fig. 1, an annular cavity 3 is defined between an arbor 1 and a sleeve 2, to which a medium (for example, water, oil, grease or the like) under high pressure is applied from a medium pressurizing unit 4 through a conduit 11 provided in the arbor 1 so as to control the extent of crowning of the roll (that is, the extent of the diametrical expansion of the roll outer diameter) by regulating the pressure of the medium by means of the unit 4.

The rolling mills of the present invention are of the types, for example, as shown in Figs. 2 to 4. In roll arrangement, the rolling mills are, in principle, multi-high rolls mainly from three-high to six-high rolls, as shown in Figs. 2A to 2F, and most suitably four-high rolls, as shown in Fig. 2C. Accordingly, the present invention will be described hereunder as being applied to the four-high rolling mill for the sake of simplicity, but it must be understood that application of the present invention is not limited thereto. In roll stand arrangement, the rolling mill may be either of single stand, as shown in Fig. 3A, or of tandem stands, as shown in Fig. 3B. With respect to additional equipment, the rolling mill is provided with a roll bender Jw or Jb in the work roll W or back-up roll B thereof.

The basic construction of the rolling mill according to the present invention resides in, as shown with reference to the three-high mill for convenience' sake in Figs. 5A to 5G, the multi-high rolling mill in which at least one of the rolls is the VC roll (hatched in the drawing). Accordingly, the three-high rolling mill according to the present invention may take any of the roll combinations shown in Figs. 5A to 5G. Special effects achieved by this construction will become clear from the ensuing description.
In an embodiment of the present invention, the four-high rolling mill has, as shown in Figs. 6A to 6C, at least one VC roll (hatched in the drawing) in the back-up rolls.

In this embodiment, the extent of crowning of the back-up rolls is first changed. The change then exerts an influence on the work rolls to bend the entire shafts of the work rolls to thereby cause a substantially predetermined extent of change in the crown of the work rolls.

Sheet crown (thickness distribution across the strip width) and shape tests were performed in the four-high rolling mill in which, as shown in Fig. 6A, the upper back-up roll is a VC roll of the size 200 mm in outer diameter and 300 mm in width under a rolling load of 20 tons using the four-high rolling mill described above. In Fig. 12, the marks O, ●, △ and X denote oil pressures $P'$ of the VC roll of 0, 165, 340, and 510 kg/cm² respectively. As seen from Fig. 12, as the oil pressure of the VC roll increases, the axial deflection of the work rolls changes. The sheet crown changes with the change in the axial deflection of the work rolls. Thus, the sheet crown control effect was confirmed.

Fig. 13 shows the results of the sheet crown tests performed on an aluminum plate of 4 mm in thickness and 300 mm in width under fixed drafts using the same four-high rolling mill described above. In Fig. 13, the marks O, ●, and △ indicate a reduction of 0.5, 1.0, and 14.5%, respectively. As seen from Fig. 13, as the oil pressure of the VC roll increases, the shape of the rolled material changes from wavy edges to center buckle and, under the predetermined reduction, good flatness is obtained at a specified oil pressure. By combining with a bender it becomes possible to correct the quarter buckle shape defect. Thus the shape control effect according to the present invention was confirmed.

The application of the VC roll to the back-up roll provides the following advantages:

1. Since the roll diameter and the sleeve thickness can be larger than in the work roll, the stress generated in the roll can be reduced.
2. Since the rolling is performed through the work rolls, the pressure-receiving sleeve part length of the back-up roll can be determined independent of the width of the material.
3. Since the hardness of the surface of the roll may be low, selection of the sleeve material is made easy.
4. Since the rotational speed is smaller than that of the work rolls at the same rolling speed, design of the rotary joint is made easy.
5. Since the sleeve thickness becomes large, the value of concavity is smaller than the value of expansion in the outer diameter.
6. (6) Since the rolling with higher speed, larger load, and larger width is made possible.

In another embodiment of the present invention, the four-high rolling mill has, as shown in Figs. 7A to 7C, at least one VC roll (hatched in the drawing) in the work rolls.

In this embodiment, the extent of crowning of the work-rolls is directly changed and the change is strengthened by the reaction of the back-up rolls.

Sheet crown and shape tests were performed in the four-high rolling mill shown schematically in Fig. 7, the work rolls and the back-up rolls of which are of the same size as those of Fig. 6A.

Fig. 14 shows the results of the sheet crown tests performed on an aluminum plate of 4 mm in thickness and 250 mm in width under the rolling load of 20 tons using the four-high rolling mill described above. In Fig. 14, the marks O, ●, and X denote oil pressures $P'$ of the VC roll of 0, 200, and 400 kg/cm² respectively. The curves of Fig. 14 show the similar tendency to those of Fig. 12.

Fig. 15 shows the results of the shape tests performed on a cold rolled coil of 0.4 mm in thickness and 300 mm in width under the reduction of 1% using the same four-high rolling mill with the oil pressure $P'$ (kg/cm²) of the VC roll changed. The curves of Fig. 15 show the similar tendency to those of Fig. 13.

The application of the VC roll to the work rolls of the four-high rolling mill provides the following advantages over the application of the VC roll to the work rolls of the two-high rolling mill:

1. In the four-high rolling mill, since the deflection in the work rolls is received by the back-up rolls, the crowning effect of the VC roll is larger than in the two-high rolling mill.
2. In the four-high rolling mill, the combination of the diametrical expansion of the VC roll with a work roll bender or with a back-up roll bender to be described hereinunder can correct complicated shape defects such as, for example, quarter buckle.

It will be readily estimated that said effect can be doubled by the use of the VC roll for both the upper and the lower back-up rolls or both the upper and the lower work rolls.

Figs. 16 and 17 show the results of the sheet crown and the shape tests, respectively, performed in a further embodiment of the present invention in which the VC roll is used in one of each of the back-up and the work rolls as shown in Figs. 8A and 8B. The sizes of the rolls of the mills and the sizes and
the quality of the specimens used in the tests of Figs. 16 and 17 are the same as those used in the tests of Fig. 14.

In Fig. 16, the marks O, ●, and X denote oil pressures $P'$ ($\text{kg/cm}^2$) of the VC roll of 0, 100 and 200 $\text{kg/cm}^2$, respectively. In the bar crown tests of Fig. 16, the rolling load was 25 tons. In Fig. 17, the marks O and ● denote a reduction of 3 and 15%, respectively.

As seen from Figs. 16 and 17, the sheet crown and shape control effects show the similar tendency to those described above, and as the number of the VC rolls used increases, the effect thereby also increases. It was confirmed that the embodiment shown in Figs. 8A and 8B is effective for control of the shape and particularly for correction of the shape defects such as quarter buckle which was heretofore difficult to be solved by the conventional rolling mills.

The foregoing description assumes that the VC rolls used in pair are of the same internal construction. As shown in Figs. 9 and 10, however, by intentionally making one of the VC rolls in pair different from the other in the variable crown construction (primarily the size of the cavity which is filled by the pressure medium), it is made possible to roll efficiently materials ranging in width radically without changing the rolls. That is, a material of large width is rolled by rolls of large width variable crown construction, a material of small width is rolled by rolls of small width variable crown construction, and a material of intermediate width is rolled by rolls of large width alone or in combination with the rolls of small width variable crown rolls.

It was confirmed that the sheet crown correction and the shape correction effects are obtained by using the VC rolls properly as described above. Accordingly, the sheet crown and shape control system can be constructed by combining the VC rolls with a detector.

For example, as shown in Fig. 11, a rolling mill 21 is provided on the exit/entry side thereof with a sheet crown and shape detector 22, a detection signal of which is transmitted to a control unit 23 in which the detection signal is compared with the set value, to control the medium pressurizing unit 4 (see Fig. 1) of the VC roll provided in the rolling mill 21.

The detector is preferably of non-contact type. Various instruments such as an X-ray thickness meter, a $\beta$-ray thickness meter, a flying micrometer and the like can be used as the sheet crown detector. There are various types of the shape detector such as optical type, electromagnetic type, displacement-type, vibration-type, and the like.

The relation between the sheet crown and the shape will now be briefly described. With respect to the sheet thickness distribution of the material to be rolled, if the sheet crown ratio on the entrance side of the mill is $\text{Cri}$ and the sheet crown ratio on the exit side of the mill is $\text{Cro}$, if $\text{Cri} > \text{Cro}$, there is no shape defect caused because the widthwise distribution with respect to the longitudinal elongation is uniform. If $\text{Cri} = \text{Cro}$, the sheet is elongated more in the center of width than in both the edges into the shape defect of center buckle. On the contrary, if $\text{Cri} < \text{Cro}$, the bar is elongated more in both the edges than in the center of width into the shape defect of wavy edges. Accordingly, the sheet crown is closely related to the shape.

Generally, since a small change in the sheet crown causes a large change in the shape, rolling is performed (particularly in cold rolling) paying attention mainly to the shape. However, in the case, as in hot rolling, where the sheet thickness is large and metal flow occurs readily, there is caused no extreme shape defect since the material readily flows widthwise when the sheet crown changes. Accordingly, the crown control is easily effected in hot rolling.

In this way, in a multi-pass rolling the sheet crown control is performed within the range of the shape defect that is not disadvantageous to the rolling operation and the shape control is performed at the final pass. In a tandem rolling, the sheet crown is performed at the upstream stand and the shape-attended control is performed at the final stand.

In the conventional rolling mill, the shape correction was performed by a work roll bender or a back-up roll bender. The present invention uses a combination of the roll bender with the VC roll. The results of numerical experiments show that this construction provides unexpected multiplication effects as described below.

The rolling mill used in the experiments is, as shown in Fig. 18, a four-high mill in which the upper back-up roll B is a VC roll and a roll bender is provided between the work rolls W. Table 1 shows the sizes of this rolling mill and the rolling conditions.
Figs. 19 to 21 show the results of tests performed on the relation between the work roll bending force \( J_w \) (ton) and the bar crown when the oil pressure \( P' \) (kg/cm\(^2\)) applied to the VC roll in this rolling mill is varied stepwise.

Fig. 19 shows the results of the cold temper rolling of a material of 1200 mm in width under a rolling load of 500 tons. The horizontal axis indicates the bending force \( J_w \) (ton) of the work rolls and the vertical axis indicates the bar crown \( \delta c \) (cm) at the position of 1/4 of width, while A denotes the conventional bending effect (19.2\( \mu \)), B denotes the effects of change in oil pressure of the VC roll only (31.3\( \mu \)), and C denotes the multiplication effect (51.6\( \mu \)) by the VC roll and the bender.

Fig. 20 shows the results of the cold tandem rolling of a material of 1000 mm in width under a rolling load of 900 tons. The horizontal and vertical axes and the reference characters A, B and C, respectively, denote the same items as in Fig. 19, with \( A=14.8\mu \), \( B=21.8\mu \), and \( C=36.5\mu \).

Fig. 21 shows the results of the hot tandem rolling of a material of 1000 mm in width under a rolling load of 900 tons. The horizontal axis \( J_w \), the vertical axis \( \delta c \), and the reference characters A, B and C, respectively, denote the same items as in Fig. 19, except that \( \delta c \) indicates the sheet crown at the point 50 mm from the edge and \( A=27.2\mu \), \( B=39.7\mu \), and \( C=66.9\mu \).

As clearly seen from Figs. 19 to 21, in the case where a single VC roll is used, the change in oil pressure from 0—300 kg/cm\(^2\) provides the equivalent or better effect than a conventional roll bender and the combination of the VC roll with the roll bender provides 2 to 4 times higher sheet crown control effect than the conventional roll bender.

While the present invention has been heretofore described with respect to its application to a single stand rolling mill, it will be obvious to those skilled in the art that the present invention is applicable to a continuous hot or cold rolling stand (Fig. 3B). In this case, it is desirable that the VC roll is applied to all the stands. However, even where the VC roll is applied only to limited stands in view of reduction in cost, sufficient effects are obtained therefrom as shown in Tables 2 and 3.

### TABLE 1

<table>
<thead>
<tr>
<th>Item</th>
<th>Mark</th>
<th>Cold rolling temper</th>
<th>Cold tandem</th>
<th>Hot tandem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll size (mm)</td>
<td>DB</td>
<td>1524</td>
<td>1524</td>
<td>1422</td>
</tr>
<tr>
<td></td>
<td>Db</td>
<td>900</td>
<td>953.9</td>
<td>781.1</td>
</tr>
<tr>
<td></td>
<td>DW</td>
<td>585</td>
<td>585</td>
<td>713</td>
</tr>
<tr>
<td></td>
<td>Dw</td>
<td>342.9</td>
<td>342.9</td>
<td>457</td>
</tr>
<tr>
<td>Rolled bar width (mm)</td>
<td>RL1</td>
<td>1200</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Mill size (mm)</td>
<td>RL2</td>
<td>1680</td>
<td>1704</td>
<td>2032</td>
</tr>
<tr>
<td></td>
<td>RL3</td>
<td>2880</td>
<td>2720</td>
<td>3124</td>
</tr>
<tr>
<td></td>
<td>RL4</td>
<td>600</td>
<td>508</td>
<td>546</td>
</tr>
<tr>
<td></td>
<td>RL5</td>
<td>2880</td>
<td>2720</td>
<td>3124</td>
</tr>
<tr>
<td>Rolling load</td>
<td>P</td>
<td>500</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td>Bending force (ton)</td>
<td>JW</td>
<td>0—80</td>
<td>0—100</td>
<td>0—180</td>
</tr>
</tbody>
</table>

(Initial crown: 0)

Figs. 19 to 21 show the results of tests performed on the relation between the work roll bending force \( J_w \) (ton) and the bar crown when the oil pressure \( P' \) (kg/cm\(^2\)) applied to the VC roll in this rolling mill is varied stepwise.

Fig. 19 shows the results of the cold temper rolling of a material of 1200 mm in width under a rolling load of 500 tons. The horizontal axis indicates the bending force \( J_w \) (ton) of the work rolls and the vertical axis indicates the bar crown \( \delta c \) (cm) at the position of 1/4 of width, while A denotes the conventional bending effect (19.2\( \mu \)), B denotes the effects of change in oil pressure of the VC roll only (31.3\( \mu \)), and C denotes the multiplication effect (51.6\( \mu \)) by the VC roll and the bender.

Fig. 20 shows the results of the cold tandem rolling of a material of 1000 mm in width under a rolling load of 900 tons. The horizontal and vertical axes and the reference characters A, B and C, respectively, denote the same items as in Fig. 19, with \( A=14.8\mu \), \( B=21.8\mu \), and \( C=36.5\mu \).

Fig. 21 shows the results of the hot tandem rolling of a material of 1000 mm in width under a rolling load of 900 tons. The horizontal axis \( J_w \), the vertical axis \( \delta c \), and the reference characters A, B and C, respectively, denote the same items as in Fig. 19, except that \( \delta c \) indicates the sheet crown at the point 50 mm from the edge and \( A=27.2\mu \), \( B=39.7\mu \), and \( C=66.9\mu \).

As clearly seen from Figs. 19 to 21, in the case where a single VC roll is used, the change in oil pressure from 0—300 kg/cm\(^2\) provides the equivalent or better effect than a conventional roll bender and the combination of the VC roll with the roll bender provides 2 to 4 times higher sheet crown control effect than the conventional roll bender.

While the present invention has been heretofore described with respect to its application to a single stand rolling mill, it will be obvious to those skilled in the art that the present invention is applicable to a continuous hot or cold rolling stand (Fig. 3B). In this case, it is desirable that the VC roll is applied to all the stands. However, even where the VC roll is applied only to limited stands in view of reduction in cost, sufficient effects are obtained therefrom as shown in Tables 2 and 3.

### TABLE 2

Examples in continuous cold mill

<table>
<thead>
<tr>
<th>Stand No.</th>
<th>Sheet crown control effect</th>
<th>Shape control effect</th>
<th>Edge drop decreasing effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>2</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>3</td>
<td>○</td>
<td>○</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>5</td>
<td>○</td>
<td>○</td>
<td>X</td>
</tr>
</tbody>
</table>
While Table 3 shows the examples of application of the VC roll to a continuous finishing mill, application of it to a roughing mill is likewise effective. Particularly, its application to a roughing mill of a semi-continuous hot strip mill is effective not only in crown control but also in improvement in the crop less at the top or bottom of the strip.

In the continuous mill, the combination of the VC roll with the conventional roll bender provides an enlarged range of control.

**Claims**

1. A multi-high rolling mill including at least one pair of work rolls (W) and one or more back-up rolls (B), at least one of the rolls (B, W) being a variable crown roll, wherein the extent of the crowning is controlled by means of a pressure medium, characterized in that roll benders (Ie, Iw) are provided between the work rolls (W) and/or the back-up rolls (B) to control the extent of crowning of the variable crown roll and the roll bending force, thereby controlling the sheet crown and the shape of the material to be rolled.

2. A multi-high rolling mill according to claim 1, characterized in that a pair of the back-up rolls (B) is a pair of variable crown rolls differing in construction from each other.

3. A multi-high rolling mill according to claim 1, characterized in that a pair of the work rolls (W) is a pair of variable crown rolls differing in construction from each other.

4. A multi-high rolling mill according to any one of claims 1 to 3, characterized in that the crowning of the variable crown rolls is controlled by a signal indicative of the shape and/or sheet crown of the material to be rolled.

**Patentansprüche**

1. Walzgerüst mit einer Mehrfachwalzenanordnung, von denen wenigstens ein Walzenpaar als Arbeitswalzen (W) und eine oder mehrere Walzen als Stützwalzen (B) ausgebildet sind, wobei von diesen Walzen (B, W) wenigstens eine Walze einen einstellbaren Ballen aufweist, dessen Balligkeit gesteuert wird durch ein Druckmedium, dadurch gekennzeichnet, daß zwischen den Arbeitswalzen (W) und/oder den Stützwalzen (B) Walzenbiegemittel (Ie, Iw) zur Steuerung der Balligkeit der mit dem verstellbaren Ballen ausgestatteten Walze und der Walzenbiegekraft vorgesehen sind, wobei die Dickenverteilung in Richtung der Breite des Bleches und die Form des Walzgutes gesteuert werden.

2. Walzgerüst nach Anspruch 1, dadurch gekennzeichnet, daß ein Stützwalzenpaar (B) als Walzen mit einstellbarem Ballen mit unterschiedlichem Aufbau voneinander ausgebildet ist.

3. Walzgerüst nach Anspruch 1, dadurch gekennzeichnet, daß ein Arbeitswalzenpaar (W) als Walzenpaar mit einstellbarem Ballen und unterschiedlichem Aufbau voneinander ausgebildet ist.

4. Walzgerüst nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß die Balligkeit der Walzen mit einstellbarem Ballen gesteuert ist durch ein Signal, das die Gestalt und/oder die Dickenverteilung in Bandbreitenrichtung des Walzgutes anzeigt.

**Revendications**

1. Laminoir à plusieurs cylindres comportant au moins deux cylindres de travail (W) et un ou plusieurs cylindres d’appui (B), l’un au moins des cylindres (B, W) étant un cylindre à bombement variable dans lequel le degré de bombardement est réglé au moyen d’un fluide sous pression, caractérisé en ce que des cintreurs de cylindres (Ie, Iw) sont montés entre les cylindres de travail (W) et/ou les
cylindres d'appui (B) pour régler le degré de bombement du cylindre à bombement variable et la force de cintrage des cylindres, réglant ainsi le bombé de la tôle et la forme du produit à laminer.

2. Laminoir à plusieurs cylindres selon la revendication 1, caractérisé en ce que deux cylindres d'appui (B) sont deux cylindres à bombement variable dont la structure diffère de l’un à l’autre.

3. Laminoir à plusieurs cylindres selon la revendication 1, caractérisé en ce que deux cylindres de travail (W) sont deux cylindres à bombement variable dont la structure diffère de l’un à l’autre.

4. Laminoir à plusieurs cylindres selon l’une quelconque des revendications 1 à 3, caractérisé en ce que le bombement des cylindres à bombement variable est réglé par un signal indicatif de la forme et/ou du bombé du produit à laminer.
Fig. 12

Fig. 13
Fig. 14

![Graph showing sheet crown (μ) vs. distance from sheet width center (mm).]

Fig. 15

![Graph showing shape (steepness) (%) vs. oil pressure (kg/cm²).]
Fig. 16

Fig. 17