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(54) Method and apparatus for correcting a widthwise bend in an end portion of a hot-rolled sheet-shaped product.

(57) A widthwise bend of an end of a hot-rolled elongate sheet-shaped metal product (1) is corrected while it is hot. The correction comprises simultaneously:

(i) holding the edges of the product (1) at at least two positions (12,13) longitudinally spaced along the product thereby to hold, at least laterally, a portion spaced from the bent end, and

(ii)pushing the end portion laterally by means of a laterally moving member (14). The method may be performed while the product is continuously moving along a path. Both steps (i) and (ii) are performed by rollers rotatable about vertical axes.

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METHOD AND APPARATUS FOR CORRECTING A WIDTHWISE BEND IN AN END PORTION OF A HOT-ROLLED SHEET-SHAPED PRODUCT

This invention relates to a method and apparatus for correcting a widthwise bend in an end portion of a hot-rolled elongate sheet-shaped metal product, the correction being performed while the product is still hot from the hot-rolling or after reheating of the product. The invention further relates to a hot strip mill including straightening apparatus for correcting such a bend. The invention is particularly applicable to hot-rolled products of steel and aluminium. The products may be intermediate products or final products.

In the hot-rolling of steel or aluminium products, typically a hot ingot is first passed several times through a roughing mill which forms it into a so-called bar, which is an elongate sheet-shaped product. Typically this bar has a width of 900 to 1500mm, a thickness of 20 to 80mm and a length of for example, 50m. This bar, when intended for further rolling into a strip, is fed into a finishing mill comprising a number of roll sets and is coiled as a strip having a thickness of, for example, 2 to 6mm, while still hot. Alternatively, the product from the roughing mill may take the finished form of a so-called sheet or plate.

All of these products from the roughing mill may suffer from the defect of a lateral bend in their head end portion or their tail end portion. The bend in the head end portion is usually larger, and causes greater difficulties, particularly if the product is a bar which is subjected to finishing rolling as described above. The bent head end causes problems during threading into the finishing train, which can lead to non-uniform thickness of the rolling in the finishing train and also a problem of folding of the leading end, as well as possible difficulties in coiling.

One solution to the problem is to cut off the bent portion, but since this may be 4m long, it amounts to perhaps 8% of the product, which is wasteful.

One proposal in the prior art has been to correct the bend during the roughing rolling, using edger rollers which engage the edges of the bar during a rolling pass through the roughing mill. These edger rollers have vertical axes which are adjustable laterally of the bar and remain fixed during a rolling operation. A problem particularly caused here is that the edger roller presses with high force against the bar, causing thickening of the bar at that side, with consequent further problems during rolling.

An alternative possibility, not disclosed in the prior art, is to adjust the rollers of the roughing mill during a rolling pass, so that they roll the bar non-uniformly, in a manner which corrects the bend. This method however is thought to be not practical, on account of the high investment cost in designing the mill to perform this action.

In a hot-rolling mill, fixed side guides are disposed at several locations on the conveyor table for the hot-rolled bar, e.g. as illustrated in the Japanese-language Iron & Steel Handbook, page 416, for example. These side guides are fixed during rolling, but may effect some straightening of a bar having a widthwise bend simply by pressing upon the bar. However, the amount of straightening is small, because such guides are designed with a clearance between them and the edges of the bar. Typically this clearance is about 50mm and is necessary because the edge of the strip is not straight. Accordingly, such a side guide cannot effect correction of a bend except perhaps over a very long length of the bar.

The object of the present invention is to provide a method and apparatus for correcting a bend in a hot-rolled product, in order to avoid at least partly the problems discussed above.

According to the invention in one aspect there is provided a method of correcting a widthwise bend of an end portion adjacent an end of a hot-rolled elongate sheet-shaped metal product while it is hot, comprising the steps of simultaneously:

(i) holding the two edges of the product at at least two positions longitudinally spaced along said product thereby to hold, at least laterally, a portion of said product spaced from said end, and

(ii) pushing said end portion laterally by means of a laterally moving member so as at least partly to correct said bend.

The present invention is based on the realization that it is possible successfully to remove, at least partly, a widthwise bend in a hot-rolled product, while it is hot, by pushing the end portion laterally relative to an adjacent portion which is maintained along an axis so as to resist the pushing force. This can be done at a location spaced from any roll set. A laterally moving member is required to provide the lateral movement of the end portion. Fixed guides are not sufficient. In order to achieve the removal of the bend, at least partially, it is necessary to effect plastic deformation. It has now been found that this can be done without loss of planarity of the sheet-shaped product, i.e. buckling, and without deformation of the edge of the product by the forces applied to it. The material of the product must be sufficiently plastically deformable; practical limits are discussed below, and depend on at least temperature, thickness and width of the product.

In applying the appropriate forces to the hot-rolled product, various factors must be taken into consideration, depending on each case. Such factors are the temperature of the product, and width and thickness of the product. If it is too thin or too wide, there may be a risk of buckling or of deformation of the edges. Thus, the product should have the appropriate deformability, based on its Young's modulus and yield stress at the temperature in question.

While in principle the invention can be applied to a hot-rolled product which is temporarily held stationary for the bending operation to take place, this is not preferred, because the stopping of the hot product is liable to cause non-uniform cooling of parts thereof, leading to problems during subsequent rolling. Therefore, the invention is preferably performed upon a product which is moving continuously.

In the invention, the product is sufficiently held against lateral movement caused by the pushing force, this restraint occurring over a holding portion having a predetermined length adjacent the bend portion. It is sufficient to support the product at only the opposite ends of this holding portion, and at least for reasons of simplicity this is preferred in the invention. Alternatively, further supports may be provided between the ends of this holding portion.

Preferably, the distance l_1 between the pushing member which effects the correction of the bending and the nearer end of the holding portion is not larger than the length l_2 of the holding portion, and more preferably l_2 is not less than 1.5 l_1.

It is particularly preferred in the invention that the distance of lateral pushing effected by the pushing member is more than that required merely to straighten the bend, that is to say an excess or overpush is performed. When the end portion is released by retraction of the pushing member, it will spring back to a certain extent. If correctly calculated, this springback will bring the end portion back to the straight position, so that the bend is completely removed. Since, at least approximately, the amount of springback is independent of the plastic deformation which has taken place, the amount of the overpush required is independent of the amount of the initial bend. Thus, it is possible to control the pushing member so that, for each of a series of similar products which are subjected to straightening, it pushes the bent end portion to the same position, giving a predetermined amount of overpush, regardless of the initial pushing position. This predetermined amount of overpush is selected in accordance with the dimensions, temperature and nature of the material of the product.

To summarize this aspect therefore, the invention lies in a method of correcting a widthwise bend of an end portion of a hot-rolled elongate sheet-shaped metal product while it is hot, comprising applying a lateral pushing force to said end portion by means of a laterally moving member so as at least partly to eliminate the bend while holding a longitudinally extending portion of the product adjacent the end portion at both edges so as to resist the pushing force. Preferably the pushing force is sufficient to cause non-elastic deformation, while maintaining planarity of said product and substantially avoiding deformation of the edges of said product.

In a second aspect, the invention provides an apparatus for correcting a widthwise bend of an end portion of a hot-rolled elongate sheet-shaped metal product while the product is hot, comprising,

(a) an elongate zone to receive said product,

(b) means for engaging the edges of said product at at least two positions longitudinally spaced along said zone, so as to hold said product at least laterally,

(c) pushing means including at least one pushing member spaced longitudinally along said zone from said engaging means and drive means to cause said pushing member to push said end portion laterally.

Preferably the edge engaging means comprise longitudinally spaced pairs of opposed rollers and means for moving the rollers laterally into engagement with the edges of the product. The means for moving the rollers may comprise a pair of side frames positioned respectively at the two sides of the elongate zone and supporting the rollers so that the roller axes on each side of the elongate zone are in a common plane, the common planes being parallel. Means are provided for moving the side frames towards and away from the elongate zone while maintaining the common planes parallel. The pushing member of the pushing means may be mounted on one of the side frames.

Suitably, the apparatus has a pair of the pushing members, mounted on opposite sides of the elongate zone, the drive means being arranged to cause the pushing member to push the bent end portion laterally from one of the opposite sides, in dependence on the direction of the bend.

In one embodiment, the edge engaging means has, at a first one of the two longitudinally spaced positions which is closer to the pushing member, roller means for contacting an edge of said product, said roller means comprising a plurality of rollers rotatable about vertical axes which, as seen in plan view, lie on a curve, so that the spacing of the axes from the elongate zone increases with decrease of the distance of the axes from the pushing member.

Preferably the two longitudinally spaced positions at which the edge engaging means engages said edges of said product are spaced apart longitudinally by a distance greater than the longitudinal distance along said zone between the pushing member and the closer of the two longitudinally spaced positions thereto.

The present invention is particularly useful when applied in a hot strip mill.

In another aspect the invention provides a hot strip mill comprising,

(a) a roughing mill;

(b) a finishing mill;

(c) conveying means for conveying elongate roughed bar product from said roughing mill to said finishing mill, and

(d) a straightener for correcting an end bend of said roughed bar product while on said conveying means, the straightener comprising at least one laterally movable member for pushing sideways on the bent end while lateral movement of a portion of the bar adjacent the bent end is restrained.

To give some non-limitative examples of dimensions and other factors which typically arise in present hot strip mill practice, and to which the invention is particularly applicable, the length of the bent end portion at the leading end of a so-called bar product emerging from the roughing mill is about 4m. Thus, the distance l_1 mentioned above is preferably in the range 3.5 to 5.5m, and the length l_2 mentioned above is correspondingly at least equal to this distance or larger. The thickness of such a product is typically in the range 20 to 80mm and its width in the range 900 to 1500mm, although narrower products, e.g. down to 600mm or wider products, e.g. up to 2m, may also be suitable in the invention. More particularly, when the width is in the range 900 to 1200mm, the thickness is preferably in the range 20 to 40mm, in order for the invention to apply satisfactorily, and when the width is in the range 900 to 1500mm, the thickness may be in the range 40 to 80mm.

In the case of steel, the products in question are normally mild steel, silicon steel or stainless steel, and the temperature of the product during the straightening operation in a hot strip mill is generally over 700° C, preferably at least 900° C. Such a product is typically moving at a speed of about 2 m/s on the roller table, so that pushing means must operate in preferably a time of 1 s or even less.

For aluminium, the relevant temperature is lower, for example in the region of 400 to 500° C.

Although the invention is in principle applicable to both the head end and the tail end, it is more effective when applied to the head end.

Embodiments of the inventions will now be described by way of non-limitative example with reference to the accompanying drawings, in which:-

Fig. 1 is a top plan view showing apparatus for correcting the bend of the leading end of a hot-rolled sheet according to one embodiment of the present invention;

Fig. 2 is a section taken along lines II-II of Fig. 1;

Figs. 3(a) to 3(d) are diagrams explaining the process for correcting the bend of the leading end;

Fig. 4 is a diagram plotting the experimental results for the depth of push;

Fig. 5 is a top plan view showing bend correcting apparatus according to another embodiment of the present invention;

Fig. 6 is an enlarged plan view of part of Fig. 5 showing the portion including the pushing rolls;

Fig. 7 is an end view taken along line VII-VII of Fig. 6;

Fig. 8 is an enlarged diagrammatic view showing an element of correcting apparatus according to still another embodiment of the present invention; and

Fig. 9 is a diagrammatic view of a hot strip mill embodying the invention.

With reference to Figs. 1 to 4, the correcting apparatus of the present embodiment is equipped with a pinch roller 2 for feeding forward a hot-rolled sheet 1 having a bend A at its leading end. This pinch roller 2 is driven by a drive motor 5 through a bearing 3 and a reduction gear mechanism 4. Downstream of the pinch roller 2, there are arranged at the two sides of the path of the hot-rolled sheet 1 a pair of side guide frames 6, which are driven to open or close by a drive motor 11 through racks 7 and 8, pinions 9 and a reduction gear machanism 10, as also shown in Fig. 2. At two longitudinally spaced portions of the side guide frames 6, there are attached two pairs of opposed vertical rollers, i.e. first rollers 12 and second rollers 13, which are moved away from or towards each other by opening or closing the side guide frames 6. Downstream of these first and second rollers 12 and 13, there are arranged another opposed pair of vertical pushing rollers, i.e. third rollers 14. These rollers 14 are attached to movable frames 15, which in turn are hinged by means of vertical pins 16 to the front end portions of the side guide frames 6. When the movable frames 14 are driven by means of cylinders 17, the third rollers 14 are pushed widthwise of the hot-rolled sheet 1.

In operation of the structure thus far described, when and after the leading end of the hot-rolled sheet 1, which is still in hot condition, passes the first and second rollers 12 and 13, the hot-rolled sheet 1 has its leading end given a sufficient counter bend and corrected by holding the hot-rolled sheet 1 centrally of its path line by means of the first and second rollers 12 and 13 and by pushing the third rollers 14 widthwise. At this time, the feeding force necessary for moving the bar during correcting of the bend of the leading end is given the pinch roller 2.

The process for correcting the bend of the leading end will be described in more detail with reference to Fig. 3.

The first, second and third rollers 12, 13, and 14 are held on standby while in the open state, as shown at (a) in Fig. 3, until the leading end of the hot-rolled sheet 1 having the bend A passes the second rollers 13. When the leading end comes near to the position of the third rollers 14, the first and second rollers 12 and 13 are moved widthwise, as shown at (b) in Fig. 3, to hold or restrain the hot-rolled sheet 1 centrally of the path line. At this time, the third rollers 14 are not yet in contact with the sides of the hot-rolled sheet 1.

As the leading end of the hot-rolled sheet 1 passes the third rollers 14, one of these rollers 14 gradually starts to push. This lateral push of the third rollers 14 is performed by forcing widthwise the roller 14 located in the bend direction of the leading end, i.e., the lower roller in the case as shown. The remaining opposite or upper roller, as shown is either caused to follow the lower one or held in its open position. Moreover, the push of the third roller 14 is performed to a position over the sheet width beyond the position corresponding to the straight sheet, i.e. there is an over-push. This is because a relatively large bend is left after the push unless the push is excessive, since the hot-rolled sheet is elastic and springs back when released.

Fig. 4 plots the experimental results concerning the relation of necessary depths of over-push Δ - (equal to the amount of the spring back) to the width B of the hot-rolled sheet 1 for different values of the parameter of span l_1 between the second and third rollers 13 and 14 and for material of Young's modulus 1.2×10^4kg/mm^{2}and yield stress of 6 kg/mm^2. It is understood from the graph that the necessary depth of push Δ becomes more for the smaller sheet width B and for the longer span l_1.

Thus, by performing the over-push estimating the extent of the springback after release, the residual bend is reduced to one quarter or less of the initial bend of the leading end. The bend of the leading end of the hot-rolled sheet 1 is usually 30 to 40mm or less. In this case the residual bend after the correction is 10mm or less. A residual bend of this order will raise no substantial problem in the passage through the subsequent finish rolling machine (or the reduction due to an unbalanced push), in the offset of the take-up machine (coiler), and in the production yield.

After the push is complete, the first to third rolls 12, 13 and 14 are rapidly opened, as shown at (d) in Fig. 3, to end the correction.

According to the present embodiment, therefore, the bend of the leading end of the hot-rolled sheet can be positively corrected to improve the passage through the finish rolling machine thereby to prevent reduction and offset at the take-up machine and to improve the production yield.

Since, moreover, the push of the hot-rolled sheet is accomplished by means of the rollers 12, 13 and 14, the correction of the bend of the leading end can be accomplished while the hot-rolled sheet is being continuously fed. With this correction during the movement of the hot-rolled sheet 1, it is possible to prevent the temperature of the hot-rolled sheet 1 from dropping and the sheet from being cooled down at the feed rollers.

In order to effect the correction during the movement of the hot-rolled sheet 1, the first to third rollers 12, 13 and 14 have to be opened or closed at high speeds. Preferably the actual pushing is accomplished in 1 s or less. On the other hand, the first and second rollers 12 and 13 and the third rollers 14 have to be operated at predetermined timings. These timings can be realized, for example, by arranging a sensor upstream of the pinch roller 2 to detect the passage of the leading end of the hot-rolled sheet, and by driving the motor 11 and by driving the cylinders 16 at predetermined times after detection.

The bend of the leading end of the hot-rolled sheet 1 is usually 30 to 40mm or less and is frequently located at a distance of about 5m from the leading end. Hence, the distance between the second rollers 13 and the third rollers 14 is desirably 5m or less, e.g. about 4m.

It will be appreciated that the direction of pushing of the bent end depends upon the direction of the bend being corrected. Since, as explained above, the end position to which the pushing member pushes the bent end can be chosen independently of the initial amount of bend, the control of the apparatus in dependence upon the particular product can be limited to control of the direction of pushing. This can be done manually, following inspection of the next product to be treated. Alternatively, a sensor may be arranged to detect the direction of the bend and control the direction of pushing accordingly.

Another embodiment of the present invention will be described with reference to Figs. 5 to 7. Parts corresponding to those of Fig. 1 are not fully described again. In the present embodiment, the pushing third rollers 14 are separated from the side guide frames.

In Fig. 5, the side guide frames 20 are constructed to carry the first and second rollers 12 and

13 only and are opened or closed by means of the mechanism of the racks 7 and 8 and the pinions 9. On the other hand, the third rollers 14 are carried by chocks 21 which can be reciprocated in a stand 22. Thus, the third rollers 14 are opened or closed by driving push means 23, which are connected to the chocks 21, by means of motors 25 through gear mechanisms (not shown) which are built in the stand 22 and reduction gear mechanisms 24.

In the present embodiment, too, similar effects can be attained by correcting the bend of the leading end of the hot-rolled sheet 1 in the same way as with the foregoing embodiment.

Still another embodiment of the present invention will be described with reference to Fig. 8 which differs only at the second rollers. In this case, the second rollers are not constructed as a single pair of rollers but are each composed of a number of vertical small-diameter basket rollers 30 having a large virtual roller diameter. As Fig. 8 shows, the axes of these rollers 30 lie on a curve, so that they are increasingly spaced from the centre line of the path of the moving hot-rolled sheet in the downstream direction. This structure is made to avoid the local deformation of the hot-rolled sheet. Specifically, what is given most intense force for the correction in the foregoing embodiments is the second rollers 13. Depending upon the specification of the hot-rolled sheet, it is necessary to avoid any significant reduction in the width due to the local pushing by the second rollers 13. According to the present embodiment, however, the load can be dispersed by using the numerous basket rollers 30 having a large virtual roller diameter so that the tendency to width reduction can be decreased.

Fig. 9 shows diagrammatically a hot strip mill to which the invention is applied. A hot ingot 40, e.g. from a soaking furnace passes through a scale breaker 42 to a roughing mill 44 where it is rolled in many passes into a bar of sheet shape. Then it is straightened by straightening apparatus 46 of the invention as illustrated above before being rolled in a single pass through finishing train roll stands 48 and being coiled at coiler 50.

One non-limitative example of the method of the invention will now be given.

Example

In straightening apparatus as shown in Fig. 1 a mild steel bar of dimensions 40mm thick, 1000mm wide and 60m long at 1000°C (Young's modulus 1.1×10^4 kg/mm^2, yield stress 6.0 kg/mm^2) is moved at 1.2 m/s. It had an initial bend of 40mm at its leading end. The span l_1 (see Fig. 4) between second rollers 13 and the pushing rollers 14 is 4500mm, and the span l_2 between the first and second rollers is 6750mm. Straightening of the bend to a residual bend of less than 10mm was achieved in the manner described above. The maximum bending force at the second roller 13 was 23000 kg.

Claims

1. A method of correcting a widthwise bend of an end portion adjacent an end of a hot-rolled elongate sheet-shaped metal product (1) while it is hot, comprising the steps of simultaneously:

(i) holding the edges of said product (1) at at least two positions (12,13) longitudinally spaced along said product thereby to hold, at least laterally, a portion of said product spaced from said end, and

(ii)pushing said end portion laterally by means of a laterally moving member (14) so as at least partly to correct said bend.

2. A method according to claim 1 wherein said steps (i) and (ii) are performed while said product is continuously moving along a path.

3. A method according to claim 2 wherein said steps (i) and (ii) are performed by rollers rotatable about vertical axes.

4. A method according to claim 3 wherein said step (i) is performed by at least two longitudinally spaced pairs of rollers (12,13), each pair comprising opposed rollers which respectively engage opposite edges of said product, said axes of said rollers lying in two parallel planes on opposite sides of said product, and said rollers being moved into engagement with said edges of said product while said planes are maintained parallel.

5. A method according to any one of claims 1 to 4 wherein said step (ii) comprises pushing said end portion laterally by an amount more than the amount of said bend, and permitting said end portion to spring back after said pushing.

6. Apparatus for correcting a widthwise bend of an end portion of a hot-rolled elongate sheet-shaped metal product (1) while said product is hot, comprising,

(a)an elongate zone to receive said product (1),

(b) means (12,13) for engaging the edges of said product at at least two positions longitudinally spaced along said zone, so as to hold said product at least laterally,

(c)pushing means including at least one pushing member (14) spaced longitudinally along said zone from said engaging means, to contact said end portion and drive means (17) to cause said pushing member to push said end portion laterally.

7. Apparatus according to claim 6 wherein said edge engaging means comprises longitudinally spaced pairs of opposed rollers (12,13) and means (6-11) for moving said rollers laterally into engagement with said edges of said product.

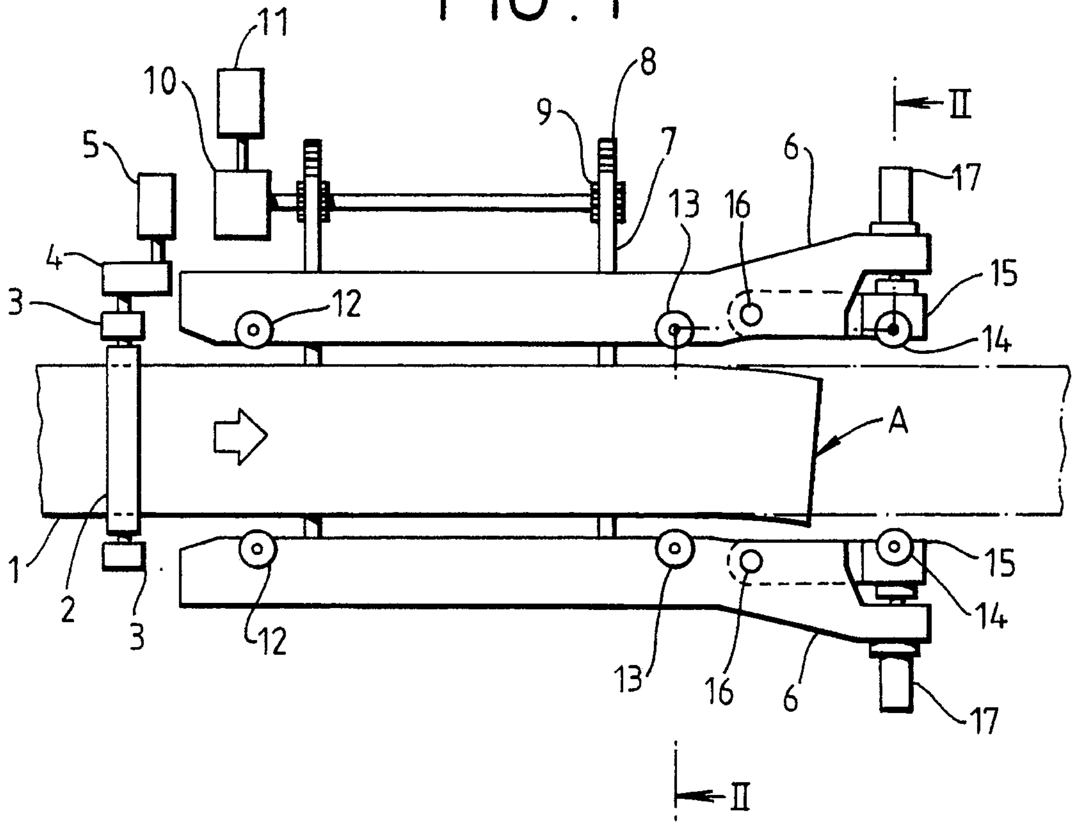
8. Apparatus according to claim 7 wherein said means for moving said rollers comprises (a) a pair of side frames (6) at the two sides of said elongate zone supporting said rollers (12,13) so that the roller axes are in parallel planes at the two sides and (b) means (7-11) for moving said side frames (6) towards and away from said elongate zone while maintaining said planes parallel.

9. Apparatus according to any one of claims 6 to 8 wherein said engaging means (12,13) has, at its end closer to said pushing member (14), roller means for contacting an edge of said product, said roller means comprising a plurality of rollers (30) rotatable about vertical axes which, as seen in plan view, lie on a curve in a manner such that the spacing of said axes from said elongate zone increases with decrease of the distance of said axes from said pushing member (14).

10. An apparatus according to any one of claims 6 to 9 wherein said two longitudinally spaced positions at which said engaging means (12,13) engage said edges of said product are spaced apart longitudinally by a distance greater than the longitudinal distance along said zone between said pushing member (14) and the closer one (13) of said two longitudinally spaced positions thereto.

11. A hot strip mill comprising,
(a)a roughing mill (44);
(b)a finishing mill (48);
(c)conveying means for conveying elongate roughed bar product from said roughing mill to said finishing mill, and
(d)a straightener (46) for correcting an end bend of said roughed bar product while on said conveying means, the straightener comprising at least one laterally movable member (14) for pushing sideways on the bent end while lateral movement of a portion of the bar adjacent the bent end is restrained.

FIG. 1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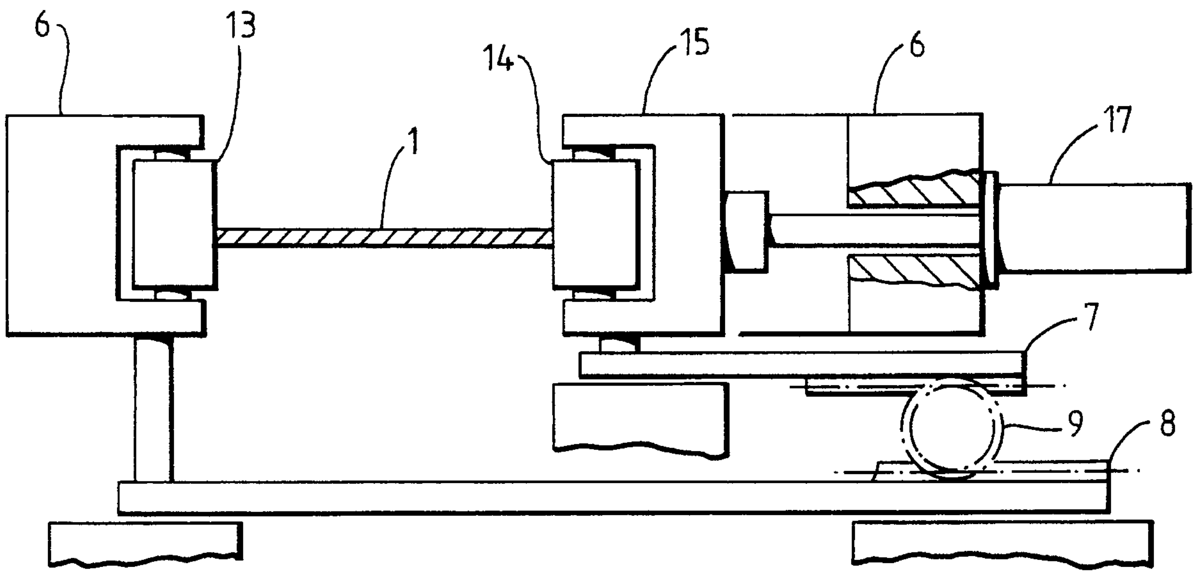
14
II

FIG. 2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14
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FIG.3

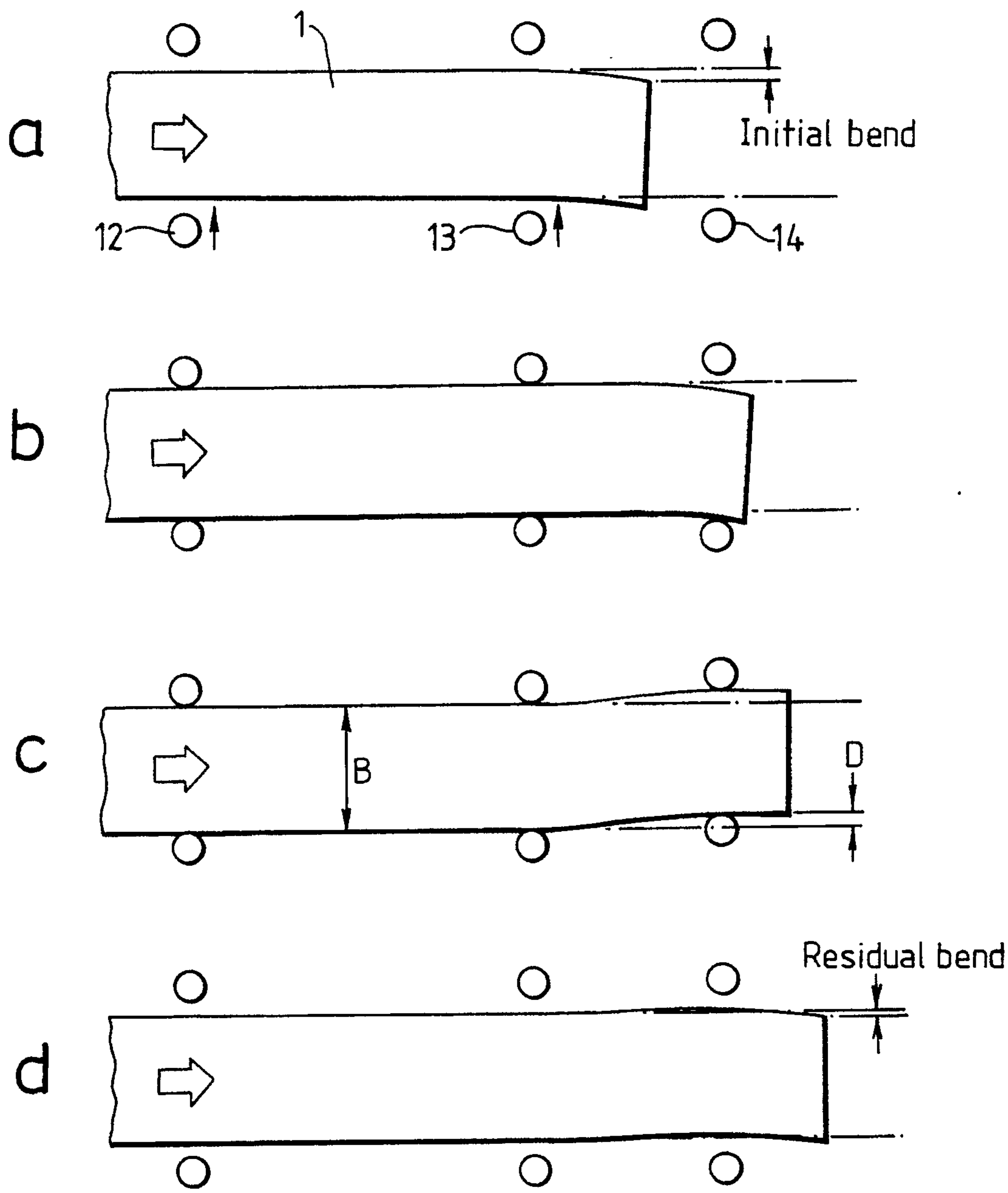


FIG.9

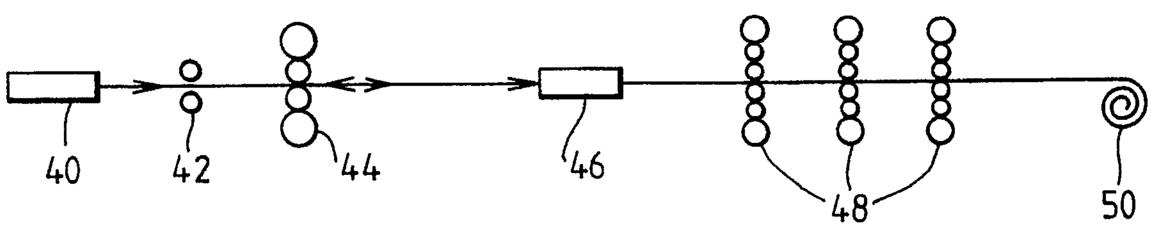
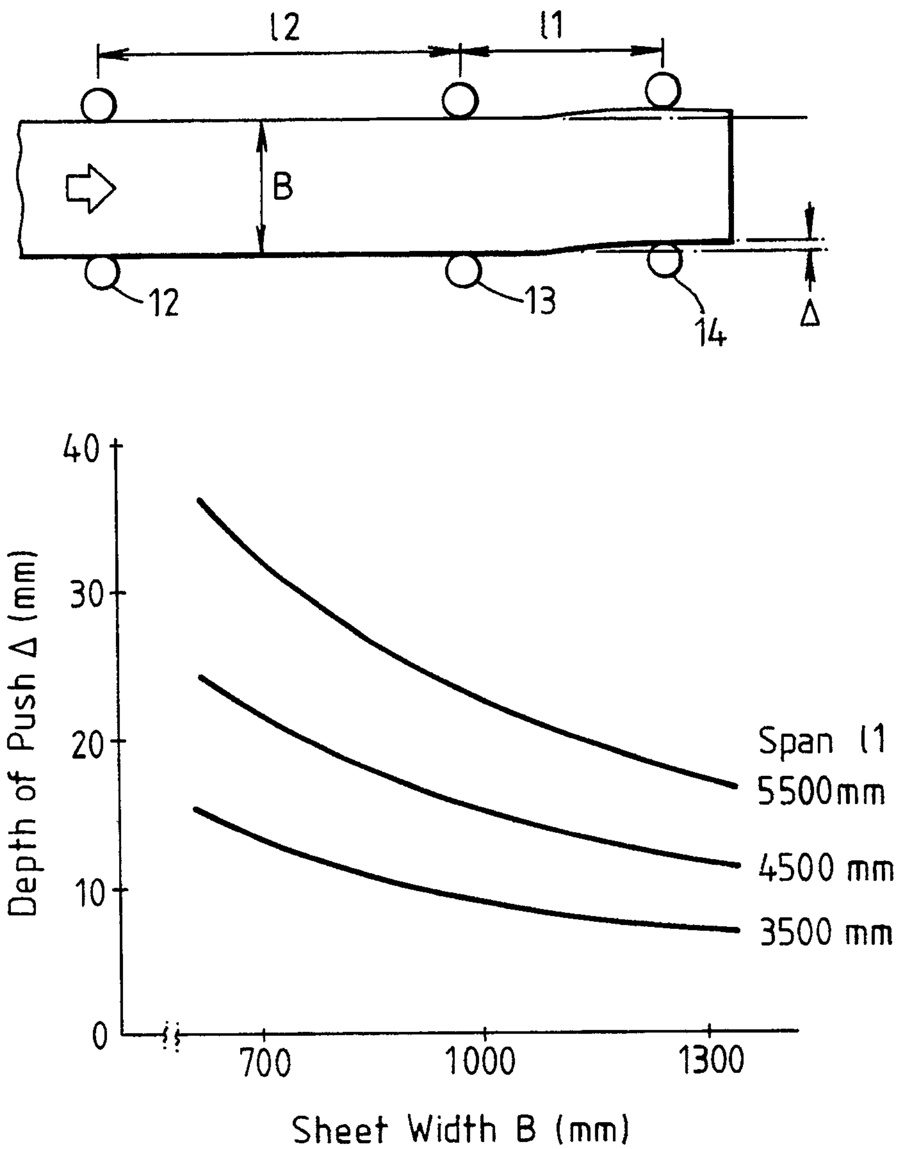


FIG. 4


l2
l1
B
12
13
14
Δ
40
30
20
10
0
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1000
1300
Depth of Push Δ (mm)
Sheet Width B (mm)
Span l1
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4500 mm
3500 mm

FIG . 5

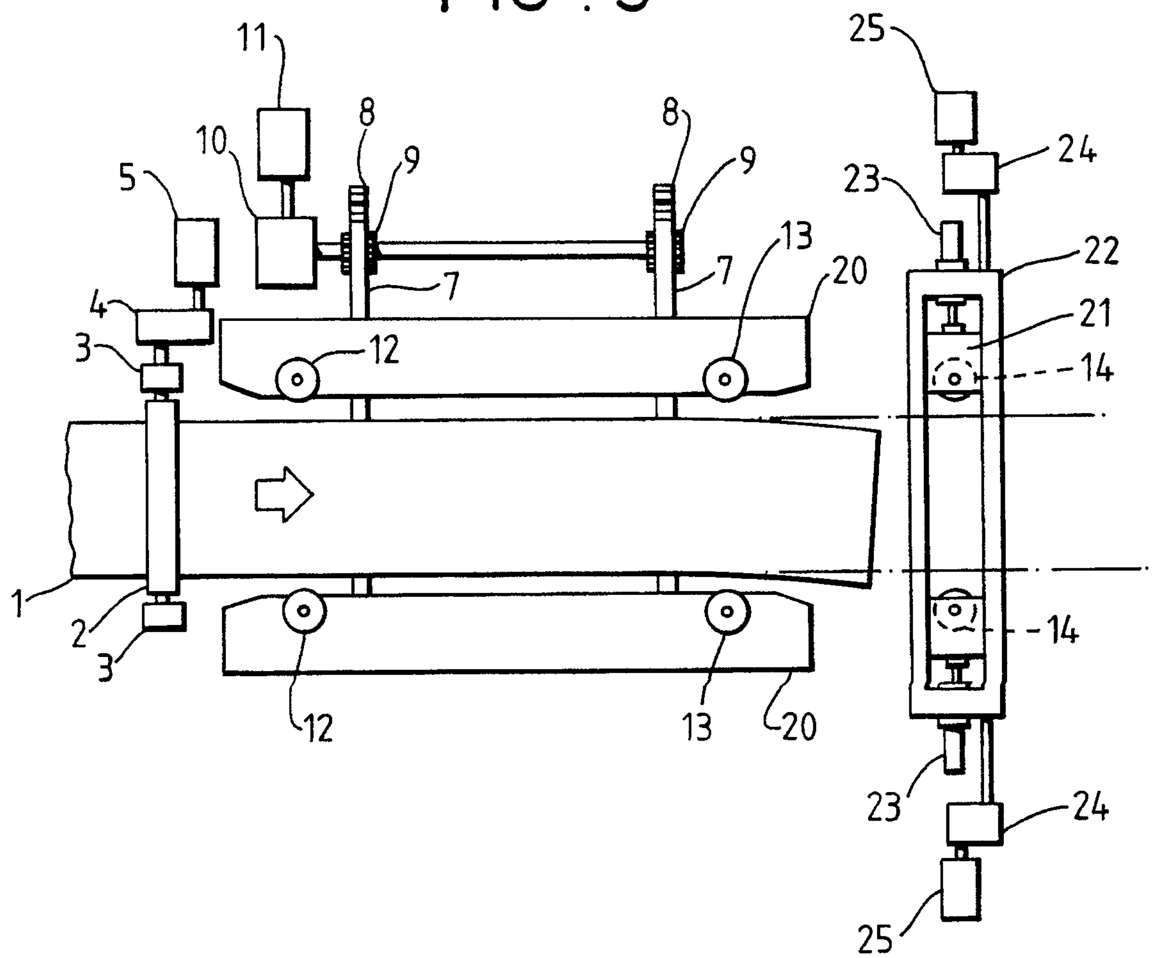
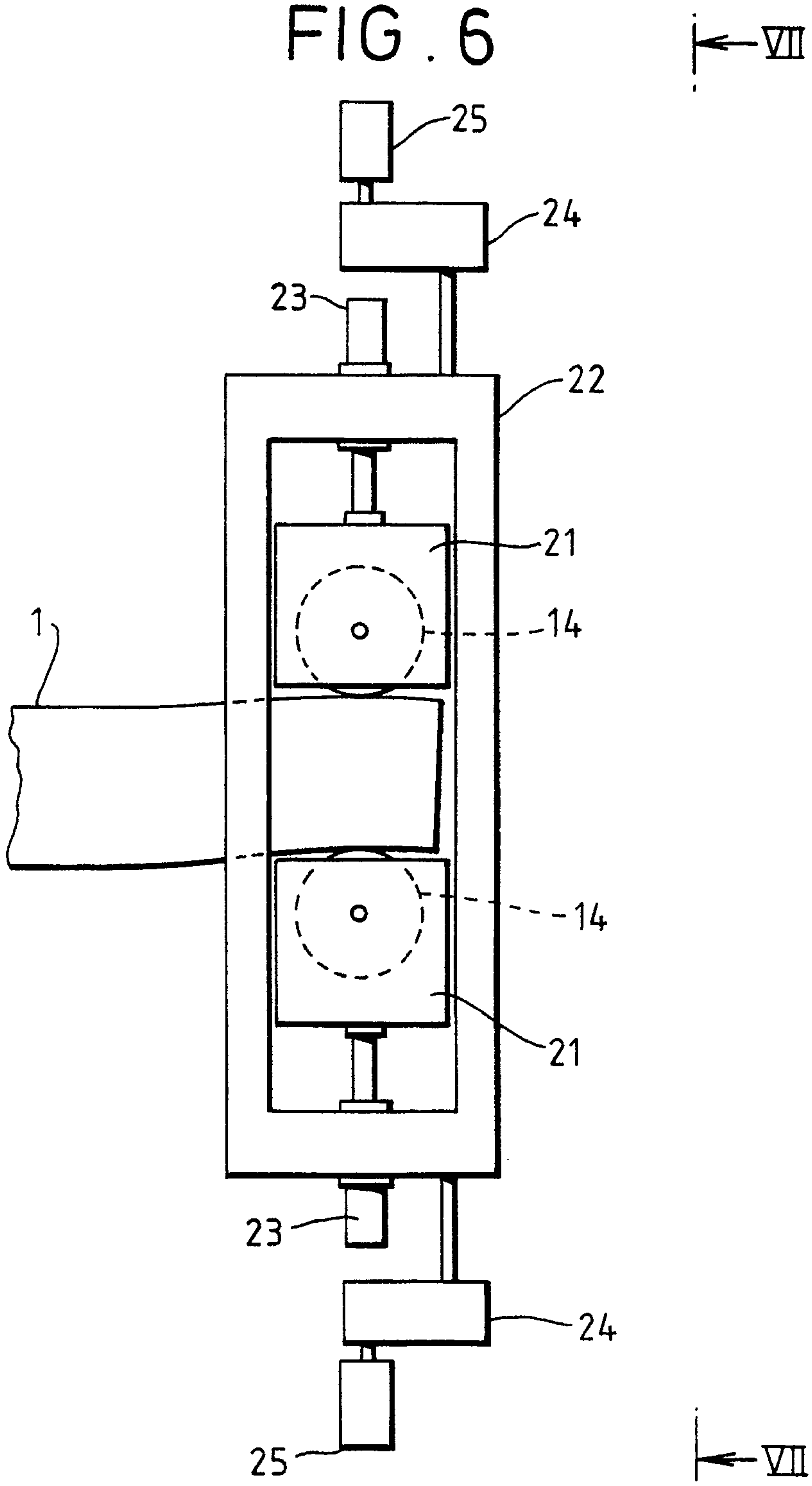


FIG. 6



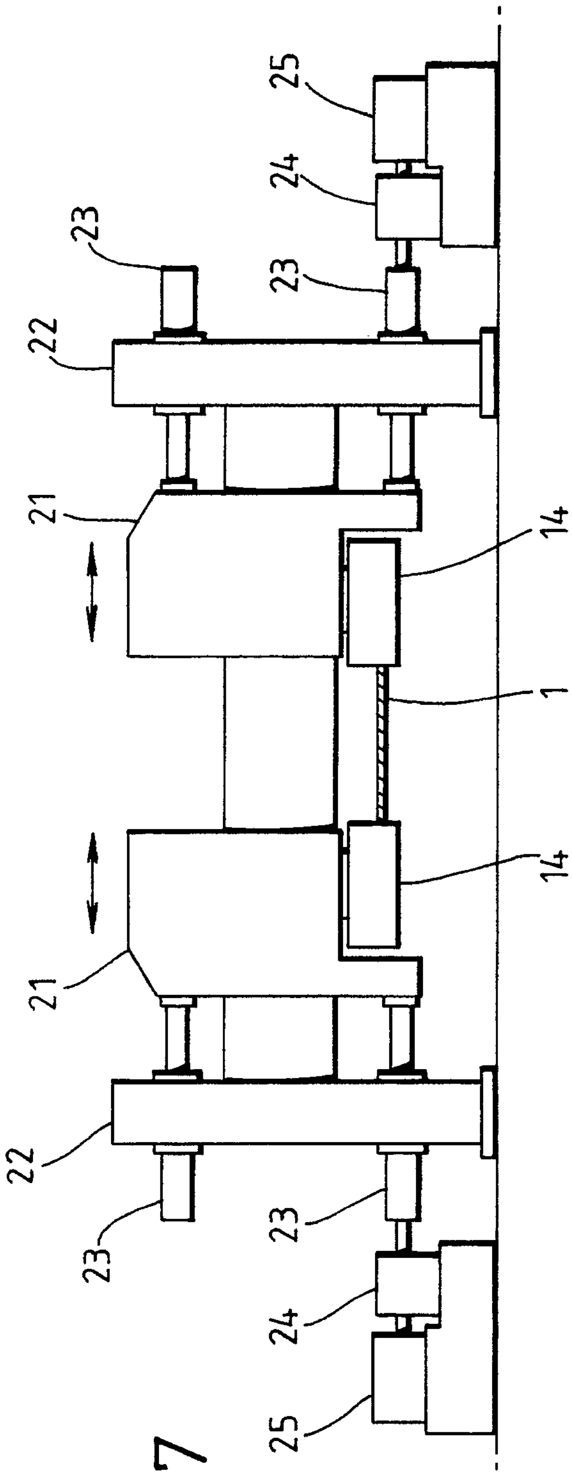


FIG. 7

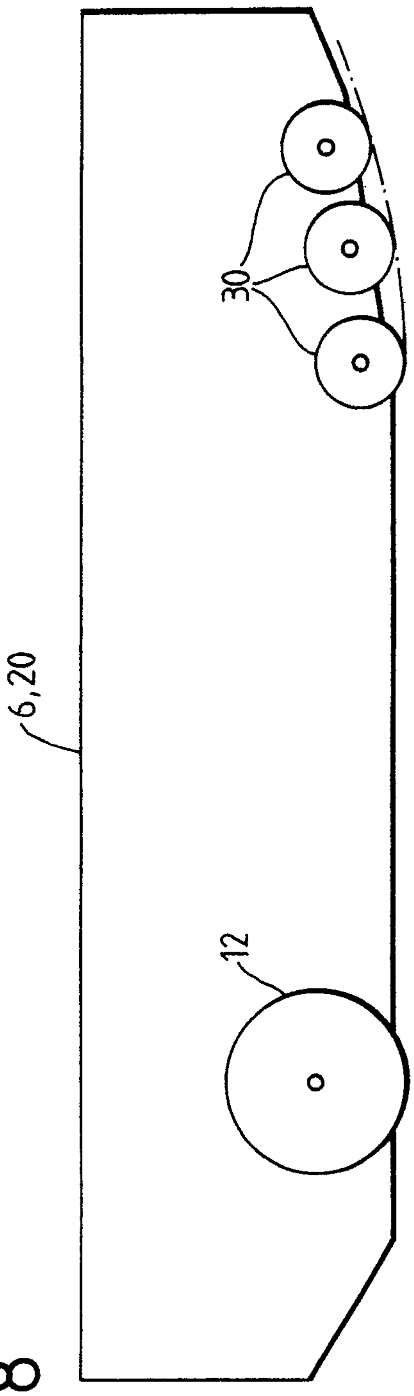


FIG. 8