United States Patent [19]

Sherwood

[11] **3,762,202**

[45] **Oct. 2, 1973**

[54] **ROLLING MILL FOR FLAT-ROLLED PRODUCTS**

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[22] Filed: **Oct. 18, 1971**

[21] Appl. No.: **189,900**

[52] **U.S. Cl.** **72/245,** 72/246

[51] **Int. Cl.** **B21b 31/32**

[58] **Field of Search** 72/245, 246, 241, 72/199

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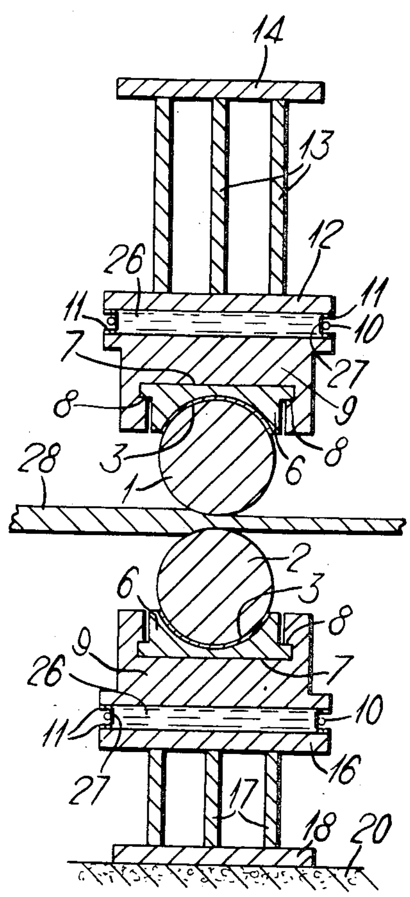
Primary Examiner—Milton S. Mehr

[57] **ABSTRACT**

The invention is a rolling mill for flat-rolled products designed in a manner to substantially eliminate bending of the rolls under load with associated convexity of the roll gap and resultant tendency towards excess convexity of bar transverse profile. The rolling mill employs the partial cylindrical surface of the roll barrel itself in contact with a corresponding work roll bearing pad, rather than roll neck end bearings, as the main load bearing mill bearings, and supports this bearing against a transversely elongated hydrostatic cushion which distributes the reaction to the roll force uniformly along the length of the work roll. Pressure equalizing cylinders at the roll ends are also used to compensate for bending effects resulting from differences between length of the hydrostatic cushion and width of the bar being rolled. The mill is intended for application to hot and cold rolling of plate, sheet and strip products made of steel, aluminum, copper and like, either in a single stand or in tandem rolling mill applications.

9 Claims, 5 Drawing Figures



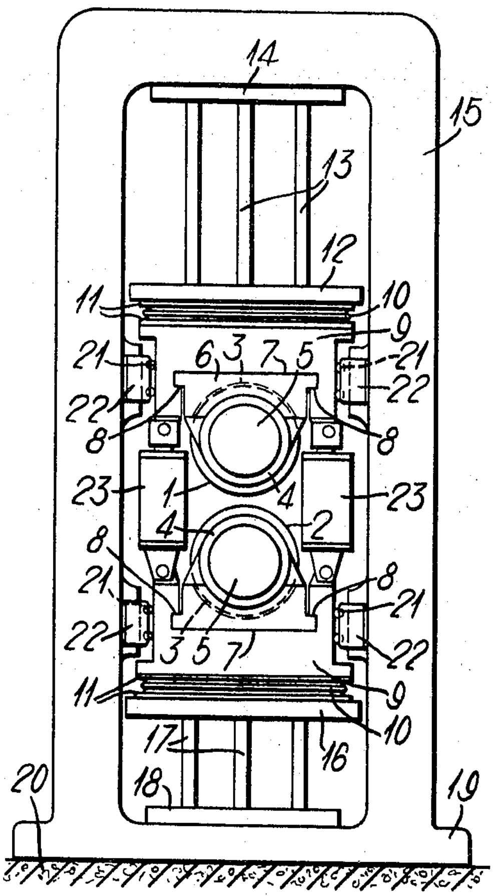


Fig. 1.

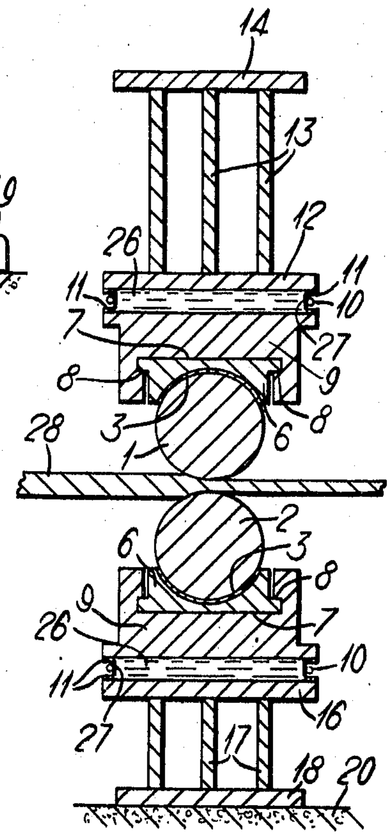


Fig. 3.

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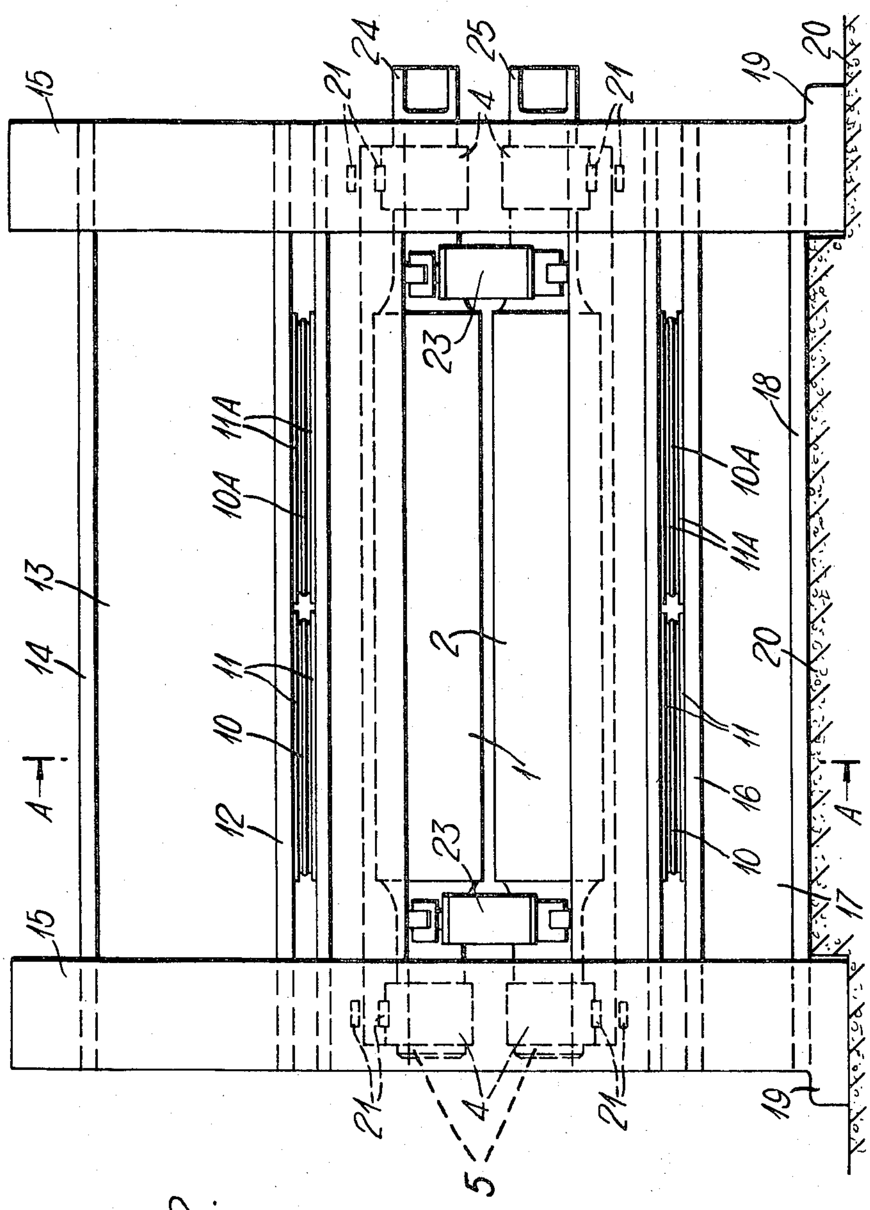

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Fig. 4.

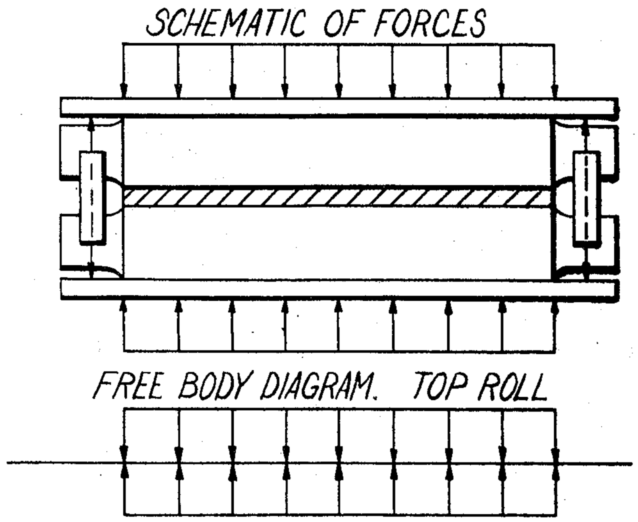
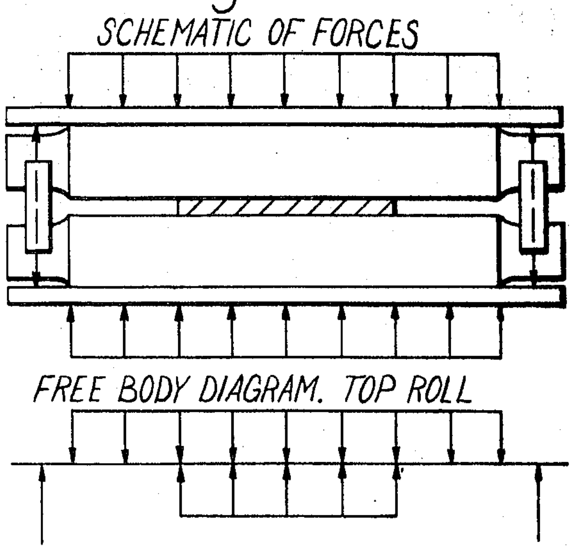


Fig. 5.



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ROLLING MILL FOR FLAT-ROLLED PRODUCTS

The invention relates to the mechanical working of metals such as steel, copper and aluminum and, more particularly, to an improved rolling mill for flat-rolled products such as plate, sheet and strip.

In conventional two-high and four-high rolling mills, work rolls and backup rolls are supported for rotation within bearings encasing necks at the ends of the rolls. In a two-high mill, the rolling forces are transmitted from the end bearings to the mill housings principally by way of the work roll bearing chocks, and in a four-high mill by the backup roll bearing chocks. Rolling of flat-rolled products generally involves very high values of total rolling force. Since the rolls are supported only at the ends, these large forces potentially lead to large values of roll deflection at the centre, with consequent unsatisfactory transverse flatness of the rolled bar. In order to minimize these effects and maintain an adequately flat transverse bar profile, work rolls and backup rolls of very large diameter, requiring correspondingly large mill stand housings, have come into common use.

It is a principal object of the present invention to provide an improved rolling mill for flat-rolled products whereby work roll bending under load can be substantially eliminated and a flat transverse bar profile maintained in a much lower cost, simpler and smaller rolling mill stand.

It is a further object of this invention to provide a means of substantially eliminating work roll bending without the use of conventional backup rolls or multiple clusters of backing rolls.

Another object is to provide an expedient for simple and continuous control and adjustment of the roll gap and therefore the thickness of the material being rolled.

Another object is to reduce the power requirements and energy required for rolling.

A further object is to reduce the capital cost of a rolling mill for flat rolled products, in particular, mills for hot and cold rolled products in the steel industry.

A further object is to eliminate the need for high reaction, concentrated load roll end bearings, backup rolls, and complex mechanical screwdowns.

Still another object of the invention is to provide a rolling mill stand particularly suited for installation in tandem for reduction of continuously cast steel slabs in a continuing sequence following their exit from the continuous casting machine, usually with an intermediate temperature equalizing heating step.

The invention is a rolling mill for flat-rolled products in which the work roll is mounted for rotation with the working surface of the roll barrel, on the diametrically opposite side to the bar, in contact with and supported by an elongated work roll bearing pad incorporated into a backup bearing assembly, whereby the rolling force is borne by this assembly, rather than by roll neck bearings at the ends of either backup or work rolls as in the usual rolling mill practice. The backup bearing assembly includes a partial cylindrical sleeve bearing or equivalent low-friction contact with the roll surface, and is supported along the length of the roll barrel against a hydrostatic cushion containing fluid under a pressure corresponding to the roll force, with the pressure distributed along the roll similarly to the rolling load. The hydrostatic cushion, in turn, is supported against a backup crossbeam connecting between the mill end housings. Owing to the action of the hydraulic cushion as a reaction pressure equalizer, bending movement and deflection of the work roll and backup bearing assembly are substantially nullified, and the deflection is taken up by the stationary backup crossbeam, but not transmitted to the steel bar. In operation, an equal and opposite force to the rolling force is exerted, but rather than being concentrated at the roll ends, the force is distributed all along the roll length, thus effectively eliminating large bending forces and roll deflections such as are normally encountered in the conventional two-high and four-high mill having rolls supported by roll neck bearings only at the roll ends.

By varying the quantity of hydraulic fluid in the hydrostatic cushion, a continuous adjustment of the roll gap is also obtained. Furthermore, by dividing the hydrostatic cushion into at least two chambers, one on either side of the centre of the rolls, the roll gap can be adjusted at one end of the rolls in relation to the other end, thereby controlling bar thickness as between the roll ends and therefore the two bar edges and thus reduce the occurrence of wedge-shaped transverse profiles of the rolled bar.

In order to balance forces within the rolling mill stand, and compensate for differences between the width of the bar and the length of the hydrostatic cushion, hydraulic equalizing cylinders are also included between top and bottom backup bearing assemblies at the roll ends for exerting controlled supplementary separating forces between top and bottom backup bearing assemblies. As bar width decreases, increased balancing forces can be exerted by these cylinders to maintain a substantially flat and uniform roll gap at various bar widths.

Various other objects, features and advantages of the apparatus of this invention will become apparent from the following detailed description and claims, and by referring to the accompanying drawings, in which:

FIG. 1 is a side view of a rolling mill stand according to this invention;

FIG. 2 is a front elevation of the rolling mill stand of FIG. 1;

FIG. 3 is a sectional view taken along line A—A of FIG. 1;

FIG. 4 is a representation of forces in the rolling mill stand of FIGS. 1–3, for the case where bar width is equal to working length of the roll barrel;

FIG. 5 is a representation of forces in the rolling mill stand of FIGS. 1–3 for the case where the bar width is significantly narrower than the working length of the roll barrel.

Referring to FIGS. 1 to 3, the top work roll 1, and bottom work roll 2, are mounted for rotation by a suitable rolling mill drive, for example, by a motor, gear reducer, coupling, pinion stand and spindles to top roll wobbler drive connection 24, and bottom roll wobbler drive connection 25. When the mill is under load by virtue of force and torque required to reduce a flat rolled bar 28, the rolling force is transmitted from the work roll barrel to bearing inserts 3 which form partial cylindrical bearing surfaces in contact with the working length of the work roll barrels 1, 2. The bearing inserts 3 are mounted within work roll bearing pads 6, which transmit the rolling force by way of pressure contact surface 7 to work roll bearing support crossbeam 9. The hydrostatic roll pressure distribution cushions 10, 11, 26 and 27 then transmit this pressure to the backup crossbeam 12, 13, 14 and bottom roll backup crossbeam 16, 17 and 18 which are supported at their ends within mill stand end housings 15.

A variety of materials are suitable for the sleeve inserts. For example, porous iron offers high strength at low cost for low speed operation. Babbit base materials, reinforced Teflon and various other materials can also be considered, the selection depending upon the force and speed conditions of the particular rolling application. In addition to the lubricating properties of the bearing material selected, the roll cooling water provides a natural lubricant. The bearing surface may also be pressure fed with water or lubricant emulsion by way of an appropriate groove system in the insert, according to known practice for sliding bearings. Since roll scale and dirt on the roll surface tend to accelerate scoring and wear of the bearing, a rotary roll cleaning brush can also be incorporated into the mill stand design.

In order to allow convenient work roll insertion and removal for surface dressing, maintenance and reassembly, the work rolls 1, 2, bearing support pads 6, bearing insert 3 and end collars 4, are made up as an integral unit assembly. The end collars also serve to hold the work rolls in position when the mill is not loaded. To effect work roll withdrawal or insertion, the entire assembly is slid along the guide slot between positioning track 8 and pressure contact surface 7 of bearing support pad 6.

The work roll bearing support crossbeam 9 is mounted for adjustable vertical movement within the sets of centering guide rolls 21 attached to support brackets 22 of end housings 15 on both entry and exit sides of the mill stands. In this manner, the work roll and backup assembly may be maintained in correct vertical alignment within the work roll housing at all times.

In the embodiment illustrated, the roll pressure distribution cushions are confined in a bellows type enclosure consisting of flanges 11, 11A, one or more expansion corrugations 10 and internal guide sleeve 27, connecting between appropriate flanges on work roll bearing support crossbeams on the work roll side and top and bottom backup crossbeams 12, 13, 14, and 16, 17, 18 on the backup side. The cushion shown is of a design equivalent to a Zallea Hyptor (high pressure toroid) or equivalent expansion joint. By controlling the quantity of hydraulic fluid 26 within the roll pressure distribution cushion, the distance between work roll support crossbeams and the backup crossbeams is thus controlled. Simply by controlling the quantity of hydraulic fluid 26 within the cushion, the work roll position and roll gap can be adjusted to vary the bar thickness without corresponding movement of the backup crossbeam.

Furthermore, according to hydrostatic principles, the pressure of hydraulic fluid 26 is transmitted equally in all directions. An equal and opposite force to the rolling force therefore is transmitted against the work roll bearing support crossbeam 9, which is distributed along the beam in proportion to the vertically projected area of the hydrostatic cushion. Although the rolling force may cause a very substantial deflection of the backup crossbeams 12, 13, 14 and 16, 17, 18 this deflection does not affect the pressure distribution within the hydrostatic cushion, and therefore does not influence the roll cambers under load of the work rolls. This is a key advantage over mills employing backup rolls to enhance mill stiffness under load.

In order to facilitate maintenance of a controlled and uniform roll gap along the roll length and to enhance roll gap stability and bar profile control, the cushion has been divided into two parts 10, 11 on one side of centre line of the roll barrel and 10A, 11A on the other side. As a further stabilizing influence, hydraulic pressure equalizing cylinders 23 are provided which will be seen to serve an additional service of compensating for differences between strip width and length of the hydrostatic backup cushions.

FIG. 4 illustrates schematically the effect of the cushion on transverse profile of the roll gap under load for the condition that strip width is equivalent to the cushion length, with cushion area uniform along the entire roll length. It may be seen the fluid pressure within the cushion creates an equal and opposite reaction force to the rolling force which is similarly distributed along the roll length, thereby creating a condition of bending moment and deflection equal to zero all along the roll length. With balancing cylinders 23 exerting no significant force, and employing straight cylindrical rolls, the resulting roll camber and transverse bar profile could be expected to be substantially flat (ignoring "bar edge effects").

FIG. 5 illustrates the case where bar width is substantially narrower than hydrostatic cushion length. As width of the rolled bar 28 decreases, the compensating force applied to the hydraulic balancing cylinders 23 is progressively increased. A substantially flat profile of the roll gap thus can be maintained over a wide range of conditions and sizes of stock being rolled.

It will be appreciated that a preferred embodiment of the rolling mill for flat-rolled products has been described and illustrated, and that variations and modifications may be made by persons skilled in the art, without departing from the spirit and scope of the invention defined in the appended claims.

I claim:

1. In a rolling mill for flat-rolled products, in which the rolling force is substantially borne by back-up supports bearing against the work roll barrel rather than by end neck bearings at the work roll ends comprising, in combination, an elongated rotating work roll, a backup bearing assembly including work roll bearing support crossbeam and partial cylindrical roll support bearing elements extending along the working length of said work roll against which the barrel of said work roll rotates under load; a backup crossbeam spanning the roll length connecting between mill end housings and adapted to accommodate the total rolling force; a hydrostatic roll pressure distribution cushion extending along the length and between said work roll bearing support crossbeam and said backup crossbeam, said hydrostatic cushion containing an essentially noncompressible hydraulic fluid and being enclosed on one side by said backup crossbeam, on the other side by said bearing support crossbeam, and enclosed around the cushion edges by an expandable - retractable sealed expansion joint, wherein said hydraulic fluid is adapted to effectively resist and counteract the rolling force with an equal and opposite reaction force to the rolling force, said reaction force being distributed along the length of the roll barrel in proportion to the perpendicularly projected area of said hydrostatic cushion; and hydraulic fluid supply means for controlling and adjust-

ing the quantity of hydraulic fluid contained in said hydrostatic cushion, thereby providing for adjustment of the size of the roll gap to maintain the desired bar thickness during rolling.

2. A rolling mill for flat-rolled products according to claim **1** which also includes separating force equalizing cylinders acting upon the work roll bearing support crossbeam near the crossbeam ends, adapted for applying a controlled separating force to the ends of the work roll bearing support crossbeam, thereby compensating for bending forces and deflection of said work roll bearing support crossbeam caused by differences in the distribution of forces on either side of the bearing support crossbeam, particularly those forces resulting from differences between the width of the bar being rolled and the length of said hydrostatic roll pressure distribution cushion as bars of different widths are rolled.

3. A rolling mill for flat-rolled products according to claim **1** in which said hydrostatic roll pressure distribution cushion is made up in two separate hydraulic chambers, one on each side of the centre of the roll barrel, including means for independently controlling the amount of hydraulic fluid as between each of said chambers, said hydraulic chambers threby being adapted to adjust the size of the roll gap at either end of the work rolls as required to maintain the desired bar profile and thickness during rolling.

4. A rolling mill for flat-rolled products according to claim **1,** in which said cushion edges comprise a packless expansion joint in the form of a flexible bellows incorporating at least one expansible corrugation disposed longitudinally along the cushion edges.

5. A rolling mill for flat-rolled products according to claim **1** in which said backup bearing assembly includes a removable bearing support pad integral with said work roll bearing support crossbeam, comprising an elongated body member with end bearing collars for retention of the roll necks at either end of the rolls, and a partial cylindrical contact surface forming a partial bearing along the roll length between said bearing pad and the roll barrel working surface, said support pad being adapted for insertion within guide tracks integral with said work roll bearing support crossbeam, whereby the opposite side of said support pad to said partial cylindrical contract surface makes a pressure contact with said work roll bearing support crossbeam by way of which contact the rolling force is transmitted between said work roll, and said work roll bearing support crossbeam, and in turn to said hydrostatic roll pressure distribution cushion.

6. A rolling mill for flat-rolled products according to claim **5** which includes a partial cylindrical bearing insert attached to said bearing pad along the roll length to form said partial cylindrical bearing surface.

7. In a rolling mill for flat-rolled products, in which the rolling force is substantially borne by back-up supports bearing against the work roll barrel rather than by end neck bearings at the work roll ends, comprising, in combination, an elongated rotating work roll, a backup bearing assembly including work roll bearing support crossbeam and partial cylindrical roll support

bearing elements extending along the working length of said work roll against which the barrel of said work roll rotates under load; a backup crossbeam spanning the roll length connecting between mill end housings and adapted to accommodate the total rolling force; a hydrostatic roll pressure distribution cushion made up in two separate hydraulic chambers, one on each side of the centre of the roll barrel and extending along the length and between said work roll bearing support crossbeam and said backup crossbeam, said hydraulic chambers containing an essentially non-compressible hydraulic fluid, and said chambers being enclosed on one side by said backup crossbeam, on the other side by said bearing support crossbeam, and enclosed around the cushion edges by an expandable - retractable sealed expansion joint, wherein said hydraulic fluid is adapted to effectively resist and counteract the rolling force with an equal and opposite reaction force to the rolling force, said reaction force being distributed along the length of the roll barrel in proportion to the perpendicularly projected area of said hydrostatic cushion, each of said chambers including means for independently controlling the amount of contained hydraulic fluid, and thereby being adapted to adjust the size of the roll gap at either end of the work rolls as required to maintain the desired bar profile and thickness during rolling; and separating force equalizing cylinders acting upon the work roll bearing support crossbeam near the crossbeam ends, adapted for applying a controlled separating force to the ends of work roll bearing support crossbeam, thereby compensating for bending forces and deflection of said work roll bearing support crossbeam caused by differences in the distribution of forces between the rolling pressure on one side and the hydrostatic cushion pressure on the other side of the bearing support crossbeam, particularly those forces resulting from differences between the width of the bar being rolled and the length of said hydrostatic roll pressure distribution cushion.

8. A rolling mill for flat-rolled products according to claim **7,** in which said backup bearing assembly includes a removable bearing support pad integral with said work roll bearing support crossbeam, comprising an elongated body member with end bearing collars for retention of the roll necks at either end of the rolls, and a partial cylindrical contact surface forming a partial bearing along the roll length between said bearing pad and the roll barrel working surface, said support pad being adapted for insertion within guide tracks integral with said work roll bearing support crossbeam, whereby the opposite side of said support pad to said partial cylindrical contact surface makes a pressure contact with said work roll bearing support crossbeam by way of which contact the rolling force is transmitted between said work roll, and said work roll bearing support crossbeam, and in turn to said hydrostatic roll pressure distribution cushion.

9. A rolling mill for flat-rolled products according to claim **8,** which also includes a partial cylindrical bearing insert attached to said bearing pad along the roll length to form said partial cylindrical bearing surface.

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